THE USE OF MARKOV CELLULAR AUTOMATA TECHNIQUE FOR PREDICTING FOREST COVER CHANGE IN ROKAN HULU, RIAU PROVINCE, INDONESIA

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ABSTRACT

ZAINAL WASSAHUA. The Use of Markov Cellular Automata Technique for Predicting Forest Cover Change. Under the supervision of I NENGAH SURATI JAYA and ANTONIUS B WIJANARTO.

The implementation of Markov Cellular Automata (M-CA) for predicting forest cover change in Rokan Hulu Regency, Riau Province was examined. The main objective of the study was to evaluate the use of M-CA to detect forest cover changes between 2005 until 2009. Land cover map for 2002 and 2005 derived from qualitative interpretation have been performed as the basis input in change detection. The methods applied include the visual image classification, Markov Chain, and Cellular Automata. The Cellular Automata can represent spatial dimension from a dynamic process of forest change. The study found that the simulation produced reasonable results, indicated by the Kappa Index Agreement of 68.5%. For the case of the change from forest to non-forest, there is disagreement only 1.2% between the simulation and the actual data.

Key words: M-CA, Markov Chain, Cellular Automata, forest cover changes, change detection method.
ABSTRAK

ZAINAL WASSAHUA. Implementasi Markov Cellular Automata untuk Memprediksi Perubahan Tutupan Hutan di Kabupaten Rokan Hulu, Provinsi Riau. Dibimbing oleh I NENGHA SURATI JAYA dan ANTONIUS B WIJANARTO.


Kata kunci: M-CA, Markov Chain, Cellular Automata, perubahan tutupan hutan, metode deteksi perubahan.
ZAINAL WASSAHUA. The Use of Markov Cellular Automata Technique for Predicting Forest Cover Change. Under the supervision of I NENGGAH SURATI JAYA and ANTONIUS B WIJANARTO.

Recently, forest degradation and deforestation have occurred in Riau Province, particularly in Rokan Hulu which has certainly been a great national attention. Deforestation occurred not only in production forest but also in protection forest. As noted by Himawan (2009), 70% out of 78,000 ha of protected forest in Rokan Hulu Regency has been changed into several uses. However, the exact area of changes had not been well estimated, because the prediction is solely based upon terrestrial measurement.

The high pressure on forest resources and the lack of data and adequate information encouraged to perform periodic monitoring of the changes. It is an essential action to keep conservation and control of forest natural resource. Nowadays, Remote Sensing technologies can be used to identify Forest natural resource. The advanced stage of this work is focused on developing M-CA to simulate forest cover change over time period of seven years.

Integration of Markov chain and cellular automata is known as Markov Cellular Automata approach incorporating the principles of forest change in a cell related to the surrounding cells (Cellular Automata Principle) with changes in the future forest determined by current and past conditions (Markov Chain). Another parameter is the map of land probability that defines the direction of changes in surrounding cells. The objective of the research is to evaluate the use of Markov Cellular Automata to detect forest cover changes in Rokan Hulu Regency, Riau Province, between 2005 until 2009.

The research has been conducted in the period of July 2009 - January 2010. The research site of study is Rokan Hulu Regency, Riau Province, Indonesia. There are several kinds of data used in this study were summarized. Landsat 7 ETM+ of 2002, 2005, and 2009 were processed using image classification to get the land cover of 2002, 2005, and 2009. Probability map derived from multiplication maps of river, road, settlement, slope, and elevation using Boolean intersection. Transition matrix derived from Markov Chain process using land cover maps of 2002 and 2005 as the inputs. Simulation map of 2009 derived from Markov Cellular Automata process using land cover map of 2005, transition matrix, and probability map as the inputs. Furthermore, land cover map of 2009 using for validating the simulation map.

This research was conducted by executing five main activities namely land cover classification, Markov Chain detection, driving factors analysis, Cellular Automata and forest change prediction analysis. The main measurement data derived from field work were ground survey. Ground survey data from the field is important to be used for assessment. Other data were required in this study especially for spatial data like raster, vector, and tabular as mentioned before. The
Short-interval trend of land cover changes (2002-2005) have been visually classified. Seven land cover classes were spectrally separable, i.e., forest, built up area, plantation, agricultural land, shrub/barren, water body, and barren land. Identification of the land cover types is based on their own characteristics.

Based on change detection statistics of report for period 2002-2005 (pixels), changes during the period 2002 to 2005 were found. Changes increases in water body about 0.3%, shrub/barren land about 21%, built up area about 0.2%, and plantation about 22%. Whereas decreases occurred in the two other land cover classes such as forest about 33%, and agricultural land about 18%.

