Prediction of land cover changes in Penajam Paser Utara Regency using cellular automata and markov model

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Abstract. Development and economic growth in an area can cause land cover changes. Penajam Paser Utara Regency, as a new capital candidate, is also predicted to experience land cover changes. Land cover changes that are not following the land's potential will cause environmental problems, so it is necessary to predict land cover changes by looking at patterns of land cover changes in the past and the factors that influence it. The purpose of this study is to analyze and predict the land cover change in Penajam Paser Utara Regency in 2031. The method used in this study is modeling using Cellular Automata - Markov. The driving factor of land cover change is used in making prediction models such as distance from the center of activity, distance from the road, distance from the river, elevation, and slope. The prediction land cover changes show that there has been an increase in plantation area and a decrease in forest area, while the development of the built-up area is not visible. The kappa test for predicted land cover showed perfect results. The resulting land cover model can be used to formulate land-use policies.

1. Introduction
Land cover change is a change in land from its original land cover to another land cover at different times. Land cover change can occur due to natural factors as well as human factors. However, the human factor causes more land cover changes, such as population increase and economic growth [1,2]. As an indicator of economic growth in an area, social activities in meeting needs such as housing, agriculture, industry, plantations, and other infrastructure can lead to land changes [3]. Penajam Paser Utara Regency is one of the areas planned as a candidate for the new capital. It can increase economic growth and development in the region and potentially land cover changes. Penajam Paser Utara Regency experienced an increase in population by 1.39% per year, followed by the development of its economy and territory, which led to changes in land cover from forests to plantations and an increase in the built-up area [4].

The land-use change that causes changes in land cover will continue to grow to trigger economic improvement. Changes in a land cover without proper planning can cause deforestation, land degradation, decreased water quality, loss of biodiversity, and increased carbon emissions [5]. So it is necessary to make predictions regarding changes in land cover to create policies or land-use plans based on interests in the long term so that developments in an area can be directed and do not cause environmental problems [6,7]. The past and present land cover information presented along with
future changes is vital for understanding and evaluating social, economic, and environmental consequences [8,9].

Analysis and prediction of future land cover changes can be carried out using Remote Sensing and Geographical Information Systems (GIS) [10]. One model that can be used and effectively predicts long-term and spatial variation of land cover change is the Cellular Automata - Markov model, widely applied by many researchers [11]. Such research conducted in Oman to monitor land use and land cover change [12], and the prediction of land cover change was carried out in Al Ain, the second-largest city in Abu Dhabi Emirate experiencing rapid urban growth and economic development [13]. Besides, research conducted in Saga, Japan, also uses natural and socio-economic factors to land-use change using the Cellular Automata - Markov land model [14].

Unlike previous research, this research was conducted in Penajam Paser Utara Regency by utilizing physical conditions and infrastructure as driving factors. Land cover prediction research is usually classified automatically using supervised or unsupervised. Still, in this study, it was made by digitizing each land cover manually so that the results were more accurate. Based on this background, this study aims to analyze land cover changes in 2009 - 2020 and predict land cover changes in Penajam Paser Utara Regency in 2031. This research is critical because Penajam Paser Utara Regency is one of the areas planned to be the capital city, which will lead to economic growth and development. Besides, this research is expected to provide information about changes and predictions of land cover useful for area management planning and become the basis for making land-use policies in Penajam Paser Utara Regency.

2. Methodology

2.1. Research area

This research was conducted in Penajam Paser Utara Regency, East Kalimantan Province, located at 116°19'30" - 116°56'35" East Longitude and 00°48'29" - 01°36'37" South Latitude (figure 1). Administratively, this regency is divided into four districts: Babulu, Waru, Penajam, and Sepaku. Penajam Paser Utara Regency location is directly opposite Balikpapan Bay and as the entrance to the southern part of East Kalimantan, traversed by country roads and connecting East Kalimantan, South Kalimantan, and Central Kalimantan, makes the Penajam Paser Utara Regency area strategic.

