URBAN GROWTH AND LAND USE/LAND COVER MODELING IN SEMARANG , CENTRAL JAVA, INDONESIA

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KEY WORDS: urban, land use/land cover, Land Change Modeling, Landsat

ABSTRACT: The research on urban growth and Land Use/Land Cover modeling has been carried out for Semarang Metropolitan Area. The objectives of the research were to study the historical growth and to understand the future Land Use/Land Cover in Semarang. Urban/non-urban area from Landsat satellite images and existing generalized Land Use/Land Cover Map of Semarang were used as the input for Land Use/Land Cover prediction using Land Change Modeler (LCM). The results show a significant increase in the built up area from 15.6% in 1999 to 44% in 2014. The period from 2007-2009 observed the highest growth of 8% (compared to only 1.9% from 1999- 2007). The results also show significant increase of built-up area in the distance 5 - 10 kilometers from the city center after 2009. The LCM predicts that in 2020, there will be an increase of 2,187 hectares of built-up area, which will cover 56% of Semarang city

1. INTRODUCTION

Urban areas can be characterized by physical traits and organization of the Earth's land cover: urban regions are places dominated by the built-up environment. The 'built environment' incorporates all non-vegetative, human-developed components, for example, streets, structures, runways, and so on (i.e. human-made surfaces), and "dominated" infers scope more prominent than half of a given scene unit (the pixel). Whenever vegetation (e.g., a park) dominates a pixel, these territories are not viewed as urban, despite the fact that regarding land use, they may work as urban space (Schneider, 2009).

As a country turns out to be progressively urbanized, understanding how urban regions are changing inside the landscape becomes increasingly important. Urban expansion is a temporal dynamic process which causes a number of major biological and natural issues in urban territories and the encompassing districts. It is imperative to comprehend the procedure of urban development and its driving components for urban growth planning and administration. The data is helpful to moderate the unfriendly effects of such development (Li et al. 2012). Urbanized areas are often the strongest indicators of human interaction with the environment, and understanding how urban areas develop through remotely detected information takes into account for more sustainable practices (Patel et al. 2014)

In urban analysis, there are extensive contrasts between the development that is arranged by a city government and the actual growth that happen on the ground in many cities in developing world. Monitoring and understanding those patterns is critical for understanding how to make proper action on them. Satellite remote sensing offers a reliable source of information about urban growth and sprawl processes because of its temporal and spatial characteristics

(Doll, 2008; Rashed et al. 2005). Remote sensing is used to gather information from distant objects by measuring the radiation that they reflect or emit. Remote sensing can play an important role in policy assessment related to urban growth, population dynamics and environmental issues within cities (Bhatta, Saraswati, & Bandyopadhyay, 2010a; Miller & Small, 2003).

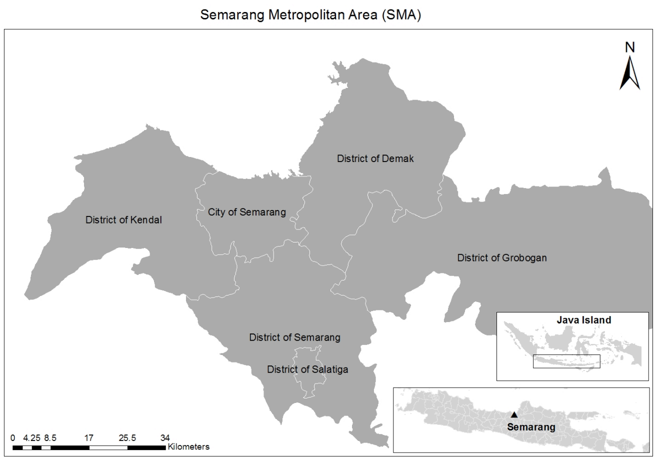
Remote sensing is widely known among urban planners, city planners and policy makers as a useful tool for extracting biophysical information about the urban environment, including land-cover and land-use mapping, urban growth, urban morphology description and analysis, vegetation distribution and characterization, hydrography and disaster relief. Urban growth trends can be detected easily using medium spatial resolution satellite images, such as SPOT and Landsat TM, taking advantage of the very different spectral properties of urban manmade structures versus rural spaces.

