Spatial modelling of land use/cover change (LUCC) in South Tangerang City, Banten

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Abstract. Urban expansion in peri-urban region remains a major issue for regional planning and development, as it converts most of the land cover into built-up settlements rapidly and extensively beyond its spatial allocation plan (RTRW). South Tangerang City is one of the municipalities in Jabodetabek with the most rapid annual population growth rate reached 6.87%. LUCC analysis from three LANDSAT land cover maps (1990, 2002, and 2014) shows that the built-up area has increased 8 times (8650 ha) in 1990-2014 with the average annual growth rate of 10.83% per sub-district (kelurahan). The most extensive land conversion type in 1990-2002 was vegetated land to open land (3605ha), while in 2002-2014 land conversion type was dominated by open land to built-up (3446ha). In general, the built-up area expansion in 1990-2002 shows irregular ribbon development pattern in district Serpong Utara, Pondok Aren, Ciputat Timur, Ciputat, and Pamulang, while district Serpong tends to represent leap frog development pattern. The expansion in 2002-2014 shows infill and ribbon development pattern continuation across the city. MLP was used to model LUCC sensitivity prediction. The model performance shows 73.16% accuracy with ROC validation of prediction output reaches 0.804 for 2014, which is qualified to predict LUCC sensitivity in 2032.

1. Introduction
South Tangerang City as a proliferated municipality from Tangerang Regency in 2008 can serve as an example of urban expansion phenomenon, which has been particularly triggered by peri-urbanization and regional agglomeration between Jabodetabek Metropolitan Region and Bandung Metropolitan Region to form a larger mega urban region called Jakarta-Bandung Region (JBR). According to Firman and Dharmapati [1] and Firman [2], the development of JBR has been significantly affected by large scale land development projects of private new towns and industrial centers that are connected by inter-region highway (toll roads) infrastructure network. These major transportation corridors have stretched even further from the western part of Banten Province (Merak) to the eastern part of Bandung Regency (Cileunyi) and northern coast of Java regencies (i.e., Paliman-Kanci, Cirebon Regency) as part of Trans Java toll roads development mega project. KEMENPUPR [3] statistics showed that there are already 544.58 km total lengths of active connected toll roads network.
that link Jabodetabek region to its surrounding outer suburbs. The JBR agglomeration has also been intensified with the construction of a 142 km long high speed railway line connecting the two regions [4]. The project is considered to cause a significant amount of land conversion not only for its infrastructure, but also for the urban settlements, new towns and other property sectors that will be attracted in along with the new railway as similar to induced ribbon development along the toll roads in Bodetabek regions. One of the studies that found this effect of main roads on urban expansion in Jabodetabek was conducted by Nagasawa and Fukushima [5], who statistically analyzed land cover category along main roads using multiple ring-buffer distance parameters.

The rapid and extensive growth of urban expansion in JBR have converted most of primary agricultural land, vegetated land (forest, plantation), dry land, and green open space into built-up areas as an environment and development trade-off. Studies on environmental and socioeconomic impacts of land conversion or land use/cover change (LUCC), its driving force factors and policy related subjects in JBR have generally evolved since 1990’s. Firman and Dharmapatni [1] has reported the negative impact of land conversion on water resources (surface and ground water), air quality, and to some extent on soil erosion. Pravitasari et al. [6] and Rustiaidi et al. [7] have analyzed the increasing of environmental degradation and anthropogenic disasters such as flood and landslides in the Jabodetabek region in terms of quantity, intensity and distribution. In addition, Firman [2, 8-11] have continually studied and updated the process and implications of land conversion for urban and regional development; the domestic and foreign direct investment driving factor; the speculative land-business behavior of large private developers; the excessive government land development permits; the social segregation and inequality; and the regional disparity and privatization phenomena as indirect impacts of rural to urban conversion in the fringe of large cities, especially in JBR. These broad perspectives of studies have brought us to believe that land conversion / LUCC related topics continue to be prominent issues in response to solve the future challenges on environmental sustainability, food security, and socio-economic stability in urban planning and development.

