Land change prediction in Bondowoso Regency using Automata Markov method

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Abstract. This study examines changes in agricultural land in Bondowoso district using Cellular Automata Markov technique. The research method uses Bondowoso Regency Satellite Image data input in 2000, 2010, and 2019. In this study several analysis processes were carried out, such as land change factors, land conversion sequences, conversion dynamics index, intensity index of conversion of agricultural land. The results of the analysis in this study are maps of land use changes in the year predicted using the validation test. The process of making maps of predicted land changes include several variables such as slope, population density, distance from arterial roads, distance from collector roads, distance from the district capital, distance from the subdistrict capital, distance from campus, distance from attractions, distance from markets, spatial pattern policy and regional integration into the provincial spatial plan. From these results obtained the dynamics of changes in agricultural land in Bondowoso district.

1. Introduction

Besuki Raya, a spatial plan area in East Java Province, is an area that is projected as an agricultural land. This area is one of the suppliers of food needs, especially from agriculture and plantations in East Java. As regional development progresses and population growth in the region, land use changes occur. Land used for agriculture is changed to non-agriculture to fulfill human needs (Krisnohadi, 2011). This phenomenon changes and influences the productivity of Besuki Raya agricultural land.

One of regency in East Java is Bondowoso. Bondowoso Regency is a regency that depends its economic activities on its agricultural sector. Taken from the LQ analysis results in Bondowoso district, the agriculture and plantation sectors have an LQ of 2.48 (BPS Data Analysis 2019). The population growth in Bondowoso regency has a figure of 0.68% per year. Land use is divided into non-agricultural activities such as for residential land, commercial land, office land and industrial land. Total number of land conversion from agricultural land to non-agricultural land from 1997 to 2006= 1750 Ha in Bondowoso (Hidayat, 2008). Trend of agricultural land conversion into non-agricultural land continues to occur. Deputy Regent of Bondowoso regency stated that the licensing agency must tighten permits for housing construction (Rahmat, 2018).

This research aims to find out changes in agricultural land in Bondowoso regency by predicting changing agricultural land to non-agricultural land. Changes in agricultural land are predicted with several variables that are the cause of land changes.
2. Methods
This research aims to predict changes of agricultural land in Bondowoso. Administratively, in this study, Bondowoso Regency is near South Jember, North Situbondo and East Banyuwangi. This study used secondary data such as Landsat TM satellite data 5 of 2000, Landsat ETM + 7 of 2010, and Landsat 8 of 2019, slope, road network map, economic center map, map of tourism location, Spatial map of Bondowoso regency and statutory data. Research secondary data was obtained from agencies and data provider sites. Land use classification in Bondowoso was obtained from remote sensing of Landsat satellite imagery. The Landsat image is taken by analyzing RGB composition. Interpreting image is an activity to study the image so that it can identify the object and the meaning of the object contained in the image (Purwanto, 2014). The elements such as size, color, hue (tone), pattern, shape, shadow will be analyzed (Lillesand, 1997). The result of those interpretations will produce land use maps Bondowoso in 2000, 2010, 2019. To find out the land conversion process, land use maps are spatially analyzed using the Markov chain method.

2.1. Land Use suitability Map
Land use conformity map is an input of the markov chain method process. Land suitability maps is generated using binary regression models in the application set. Binary Logistic Regression produces probability prediction map output, a class of land use that can change based on tested various variables. The probability map of land use change is obtained by involving the dependent variable such as existing land use raster data and free variable raster data, a driving factor which influences land use existence in the study area. The probability map can be used as a map of land use suitability. The coefficient value of the predictor variable produced in logistic regression shows a relationship of suitability at a particular location that has the potential to become a specific land use class.

2.2. Markov Chain
Markov is a mathematical technique used to predict changes in certain variables on model knowledge, pattern of the previous objects (Nawangsari, 2014). The findings of Markov analysis are probability matrix and transition area matrix. Markov analysis was carried out using the software.