![Figure 1. Research area.](image)

2.2. Data

The data used in this study is multi-temporal land cover data, which is then used for the Cellular Automata - Markov process. Land cover was obtained from the results of image processing Landsat 5 TM, Landsat 7 ETM, and Landsat 8 OLI in 2009, 2015, and 2020 path 116 row 61 and path 117 row 61. Besides, data on the distance from the road, distance from the river, distance from the center of
activity, elevation, and slope were used to drive land cover change. Data on roads, rivers, and activity centers were obtained from maps of the RBI Geospatial Information Agency. Elevation and slope data were obtained from DEM data.

2.3. Method
In this study, the data processing consisted of several stages of interpreting and classifying multitemporal images, processing data on the driving factors, and making land cover prediction models. Data processing was performed using ArcGIS 10.5 and IDRISI Selva software. Image interpretation and classification processes are carried out by manually digitizing each land cover class in each image data to produce land cover maps for 2009, 2015, and 2020. The land cover classification is divided into eight types: forest, plantation, built-up area, mangrove, paddy field, shrubs, ponds, and water body based on SNI 7645: 2010 [15]. Driving factor data such as distance from the road, distance from the river, distance from the center of activity, elevation, and slope are determined to determine the land cover location that can change to other land cover types.

Furthermore, the Cellular Automata - Markov model analyzes land cover changes and creates predictive models for future land cover. Cellular Automata - Markov Model is a combined Cellular Automata model and the transition probability matrix of a series of events in the present to predict future events [16]. Before the model is used to indicate the year 2031, the model is validated first. Validation was carried out using land cover maps for 2009 and 2015 to predict 2020 land cover. A test of the predictive model's accuracy for land cover with actual land cover produced in 2020 was carried out to ensure the model's correctness.

3. Results and discussion

3.1. Analysis of land cover changes
Based on the interpretation of Landsat imagery in 2009, 2015, and 2020, Penajam Paser Utara Regency consists of eight land cover classes: forest, plantation, built-up area, mangrove, paddy field, shrubs, ponds, and water body (figure 2). The vastest land cover for paddy fields and ponds is in the Babulu District, which is in the southernmost part of Penajam Paser Utara Regency. The built-up areas are scattered in areas close to the main road and mostly in Penajam District. Meanwhile, the most dominant forest land cover is in Sepaku District.

![Figure 2. Penajam Paser Utara Regency land cover in 2009, 2015 and 2020.](image-url)
The largest land cover in Penajam Paser Utara Regency in 2009 was dominated by forest, namely 44.29%. However, in 2015 the forest area decreased to 39.60%, especially in Penajam District. In 2009, the second largest land cover was a plantation area of 42.67% and increased in 2015 to 47.22%, in line with the reduction in forest area. During the 2009-2015 period, the built-up area and mangroves increased by 0.34% and 0.29%, especially in Penajam District. Meanwhile, ponds and shrubs decreased by 1.72% and 0.22%, respectively. The largest decrease in pond area occurred in Babulu District, while the largest decrease in shrubs occurred in Sepaku and Babulu Districts.

In the 2015 - 2020 period, the plantation area increased to 52.12%, which filled half of Penajam Paser Utara Regency, while the forest area continued to decline to 32.53%, and the built-up area also continued to increase by 0.26%. Most of these changes occurred in Penajam District. Shrubs and ponds that previously experienced a decline in 2020 increased by 1.86% and 0.03%. The increase in the shrubs area occurred in Sepaku and Penajam Districts, while the increase in pond areas occurred in Babulu District. On the other hand, mangroves decreased by 0.08%, especially in Penajam and Sepaku Districts. The area of water bodies tends to be constant from 2009 to 2020. Changes in land cover in Penajam Paser Utara Regency can be seen in table 1.