In general, the Jabodetabek built-up area has increased 31 times (± 195,000 ha) in 1972-2012. Forest area was falling significantly with approximately 71 % or 152,000 ha; and the dry land has also reduced by 31 % or 71,000 ha during the same period [7]. In another LUCC study with different temporal high resolution satellite images by Nagasawa and Fukushima [5], the expansion of urban built-up area in Jabodetabek has increased by 11% (35,000 ha) in the 20 years between 1989 and 2009. In contrast, the vegetated area has decreased by approximately 12% through the period. Nagasawa and Fukushima [5] study also shows that the most significant land conversion pattern of urban built-up area in Bodetabek region occurred in Tangerang Regency, which is the parent region of South Tangerang before proliferation in 2008. The expansion of the urban built-up area in this city in 1989, 2001, and 2009 have respectively reached ≈ 7,000 ha, 11,000 ha, and 17,000 ha exceeding other municipalities and regencies in Bodetabek region.

South Tangerang has become one of municipalities in Jabodetabek with the most rapid annual population growth rate reached 6.87%. Based on land use map of 2011 in South Tangerang spatial planning documents (RTRW 2011-2031), this city has been dominated by settlement land use type as large as 9.095 ha (61,79% of the total area). This number exceeds the allocation area of housing (horizontal and vertical housing) in RTRW, that is only as large as 7.610,67 ha.

Spatial studies on urban expansion that utilize GIS (Geographic Information Systems) and remote sensing technology have been summarized by Bhatta [12], including the use of LUCC modelling with transition matrices, spatial metrics, and spatial statistics. These approaches now are not only capable to measure, analyze, and map the spatial pattern of LUCC, but also to model the relationship between LUCC and its driving factors. The model can then be used to simulate / predict the future LUCC by the inductive pattern-based approach that utilizes the transitional spatial pattern of the observed LUCC; by the deductive theory / expert knowledge-based approach that relies on the explicit descriptions of the process; by the emulation of individual decision makers / agent-based behavior; or by the hybrid combinations approach [13][14]. The spatial modelling of LUCC in this study belongs to inductive pattern-based approach that employs one of the machine learning algorithms (i.e., Artificial
Neural Network) called Multi Layer Perceptron (MLP) in LCM (Land Change Modeler) IDRISI platform. According to Eastman [15], MLP as a non-parametric statistic has the ability to model various forms of relationship between dependent and independent variables that are linear or complex non-linear without considering any form of data distribution (distribution free).

In general, the LUCC spatial modelling objectives are: 1). to measure the LUCC and explain its dynamics; 2). to identify the spatial pattern of LUCC and urban expansion rate; 3). to model the spatial relationship between LUCC and its driving factors; and 4). to predict the LUCC sensitivity in the future.

2. The LUCC Dynamics in South Tangerang

The first stage of LUCC modelling in LCM IDRISI is change analysis or change detection stage using post-classification comparison method [12]. In post-classification comparison, each date of rectified imagery is independently classified to fit a common land type schema. LCM requires equal number and type of land-cover classes in an exact order for comparing the land cover maps. This study uses 3 satellite images including the following: Landsat 5 TM (1990), Landsat 7 ETM (2002), and Landsat 8 (2014) derived from USGS (United States Geological Survey) at coordinate path 122 and row 64. All of the images were classified using combination techniques between NDVI (Normalized Difference Vegetation Index) and manual editing with the help of Google Earth high resolution images and ground truth survey to correct the NDVI classification errors in ArcMap. These techniques have divided land cover into 4 classes: 1). Built-up area; 2). Vegetated area; 3). Open / bare area; and 4). Water body (rivers and lakes). The resulting land cover maps are then overlaid and compared on a pixel-by-pixel basis in Change Analysis Tab in LCM.

The LUCC analysis in this study has been divided into two periods: 1990-2002 (LUCC I), and 2002-2014 (LUCC II). This division is designed not only to match LCM validation scheme recommended by Eastman [15], but also to understand the dynamics and the spatial process of LUCC in South Tangerang across all of the periods. The figure 1 and 2 below are the result of the first stage containing LUCC quantitative graphics (i.e., gains and losses, net change, and contributors to net change).

