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Model of land cover change with cellular automata, Mataram city, West Nusa Tenggara

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Abstract. Along with the increase of population, the needs for space for agriculture, settlement, infrastructure, and industry are increasing. It affects the extent to the availability and sustaining human needs. The objectives of this research are: (1) to analyze land cover change in Mataram in 2008, 2013, and 2017, (2) to predict land cover in 2031 in Mataram using Cellular Automata spatial modeling. The Method used to predict land cover changes is by modeling Cellular Automata. Driving factors used in this research, are: slope, elevation, distance from roads, distance from the river, distance from shoreline, and distance from the central government. From 2008 to 2017 Mataram had a significant decrease of agricultural land area by (-)12,63% and the increase of the land and settlement building by 26,35%. The result of land cover prediction of 2031 shows agricultural area reduce by (-)15,18% and sharp increase in built and settlement area by 20,52%.

1. Introduction

Along with the increased population, the need for space for agriculture, settlement, infrastructure, and industry is increasing. It affects the extent to the availability and ability of land in sustaining human needs. According to Baja (2012) [1], the land also has an important role in regional development, to meet the needs of human life and environmental protection. The basic problem of land is the increasing of human population, the need for land continuous to increase, but the availability of land is limited.

Mataram has a strategic location and become the center of various activities such as government center, education, trade, industry and services. Mataram has been developed into a tourism city. The existence of various supporting facilities is one of the considerations in the development of the Mataram into a tourist city. Establishment of Mataram as the center of national activities and one of tourism destinations requires the region to develop infrastructure, such as road networks, hotels, shopping malls and other facilities.

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This research was intended to employ Geographical Information System and Remote sensing techniques to detect land cover change in 2031. Several driving factors on land cover change used in this research refer to the references from Sujarto (1992) [2], based on physical factors and accessibility factors. Driving factors in this research are slope, elevation, distance from river, distance from shoreline, distance from road, and distance from central government.

The prediction of this research is done by make a dynamic model of land cover, with the approaching of Cellular Automata (CA). Cellular Automata (CA) is a discrete agent-based method, commonly used in the most widely used cell-based application to simulate land use change over the last few decades (Davies, et al. 2014 & Chia-An, 2016) [3]. The land use model using CA has been implemented as a tool to support land use planning and policy analysis to exploring scenarios for future development (Van Vliet et al., 2009) [4]. Modeling with dynamic system approach has dynamic properties in time, so it can predict condition in the future. Therefore this research was intended to employ Geographycal Information System and remote sensing techniques to detect cover change in Mataram City in 2008, 2013 and 2017, and Markov - Cellular Automata (CA) methodologies to simulating land cover change in 2031 using Land Change Modeler tools on Idrisi Selva software.

2. Method

2.1 Study Area

Mataram was established based on the Law Number 4 in 1993 on the Formation of Municipality of Mataram. Mataram is the Capital of West Nusa Tenggara Province and flanked by West Lombok District and Lombok Strait. Geographically Mataram lies between $116^{0}04$'- $116^{0}10$' E and between $08^{0}33$'-$08^{0}38$' S. Based on the Regional Regulation of Mataram Number: 3 in 2007, Concerning Expansion Sub-district in Mataram, the previous sub-district that consist of 3 (three) sub-district has been divided into 6 (six) sub-district. Administratively, Mataram consist of 6 districts namely, District Ampenan, Cakranegara, Mataram, Sandubaya, Selaparang and Sekarbela (Figure 1).