2.3. Cellular Automata Markov
The CA Markov model is a combination of Cellular Automata and Markov Chain. Cellular is an analysis of land use conservation. Cellular Automata Analysis is divided into 3 types, namely: determinism, stochasticity, and modeling. The first category model has similarities with deterministic CA modes in determining variables in modeling. The second category is a combination of deterministic and stochastic methods. The estimation of land change and the transition algorithm are determined deterministically, but the probability of change is calculated using the stochastic method. (Almeida et al, 2005).

3. Result and Discussions
The land use in Bondowoso district is classified into eight types, such as forests, gardens, mixed areas, developed land, paddy fields, fields / fields, water bodies, open land, and shrubs. The land use map in Bondowoso is showed in the figure below. The land is used for fields / fields (32%), rice fields (18%), and Forests (18%). The forest is located in the southern area, the dryland is in the southern area, and paddy land use is in the northern part of Bondowoso district.

3.1. Land Use Change
The total area of land use conversion in 2000 - 2019 was 71529 Ha, or 46% of total area of Bondowoso. The land conversion data showed that the land in Bojonegoro is mostly used for gardens / plantation land, dryland, and built land compared to other land uses. The land cover increased by 332%, plantations increased by 172% and moor increased by 32%. On the other hand, the paddy fields, forests and shrubs dropped by 22%, 37% and 48%.
Figure. 1 Bondowoso Administration Map

Table 1. Land Use Change Area in Bondowoso District

| No. | Land Use  | Land Area 2000 (ha) | Land Area 2010 (ha) | Land Area 2019 (ha) | Change Area (Ha) | % Land Change |
|-----|-----------|---------------------|---------------------|---------------------|------------------|---------------|
| 1   | Forest    | 44,470              | 33,941              | 28,012              | -10529 -5930 -16459 | -37.01        |
| 2   | Farm      | 7,360               | 17,074              | 20,028              | 9714 2954 12668   | 172.12        |
| 3   | Moor      | 36,958              | 41,787              | 48,834              | 4829 7046 11875   | 32.13         |
| 4   | Land Cover| 3,379               | 7,903               | 14,600              | 4524 6697 11221   | 332.06        |
| 5   | Open Field| 5,277               | 5,281               | 4,120               | 3 -1161 -1157 -21.93 |
| 6   | Rice Field| 36,722              | 32,556              | 28,309              | -4166 -4247 -8413 -22.91 |
| 7   | Copse     | 19,949              | 15,574              | 10,214              | -4375 -5360 -9735 -48.80 |
| 8   | Water Body| 228                 | 228                 | 228                 | 0 0 0 -37.01      |
|     | Total     | 154,344             | 154,344             | 154,344             | 38,141 33,395 71,529 |               |
3.2. Land Use Transition Probability

The transition probability is the probability of transitioning from one state of land use to another land use. The research data of transition probabilities were analyzed using cross tabulation from data of land use in year 2000 and year 2019. The transition probability matrix is showed into 8x8 matrix below:

**Table 2. Transition Probability Matriks**

| Cl. 1 | Cl. 2 | Cl. 3 | Cl. 4 | Cl. 5 | Cl. 6 | Cl. 7 | Cl. 8 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| Class 1 : 0.5984 0.1757 0.1292 0.0047 0.0293 0.0028 0.0598 0.0000 |
| Class 2 : 0.0000 0.8873 0.0431 0.0637 0.0059 0.0000 0.0000 0.0000 |
| Class 3 : 0.0000 0.0019 0.8339 0.0899 0.0017 0.0604 0.0122 0.0000 |
| Class 4 : 0.0071 0.0071 0.0071 0.9500 0.0071 0.0071 0.0071 0.0071 |
| Class 5 : 0.0000 0.0000 0.0285 0.8405 0.1310 0.0000 0.0000 0.0000 |
| Class 6 : 0.0000 0.0791 0.1256 0.1042 0.0000 0.6600 0.0311 0.0000 |
| Class 7 : 0.0000 0.1695 0.3382 0.0235 0.1089 0.0540 0.3059 0.0000 |
| Class 8 : 0.0071 0.0071 0.0071 0.0071 0.0071 0.0071 0.0071 0.9500 |

**Information:**
- Class 1 : Forest
- Class 2 : Farm
- Class 3 : Moor
- Class 4 : Land Cover
- Class 5 : Open Field
- Class 6 : Rice Field
- Class 7 : Copse
- Class 8 : Water Body
3.3. Model Validation

Model validation is used to test the accuracy level between the projected land use in 2019 and the images interpretation in 2019, the greater the similarity, the more accurate the model.