![Figure 1. Change analysis quantitative graphics output of LUCC I (1990-2002) (ha)](image)

The result of the overall LUCC analyses in 1990-2014 show that vegetated area is the most extensively converted land cover type with 56.01% of the total area reduction. In contrast, the built-up area is the most developed land cover type with 52.28% of the total area increase. In general, the expansion of the built-up area in South Tangerang between 1990 and 2014 has reached 8 times (8650 ha). According to Figure 1, the most extensive land conversion type in 1990-2002 was vegetated area to open area (3605 ha), followed by vegetated area to built-up area (1667 ha); while the land conversion type in 2002-2014 (Figure 2) was dominated by open area to built-up area (3446 ha), followed by vegetated area to built-up area (2176 ha). The water body in this study was classified to be constant since it is a protected area with insignificant area change that cannot be detected by Landsat spatial resolution.
The alteration of the dominant land conversion type between 1990-2002 and 2002-2014 has explained the spatial process dynamics of South Tangerang LUCC that are linearly related to the large scale land acquisition and subdivision projects to develop new towns and their supporting infrastructure in Jabodetabek region at the property boom bust period during mid-1980s until the economic crisis in 1997. There are many open / bare areas (i.e., ready to build areas) acquired by private developers that were left opened and undeveloped since the economic crisis collapsed the property sector. This condition was supported by Winarso and Firman [16] and Firman [8] studies that have noted the increase of urban land demand; the excessive land development and property sector projects that had been part of triggering economic crisis; and the expansive land conversion during the boom bust periods in Jabodetabek regencies and municipalities. It is particularly interesting to note that the amount of infertile (idle) land in the area increased by 1600 %, which partly indicated the increasing abandonment of land to speculation, acquisition and subdivision projects by the private developers. The disproportion between the proposed area of land development permits (i.e., location permits) and the actual realization of land development and housing production has promoted the increase of the unutilized open areas that were inefficient. At the mid-1980s to 1995, BPN had issued 345 land development permits as large as 81,200 ha, with the annual average reached 8000 ha/year, but then only 2/5 of the total area in the permits that were actually developed in Bodetabek region, where the remaining portion had become idle / unutilized land [8].

In the case study of South Tangerang, Winarso [17] has compiled 60 land development projects for new town in Tangerang Regency and municipality since 1980’s, where 24 of them were developed in South Tangerang. There are 3 largest new town projects in South Tangerang, including the following: BSD City (6000 ha) in Serpong and Setu District; Bintaro Jaya (2300 ha) in Pondok Aren District; and Alam Sutera (700 ha) in Serpong Utara District. These new self sustained towns have attracted migrants from inside and outside Jabodetabek region [18], and become pull factors for other commercial, industrial, property, and service sectors to thrive around the regions. The districts within the new towns together with densely populated district in Ciputat Timur, Ciputat, and Pamulang have shaped Cipasera region as the origins of South Tangerang municipality.

The dominant land conversion type in 2002-2014 is largely attributed to the spatial process resumption of land development projects for property sector that had been halted for several years due to prolonged monetary crisis in 1997. The pattern of urban built-up area development in 2002-2014 tends to utilize the available open areas / idle areas that had been acquired by developer groups over the previous years. According to BSD [19] annual report from Sinar Mas Land developer group, the undeveloped land in BSD City new town at the end of 2015 have reached 2307 ha from the total areas (6000 ha) that have been acquired by the company since 1984. This kind of extensive oligopolistic land tenure is certainly contradictory to KEMENATR [20] regulation number 5/2015 that regulates the maximum area limit of the land tenure location permits hold by a residential developer company (i.e., 400 ha for 1 province and 4000 ha for the whole of Indonesia).
3. The Spatial Pattern of LUCC and Urban Expansion Rate

