Modelling of land use change in Indramayu District, West Java Province

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Abstract. Indramayu District into a strategic area for a stopover and overseas from East Java area because Indramayu District passed the north coast main lane, which is the first as the economic lifeblood of the Java Island. Indramayu District is part of mainstream economic Java pathways so that physical development of the area and population density as well as community activities grew by leaps and bounds. Growth acceleration raised the level of land use change. Land use change and population activities in coastal area would reduce the carrying capacity and impact on environmental quality. This research aim to analyse landuse change of years 2000 and 2011 in Indramayu District. Using this land use change map, we can predict the condition of landuse change of year 2022 in Indramayu District. Cellular Automata Markov (Markov CA) Method is used to create a spatial model of land use changes. The results of this study are predictive of land use in 2022 and the suitability with Spatial Plan (RTRW). A settlement increase predicted to continue in the future the designation of the land according to the spatial plan should be maintained.

1. Introduction

Along with the increasing human activities in various sectors, especially the economic sector, hence the demand for land resources will also increase. The availability of land relatively fixed will lead to high competition of land use. Land use changes would be a problem if it occurs in areas that have a conservation function or agriculturally productive because it can cause food production decreased and environmental losses [1]. Land-use system is a natural, social and economic complex spatial dynamics with open, non-linear, comprehensive, random, hierarchical, dynamic, and uncertainty of complex characteristics. Dynamic evolution of urban land use is highly complex affected by the natural, social, economic, cultural, political and legal and other factors. At present, urban land use changed dramatically under the common influence of physical geography and human environmental system, affecting all aspects of sustainable urban development, the problems brought to mankind [2].

The CA-Markov land use change model can be applicable for spatial land use simulation and landcover reconstructions. Using satellite-derived land use or cover maps, Courage *et al.*[3] combined the Markov-cellular automata model to simulate land use changes in the Musana and

Masembura case in Zimbabwe. Although this study represented an important contribution to land use modeling by the integration of biophysical and socioeconomic data into a spatially explicit Markov cellular automata land use simulation model in a landscape, these simulation result lack of model validation and accuracy assessment. Some researchers in China used this robust approach to simulate the land use change and analysis the structure the land use in the future [4, 5].

In this paper, the study area was Indramayu District, West Java Province. Indramayu District into a strategic area for a stopover and overseas from East Java area because Indramayu District passed the north coast main line, which is the first as the economic lifeblood of the Java Island. Indramayu District is one district that included the Regional Development Ciayumajakuning (Indramayu-Cirebon-Majalengka-Kuningan) located in the northern part of West Java Province. This distric located on the northern coast of West Java Province and rear area (hinterland) from Cirebon City. Cirebon City be directed to the National Even Centre while Indramayu District directed into a Regional Activity Centre [6]. Indramayu District is part of mainstream economic Java pathways so that physical development of the area and population density as well as community activities grew by leaps and bounds. Growth acceleration raised the level of land use