Miller and Small (2003) reviewed the potential applications of remote sensing in urban environmental research and policy. They showed that remotely sensed data could be used to obtain internally consistent measurements of physical properties at a lower cost than that of in situ measurements. The use of remote sensing data is usually more suitable for measuring and monitoring urban environmental conditions than for urban planning purposes because in the latter case, governmental and private sector data are more easily obtained.

The use of remote sensing and GIS analysis in urban related researches have been carried out in Indonesia since early 2000. In Semarang, these techniques only recently being used to understand the environmental and socio-economic conditions of Semarang urban (Widyasamratri et al. (2013), urban growth and its relation to population (Handayani and Rudiarto, 2014). These researches used remote sensing mainly to extract the information on land use/land cover (urban/non-urban) in Semarang. There was a lack of research in GIS modeling to predict the urban growth in Semarang. Urban growth modeling benefits the city government to make a better planning by considering several alternatives. This was the reason why the research was carried out. The aim of the research was to implement remote sensing, GIS and modeling technique to analyze urban expansion in Semarang. The objectives of the research were: (1) to explore the temporal and spatial characteristic of urban expansion in Semarang in last 20 years, (2) to analyze the main drivers for urban growth in Semarang and (3) to simulate the future land use cover change and urban growth pattern.

2. Description of the study area

Semarang city is the sixth most populated city in Indonesia with a population of 1.55 million as per the 2010 census. It is the only city in the province of Central Java that can be categorized as a metropolitan center. The city is an international seaport and serves as a transit node between the two main growth poles of Indonesia, Jakarta and Surabaya.



3. Data

Landsat TM (satellite imagery) was used to create urban/non- urban maps of 1999. Urban/non-urban maps of 2011 and 2014 were derived from merged class of Land Use and Cover Maps of 2011 (BAPPEDA Semarang) and 2014 (UNDIP - Univ. of Queensland).

Eleven maps as driver variables were successfully used as inputs to Land Change Modeler i.e. road access, urban access, land disturbance, port access, Digital Elevation Model (DEM), water access, terminal access, industry access, train access, slope and airport access.

3. METHODS

3.1 Urban growth

Although Jensen and Cowen (1999) stated that the most important requirement for properly identifying urban socio-economic attributes using satellite remote sensing is the spatial resolution, several works have used satellite remote sensing at a medium resolution, such as Landsat MSS, TM and ETM+ imagery, to explore the relationships between land cover and socio-economic data (Emmanuel, 1997; Forster, 1983; Jenerette et al., 2007; Mennis, 2006). Landsat imagery is available dating back to the 1970s which is very well suited to study and to monitor urban changes and growth trends (Pham, Yamaguchi, & Bui, 2011; Rashed et al., 2005; Sabet, Ibrahim, & Kanaroglou, 2011; Van de Voorde, Jacquet, & Canters, 2011; Weng, 2012).

Landsat and ASTER images have been tested in research on relationships between urban land-cover and socio-economic data and their changes over a time span of decades in several cities in the US (Emmanuel, 1997; Jenerette et al., 2007; Mennis, 2006; Mennis & Liu, 2005; Rajasekar & Weng, 2009). Emmanuel (1997) found a significant and positive relationship between increases in urban vegetation measured from Landsat images from 1975 and 1992 and demographic factors associated with urban decay in Detroit, Michigan.

Madhavan, Kubo, Kurisaki, and Sivakumar (2001) used Landsat TM images to measure and analyse the spatial growth of the Bangkok metropolitan area of Thailand. Their approach was based on an image classification scheme and the VIS model (Gluch & Ridd, 2010, chap. 6; Ridd, 1995). Urban land-use/land-cover maps for 1988 and 1994 were produced from the classification processes, and changes in each of the urban land classes were measured with traditional post-classification methods. The VIS model was used in a later stage to visualise the trends of those changes in terms of the changes in vegetation, impervious surface and soil fractions and their trajectories for selected sites between the two dates. An analysis of these outputs led the researchers to conclude that the observed change in land-use led to improper urban land development in some areas of the city. Weng and Lu (2006, chap. 4) applied the same concept to characterise urban landscape patterns and to quantify spatial and temporal changes in urban land-scape compositions in Indianapolis, Indiana.