The spatial distribution mapping of each LUCC resulted from the first section will be the second stage of LUCC modelling. The change maps panel in Change Analysis Tab in LCM IDRISI is able to create different kind of maps, including the following: changes map; persistence map; gains and losses map; and transitions or exchanges map. However, this section will focus on the spatial trend of change panel (i.e., the last panel in Change Analysis Tab) to directly identify the actual spatial pattern of each dominant land conversion that has taken place in South Tangerang in 1990-2002 and 2002-2014. This panel works by the principle of polynomial order to generalize the spatial pattern / trend of LUCC between the two land cover maps. According to Eastman [15], the spatial trend of change panel in LCM is developed based on Trend Surface Analysis (TSA) as in the TREND module in IDRISI. This panel calculates 1 to 9 order trend surface polynomial equations for spatial data sets, and interpolates surfaces based on those equations. The generic equation for the polynomials fitted by TREND is:

$$Z = \sum_{i=0}^{k} \sum_{j=0}^{i} b_{ij}x^i y^j$$

(1)

In this equation, $k$ is the maximum order to be fitted; $b$ is a coefficient of the polynomial equation; both $i$ and $j$ are iteration variables associated to $k$, in which $i = 0, \ldots k$ and $j = 0, \ldots i$. For example, to fit a cubic trend $k = 3$, the equation is:

$$Z = b_{00} + b_{10}x + b_{11}y + b_{20}x^2 + b_{21}xy + b_{22}y^2 + b_{30}x^3 + b_{31}x^2y + b_{32}xy^2 + b_{33}y^3$$

(2)

The outputs of spatial trend of change panel in Figure 3, 4, and 5 are raster surface maps with numeric values that do not have any special significance nor measurement unit, other than to provide an indication of where the change was more intense (higher numbers) or less intense (lower numbers).

![Figure 3. Spatial trend of vegetation to open area change in 1990-2002 (9th order trend).](image)

![Figure 4. Spatial trend to built-up area change in 1990-2002 (9th order trend).](image)

The mapping result in Figure 3 identifies the spatial trend of vegetation to open area change as the most extensive land conversion type in 1990-2002. The spatial trend pattern in Figure 3 also implies the locations of land acquisition, land clearing, and land subdivision with moderate to high intensity prior to the built-up area construction in all districts. The highest intensity of this transition occurred in Pondok Aren District (Jurang Mangu Barat, Pondok Jaya, and Pondok Pucung Sub-district); Ciputat District (Sawah Lama and Sawah Baru Sub-district), and Ciputat Timur District (Pondok Ranji Sub-district). The transition intensity in these regions showed radial / concentric spatial pattern that were centered in Pondok Jaya Sub-district, Pondok Aren District. This spatial concentration is matched to the actual condition of the land development performed by developer company (PT. Jaya Real Property) in preparing Bintaro Jaya New Town (sector 1 to 9) as large as ± 2300 ha since 1979. The developer has also designed the development of Bintaro X Change Mall CBD (Central Business District) Superblock.
in part of Pondok Jaya Sub-district that was opened in 2013. The development of Bintaro CBD as one of economic strategic area in South Tangerang has been supported by the construction of JORR (Jakarta Outer Ring Road) network progressively since 1990s together with the commuter line railway network and stations that connect BSD City – Bintaro Jaya – Jakarta City.