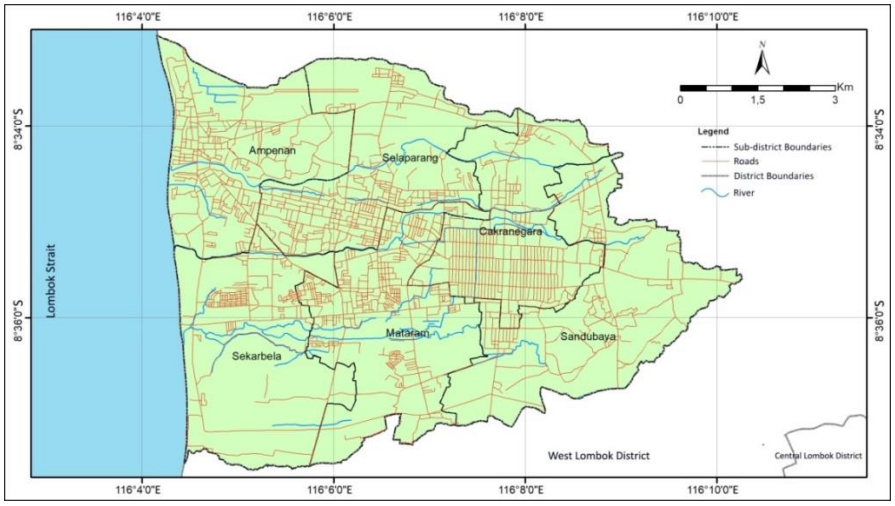


Figure 1. Map of Mataram City

2.2 Materials

- Satellite Data: Landsat image 116 and row 66, the image used in this research is Landsat Image 7 and 8 with a spatial resolution of 30 meters. The image is obtained from USGS, the image used is the image of Mataram in 2008, 2013, and 2017 to see temporal land cover changes in the region. Landsat 7 ETM for 2008 and 2013, Landsat 8 OLI for 2017.
- Software: Idrisi Selva 17, ENVI 5.1, dan Arc GIS 10.3.

2.3 Data Analysis

- Image Classification: The land cover classification used is supervised classification using ENVI 5.1 software. The classification process produces land cover maps in 2008, 2013 and 2017. Classification of land cover used is 5 classification, namely: agricultural area, non-agricultural area, open field, built and settlement area.
- Land Cover Change: Land cover change detection was conducted by postclassification comparison change detection using ARC GIS 10.3. This was achieved by comparative analysis of the years 2008-2013 and 2013-2017 (Figure 2 and 3).

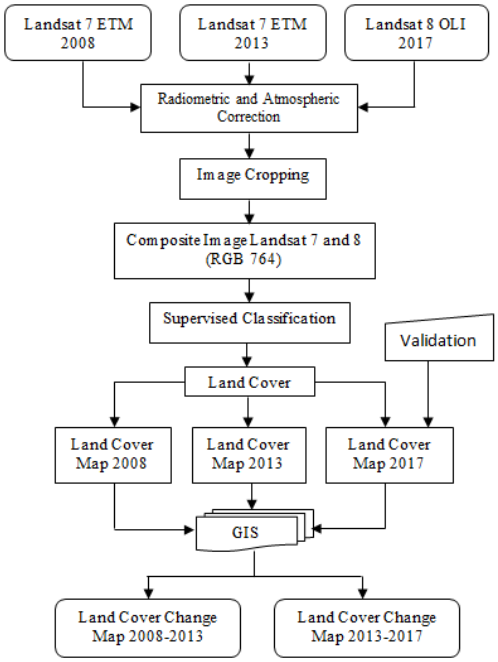


Figure 2. Image Analysis and Detection Process

- CA –Markov: Markov chain and CA are the discrete dynamic model in time and state [5]. One inherent problem with Markov is that it provides no sense of geography. The transition probabilities may be accurate on per category basis, but there is no knowledge of the spatial distribution of occurrences within each landuse category [3]. The Idrisi Selva 17 integrates CA with Markov very well [6]. In this research, we take the Idrisi GIS software to simulate the land cover in Mataram City. The driving factors that used in this research are slope, elevation, distance from road, distance from river, distance from central government, distance from shoreline.

3. Results and Discussions

3.1 Land Cover Change 2008, 2013, and 2017

Land cover change in Mataram City were carried out by visual interpretation of landsat images in 2008, 2013 and 2017. There are five classification of land cover that used here, namely : water bodies, agricultural land, non-agricultural land, open land, built-up land and settlements. The result of land cover has five classification, namely: water bodies, agricultural area, non-agricultural area, open field, built and settlement area. The change in land cover of Mataram is shown in Figure 4 and 5. Land cover change in Mataram in 2008 to 2017 experienced a widespread increased for built up and settlement area of 1.585,52 hectare (26,35%), open field of 7,02 hectare (0,12%). Meanwhile, water bodies decreased by -6,64 hectare (-0,11%), non-agricultural area by -825,81 hectare (-13,72%), and

agricultural area of -760,10 ha (-12,63%) (Tables 1 and 2). Trend of decreasement of agricultural land in the city of Mataram in 2008 to 2017 indicates there is increasement of built-up area and settlements. Conversion of agricultural land into built-up land and settlements can be seen in the picture. (Input Pic 1 and 2, see the thesis).

Over time, the trend of increasement area of built-up land and settlements in 2008 to 2017 is one of the factor of increasing population every year. Mataram City has considerable attraction in attracting resident from outside the city, because Mataram City is one of tourism destination and has the potention as a hub of the surrounding tourism area. The Tourism area which has the influence on the development of the city are Senggigi Beach, Kuta Beach, Gili Trawangan, Gili Air, Gili Meno, Mount Rinjani, etc.