Based on the previous researches, Landsat imageries were used to understand the urban growth in Semarang City. Landsat TM/ETM imageries from 1999, 2007, 2009 and 2014 with lowest cloud cover were selected for the study. Normalized Built-Up Area Index (NBAI) (Equation 1) was used to extract information on built-up areas for each image (Waqir et al. 2012). Built-up areas assumed to have higher reflectance in Far Infra Red (TM7) than the ratio of Middle Infra-Red (MIR) and Green Channel (TM2).

$$NBAI = (TM7 - TM5/TM2) / (TM7 + TM5/TM2) \qquad \text{(Equation 1)}$$

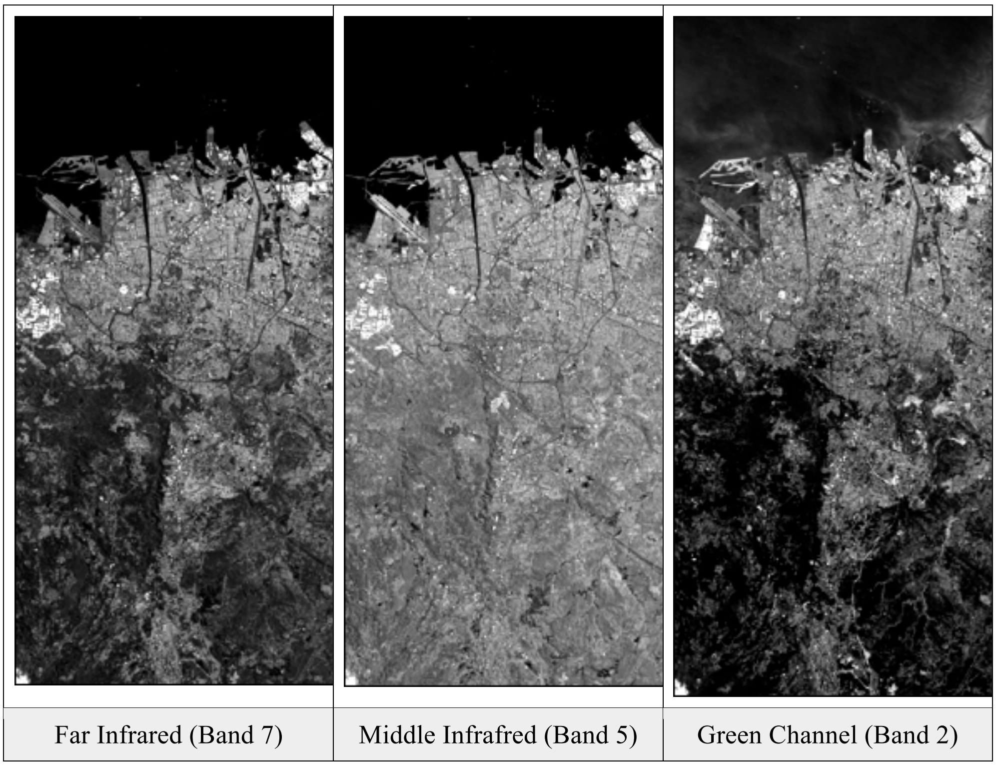


Figure 1. Band 7, 5 and 2 of Landsat TM/ETM to extract urban areas

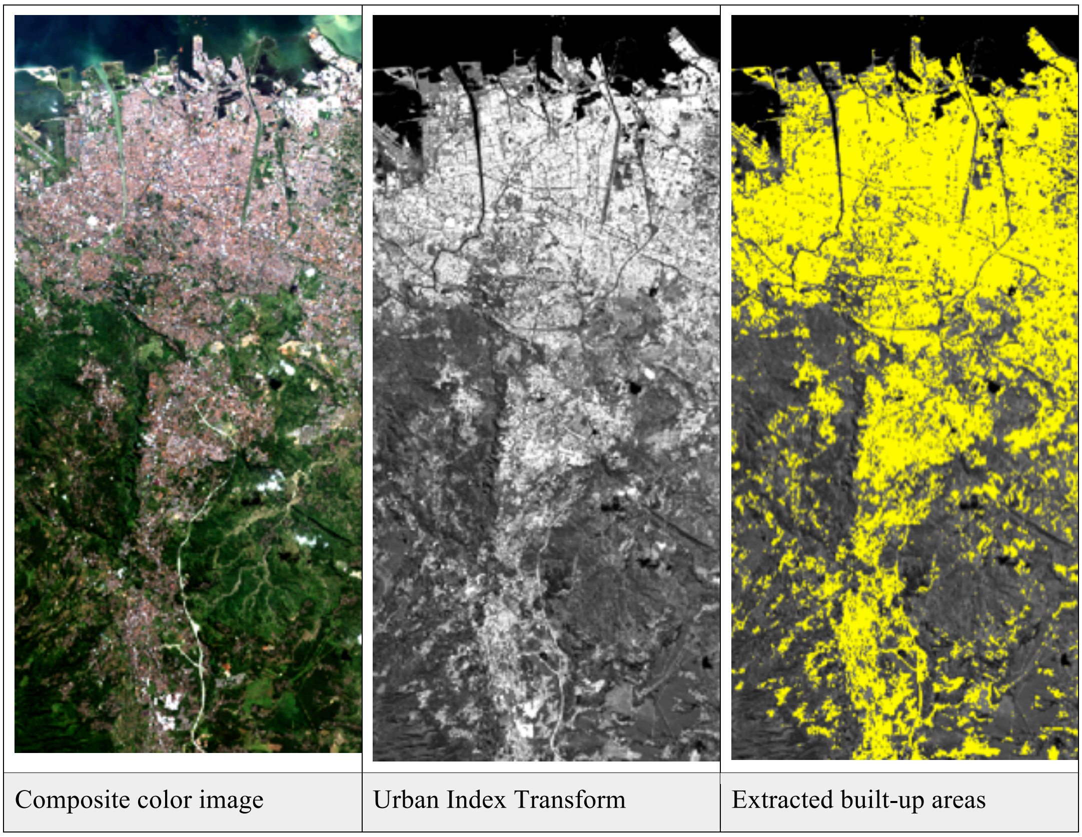
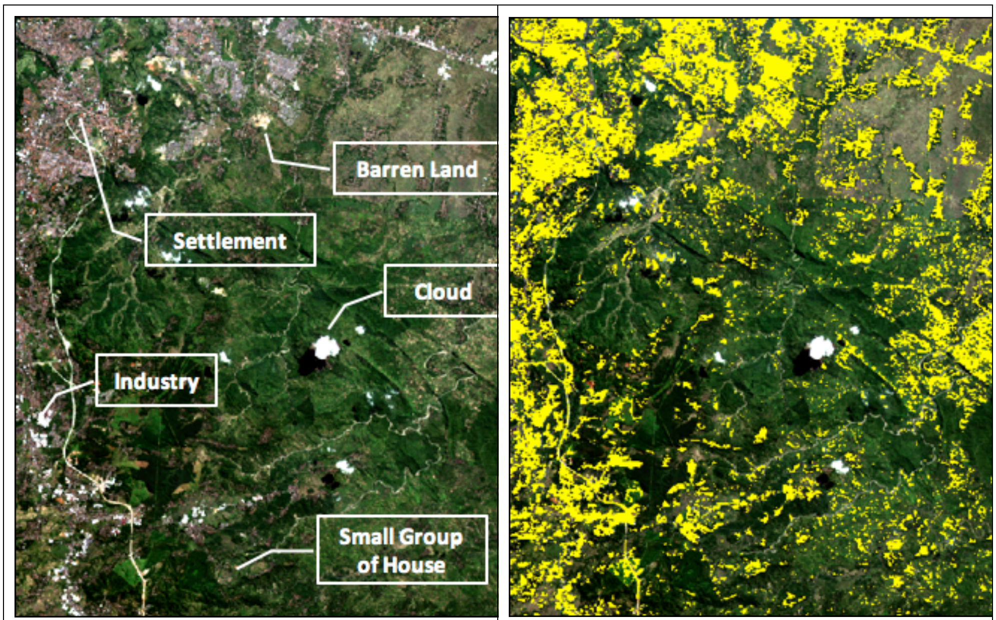