The transition to open area in Setu District (Muncul, Kademangan, Setu, Babakan, and Bhakti Jaya Sub-district), the western part of Pamulang District (Pondok Benda and Pamulang Barat Sub-district) and the southern part of Serpong District (Serpong and Buaran Sub-district) have been influenced by the development of Taman Tekno Industrial Park in BSD City and PUSPIPTEK (Center for Research, Science and Technology) that were also induce the housing development for the workers in the surrounding area. PUSPIPTEK have been developed since 1976 with total investment of more than 500 million USD and covering 460 ha total area that contains 47 research, development and testing centers under non-ministerial government institutions, including LIPI, BPPT and BATAN [21]. The spatial trend concentration of vegetated area to open area transition also occurred from Serpong Utara District (Pakujaya and Pondok Jagung Timur Sub-district) to the western part of Pondok Aren District (Pondok Kacang Sub-district) which is the area of Kebayoran Regency (Graha Raya) housing development as large as 400 ha. This housing area is also directly adjacent to Alam Sutera new town development in Serpong Utara District that has been developed and expanded now to more than 800 ha since 1990s. In the southeastern part of South Tangerang, the transition to open area intensity in Pondok Cabe Ilir Sub-district (Pamulang District) has been triggered by the opening of Pondok Cabe airport by Pertamina in 1972 which attracted the urban settlement development in its surroundings, including Pisangan and Cirendeu Sub-district (Ciputat Timur District). These districts are also crossed by the main street network connecting South Tangerang with adjacent municipalities (i.e., South Jakarta and Depok) which in turn become densely populated districts.

According to Figure 4, the spatial pattern of urban built-up area expansion in 1990-2002 has distributed irregularly with the spatial concentration trend in some districts including the following: Serpong Utara, Serpong, Pondok Aren, Ciputat Timur, Ciputat, and Pamulang. The urban built-up area expansion in those districts except for Serpong, tend to represent ribbon development pattern which is linear to the main street network and the distance to the nearest regional service centers, while the urban built-up area expansion in Serpong District tend to show leap frog development pattern that is relatively detached (isolated) from other adjacent regions. This leap frog development was largely influenced by the development of BSD City since 1980s that was designed to become new self sustained city and economic center with powerful infrastructure and numerous employment and urban service centers.

To explain the leap frog development pattern in BSD City, Winarso [17] has studied the residential land developer behavior in selecting land for the location of their residential projects including in South Tangerang. The result of his study found that the low-priced land was a stronger determinant of developers’ locational decisions than access to main roads. There is possibility of a higher profit margin if the development is located farther and isolated from Jakarta, where land prices are cheaper. Low priced land enables developers to achieve economies of scale. By acquiring low-cost land, developers were able to construct on-site major infrastructure and service facilities, including streets and roads, and even a toll road connecting their projects with Jakarta. With the construction of streets and roads developers boosted the land price and enjoyed not only the value added beyond costs to the land’s selling price due to the possibilities for urban use after the installation of basic infrastructure, but also the value gained beyond building and site service costs in the selling price of a house caused by the demand for urban housing with the amenities provided by these developers [17].

The urban expansion in Serpong Utara in 1990-2002 (Figure 4) has been primarily triggered by the development of Serpong Utara District in 1990-2002 (Figure 4) has been primarily triggered by the development of adjacent Tangerang municipality, Alam Sutera, BSD City and Gading Serpong New Town in Tangerang Regency since 1990s. While, the urban expansion in the eastern part of South Tangerang, Pondok Aren, Ciputat Timur, Ciputat and Pamulang District were largely influenced by South Jakarta City; the national housing project (Perumnas KPR BTN); and the government employees housing in the remaining districts.
The spatial pattern of built-up area expansion in 2002-2014 in Figure 5 has generally showed infill development pattern continuation across the city that utilizes the undeveloped open areas as well as intensifies the densification of the available built-up areas (i.e., vertical development). The ribbon development pattern of built-up area expansion have also still occurred in the intersection area, along the arterial and collector roads as well as JORR toll network that connect between the urban service centers. The development of JORR that built across Pondok Aren, Ciputat Timur, Ciputat and Serpong have played important roles in improving urban accessibility and accelerating the distribution of the built-up area expansion in regions around South Tangerang. Figure 5 shows the dense spatial concentrations in several districts comprising Serpong Utara (Pakualam, Pakujaya, Pakulonan, and Pondok Jagung Timur); Pondok Aren (Pondok Jaya, Pondok Aren, Jurang Mangu Barat, and Pondok Pucung); Ciputat (Serua Indah, Serua, Sawah Baru, Sawah Lama, and Jombang); Pamulang (Pondok Benda and Pamulang Barat); and Setu. The urban expansion in 2002-2014 has developed a government center strategic area located in Ciputat District and 3 economic strategic areas that serve as CBDs, including BSD City (Serpong), Living World Alam Sutera (Serpong Utara), and Bintaro Jaya Xchange (Pondok Aren).

