CA-Markov Model for Predicting Paddy-Field Land in Babulu Subdistrict, North Penajam Paser Regency, East Kalimantan

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Abstract. Paddy-fields in Indonesia continue to change their function every year as a result of the increase in land for settlements, as well as in North Penajam Paser Regency. The plan to relocate the capital city to North Penajam Paser Regency can support various impacts on land conversion, such as reducing paddy-fields so that paddy-fields productivity can be disrupted and reduce food availability. The purpose of this study to analyze and predict the availability of paddy-fields in 2031 in Babulu Subdistrict, North Penajam Paser Regency, using the CA-Markov method. Changes in paddy-field use were identified using remote sensing. This study's driving factors are the distance from the river, distance from the road, distance from the settlement, slope, and elevation. The results showed that paddy-fields in the Babulu Subdistrict have increased during the period 2009 – 2020. Paddy-fields in 2031 will reach 12.3% of the total area. Paddy-fields have an increased probability in the regions that are high and close to rivers. The model shows that the paddy-fields land in the Babulu Subdistrict has increased in line with the increasing trend of the plantations and settlements area.

1. Introduction

CA-Markov Chain modeling is one of the models in Geographic Information Systems (GIS), which can predict a situation in the future [1]. Geographic Information System (GIS) is a unique information system because it uses spatial data as data input. The resulting information is a solution to solving spatial problems that may not be solved by other information systems [2]. CA-Markov Chain is dynamic modeling that combines Cellular Automata (CA) and Markov Chain to predict land use spatially and temporally [3]. The CA-Markov model can simulate changes and indicate land use over decades using satellite imagery. Satellite imagery such as Landsat, IRS, and IKONOS can provide important information about land use to make predictions [4]. CA-Markov Chain can predict land use for various sectors, one of which is the agricultural sector.

The agricultural sector is the main driving force for the economy and national development. Indonesia is known as a farming country that has great potential and abundant natural resources of farm products. One of the land uses for the farming sector is paddy-fields. Paddy-fields in Indonesia are decreasing over time. It is due to the occurrence of land function experts from paddy-fields to non paddy-fields. Paddy-fields have begun to be replaced by developed land for settlements or another more...
productive land. The condition of limited land resources, while high population growth causes land values to grow every year [5]. The uncontrolled conversion of agricultural land can threaten the capacity of food supply, and even in the long term can cause social losses [6]. The decline in agricultural land could affect food production in the future [7].

North Penajam Paser Regency is an area designated as a candidate for the new capital city. As a candidate for a new capital city, there will undoubtedly be massive development and population migration to increase land need. Land-use changes cannot be avoided in developing development, rapid population growth, and the increasing demand for land [8]. Land use is closely related to human activities that include service and management and impact land use [9]. Babulu Subdistrict has the largest area of paddy-fields in the North Penajam Paser Regency [10]. Hundreds of hectares of paddy-fields in the Babulu Subdistrict experienced the function of becoming oil palm plantations in 2016 [11]. Changes from paddy fields to oil palm plantations and settlements were also found in Banyuasin Regency [12]. It shows that the potential for conversion of paddy-fields to more good land is indeed high. Land changes will be distributed to places with an excellent possibility to have patterns of land-use change [8]. Based on this background, this study aims to analyze and predict the availability of paddy-fields in 2031 in the Babulu Subdistrict, North Penajam Paser Regency, using the CA-Markov method.

2. Research Area
This research was conducted in the Babulu Subdistrict, North Penajam Paser Regency, with 399.46 km². Administratively, this subdistrict is bordered by Waru Subdistrict in the north, Makassar Strait in the east, Long Kali Subdistrict, Paser Regency in the south, and Long Kali and Waru Subdistricts in the west. The research area can be seen in Figure 1.

![Research Area](image.png)

Figure 1. Research Area

3. Methods
This study's data processing consisted of several stages; multitemporal image interpretation and classification, data processing for driving factors using Fuzzy Logic, and prediction models. Data processing was performed using ArcGIS 10.1 software, Google Earth Pro, IDRISI Selva, and Microsoft Excel.