Figure 2. Comparison between composite color image, greyscale image after Urban Index Transformation and extracted built-up areas



Composite colour image	Extracted urban areas (yellow)

Figure 3. Comparison of extracted built-up areas with existing objects

WorldView 2, 2014	Extracted built-up area

Figure 4. Comparison of extracted built-up areas with high resolution image

Landsat images of 1999, 2007, 2009 and 2014 were used to analyze the historical urban growth in Semarang City. Landsat images are freely available and images with minimum cloud cover were selected for the study. Urban areas assumed to have higher reflectance in middle infra red (IR) than in near infra red (NIR) and the normalized difference built-up index (NDBI) uses these two bands to extract urban areas (Waqir et al. 2012).

Band 4 (NIR) and Band 5 (MIR) of Landsat images or Band 5 and Band 6 of Landsat 8 (2014) were used to estimate the NDBI. Urban areas were then extracted from the NDBI image using the unsupervised classification technique. To compare the result after the classification of Landsat 2014, a high resolution image acquired in 2014 by the WorldView 2 satellite was used.

3.2 Land Use/Land Cover Prediction

Land Change Modeler (LCM) was selected as a tool to predict the Land Use/Cover of Semarang city in 2020. LCM is an inductive pattern-based approach model with the procedure steps as follow:

1. Identifying the dominant transitions from past land use change and link to driver variables of change.
2. Extract the relationship between land use change transitions and driver variables using Multi-Layer Perceptron (MLP).
3. Extrapolate the relationship to create a map for each transition - a map that predicts a time specific potential for change in the future.

4. RESULTS

4.1 Urban Growth

The results show a significant increase in the built up area from 15.6 % in 1999 to 44 % in 2014. The period from 2007-2009 observed the highest growth of 8 % as compared to the rate of change of only 1.9 % from 1999- 2007. The most like cause of the built up area expansion was inward migration to Semarang (Wilonoyudho 2010).