This study also uses choropleth mapping technique in ArcMap to map the urban expansion rate aggregated over each sub-district by adding a new built-up area growth rate field; inputting its data into the attribute table of sub-district polygon; and classifying the quantities of the growth rate field based on natural breaks. Prior to the choropleth mapping, the analysis of built-up area growth rate were calculated based on exponential growth model with the assumption of large undeveloped potential areas acquired by developers and the fact that the growth rate of built-up area is still constantly increasing each year in South Tangerang. According to the urban expansion rate map of South Tangerang in 1990-2014 (Figure 6), Pondok Jaya (Pondok Aren), Babakan (Setu), Serua Indah (Ciputat), Parigi Baru (Pondok Aren), and Buaran (Serpong) are the top 5 sub-districts with the highest growth rate. While, Muncul (Setu), Pamulang Barat (Pamulang), Ciputat (Ciputat), Serua (Ciputat), and Rempoa (Ciputat Timur) are the top 5 sub-districts with the lowest growth rate. The annual growth rate average of each sub-district is 10.83%. To identify the spatial pattern of urban expansion rate objectively, this study employs Global Moran’s I Spatial Autocorrelation analysis in ArcMap’s spatial statistics toolbox. The Global Moran’s I is capable to measure whether the spatial pattern of the urban expansion rate is distributed at random, dispersed, or clustered pattern based on statistical significance test using z-score and p-value. The result concludes that the urban expansion rate in 1990-2014 is distributed in random spatial pattern since the statistical test showed insignificant result (i.e., Moran’s Index = 0.088; z-score = 1.32; p-value = 0.186).
4. The Multi Layer Perceptron (MLP) Modelling and The Prediction of LUCC Sensitivity

In order to predict sensitivity of LUCC in the future, the transition potential map of LUCC have to be created in LCM Transition Potential Tab. This study only used transitions to built-up area (i.e., vegetation to built-up area, and open area to built-up area transition) since the main concern of this study is the urban built-up area expansion. Hence, the actual final output of this study is the sensitivity prediction of built-up area transition from the urban expansion. There are 3 model options in Transition Potential Tab, including MLP, Sim Weight, and Logistic Regression. Eastman [15] recommends MLP because of its capability to run multiple transitions (up to 9) of each sub-model at once.

MLP as a non-parametric regression analysis also has both a dependent and independent (predictor) variables. The dependent variable used in MLP is all of the built-up area transitions in 1990-2002 and 2002-2014 that were reclassified into binomial classes (i.e., No change: Y=0; Change: Y=1). While, the independent variables are the driving factors of the urban expansion in South Tangerang including the following: 1). Population density (head/km²) per sub-district in 2003 and 2014 (X₁); 2). Agriculture household per district in 2003 and 2013 (X₂); 3). Number of IMB (built-up area construction permits) per sub-district in 2014-2015 (X₃); 4). Total value of domestic and foreign investment (PMDN-PMA) per sub-district in 2014 (X₄); 5). Number of companies based on SIUP and TDP per sub-district in 2014-2015 (X₅); 6). Number of vehicles per sub-district in 2015 (X₆); 7). Regional development (hierarchy) index value per sub-district in 2003 and 2014 (X₇); 8). Land value zone in 2014 (X₈); 9). Distance to built-up area in 1990 and 2002 (X₉); 10). Vegetated area in 1990 and 2002 (X₁₀); 11). Open area in 1990 and 2002 (X₁₁); 12). Water body area (X₁₂); and 13). Distance to road network (X₁₃).