3.1. Multitemporal Image Interpretation and Classification
Land use is classified into six land use; pond, plantation, settlement, paddy-field, and barren land. Land use was interpreted using Landsat/Copernicus imagery on Google Earth Pro. The Historical Imagery feature in Google Earth Pro is used to view imagery for 2009, 2014, and 2020.
3.2. Fuzzy Logic
There are spatial phenomena with uncertain boundaries; fuzzy logic has been widely applied in Geographic Information Systems (GIS). In using fuzzy logic for land suitability assessment, there is a range of values from 0 (less suitable) to 1 (very reasonable) defined for each criterion [13]. This study's driving factor is the distance from the river, the distance from the road, the distance from the settlement, slope, and elevation to see the areas that can change. Each driving factor is processed using the Fuzzy Membership feature in ArcGIS 10.1. Fuzzy membership can be determined subjectively or objectively; a suitable and universally accepted approach can improve prediction accuracy [14]. The results of each driving factor are combined in the Fuzzy Overlay feature to produce the Babulu Subdistrict driving factor map.

3.3. CA-Markov Chain
The CA-Markov Chain model was developed by combining the Cellular Automata and the transition probability matrix based on the land change produced by cross-tabulation of two images adjusted for proportional error [4]. Markov Chain is used as a simulation technique to predict a stochastic model that describes the possible change from one state to another [15]. Markov Chain and CA-Markov Chain land use in 2020 and 2031 were processed using IDRISI Selva. It is done by developing a suitable transition probability matrix in 2020 and the transition probability matrix in 2031. The 2020 transition probability matrix is obtained from land use processing in 2009 and 2014, while the transition probability matrix in 2031 is obtained from the year land use processing in 2014 and 2020. The transition probability matrix was used to model the CA-Markov Chain.

3.4. Kappa Accuracy Test
The Kappa accuracy test is the most common quantitative method used by comparing data consistency [17]. An accuracy test was conducted to test the land use classification process [18]. If the value of the model validation result is more than 75%, the land-use change model can be used to predict land-use change [19]. The Kappa accuracy test was done using IDRISI Selva.

4. Results and Discussion

4.1. Landuse Change in Babulu Subdistrict, North Penajam Paser Regency
Forest is the dominant land use in Babulu Subdistrict. In 2009, the forest area reached 75.28% of the total area. However, the forest area continues to decrease until 2020. The forest area only becomes 57.42% of the total area—land conversion into plantations, settlements, and paddy-fields. Meanwhile, the paddy-fields in Babulu Subdistrict continued to increase in the period 2009 – 2020. When compared to 2009, in 2020, the area of paddy-fields increased to 1,000 ha. Increase in paddy-fields in areas close to existing paddy-fields. The increasing of paddy-field is land that has changed its function from forests and plantations. The rise also followed the increase in the paddy-field area in farms and settlements. The plantation area in Babulu Subdistrict has increased significantly. In 2009, the plantation area was only 8.61%, while in 2020, it was 22.64%. The settlement has risen from 1.9% to 3.27%. For barren land and ponds, only <5% of the study area. Barren land experienced an increase in 2009 – 2020, while the pool experienced a decrease and increase. The size of land use in the Babulu Subdistrict in detail can be seen in Table 1.

Table 1. The landuse area of Babulu Subdistrict in 2009, 2014, and 2020

| Landuse   | Year  | Area (Ha) | Percent (%) | Area (Ha) | Percent (%) | Area (Ha) | Percent (%) |
|-----------|-------|-----------|-------------|-----------|-------------|-----------|-------------|
|           | 2009  | 2014      | 2020        |
| Barren Land | 190   | 0.19      | 350         | 0.35      | 1,744       | 1.76      |
| Forest    | 74,687| 75.28     | 66,475      | 66.69     | 56,969      | 57.42     |
| Paddy-field| 7,162 | 7.22      | 7,961       | 8         | 8,561       | 8.63      |
| Plantation| 8,547 | 8.61      | 15,998      | 16.07     | 22,463      | 22.64     |
| Pond      | 4,733 | 4.77      | 4,022       | 4.04      | 4,218       | 4.25      |
| Settlement| 1,888 | 1.9       | 2,813       | 2.83      | 3,244       | 3.27      |