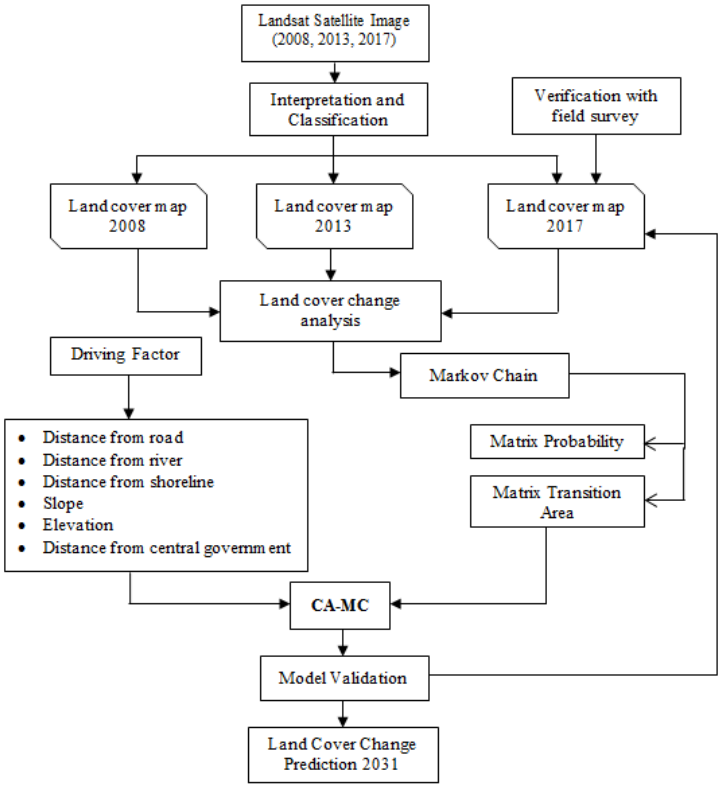
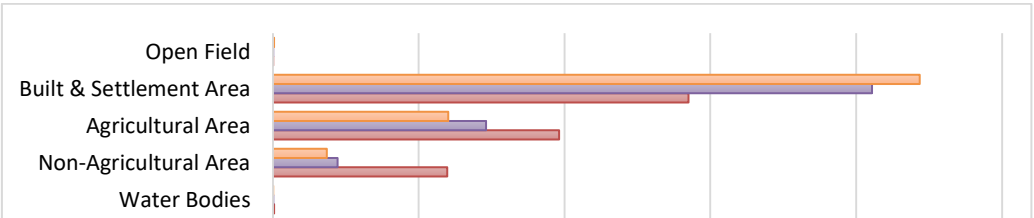


Figure 3. Land Cover Modeling Process



	Water Bodies	Non-Agricultural Area	Agricultural Area	Built & Settlement Area	Open Field
2017 (Ha)	1.53	369.67	1202.43	4435.42	7.83
2013 (Ha)	2.61	443.51	1461.62	4108.37	0.72
2008 (Ha)	8.17	1195.48	1962.52	2849.90	0.81