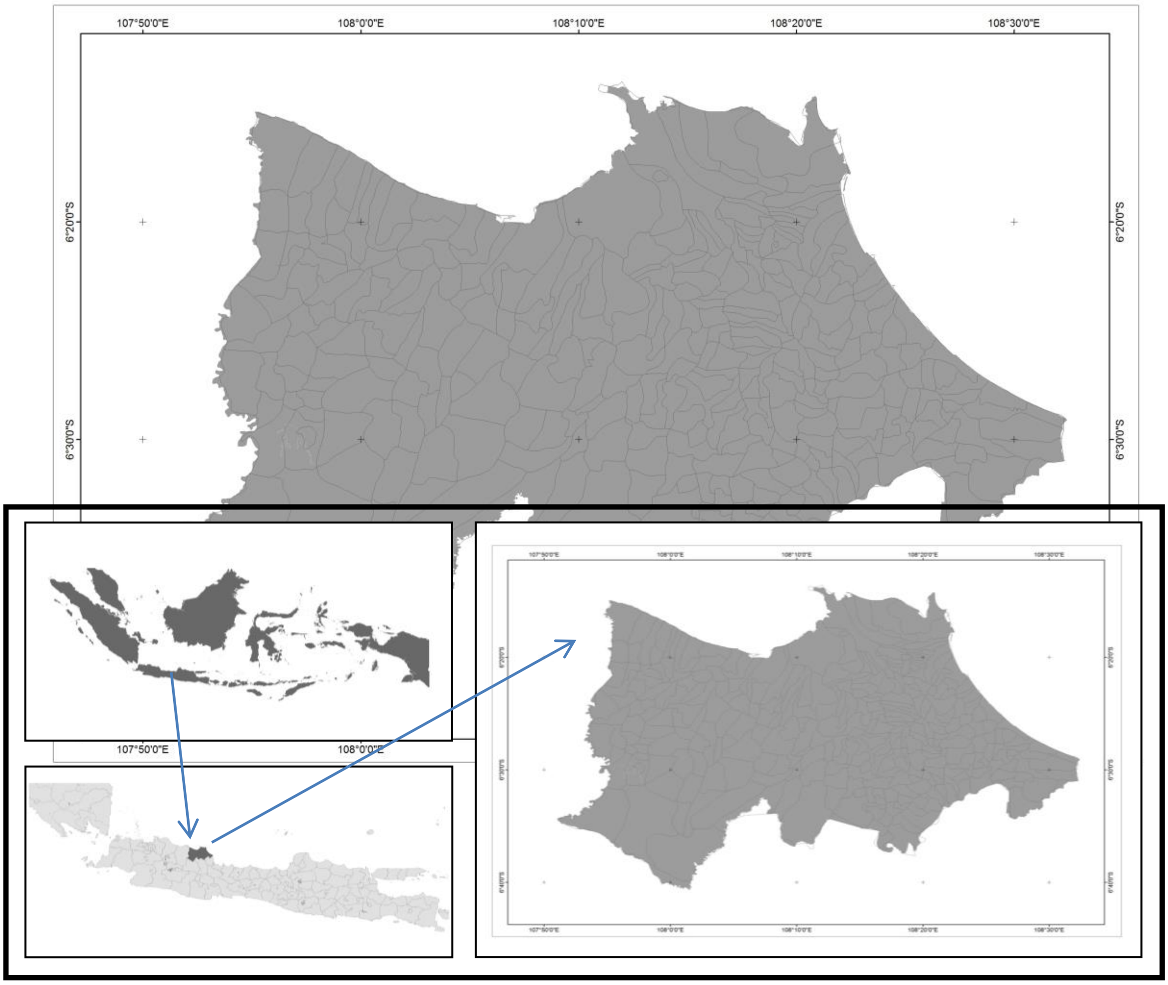

Figure 1. Study area

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2.2. Data collection

The main data used in this research is satellite images data. The images data are Landsat 7 ETM (2000 and 2011). Besides the satellite images, this research also need Indonesia Digital Map (RBI) at Indramayu scene. This RBI data will be used for geometric correction. The tools that used in this research were varied. The main tools are ArcGIS 10.1 software and Idrisi Selva. These tools serve to collect, to save, and to analyze data.

Table 1. Research's material, source, and its function.

Material	Unit	Source	Tool's function
Digital Map (RBI)	Vector	Geospatial Information Agency	Earth Surface Map
Satellite Images Path 121 row 064 and 065	Landsat 7 ETM (Raster) 30x30 m pixel resolution	earthexplorer.usgs.gov U.S Geological survey	Land Use Change Analysis

2.3. Land use analysis

Satellite images obtained prior correction of geometry into place in accordance with the position of objects on the Earth's surface. The image that has been corrected and then a visual interpretation refers to the interpretation that the key hue, texture, pattern, size, shape, shade and sites [7]. Interpretation of results were then verified to determine the accuracy of interpretation by interpreters.

2.4. Land use suitability map

Land use suitability maps for each land use is one of the inputs in the process of CA-Markov. The series serves as a reference map of allocating a land use [8]. Land suitability map serves as a reference for land use allocation. Land suitability evaluation is an attempt to evaluate the use of land, where the land use should be tailored to the land characteristics (physical and chemical) [8]. In this study, land suitability analysis was limited to the physical characteristics of the land only, include: soil physical properties (rock material type, soil type and soil texture), slope, elevation, rainfall, lithology, and analysis of competitive commodities. Land suitability maps were made for eight land use. Land suitability classes consist of two classes of grade appropriate (S) and is not suitable (N). Conformance criteria based on the criteria [9].