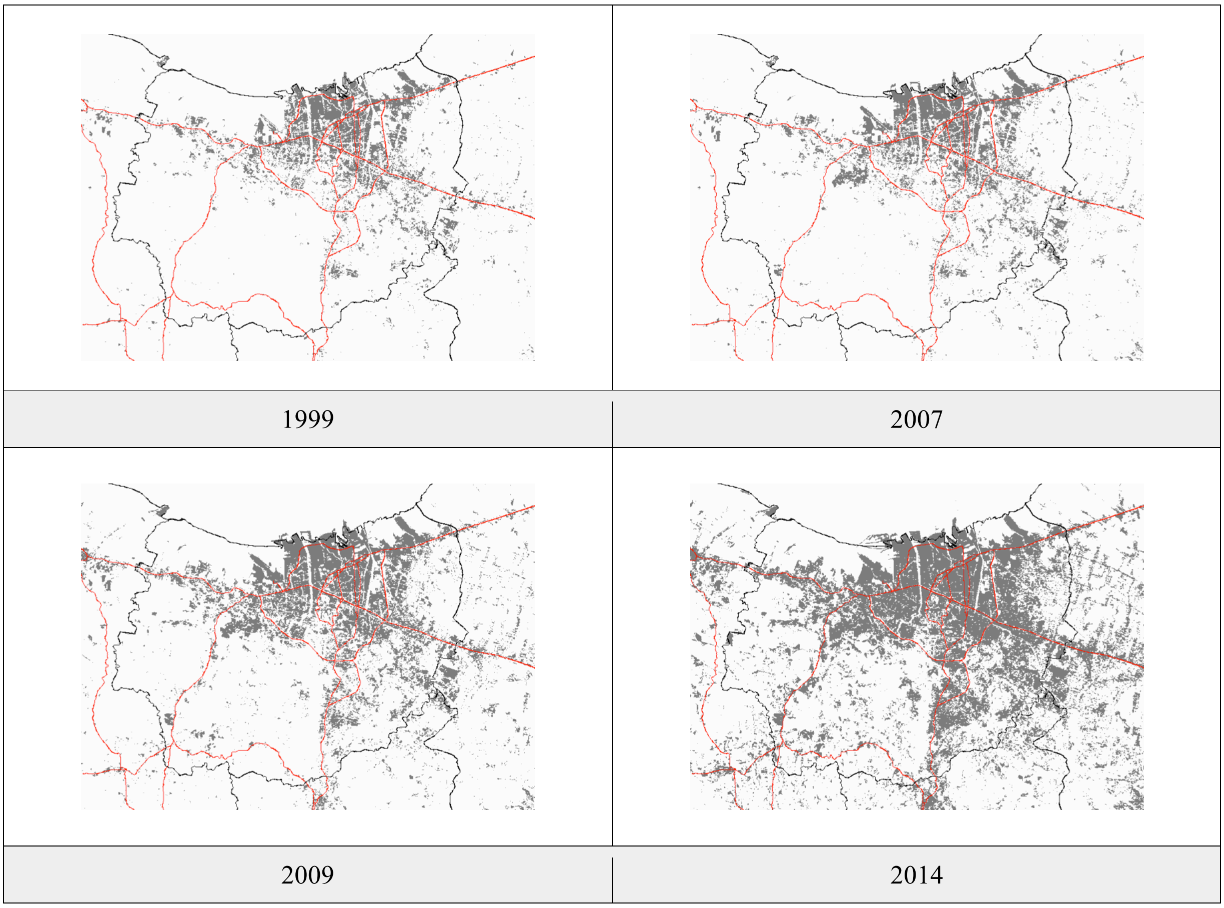


Figure 5. Extracted urban area from Landsat in Semarang

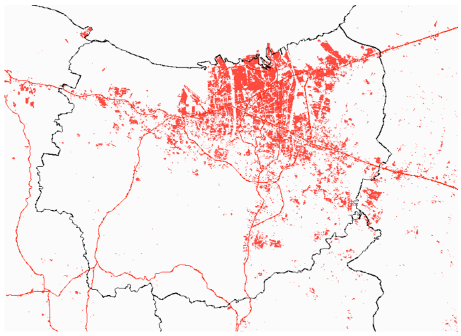
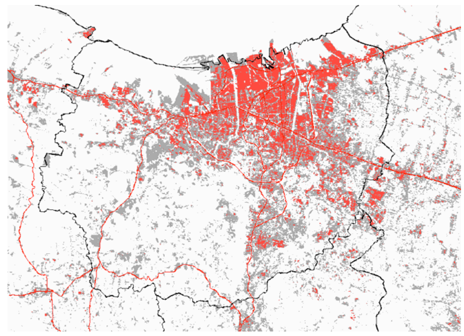
	
Built-up areas in 1999 (red)	Built-up areas in 1999 (red) and 2014 (grey)

Figure 6. Urban growth in Semarang from 1999 to 2014

Until 2009, the highest proportion of built up area was found within the 5km distance from the city center and the proportion of built up area decreased steadily with the distance from the city center. In 2014, as shown in Figure 7, the highest proportion of built up area was within the 5 - 10 km band (from the city center). This result indicates that the city is growing further to outside. One of the reason was the development of settlements in eastern part of Semarang.