This set of independent variables was chosen based on preliminary investigations over the case study as well as academic literature study. All of the variables in the model had to be converted to raster format at 30 m resolution and at equal spatial extend (columns and rows) in the same coordinate reference system. In accordance with Arsanjani [13], all of the independent variables used in MLP were already calibrated and refined individually with IDRISI logistic regression test to pick the optimal variable set that had to reach the highest ROC (Relative operating characteristic) statistics value (0,5-1). ROC = 1 indicates a perfect fit, while ROC = 0.5 indicates a random fit and values in between have a degree of membership. The logistic regression with the sampling rate applications (i.e., random or systematic sampling) of each independent variable was also functioned to reduce the impact of spatial dependency (spatial autocorrelation) between observations [15]. This study also employed correlation test between the independent variables in order to measure the linear relationship between each variable and to check for severe multi-collinearity prior to running the MLP transition model. Table 2 below is the result of MLP transition model with 13 independent variables combination.

| Model | Variables included | Accuracy (%) | Skill measure |
|-------|--------------------|--------------|---------------|
| With all variables | All variables | 73.16 | 0.6421 |
| Step 1: var.[4] constant | [1,2,3,5,6,7,8,9,10,11,12,13] | 73.23 | 0.6431 |
| Step 2: var.[4,12] constant | [1,2,3,5,6,7,8,9,10,11,13] | 73.23 | 0.6431 |
| Step 3: var.[4,12,3] constant | [1,2,3,5,6,7,8,9,10,11,13] | 72.97 | 0.6396 |
| Step 4: var.[4,12,3,6] constant | [1,2,3,5,6,7,8,9,10,11,13] | 72.61 | 0.6348 |
| Step 5: var.[4,12,3,6,5] constant | [1,2,3,5,6,7,8,9,10,11,13] | 72.20 | 0.6294 |
| Step 6: var.[4,12,3,6,5,2] constant | [1,2,3,5,6,7,8,9,10,11,13] | 71.76 | 0.6235 |
| Step 7: var.[4,12,3,6,5,2,13] constant | [1,2,3,5,6,7,8,9,10,11,13] | 71.44 | 0.6192 |
| Step 8: var.[4,12,3,6,5,2,13,7] constant | [1,2,3,5,6,7,8,9,10,11,13] | 70.07 | 0.6009 |
| Step 9: var.[4,12,3,6,5,2,13,7,10] constant | [1,2,3,5,6,7,8,9,10,11,13] | 68.89 | 0.5852 |
| Step 10: var.[4,12,3,6,5,2,13,7,10,1] constant | [1,2,3,5,6,7,8,9,10,11,13] | 66.49 | 0.5532 |
| Step 11: var.[4,12,3,6,5,2,13,7,10,1,8] constant | [1,2,3,5,6,7,8,9,10,11,13] | 62.78 | 0.5037 |
| Step 12: var.[4,12,3,6,5,2,13,7,10,1,8,9] constant | [1,2,3,5,6,7,8,9,10,11,13] | 49.94 | 0.3325 |
The backward stepwise MLP result in Table 1 was used to assess the best model combination of independent variables based on accuracy rate (%) and skill measure by consecutively eliminating the weakest independent variable one by one. The result in Table 1 and the rerunning MLP test prove that the 13 independent variable combination to be the best model combination with 73.16% of accuracy rate and 0.6421 of skill measure. MLP rerunning test with the elimination of variable 4 and 12 to confirm the higher accuracy rate of the two variables have proved to be imprecise and outperformed by the 13 independent variable result. This combination was then used to project sensitivity of urban built-up area expansion in 2014 and 2032 as shown in the Figure 7 and 8, by activating the create soft prediction option and running the model in the Change Allocation panel in LCM Change Prediction Tab.

Figure 7. The Prediction of Urban Built-up Area Expansion Sensitivity in 2014

Figure 8. The Prediction of Urban Built-up Area Expansion Sensitivity in 2032

The sensitivity prediction map in 2014 (Figure 7) were validated with the actual transition to built-up areas map in 2002-2014 as the reference image in ROC module to assess its prediction accuracy. The validation result showed a ROC value of 0.804 that was considered as a good accuracy (i.e., ROC = 1 as a perfect fit). Hence, the MLP model was qualified to predict the sensitivity of urban built-up area transition in 2032 as shown in Figure 8. A raster cell with the probability value close to 1 (dark red) is more vulnerable to built-up areas transition than one that close to 0 (white cream). Zero probability of a raster cell inside the boundary means that the raster cell were already developed an intense built-up area.