The trends of changes in land cover areas that occurred during 2002-2009. There was a decrease in forest cover area of 57,640.6 ha in 2005 and 111,521.4 ha in 2009 compared to 2002. Decrease in forest cover area is followed by an increase in plantation areas. The use of land for plantations increased dramatically and very dominant since 2005 till 2009 (194,065.4 ha in 2002, 249,579.9 ha in 2005, and 440,040.2 ha in 2009).

Simulation of forest cover changes using M-CA has been done by making the three components as inputs. These components are basis land cover image, markov transition area file and, transition probability image collection. This process was done by determining the number of the 4 time steps (2005-2009) as the total number of iterations. While, filtering type 5x5 cell contiguity filter is used for forest cover from 2005 to 2009.

Calculation of KIA was obtained 68.5% overall accuracy. The validation of the Markov Cellular Automaton is understood as the assessment of how closely it resembles the simulations to reality.

Trend of forest cover change is a major concern which continues to be degradation from year to year respectively of 2002, 2005, and 2009. Total area of non forest is 503,367.95 ha and the forest area is 503,367.95 ha or 31.72% from total area in 2002. The forest area is 176,177.39 ha with 23.90% from total area or decrease to 57,640.6 ha in 2005. At the different time, the same thing happened in the forest area of 2009 (classification result) is 122,296.58 ha or 16.59% from total area. The forest area decreases to 57,640.6 ha in 2005 and 111,521.4 ha in 2009 (classification result). Thus, from observations through the three time series shows the changes in forest cover decreased. On the other hand, result from the simulation look a little different with the actual conditions. This difference is shown by the 113,758.17 ha forest areas or 15.43% from total area in 2009 (simulation) compared with 122,296.58 ha or 16.59% from total area in 2009 (actual). The ratio of forest cover areas in simulation is 8,538.41 ha less than the actual area in 2009.

Further analysis related to this study is change of forest area in protected forest area. The total protected forest area is 50,659.42 ha (100%), and Bukit Suligi protected forest area is 17,227.51 ha (34.01%). Likewise, Mahato protected forest area is 17,905.09 ha (35.34%) and Sei Rokan protected forest area is 15,526.83 ha (30.65%). Mahato protected forest has a larger area than Bukit Suligi and Sei Rokan, respectively in 2002. In 2005, the total protected forest area decreased to 32,667.42 ha, Bukit Suligi protected forest is 13,171.60 ha (40.32%). Mahato protected forest area decreased to 4,371.10 ha (13.38%) and Sei Rokan
protected area to 15,124.73 ha (46.30%). A decrease in the protected forest areas also occurred in 2009. The total protected forest area was reduced to 24,184.78 ha as a result from the decreasing protected forest areas of Bukit Suligi, Mahato, dan Sei Rokan with areas of, 9,290.47 ha (38.41%), 734.83 ha (3.04%), and 14,159.48 ha (58.55%), respectively in 2009 (actual). While, the total protected forest areas is 22,824.01 ha accumulated from degradation of protected forest area of Bukit Suligi (7,764.33 ha or 34.02%), Mahato (3,027.59 ha or 13.26%), and Sei Rokan (22,824.01 ha or 52.72%) in 2009 (simulation). There is a real difference between the actual and simulation as seen by the changes in the Mahato protected forest area with a ratio of 2,292.76 ha area in simulation which is greater than the actual. The decrease in protected forest area is supported by land conversion activities of Mahato protected forest area to oil palm plantation by the local people.

From the foregoing discussion, the conclusion can be described as follows. First, the M-CA produced reasonably good result, indicated by the Kappa Index Agreement of 68.5%. There is a miss-agreement of forest and non forest classes between the predicted result and the actual data mainly due to forest conversion rate. Second, the most effective data required in M-CA to detect forest cover change are as follows: land covers map, transition area matrix, and transition probability matrix for forest cover change.

Furthermore, the recommendation from the study can be described as; to improve the prediction of forest cover change, it is recommended to apply more time series data. Since the agreement is only 68.5%, the model can be used to only predict forest cover change in the near future indicatively. Careful application should be taken into correct particularly for forest cover change having unstable (fluctuated) rate of change.

Key words: M-CA, Markov Chain, Cellular Automata, forest cover changes, change detection method.
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Hopefully, this thesis could give the positive contribution for anyone who reads it.
CURRICULUM VITAE

Zainal Wassahua was born in Kabauw, Maluku, Indonesia on July 6th 1982. He was graduated from Muslim Indonesia University, Fishery Faculty, and Utilization of Fishery Resources Department in 2006. He was entered the IPB Graduate School in year 2007. He was enrolled as private student in Master of Sciences in Information Technology for Natural Resources Management, Bogor Agricultural University in 2007, and completed his master study in 2010. His final thesis is “The Use of Markov Cellular Automata Technique for Predicting Forest Cover Change in Rokan Hulu, Riau Province, Indonesia”
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