Land use/cover changes and spatial distribution pattern of rice field decreasing trend in Serang Regency, Banten Province

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Abstract. Serang is one regency in Banten Province which is located near to Jabodetabek, the largest metropolitan area in Indonesia. The economic growth at its periphery has a negative impact on the decreasing of rice field in the regency. Objectives of this research are: (1) to analyze decreasing of rice field in Serang Regency from 2006 to 2018 and to project land-use change in 2030, and (2) to identify spatial distribution pattern of rice field in Serang Regency. Land-use change was conducted by ArcGIS10.3 using Landsat images. Identification of spatial distribution pattern of rice field was conducted by Moran and LISA (Local Indicator of Spatial Autocorrelation). Meanwhile, land-use change projection was conducted using CA-Markov. Results show that during 2006-2018 there has been an increase of built-up area (7,295 hectares) and decreasing of rice field from 60,949 hectares to 54,232 hectares. A larger decreasing rice field occurred at districts located at the eastern part of Serang Regency. The result of land-use change projection shows the increase of built-up area and rice field conversion in Serang Regency in 2030. Decreasing rice field in the long term may threaten food security at the local and regional level.

Keywords: CA-Markov, food security, land conversion, rice field, sustainable agriculture land

1. Introduction
Urbanization, population growth, social structure change, and economic development of a region cause an increase in demand for land from time to time [1, 2, 3]. On the other hand, the availability of land relatively does not increase. Thus, this condition leads to land conversion [4, 5]. Land conversion will be a problem if it occurs on productive agricultural land [6]. Agricultural land conversion will cause a decrease in food production and environmental losses, such as a decrease of spaces with conservation functions [3, 7]. Based on data obtained from Statistics Indonesia, the rice field area in Indonesia decreased from 8.13 million hectares in 2013 to approximately 7.1 million hectares in 2018 [8].

Serang Regency has experienced very dynamic changes, both in the use of space as well as in socioeconomic and institutional aspects. The regency is a part of Banten Province, which is located near to

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capital Jakarta and to Jabodetabek, the largest metropolitan area in Indonesia. The increasing population in Jabodetabek metropolitan area has influenced the increase in the population in Serang Regency. The annual population growth rate in Serang Regency from 2010-2017 was 1.31. Growth of economic activities (industry, service, and commerce) in its periphery, namely in Jabodetabek, Serang City, and Cilegon City, has a negative impact on the decreasing of rice field area in the regency. Compared to all regencies and cities in Banten Province, Serang Regency has the most extensive technical irrigated rice field area of 41,735 hectares, although in terms of the total area of rice fields and other agricultural lands, Lebak Regency and Pandeglang Regency rank first and second in the province [9].

Based on some previous researches [10, 2, 11], the conversion of agricultural land in Jabodetabek and its surroundings occurred due to many factors, including population growth, urbanization, development of the region, development of toll roads, as well as the development of transportation modes that facilitate mobility between Jakarta and its surrounding regions. The changes in land-use especially change from agricultural land to built-up land as shown by previous studies [12, 13, 14].

Regional development and economic growth generally have an influence on land-use change. Land-use changes that occur in an area are a result of human actions and interactions in utilizing and managing natural resources together with its environment [15]. Observation on land cover changes can be conducted using spatial data from land use maps at desired time points. The existence of rice fields is closely related to population growth. An increase in the number of populations of a region will increase the region's burden in providing space for its population [16]. Based on land-use changes that occur in a certain period, a model that is able to predict land use in the future can be obtained [17].

The importance of land-use change models is evident from the wide range of existing modeling approaches and applications [18, 19, 20, 21]. Land-use prediction is essential since land-use change possibilities in the years to come can be foreseen. It made possible to anticipate whether there are productive agricultural lands that are prone to be converted to other land uses, especially to built-up land. The pattern of paddy field distribution and spatial autocorrelation of decreasing paddy field areas are also important to be analyzed in order to identify locations of paddy fields that are likely to be converted so that future policy can protect productive agricultural lands in the region.

Objectives of this research were: (1) to analyze the dynamics of land-use change, particularly rice field area in Serang Regency from 2006 to 2018, and to project land-use change in Serang Regency in year 2030; and (2) to identify spatial distribution pattern and analyze spatial autocorrelation of rice field in Serang Regency during the period.

2. Materials and Methods
The location of the research was Serang Regency, Banten Province (figure 1). Serang Regency has an area of 1,734.28 km² with population of 1,493,591 people and population density of 861.21 people/km² [22]. Administratively, Serang Regency consists of 29 districts and 326 villages. Land use/cover change dynamics uses four-year points, namely 2006, 2010, 2014, and 2018. Landsat images dataset used for these three-year points: 2006, 2010, and 2014. The land cover maps source is from the Ministry of Environment and Forestry (MoEF) and obtained through the Center for Regional System Analysis, Planning, and Development (Crestpent) IPB University. Land use map updates were also carried out in 2018 based on Sentinel 2B satellite imagery, with October 2018 sensing time using visual interpretation (digitize on screen) on a scale of 1: 125,000. Land-use change in this research was conducted by applying GIS analysis using ArcGIS 10.3. Field observations were carried out in 40 points for verification (figure 2).
Figure 1. Research location.