2.5. Land use change analysis with Markov-Cellular Automata

Markov Chain is approach in order to get transition probability matrix from past periods of land use to predict land use in future periods. The main factor in Markov Chain is transition probability, a conditional probability for system to undergo transition to new state and gives current state of the system. Transition matrix is representing the changes among two land use occurred during that period. The changing happened in two different land use will form transition matrices. [10] explained that Markov Chain can be used to predict future matrix of vector (tn) based on past matrix of vector (t1) by transition probability matrix, while transition probability matrix is derived from probability changing between past matrix vector and previous (t1 and t0).

$$Q_{t+1} = Q_t^T P^n$$

$$\begin{matrix} q_1 \\ q_2 \\ \dots \\ q_m \end{matrix} = \begin{matrix} q_1 \\ q_2 \\ \dots \\ q_m \end{matrix}_t^{\;T} \begin{matrix} q_1 & q_1 & \dots & q_1 \\ q_1 & q_1 & \dots & q_1 \\ \dots & \dots & \dots & \dots \\ q_1 & q_1 & \dots & q_1 \end{matrix}^{\;n} \qquad (1)$$

Where:

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n = number of time steps
m = number of states
Q_t = vector initial states at an initial time t
Q_{t+1}= vector of states at the next time $t+1$
P = transition probabilities matrix

Cellular Automata (CA) is one of application in spatial dynamics modeling that mainly in land use change simulation [11]. Cellular Automata are neighborhood based cell while transition between it is determined by states in its neighborhood and probability transition. Standard cellular automaton can be defined as function that defines change of state from time past time to future and influenced by neighborhood of all cells [12]. Cellular Automata as modeling approaches has basic elements comprises of series of cells or grid, set of local states, a neighborhood and transition rules. There are several factors involved in Cellular Automata model such as Transition Probability which is from Markov Chain, Suitability factors and Neighborhood influences. The explanation of those factors explained as follows: suitability indexes and neighborhood indexes.

Inputs for Markov Chain were:
1. Land use image of t1=2000; t2=2011
2. Defining number of time periods between t1 and t2
3. Defining number of time periods to project forward from t2

Outputs from Markov Chain analysis were:
1. Transition probability matrix (TPM) which express probability of each land use category that will change to every other category.
2. Transition areas matrix which express the total area (number of pixels) which expected to change in next period.
3. A set of conditional probability images which express the probability that each pixel will belong to the designated class in next period.

Inputs for Cellular Automata model were
1. Basis land use image of t2
2. Transition Probability Matrix (TPM 2000-2011)
3. Land suitability
4. Defining the moving filter size as 5x5 where central pixel where this filter will move and weighted the pixel one by one.
5. Defining iteration of model: 2, 4, 8, 11, 22, 33

Outputs from Cellular Automata analysis were:
1. Predicted of land use of t=2022
   Firstly, CA-Markov modeling was conducted in order to validate the model at various iteration Validation was conducted by assessing predicted land use t=2022 with actual land use t=2011 using Kappa Accuracy assessment.
2. Predicted of land use change in future years t=2022
   Secondly, CA-Markov modeling was conducted to predict land use t=2022 by using iteration that had optimum accuracy result based on model validation. The result of predicted land use then was used to analyze future condition of land use.

The first model is done by executing input models with base year is 2000, and the matrix area trasition 2000-2011 resulting in a prediction map land use in 2011. Validation is done with the existing land use map in 2011 which is based on the value of kappa [13],

$$Kappa\ Accuracy = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \times x_{+i})} \quad (2)$$

x_{+I} :wide of land use type-i observation result

x_{i+} : wide of land use type-i simulation result
x_{ii} : wide of land use type-i simulation result correspond with observation result
i : Path and row
r : number of land use type
N : total area all of land use type
Kappa value in validating the model is expected to get a percentage of more than 85%.

2.6. Control of land use change scenario

Preparation of land use change control scenarios in Indramayu District, carried out using land suitability based on the policies to be taken. The scenario in Indramayu geared to fit the pattern space Spatial Plan (RTRW) 2011-2031 Indramayu district. The scenario that has the smallest mismatch with space on spatial pattern is the most ideal scenario for controlling land use changes.

3. Results and discussions

3.1 Land use change 2000-2011

Based on the result at interpretation process, the images were classified into 8 classes: plantation, settlement, dryland farming, paddy field, scrub, fishpond, fishpond, open field, and water. Value kappa accuracy of Landsat imagery interpretation results is 85.01%. This classification produces land use map year of 2000 and 2011 (figure 2 and 3).