5. Conclusions

In general, the paper is part of thesis research project on the topic of LUCC, urban expansion, and urban sprawl phenomenon in South Tangerang as part of Jabodetabek Mega Urban Region. This paper serves as introductory research on providing general measurement and analysis by spatial simulation models to better understand the LUCC as a broad phenomenon and the urban expansion as a more specific issue.

The result findings in LUCC dynamics provide the basic information on how large the urban expansion during the Jabodetabek’s land development boom bust period to the post economic crisis affects the land cover and penetrates into South Tangerang interior region. The alteration of the dominant vegetated area to open area transition in 1990-2002 (LUCC I) and the open area to built-up area transition in 2002-2014 (LUCC II) have confirmed the dynamics of the excessive land development in the peri-urban regions of Jakarta especially in South Tangerang that were intensively studied by Winarso and Firman [16], Winarso [17], and Winarso et al. [18]. To account for the scale of urban expansion in South Tangerang, the change analysis in this study have found 8 times increase (8650 ha) of the built-up area in 1990-2014. The spatial pattern mapping of each LUCC have also confirmed the locations and the influences of large developer company’s new town and housing...
projects together with their infrastructures that progressively accelerated and intensified the whole urban development in South Tangerang. The developer preferences on constructing the new large residential projects and infrastructure in the farther and isolated peri-urban region to gain super-normal profit [17] were captured in the spatial trend of change maps.

The spatial trend of vegetation to open area change map (Figure 3) has showed the land acquisition, land clearing, and land subdivision of the large land development projects in 1990-2002 with moderate to high change intensity especially in Pondok Aren, Ciputat, and Ciputat Timur District. It showed radial/concentric spatial pattern that were centered in Pondok Jaya Sub-district as a CBD of Bintaro Jaya new town. The spatial trend to built-up area change map in Figure 4 has also showed the leap frog urban development pattern in 1990-2002 that occurred relatively in Serpong (BSD City) and the inner part of Pamulang District; and the irregular ribbon development patterns that were also found in Serpong Utara, Pondok Aren, Ciputat Timur, Ciputat, and Pamulang district. The spatial trend to built-up area change in 2002-2014 showed infill and ribbon development pattern continuation across the city. In this study, the aggregated urban expansion rate of each sub-district in 1990-2014 was also mapped and spatially analyzed by the Global Moran’s I Spatial Autocorrelation analysis to conclude the general spatial pattern of urban expansion rate in South Tangerang. The annual urban expansion rate average of each sub-district is 10.83% and the result of the Global Moran’s I showed a random / irregular spatial pattern.

The last result finding to conclude is the MLP LUCC model with 13 independent variables that showed the best model performance with 73.16% of accuracy rate and 0.6421 of skill measure. This MLP model combination then was used to produce the sensitivity prediction map in 2014. The output map then was validated with the actual built-up transition map to assess its accuracy by ROC statistics. The result showed a ROC value of 0.804 that was considered as a good accuracy and qualified to predict the future urban built-up area transition sensitivity map in 2032.

As mentioned above, all of the modelling stages in this study are meant to provide basic information to be elaborated and explored in the future researches. The sensitivity prediction of urban built-up areas map in 2032 can be aggregated into administrative units to draw attention and prioritization for supporting the regional plan, policy and decision making. The sensitivity map can also be overlaid with the existing spatial plan to evaluate its consistency. The single use of MLP model should be validated with other LUCC models to understand the model behavior and compare their advantages and disadvantages in understanding the LUCC and urban expansion phenomena. Our next research will cover the logistic regression as another model option in LCM. We will also compare these raster based models in LCM with exploratory OLS and GWR regression as vector based models to assess the model performance, the independent variables selection process, and the final prediction results.

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