Figure 2. Location of 40 field observation points.

Prediction of land cover in 2030 is carried out using CA-Markov model method on IDRISI Selva through the construction of two models to run the CA Markov validation scheme. The two models namely Model 1 to predict land cover in 2018 and Model 2 to predict land cover in 2030. The basic principle of CA Markov is to measure probabilities using a transition probability matrix that describes the likelihood of changes in each pixel from one land use/land cover to another between two-time points [23]. The validation process of the predicted results of land cover changes is carried out with a kappa accuracy test to compare the 2018 land cover map of the predicted results with the actual 2018 land
cover map. The higher the kappa value, the higher the level of accuracy of the predicted land cover. Kappa values are substantial if they are between 0.61–0.80 and close to perfect if they are between 0.81–1.00 [24, 25]. If the kappa value is good enough, then the second model to predict the land cover in the future can be built.

Identification of spatial autocorrelation or spatial distribution pattern of rice field was conducted using Global Moran Index (figure 3a). The measurement of spatial autocorrelation for spatial data locally can be calculated using the Local Moran's Index method or LISA (Local Indicat of Spatial Autocorrelation) (figure 3b) approach which can be calculated using GeoDA software [26]. LISA is used to identify how the relations between a location of observation locally to another observation location. The formula and result’s interpretation of Global and Local Moran’s I or LISA statistic can be seen as follows [27]:

\[
I = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}(x_i - \bar{x})(x_j - \bar{x})}{Z_x \sum_{j=1}^{n} W_{ij}} \quad (1)
\]

\[
I_i = \frac{\sum_{j=1}^{n} W_{ij}(x_i - \bar{x})(x_j - \bar{x})}{Z_x \sum_{j=1}^{n} W_{ij}} \quad (2)
\]

Where:
- \( I \) : Global Moran’s Index
- \( I_i \) : Local Moran’s I or LISA statistics
- \( x_i \) : The value of \( X \) on i-th regency
- \( \bar{x} \) : The average value of \( X \)
- \( W_{ij} \) : Contiguity matrix; representing the proximity of i-th district i’s and district j’s locations
- \( n \) : The total number of districts
- \( Z_x^2 \) : The variance of the \( X \).

![Figure 3a. Result of Global Moran Index](image1)

![Figure 3b. Result of Local Moran Index (LISA)](image2)
3. Result and discussion

3.1. Dynamics and projections of land-use change in Serang Regency

The dynamics and projections of changes in land use in 2006 to 2030 show that there are eight types of land use in Serang Regency, namely water bodies, forests, dryland, built-up lands, idle lands, rice fields, fishponds, and annual crops (figure 4). Agricultural activity still dominates land use in Serang Regency, especially paddy fields (39%) and dryland (32%) (table 1). However, in terms of its trends from 2006 to 2018, including the results of the projected model for land-use change in 2030 (table 1), the area of paddy fields and other agricultural lands in Serang Regency, has decreased mainly due to land conversion to settlements or other developed lands. It also can be seen from the results of previous studies [28, 29]. The rate of population growth increased, it caused pressure on the food available from the region's own production, thereby increasing the need for land, both for meeting food production and for settlements. Despite currently, the percentage of total built-up area in Serang Regency is merely around 13%, it is estimated that the trend will increase, along with the increasing population and regional development in the area. Changes in land-use from agricultural land or non-built-up land to built-up land are common due to the value of land rent of built-up land is higher than land rent of non built-up land, such as agricultural land [30]. Generally, land conversion occurs on land that has a low land rent value so it becomes land uses that have high land rent [31]. The conversion of agricultural land to non-agricultural land is usually irreversible [32]. Agricultural land conversion is generally accompanied by changes in the economic, social, cultural, and political orientation of the community, which are also generally non-reversible.

Changes in land use from 2006 to 2018 are presented in table 2. It can be seen that from 2006 to 2018, the largest decreasing trend occurred in paddy land, which decreased by 6107.32 hectares. Meanwhile, built-up land experienced an increase in the area of 8321.09 hectares. When compared with the area of land use predicted by the CA Markov model in 2030, the largest predicted decrease from 2006 to 2030 is paddy fields, -6525.78 hectares. Meanwhile, dryland and settlement areas (built-up area) will increase the most, namely 10123.94 hectares and 8748.1 hectares respectively.