### Table 1. The land cover area of Penajam Paser Utara Regency in 2009, 2015, and 2020.

| Land Cover     | Area       | 2009 | 2015 | 2020 |
|----------------|------------|------|------|------|
|                | Ha         | %    | Ha   | %    | Ha   | %    |
| Forest         | 134030.18  | 44.29| 119832.44 | 39.60| 98451.02 | 32.53|
| Plantation     | 129131.77  | 42.67| 142905.95 | 47.22| 157722.82 | 52.12|
| Built Up Area  | 3077.09    | 1.02 | 4109.23 | 1.36 | 4899.20 | 1.62|
| Mangrove       | 13464.72   | 4.45 | 14335.28 | 4.74 | 14090.39 | 4.66|
| Paddy Field    | 11476.02   | 3.79 | 11490.83 | 3.80 | 11766.81 | 3.89|
| Shurbs         | 3378.61    | 1.12 | 2699.56 | 0.89 | 8343.26 | 2.76|
| Water Body     | 2138.60    | 0.71 | 2138.54 | 0.71 | 2160.19 | 0.71|
| Pond           | 5932.82    | 1.96 | 5118.01 | 1.69 | 5196.10 | 1.72|

### 3.2. Land cover change transition probability matrix

The transition probability matrix resulting from the Markov process is the result of calculating the probability of changing one land cover to another land cover [16]. The transition probability matrix results, shown in table 2, show that changes in the forest to plantations and shrubs to plantation have a significant change value. Conversely, based on the probability matrix, other land cover changes have low change values.

### Table 2. Land cover change transition probability matrix.

| Land Cover | Forest | Plantation | Built-Up Area | Mangrove | Paddy Field | Shurbs | Water Body | Pond |
|------------|--------|------------|---------------|----------|-------------|--------|------------|------|
| Forest     | 0.88   | 0.12       | 0.00          | 0.00     | 0.00        | 0.00   | 0.00       | 0.00 |
| Plantation | 0.03   | 0.94       | 0.01          | 0.01     | 0.00        | 0.01   | 0.00       | 0.00 |
| Built Up Area | 0.00 | 0.00       | 0.98          | 0.00     | 0.00        | 0.01   | 0.00       | 0.00 |
| Mangrove   | 0.00   | 0.04       | 0.00          | 0.95     | 0.00        | 0.00   | 0.00       | 0.00 |
| Paddy Field | 0.00 | 0.02       | 0.01          | 0.00     | 0.96        | 0.01   | 0.00       | 0.00 |
| Shurbs     | 0.00   | 0.65       | 0.03          | 0.00     | 0.00        | 0.28   | 0.00       | 0.04 |
| Water Body | 0.00   | 0.00       | 0.00          | 0.00     | 0.00        | 0.00   | 1.00       | 0.00 |
| Pond       | 0.00   | 0.05       | 0.00          | 0.08     | 0.00        | 0.02   | 0.00       | 0.84 |
3.3. Driving factors
In the land cover driving factors, the Cramer's v test is carried out to measure the relationship between a variable with a land cover class with a value between 0-1 [3]. Based on Cramer's test results, the five driving factors can be used in making prediction models for land cover (table 3). Driving factors that have a considerable influence on land cover change are a distance from the rivers, elevation, and distance from the centers of activity.

Table 3. Test Cramer's v driving factors for land cover change.

| No | Driving Factors                      | Test Cramer's v |
|----|-------------------------------------|-----------------|
| 1. | Distance from The Road              | 0.1333          |
| 2. | Distance from The River             | 0.2894          |
| 3. | Distance from The Center of Activity| 0.2731          |
| 4. | Elevation                           | 0.2793          |
| 5. | Slope                               | 0.2390          |

3.4. Prediction of change in land cover in 2031
The resulting 2020 land cover model is then validated with the actual land cover in 2020. Based on the validation results, the Kappa value is 91%, this value shows very good results, and the model can be used to make a prediction map of land cover in 2031. Land cover in 2031 in Penajam Paser Utara Regency can be seen in figure 3. Based on the prediction results, the plantation is the largest land cover, namely 55.06%, which has increased from 2020. Forest land cover continues to decrease along with the increase in the plantation area. In the period 2020-2031, the forest has decreased by 3.31%. Changes from forest land to plantations tend to occur in Penajam District. The land cover that had increased were ponds, mangroves, and paddy fields by 0.29%, 0.24%, and 0.02%, respectively, while the pond area decreased by 0.17%. An increase in the paddy field area and a decrease in pond area occurred in Babulu Regency. Meanwhile, the increase in the mangrove area occurred in Penajam and Sepaku Districts. Change in the land cover area in 2031 can be seen in table 4.
Table 4. The area of Penajam Paser Utara Regency land cover in 2031.