Figure 4. Land Cover Graph of Mataram in 2008, 2013, and 2017

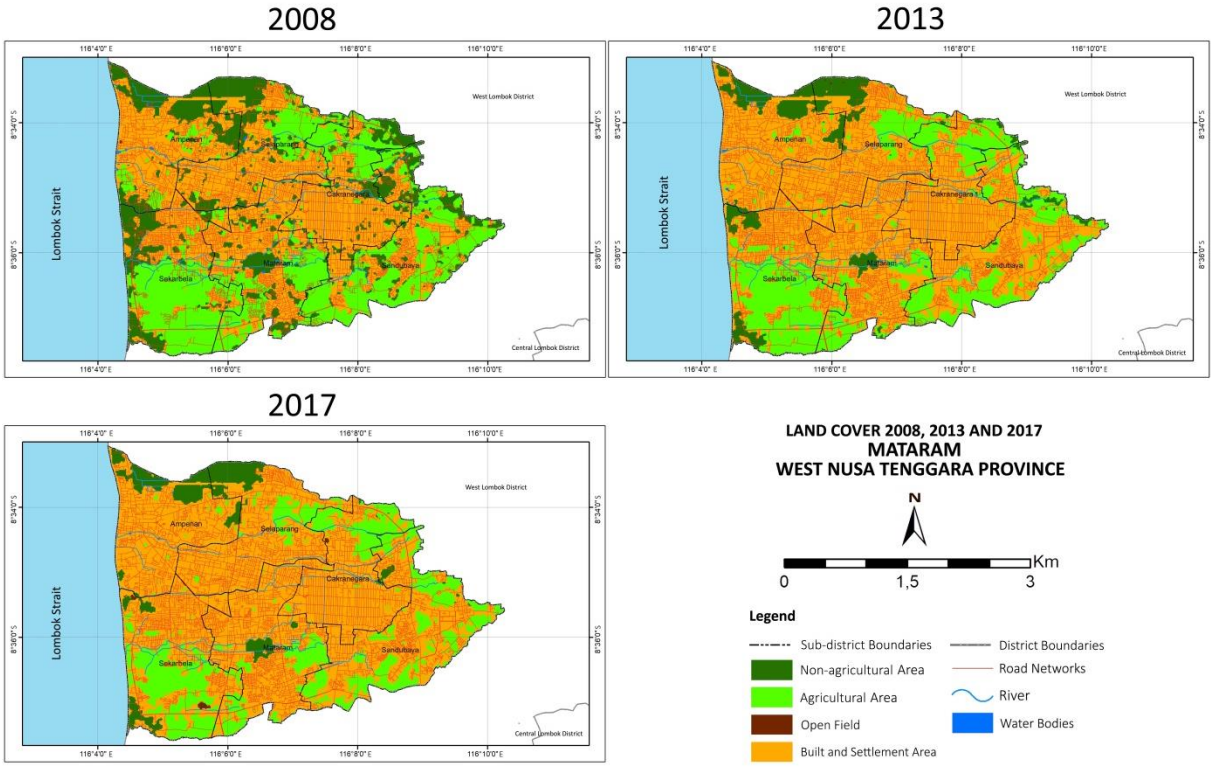


Figure 5. Land Cover Change of Mataram in 2008, 2013, and 2017

In Table 2. Based on the results of the interpretation that change in the built-up area and settlements in 2008 to 2017 showed an increasing to 26.35%. Coverage of built-up area and settlements in the interpretation results is a combination of settlements, buildings, factories or industrial areas. Built-up land and settlements are the result of the conversion of agricultural land use such as rice fields. Based on the ground check result on April 26, 2018 – May 3, 2018, there are lot of functional changes over the use of rice fields to become residential areas and shopping areas. This indicates that there is high demand for residence that makes conversion of agricultural land into built-up area and settlement higher every year.

Table 1. Land Cover Composition of Mataram in 2008, 2013, and 2017

Land Cover	Land Cover Area					
	2008		2013		2017	
	Hectare	%	Hectare	%	Hectare	%
Water Bodies	8,17	0,14%	2,61	0,04%	1,53	0,03%
Non-Agricultural Area	1.195,48	19,87%	443,51	7,37%	369,67	6,14%
Agricultural Area	1.962,52	32,62%	1.461,62	24,29%	1.202,43	19,98%
Built and Settlement Area	2.849,90	47,37%	4.108,43	68,28%	4.435,42	73,72%
Open Field	0,81	0,01%	0,72	0,01%	7,83	0,13%

Table 2. Land Cover Change of Mataram in 2008, 2013, and 2017

Land Cover	Changes					
	2008 – 2013		2013-2017		2008-2017	
	Hectare	%	Hectare	%	Hectare	%
Water Bodies	-5,56	-0,09%	-1,08	-0,02%	-6,64	-0,11%
Non-Agricultural Area	-751,97	-12,50%	-73,83	-1,23%	-825,81	-13,72%
Agricultural Area	-500,91	-8,33%	-259,19	-4,31%	-760,10	-12,63%
Built and Settlement Area	1258,53	20,92%	326,99	5,43%	1585,52	26,35%
Open Field	-0,09	0,00%	7,11	0,12%	7,02	0,12%

Tabel 3. Transition Matrix Area of Mataram in 2031 (pixel)

2017 \ 2031	Water Bodies	Open Field	Built and Settlement Area	Non-Agricultural Area	Agricultural Area
Water Bodies	29	0	0	0	0
Open Field	0	8	0	0	0
Built and Settlement Area	0	0	45.651	0	0
Non-Agricultural Area	0	0	4.271	623	0
Agricultural Area	0	0	13.045	0	3.214

Tabel 4. Land Cover Comparison Area in 2017 with 2031 Prediction Results in Mataram