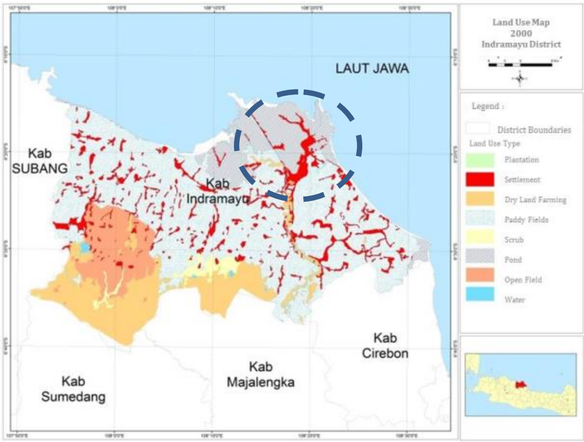

Figure 2. Land use map 2000

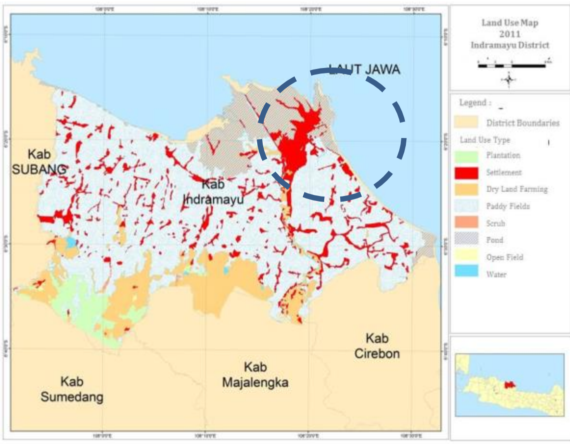

Figure 3. Land use map 2011

The paddy field landscape (figure 2 and 3) is still dominated the area in 2000 and 2011because Indramayu District dominated by alluvial deposits. Alluvial deposits came from sediment of river cause many sub watershed contained in Indramayu (32 sub watersheds), it suitable for paddy field that supported with rainfall ranging between 1900-4100 mm/year. Indramayu District dominantly used by slope class 1 (0-3%), that used for paddy field, settlement, and pond. The interpretation results showed the settlement increased from 2000 to 2011 (blue circle). Settlement area located in the northern part of the district, it is due to the northern coastal road into artery lane of transportation in Java Island. In the southern of the district bordering with Majalengka District, in 2000 was dominated by scrubs and dryland farming, this is due to have a slope grade 3 (8-15%) and 4 (15-45%), while in the year 2011 was dominated by dry land farming, and the scrub converted into a plantation. Indramayu District land use is dominated by paddy fields with an area of 146.115 ha is equivalent to 69.59% of total area. While the settlements area of 18.520 ha approximately 8.82% of the Indramayu District total area.

The prediction results of land use in 2022 compared to 2011 are presented in figure 4-9.