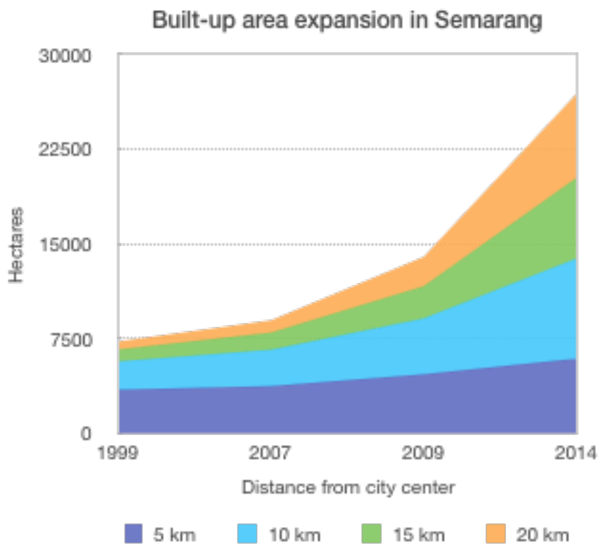


Figure 7. Built-up area expansion in Semarang from city center

4.4 Land Use/Land Cover Prediction

Calibration

Twelve driving factors for urban growth were tested first in LCM using Cramer's Coefficient before being selected as variables in the LULC model- ing. The test indicates the degree to which explanatory variable is associated with the distribution of Land Use/Cover categories. It will be selected if con- tribute significantly to the explanation of the spatial distribution of the land cover of interest (Perez-Vega et al., 2012). In general, variables that have a Cramer's Coefficient about 0.15 or higher are useful while those with values of 0.4 or higher are good (Eastman, 2015). Figure 8 shows Crammer's V coefficients for 12 drivers indicating their contribution.

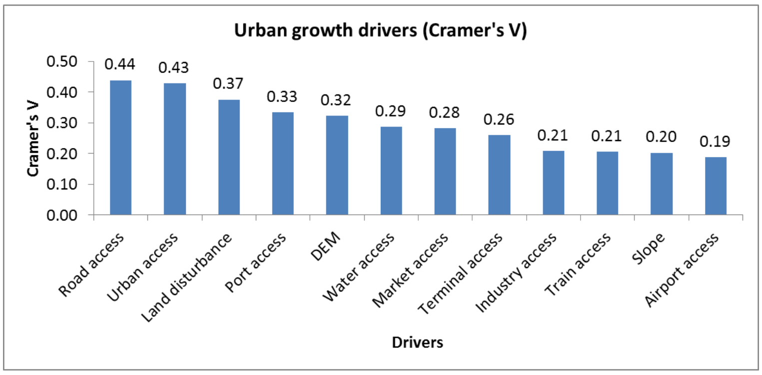


Figure 8. Cramer's V coefficients for 12 urban growth drivers

Validation

Validation is the process of determining the degree to which a simulation model and its associated data are an accurate representation of the real world. Validation was carried out by examining and comparing the spatial similarity between the reference map (2014) and the simulated map (2014) of urban/non-urban areas at different scales.

The degree of spatial similarity between the maps is presented in Figure 9, which shows the predictive power of the model at varying spatial scales. The model has produced more than 86% similar spatial patterns at the pixel level. Overall, spatial similarity improves with the increasing window size meaning that the model can predict spatial patterns more accurately at a coarser spatial resolution (12.5 meters).

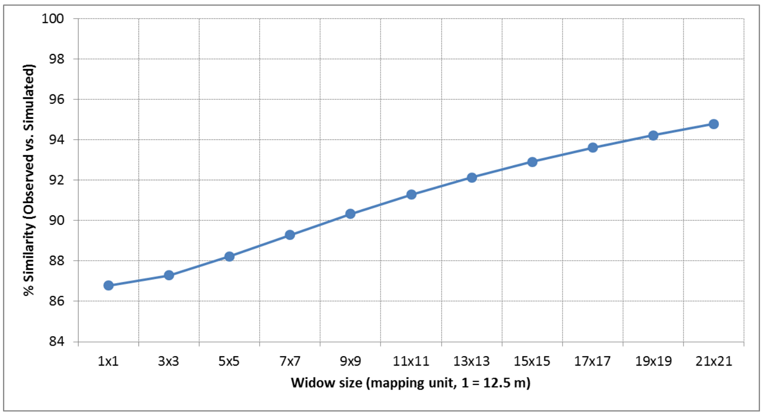


Figure 9. Validation graphic between simulated maps and reference map

Simulation of Land Use/Land Cover for 2020

Figure 10 shows the landuse cover map of Semarang city for 2014. The built up area is the most dominant class in and in 2014 the city had a built up area of 19,189 ha which is approximately 50 % of the total area of the city.