| Land Cover      | 2020     | 2031     |
|-----------------|----------|----------|
| Forest          | 98451.02 | 88436.65 |
| Plantation      | 157722.82| 166626.34|
| Built Up Area   | 4899.20  | 5773.96  |
| Mangrove        | 14090.39 | 14828.35 |
| Paddy Field     | 11766.81 | 11816.08 |
| Shrubs          | 8343.26  | 8329.78  |
| Water Body      | 2160.19  | 2140.89  |
| Pond            | 5196.10  | 4680.05  |

The land cover in Penajam Paser Utara Regency that has experienced the most significant changes is in Penajam District, which is the center of government in Penajam Paser Utara Regency. Changes and developments in the built-up area in Penajam Paser Utara Regency are not too large compared to changes in plantations and forests. Therefore, changes in the built-up area are not very noticeable despite an increase in size. This condition can occur because Penajam Paser Utara Regency still has a very large forest and plantation area so that changes in land cover are more visible with a reduction in the forest area. Suppose changes in forest land cover are allowed to continue. In that case, the forest area will continue to decrease and cause problems for the environment, such as stopping habitat, increasing pollution, and increasing disasters. Based on the analysis and prediction of land cover, it is necessary to make a land-use policy and evaluate the spatial plan in Penajam Paser Utara Regency. Policy and assessment of spatial strategies need to be done, so forest land cover does not continue to decrease, area development is well maintained and does not cause environmental problems.

4. Conclusion
The results showed that the Cellular Automata - Markov model could predict land cover changes in the Penajam Paser Utara Regency with an excellent kappa value of 91%. The driving factors that significantly affect land cover changes are the distance from rivers, distance from centers of activity, and elevation. The land cover change trend is centered in the Penajam District, which is the center of Penajam Paser Utara Regency government. Based on predictions of land cover in 2031, changes in land cover in Penajam Paser Utara Regency will cause an increase in plantation area and a decrease in forest area, while the development of built-up areas is not very visible. Therefore, it is necessary to make a land-use policy in Penajam Paser Utara Regency, so that forest land cover does not continue to decrease, area development is well maintained and does not cause environmental problems.

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References
[1] Yusuf S M, Murtiliksono K, Hidayat Y and Suharnoto Y 2018 Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan 8(3) 365
[2] Shofiana R, Subardjo P and Pratikto I 2013 Journal of Marine Research 2(3) 35
[3] Fitriyanto B R, Helmi M and Hadiyanto 2019 Jurnal Teknologi Technoscientia 11(2) 137
[4] Widjayatnika B, Baskoro D P T and Pravitasari A E 2017 Journal of Regional and Rural Development Planning 1(3) 243
[5] Wang S W, Gebru B M, Lanchin M, Kayastha R B and Lee W K 2020 Sustainability 12 3925
[6] Islam K, Rahman M F and Jashimuddin M 2018 Ecological Indicators 88 439
[7] Mosammam H M, Nia J T, Khani H, Teymouri A and Kazemi M 2017 The Egyptian Journal of Remote Sensing and Space Sciences 20 103
[8] Parsa V A and Salehi E 2016 Journal of Urban Management 5 43
[9] Saputra M H and Lee H S 2019 Sustainability 11 3024
[10] Dradas M, Shafri H Z M, Ahmad N, Pradhan B and Safarpour S 2015 The Egyptian Journal of Remote Sensing and Space Science 18 35
[11] Munthali M G, Mustak S, Adeola A, Botai J, Singh S K and Davis N 2020 Remote Sensing Applications: Society and Environment 17 100276
[12] Mansour S, Al Belushi M and Al Awadhi T 2020 Land Use Policy 91 104414
[13] Yagoub M M and Bizreh A A A 2014 J Indian Soc Remote Sens 42 665
[14] Guan D, Li HF, Inohae T, Su W, Nagaie T and Hokao K 2011 Ecological Modelling 222 3761
[15] Badan Standardisasi Nasional 2010 Klasifikasi Penutup Lahan SNI 7645:2010 Jakarta: BSN
[16] Hyande C and Martz L W 2017 International Journal Of Remote Sensing 38 64