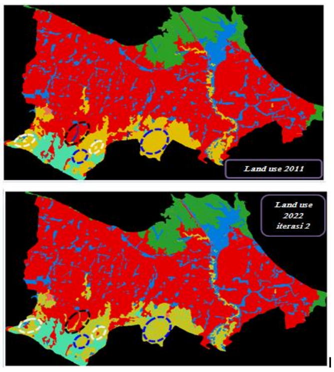

Figure 4. Land use in 2022 iteration 2

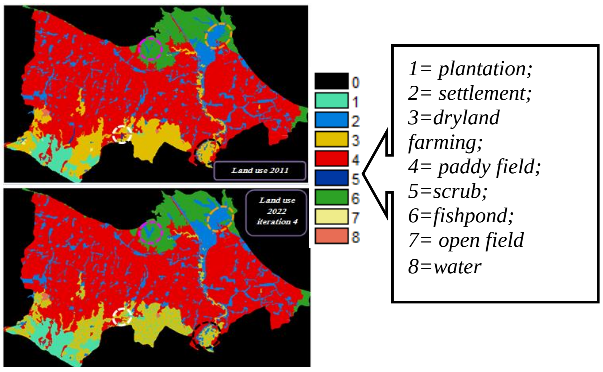

Figure 5. Land use in 2022 iteration 4

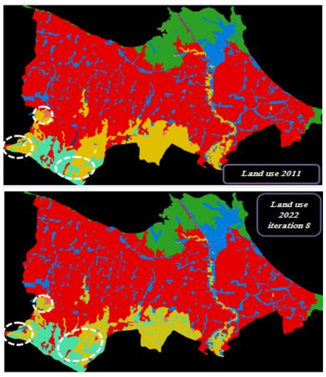

Figure 6. Land use in 2022 iteration 8

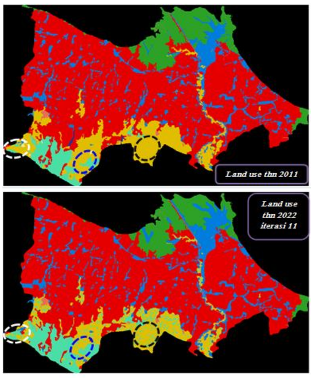

Figure 7. Land use in 2022 iteration 11

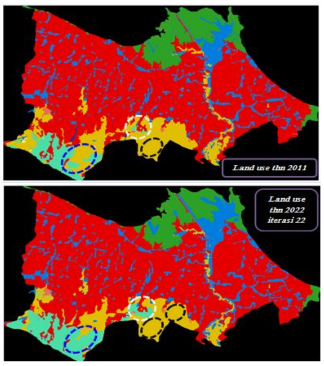

Figure 8. Land use in 2022 iteration 22

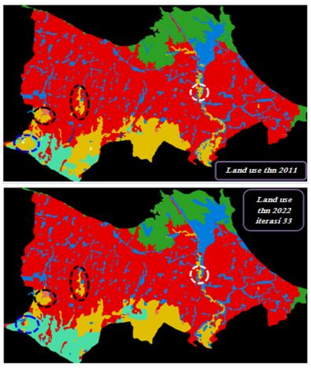

Figure 9. Land use in 2022 iteration 33

Based on the validation results is kappa values for all kinds of iterations shows that all products are estimated based on ca-Markov produced can be quite good for kappa values of all the results of the validation approach 1, where in kappa values of each iteration it is; iteration 2 is 0.9116 (91.16%), iteration 4 is 0.9079 (90.79%), iteration 8 is 0.9079 (90.79%), iteration 11 is 0.9086 (90.86%), iteration 22 is 0.9085 (90.85%) and iteration 33 is 0907 (90.7%). The highest kappa value validation results prediction of land use in 2011 obtained the iteration 2 is equal to 91.16%. Transitional Probababilty Matrix, land suitability, filter 5 × 5 and iteration 2 then used to make predictions of land use for a period of 11 years into the future is the use of land in 2022 (figure 8).

The matrix table (figure 9) shows that the numbers in red circles are a component of land use changes that seemed less appropriate, that occurs in class2-class4 (transition 236 cell of the settlement into paddy fields) and class2-class6 (transition 6 cell of the settlement into the pond) , Components class1-class1, class2-class2, class3-class3, class4-class4, class5-class5, class6-class6, class7-class7 and class8-class8 indicates that changes the class follow the types of land use before (predicted not easily turned into other land use class, for example will remain a paddy field).

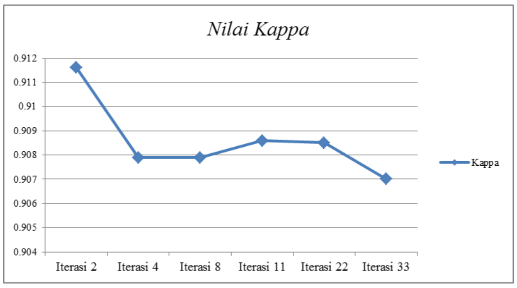

Figure 8. Comparison of Kappa value in transition the various iterations of use for estimations of land use for the year 2022

	cl. 1	cl. 2	cl. 3	cl. 4	cl. 5	cl. 6	cl. 7	cl. 8
Class 1 :	87207	0	0	0	0	0	0	0
Class 2 :	0	246206	17	236	0	6	0	0
Class 3 :	66629	8577	197882	14059	0	0	1	0
Class 4 :	0	2426	19390	1385778	0	1279	0	0
Class 5 :	328	0	1801	298	156	0	0	0
Class 6 :	0	24617	0	60	0	195536	0	0
Class 7 :	0	0	0	1888	0	0	20	0
Class 8 :	0	0	0	0	0	0	0	12046

Figure 9. Prediction number of cells undergoing

On the map, red circle shows unsuitability land use designation in the draft Spatial Plan (RTRW) Indramayu District, which in the north (coastal) is ponds land use while the allocation is protected areas (red circle).
in accordance with the analysis, it is known that unsuitability RTRW 2011-2031 with land use in 2022 in the amount of 67.576 ha and area suitibility with RTRW is 136.221 Ha.