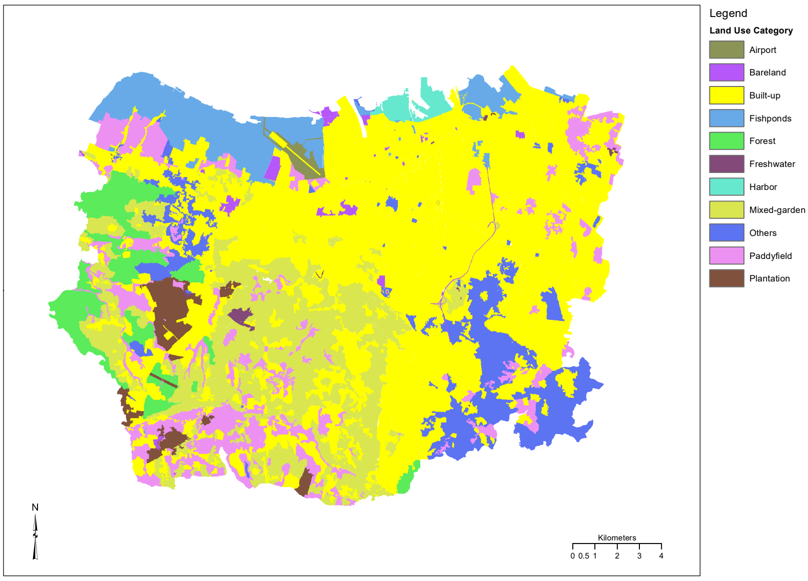


Figure 10. Land Use/Land Cover Map of Semarang in 2014

Figure 11 shows the simulated landuse cover map of Semarang city for 2020 and by then approximately 56% of city will be covered by the built up area with a total area of 21,456 ha. This figure will be 2,187 hectares more than that of 2014. The new urban areas would mostly develop in the east, south- east and south-west of the city. The east side of the city will be completely urbanized by 2020 except for a few patches of forests due to restrictions.

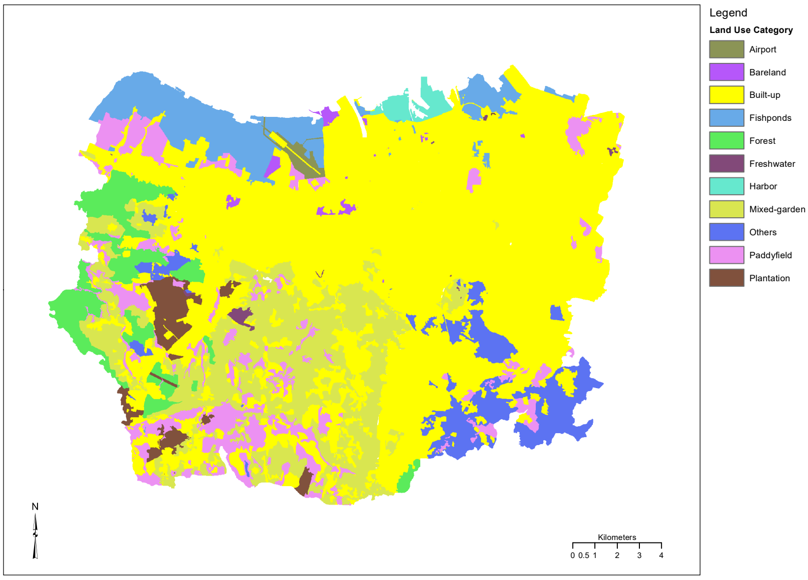


Figure 11. Simulated Land Use/Land Cover Map of Semarang in 2020

The urbanization is expected to happen at the cost of bare land, paddy fields and other croplands. From 2011 to 2020 bare land would decrease from 1.09% to 0.44%, paddy fields from 8.74% to 7.84% and other croplands from 9.09% to 5.45%. The main reason for the conversion is due to high demand for land and it would be easy to convert them due to fewer or no restrictions. These land use types facilitate urbanization as these classes have more potential to change to urban areas. For example, it can be observed that the amount of bare land is continuously decreasing with the increase of built up areas.

5. CONCLUSIONS

- Normalized Difference Building Index (NDBI) transformation using Landsat image can be used to extract built-up areas.
- The urban area of Semarang City growth to the fringe area to the east, south-east and south-west due to the rapid development of housing estates and education.
- Land Change Modeler (LCM) can be used as a tool by the City Govern- ment to estimate the future land cover condition, which will help them to create better planning.

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