Agricultural land use is more dominant in the eastern part of Serang Regency, while the western part is dominated by forest area and dryland. Judging from the physical condition of the area, the eastern part of Serang Regency is relatively flat so it is widely used as a rice field. Meanwhile, the western part is rather hilly with a high elevation and the types of land use that are mostly found are forests and dryland (figure 4). Many rice fields in the eastern part of Serang Regency are now occupied by developers and have been turned into residential areas.
Figure 4. Map of land-use in Serang Regency in 2006, 2009, 2014, 2018, and projected land-use in 2030

Table 1. Distribution of land-use in Serang Regency (hectare)

| Land-use types       | 2006    | 2010    | 2014    | 2018    | 2030    |
|----------------------|---------|---------|---------|---------|---------|
| Water Bodies         | 611.67  | 611.67  | 611.67  | 611.67  | 610.22  |
| Forest               | 12980.60| 10021.46| 10021.46| 9936.84 | 7689.16 |
| Dryland              | 44263.60| 46548.79| 51611.47| 50461.81| 54387.54|
| Built-up areas       | 10313.90| 10739.71| 11275.80| 18634.99| 19062.00|
| Abandoned land       | 794.66  | 1018.16 | 278.12  | 278.12  | 224.43  |
| Rice fields          | 60949.14| 60973.77| 60092.94| 54841.82| 54423.36|
| Fishpond             | 6809.01 | 6809.01 | 6876.67 | 6642.52 | 6648.82 |
| Annual crops         | 7091.99 | 7091.99 | 3056.44 | 2406.80 | 1318.29 |

Table 2. Changes in land-use in Serang Regency

| Land-use type          | 2006-2010 | 2010-2014 | 2014-2018 | 2018-2030 | 2006-2018 | 2006-2030 |
|------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| Water Bodies           | 0         | 0         | 0         | -1.45     | 0         | -1.45     |
| Forest                 | -2959.14  | 0         | -84.62    | -2247.68  | -3043.76  | -5291.44  |
| Dryland                | 2285.19   | 5062.68   | -1149.66  | 3925.73   | 6198.21   | 10123.94  |
| Built-up Areas         | 425.81    | 536.09    | 7359.19   | 427.01    | 8321.09   | 8748.1    |
| Abandoned Land         | 223.5     | -740.04   | 0         | -53.69    | -516.54   | -570.23   |
| Rice Fields            | 24.63     | -880.83   | -5251.12  | -418.46   | -6107.32  | -6525.78  |
| Fishpond               | 0         | 67.66     | -234.15   | 6.29      | -166.49   | -160.2    |
| Annual Crops           | 0         | -4045.55  | -639.64   | -1088.51  | -4685.19  | -5773.7   |
3.2. Identification of spatial distribution patterns of rice field use in Serang Regency
The results of spatial autocorrelation analysis using global and local Moran Index (LISA) are presented in figure 5 below.

Figure 5. Spatial distribution patterns of LISA cluster map, significance and Global Moran’s index
Based on the interpretation of the Global Moran Index and Local Moran Index (LISA) value as presented in figure 5, it can be seen that the spatial pattern of land-use in the Serang Regency is clustered, because the Global Moran Index values range from 0 - 1 (positive). However, if we compare the Global Moran Index values from 2006 to 2030 (based on the CA Markov model projections), it can be seen that the index value is getting lower and lower, namely 0.723 in 2006 to 0.036 in 2030. This means that in the year 2006, paddy field areas are still quite extensive and the location is centralized (clustering) especially in the eastern part of Serang Regency. Whereas in the following years, paddy field land use has decreased in that area, resulting in a lower value of the Global Moran Index, which indicates that the spatial distribution pattern is getting more random (the index value is getting closer to zero).

Based on the Local Moran Index (LISA statistics), it can be seen that in 2006, there were a number of areas which had a HH (high-high) spatial autocorrelation of rice field distribution, particularly located in the eastern part of Serang Regency (red color area of LISA cluster map in figure 5). On the other hand, the LL (low-low) spatial autocorrelation areas were located in the western part of the regency (blue color area). HH spatial autocorrelation indicates that in that location there is a large paddy field, where the neighboring area also has a large paddy field, or in other words in the area there is a centralized paddy field location. Whereas LL spatial autocorrelation indicates that there are minimal paddy fields (or there may be no paddy fields), and the neighboring area is also an area with minimal paddy fields or no paddy fields. From the LISA cluster map presented in figure 5, it can be seen that the red area is gradually decreasing and become none in 2030, which shows that there is a gradual decrease in paddy field areas in Serang Regency.

4. Conclusion
Dynamic land-use/cover changes occurred in Serang Regency. From 2006 to 2018, there has been an increase of the built-up area of 7,295 hectares and a decreasing trend of rice field area from 60,949 hectares to become 54,232 hectares. Based on the land use prediction model, it is discovered that the rice field area in Serang Regency tends to decrease even until 2030. From 2006 to 2030, the decreasing in the rice field is about 6525,78 hectares. Most of the rice fields are converted to dryland and built-up area. From the spatial distribution pattern and spatial autocorrelation value, it is discovered that larger rice field land decreasing occurred at districts located at the eastern part of the Serang Regency, particularly at areas near to the regency’s capital and areas directly bordered with Tangerang Regency. These rice field areas are prone to land conversion. This research is essential since can show rice field land conversion trend and see potential lands that might be converted in the future. If the land depreciation is not controlled, it may cause a decrease in rice production, which in the long term may threaten food security at the local and regional level.

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