Land Cover	Area (hectare)				Changes 2017-2031	
	2017 (ha)	%	2031 (ha)	%	hectare	%
Water Bodies	1,53	0,03%	0,72	0,01%	-0,81	-0,01%
Non-Agricultural Area	369,67	6,14%	56,34	0,94%	-313,33	-5,21%
Agricultural Area	1.202,43	19,98%	288,78	4,80%	-913,65	-15,18%
Built and Settlement Area	4.435,42	73,72%	5.670,05	94,24%	1.234,63	20,52%
Open Field	7,83	0,13%	0,99	0,02%	-6,84	-0,11%

3.2 Land Cover Prediction Simulation in 2031

The prediction of land cover change is intended to estimate land cover change in 2031. Determination of prediction is done by making land cover 2008 as the base year and 2013 as a second year in CA analysis, then prediction of land cover 2017 will be compared with land cover actual in 2017. If validation model yields a high accuracy value, the accuracy rate received in this model is 80% (Eastman, 2003). The result of validation test obtained the accuracy value is 82,32% in Mataram and shows the simulation model is done very well. Based on these result, the model with the 6 (six) driving factors tested, can be used to predict land cover changes in 2031.

The CA analysis for Mataram is shown based on the probability value of land cover change in 2017 indicates that in Mataram, agricultural area is converted to built and settlement area of 13.045 pixels or equal to 1.174,05 hectare. Besides that, the dominant change opportunity is from non-agricultural area to build and settlement area of 4.271 pixels or equivalent to 384,39 hectare (Table 3). The land cover predictive result (Figure 6) in 2031 also shows decrease of agriculture area (-) 15,18%, non-agricultural area decreased (-) 5,21%, open field and water bodies decreased by (-) 0,11% and (-) 0,01%. While the sharp increase occurred in built and settlement area by 20,52% or an increase of area of 1.234.63 hectare in 2031 (Table 4).

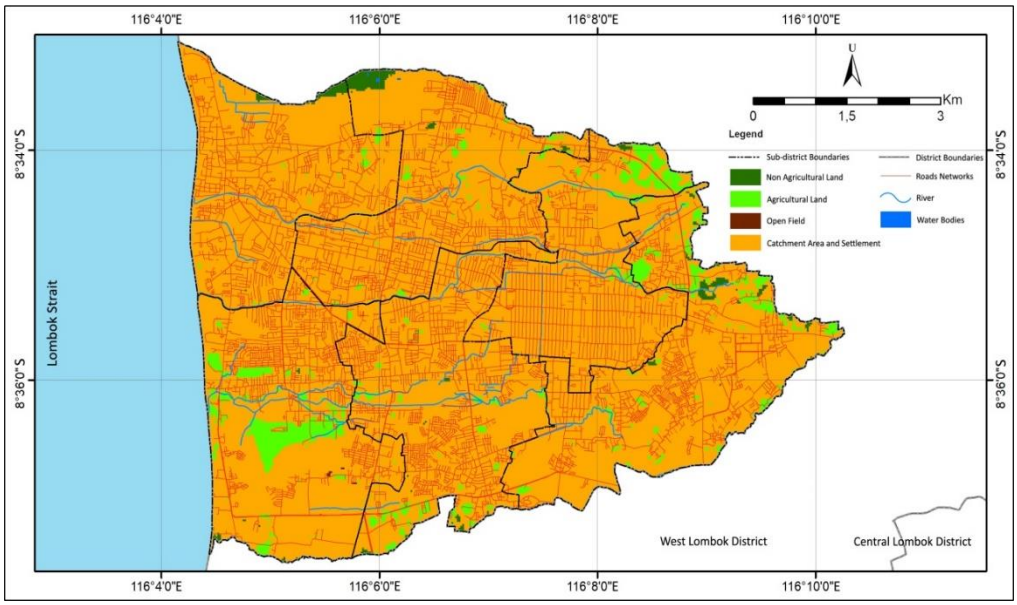


Figure 6. Land Cover Prediction of Mataram in 2031

4. Conclusion

Mataram consist of 5 types of land cover that is (1) Agricultural Area, (2) Non-Agricultural Area, (3) Built and Settlement Area, (4) Open Field, and (5) Water Bodies. Mataram experienced a significant decreased in agricultural area of (-)12,63%. While the built and settlement area showed an increase of 26,35%. One of the factors that increase built-up area and settlement is because Mataram City has a considerable attraction in attracting resident from the outside, because Mataram City is one of the tourism destination and have potention as hub of the surrounding tourism areas, so the population always increase every year. The result of land cover prediction in 2031 shows a much larger decrease of agricultural area from 2017. Mataram has decreased in agricultural area up to (-)15,18% of area in 2017. While the sharp increase occurred in built and settlement area by 20,52% in 2031.

Acknowedgement

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