4.2. Driving Factors of Paddy-field Land Conversion
There is a value range of 0 - 1 for each driving factor processing in determining land suitability [13]. Areas that are close to zero or colored red have a low probability of changing. Meanwhile, close to number one or colored green areas show that the region has a high probability of changing. Combining each driving factor indicates that the increased likelihood of converting paddy fields to non-paddy fields is in the east and south of the Babulu Subdistrict. The area is in good physical condition (flat), close to settlements and roads. Driving factors of paddy-field Land Conversion in the Babulu Subdistrict in detail can be seen in Figures 3a and 3b.
4.3. Prediction of Paddy-fields in Babulu Subdistrict, North Penajam Paser Regency

4.3.1. Prediction of Paddy-fields in 2020. The 2020 modeling results carried out by the CA-Markov Chain method can be seen in Figure 4. It shows that the 2020 land use and 2020 land-use models are not that different. The difference in land use differs only in barren land and paddy-fields. The existence of paddy-fields in the Babulu Subdistrict has a probability of being constant or increasing. The paddy-field area in 2020 was 8,561 ha, while the prediction model was 8,755 ha. The change from paddy-fields to non-paddy-fields in this subdistrict is not very significant. Paddy field changes only occur in areas with the right physical conditions. The kappa accuracy test for both lands shows a figure of 80% or >75%, so that land-use change models can be used to predict a land-use change in 2031[19].
4.3.2. **Prediction of Paddy-fields in 2031.** The prediction results of land use in 2031 show that forests still dominate Babulu Subdistrict as much as 41.2% of the total area. Plantation will also continue to increase until 2031. The plantation area reaches 36% of the entire Babulu Subdistrict. In the predictions of 2031, the conversion of forest land to plantations has a high probability.

4.3.3. Meanwhile, the paddy-fields in Babulu Subdistrict also increase to 4,000 ha compared to the paddy field area in 2020. Paddy-fields in 2031 will reach 12.3% of the total area—grew paddy fields in high places and close to rivers. The paddy field area increase occurred in the northern part of the Babulu Subdistrict and near the existing paddy fields. It shows that in 2031, paddy fields are still available in Babulu Subdistrict because there is no significant conversion of function. The settlement has also increased when compared to 2020. The continuing increase in settlement indicates that land demand increases due to population growth [5]. The prediction results for 2031 can be seen in Figure 5, and the detailed predicted land areas in Table 2.
Figure 5. The landuse model of Babulu Subdistrict in 2031

Table 2. The landuse model area of Babulu Subdistrict in 2031

| Landuse     | Area (Ha) | Percent (%) |
|-------------|-----------|-------------|
| Barren Land | 1,846     | 1.9         |
| Forest      | 40,051    | 41.2        |
| Paddy-field | 12,005    | 12.3        |
| Plantation  | 34,942    | 36          |
| Pond        | 4,088     | 4.2         |
| Settlement  | 4,273     | 4.4         |

5. Conclusion
The paddy-fields in Babulu Subdistrict continued to increase in the period 2009 – 2020. The area of paddy fields in 2020 shows that the paddy fields continued to grow compared to previous years. The change from paddy-fields to non-paddy-fields in this subdistrict is not very significant. Paddy-field changes only occur in areas with good physical conditions. The kappa accuracy test shows the number 80% so that it can predict land-use changes. Modeling using the CA-Markov Chain in 2031 shows that the paddy-field area has a probability of increasing. Paddy-field in 2031 will reach 12.3% of the total area. Paddy-fields have an increased probability in areas that are high and close to rivers. In conclusion, in 2031, there will still be sufficient paddy-fields in Babulu Subdistrict. However, the paddy-fields land in the Babulu Subdistrict has increased in line with the increasing trend of the plantations and settlements area.
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