![Figure 3. Land Use Change Simulation Bondowoso Period 2000-2019](image)

![Figure 4. Model Validation](image)

Model output accuracy interpretation of the Kno analysis is an indicator to measure the overall agreement. The Kno score showed 0.8671 points meaning that 86% of data has complete similarity. KLocation is an indicator to measure the agreement level between inputs in a certain location. KLocation showed 0.8732 points meaning that 87% of the data has spatial similarity in location. Strata Klocation is an indicator to measure the total approval. Strata Klocation showed 0.8732 points meaning that 87% of the data above has similar score. In general, data has high accuracy and valid. It
can be used to as a projection.

**Figure 5.** Land Use Change Simulation Bondowoso Period 2019-2038

**Table 3.** Land Use Change Matrix Bondowoso 2019-2039

| No. | Land Use Change 2019 | Forest Area (ha) | Farm Area (ha) | Moor Area (ha) | Land Cover Area (ha) | Open Field Area (ha) | Rice Field Area (ha) | Copse Area (ha) | Water Body Area (ha) | Total Area (ha) |
|-----|---------------------|-----------------|----------------|----------------|----------------------|---------------------|---------------------|----------------|----------------------|----------------|
| 1   | Forest              | 16,816          | 4,963          | 3,851          | 160                  | 795                 | 61                  | 1,375          | 61                   | 28,012         |
| 2   | Farm                | 17,621          | 1,025          | 1,215          | 130                  | 26                  | 11                  | 20,028         |                      |                |
| 3   | Moor                | 397             | 40,641         | 4,554          | 330                  | 2,618               | 295                 | 48,834         |                      |                |
| 4   | Land Cover          |                 | 14,600         |                |                      |                     |                     |                |                      |                |
| 5   | Open Field          | 51              | 268            | 872            | 2,874                | 3                   | 52                  | 4,120          |                      |                |
| 6   | Rice Field          | 2,094           | 3,415          | 3,185          | 61                   | 19,296              | 258                 | 28,309         |                      |                |
| 7   | Copse               | 1,594           | 3,031          | 251            | 855                  | 70                  | 4,413               | 10,214         |                      |                |
| 8   | Water Body          |                 |                |                |                      |                     |                     |                |                      | 228            |
|     | Jumlah              | 16,816          | 26,710         | 52,229         | 24,837               | 5,045               | 22,075              | 6,405          | 228                  | 154,344        |

Based on data analysis, it can be concluded that there will be a significant change of land use in Bondowoso in 2039. The most significant change of land use is for built-up land or 70% of the total area in 2019, 10238 Ha. Followed by farm, total are for farm will be 6681 Ha or 33.36% of the total area in 2019. However, the total number for forest, copse, and paddy fields has decreased. It showed thoroughly as 11196 ha, 3809 ha, dan 6234 ha. Land use has changed in almost all locations in Bondowoso. Total area of forest is converted into farm= 4953 ha, and into moor= 3851 ha. The copse land mostly is converted into farm, and moor. Most paddy field is converted into the moor= 3415 ha, the built up area= 3185 ha, and farm= 1594 ha.

4. **Conclusions**

From the result of data analysis, it showed that land change activities in Bondowoso mostly existed during 2019 to 2039. There are 3 types of land use which decreased in number numerously such as: 1). forest, 2). Paddy fields, 3). Copse. The land that has been turned into built-up land is moor= 4554ha, paddy fields= 3185ha, and farm= 1215ha. The land that is the least converted to developed land is forest = (160 ha) due to government policies on land change.
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