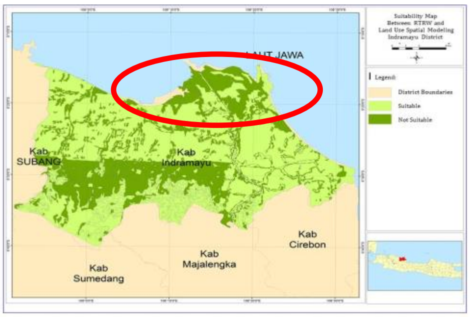

Figure 10. Suitability map

4. Conclusion

Land use changes in 2000-2011 increased in the total area of settlement (18 520 ha approximately 8.82% of the total area of Indramayu district). Based on modeling results, it is known that unsuitability RTRW 2011-2031 with land use in 2022 attained 67.576 ha. Hence necessary for government intervation related the control of Land functional shift. Thus, the designation of the land according to the spatial plan should be maintained. The intervention of the government can not directly change the previous land use, example pond as a protected area (mangrove). This is because the associated livelihoods of coastal residents. It is hoped that the restoration of the protected areas do not affect the population income and socio-economic conditions in the region.

References

[1] Pribadi D O, Shiddiq D and Ermyanyla M 2006 Model Perubahan Tutupan Lahan dan Faktor-Faktor yang Mempengaruhinya *Jurnal Teknologi Lingkungan* **7** 35-51
[2] Wang S Q, Zheng X Q and Zang X B 2012 Accuracy Assessment of Land Use Change Simulation Based on Markov-Cellular Automata Model *Procedia Environmental Sciences* **13** 1238-1245
[3] Kamusoko C, Aniya M, Adi B, Manjoro M and Eason G 2009 Rural sustainability under threat in Zimbabwe-Simulation of future land use/cover changes in the Bindura district based on the Markov-cellular automata model *Applied Geography* **29** 435-47
[4] Hou X Y, Chang B and Yu X F 2004 Land use change in Hexi corridor based on CA-Markov methods *Transactions of the CSAE* **20** 286-91.
[5] Yang G Q, Liu Y L and Wu Z F 2007 Analysis and simulation of land-use Temporal and spatial pattern based on CA-Markov model *Geomatics and Information Science of Wuhan University* **32** 414-7

[6] BAPPEDA 2012 Local Regulation No 1 *Spatial Plans Indramayu District 2011-2031*. Retrieved from *http://www.indramayukab.go.id*. on Desember 2015; Dated 2012 (in Indonesian)
[7] Lilesand M T and Kiefer R W 1993 *Penginderaan Jauh dan Interpretasi Citra [terjemahan]* (Yogyakarta (ID): Universitas Gadjah Mada)
[8] Munibah K 2008 Model Spasial Perubahan Penggunaan Lahan dan Arahan Penggunaan Lahan Berwawasan Lingkungan Studi Kasus DAS Cidanau, Provinsi Banten *Disertation* (Bogor: Sekolah Pascasarjana Institut Pertanian Bogor)
[9] Hardjowigeno and Widiatmaka 2007 *Evaluasi Kesesuaian Lahan dan Perencanaan Tataguna Lahan* (Yogyakarta: Gadjah Mada University Press)
[10] Ozah A P, Adesina F A and Dami A 2012 *A* Deterministic Cellular Automata Model for Simulating Rural Land Use Dynamics: A Case Study of Lake Chad Basin *IJEE* **2** 22-34
[11] White R and Engelen G 2000 High-Resolution Integrated Modelling of The Spatial Dynamics of Urban and Regional Systems *Comput Environ Urban* **24** 383- 400
[12] Li X and On Yeh AG 2001 Zoning Land for Agriculture Protection by The Integration of Remote Sensing, GIS and Cellular Automata *Photogramm Eng Rem S* **67** 471-477
[13] Jensen J R 1996 *Introductory digital image processing: A remote sensing perspective* 2nd Edition (New Jersey (US) Prenctice Hall)

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