Landuse change prediction model based on Cellular Automata (CA) method in Bandung City

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Abstract. Landuse change in a city is a natural event that cannot be avoided. One approach that can be used to detect landuse change is to use remote sensing technology. One of the method to predict landuse change is using Cellular Automata method. When landuse data is calculated, there is a lot of significant change of settlement in Bandung city from 1990 to 2017, but when we see the prediction of the settlement area in 2031 is not too much change, this can be caused by fewer land areas that can be converted, or the model must be added the new parameter of the driving force.

1. Introduction
Land in urban area is an interesting phenomenon, because the number of land in urban area is not increasing, but the human need for land in the city from year to year continues to increase, this causes land to change in urban areas. The phenomenon of urban land changes has been widely studied by many researchers, one approach to seeing this phenomenon is to use remote sensing. Many uses of remote sensing technology can be utilized, namely to identify Vegetation Index, Temperature and others [1]. The advantage of using remote sensing technology is that the data used can be in the form of time series data, this can help to detect changes over time.

Urban growth will continue to expand further in the future, with critical impacts on land resources, unless some preservation mechanism is implemented [2]. Many method used to study land use change, one of the method is vector based model, in the research showed that vector-based Cellular Automata (CA) model is an appropriate method for exploring the regularity of Land Use Land Cover (LULC) processes in single center study areas with water area and transportation land in it [3]. Other research, use Multi Criteria Evaluation (MCE) method, The method suitability transition maps with Multi Criteria Evaluation (MCE) delivers the best results for the prediction of LULC [4]. The hybrid urban expansion model model, which relies on the combination and integration of remote sensing, Geographic Information System (GIS) and the CA model, represents an innovative and effective approach to simulate the urban evolutionary process, project for its future spatiotemporal dynamics and provide useful information about possible environmental implications of future urbanization [5]. Among all developed urban growth models, CA models have better performance in simulating urban development than conventional mathematical models [2]. Changes in landcover can also be caused by rapid population growth [6], this is directly related to the condition of the population in the city of Bandung which grew significantly which can lead to land changes in the city of Bandung.
Land cover changes, that is changes from land not built into built up land, will result in an increase in the amount of flowing water that exists, and this will endanger the environment, especially will cause flooding, one example is the increase in runoff volume resulting in increased flood volts in the regency of Bandung [7].

With increasing land change, and the absence of research on predictions of land change in the city of Bandung, a study is needed to predict land cover in Bandung, making this research very useful to be input to the city government of Bandung.

2. Material and method

2.1. Research location
Bandung city is a city in Indonesia which has a population of around 2.4 million. Bandung is one of the cities that has a very rapid development in Indonesia. Bandung city is the capital of West Java province which makes Bandung city the center of economic activity in the western province of Indonesia and even in Indonesia.

As expressed in the theory of urban development such as the theory of central place and urban place, it is stated that the development of cities as a result of its function in providing goods and services for the surrounding area. This is relevant to the condition of the city of Bandung which is the center of government in West Java which is also a provider of goods and services to the surrounding area. Bandung city is a residential area that is developing very fast, land cover in the form of settlements or public facilities, many of which are the result of conversion from agricultural or forest land cover [8].

2.2. Data used
There are some data used in this study, the main data used is satellite image data, Landsat image data has good results in terms of classifying land cover [9]. In this study there is two types of data satellite landsat were used, namely Landsat 5 satellite data for 1990 image data and using results from Landsat 8 satellite for 2017 image data that show in figure 1.

![Figure 1. Image satellite Landsat 5 year 1990 and Landsat 8 year 2017.](image)

The next data used is road network data, network data has a close relationship with population growth and urban development [10,11]. The latest data used is altitude data and slope data, altitude data has a close relationship with settlements, many people prefer to have homes in low slope areas. Road, elevation and slope data is obtained from the Geospatial Information Agency in the form of Geographic Information System digital data.

2.3. Change analysis and modelling
Land change analysis and modelling is using IDRISSI Land Change Modeller (LCM) software. There are three steps in using this system, the first one is analysis of the landuse change from 1990 to 2017, the second is to create transitional potential modelling and the last one is to predict the landuse change
model. In this scenario, the validation is not used because the lack of the data. The model is running using 3 driving factor which is distance from the road, elevation and slope that can be seen in figure 2. This method uses the Markov-CA algorithm that has successfully predicted future land cover [12,13].

![Driving factor on the model.](image)

**Figure 2.** Driving factor on the model.

**2.4. Methodology**
In this research, data image satellite is processed into data landuse, the two data is produce Landuse year 1990 and Landuse year 2017. The data is for input from the model that is running in LCM software. The three driving factor (distance from road, slope and elevation) is used in this model to create a model that is similar to the real world situation, after that the LCM software is calculation the Cellular Automata and Markov model to create the landuse prediction, all of that can be seen in the flowchart on figure 3.

![Flowchart of the research.](image)

**Figure 3.** Flowchart of the research.

**3. Result and discussion**
The output image from two satellite image data that processed using a classification is produce landcover data in 1990 and 2017 which can be seen in Figure 4 and Figure 5. By using two images with different times, it will be easy to detect land changes and land cover classifications [10]. The result of classification of landuse divide into 5 type, which is Agriculture, Road, Settlement, Forest and Bare Land, but for this study focused on the settlement.
In the figure 4 and figure 5, can be seen that many forest (green) in year 1990 has converted into settlement in year 2017. Not only forest, the agriculture has a great contribution to increasing the settlement in Bandung city. From the result of the model, that can be seen the spatial conversion from all of the type landuse to settlement occurred the eastern city of the Bandung City, which can be seen in figure 6. In eastern Bandung City there is a lot of housing development occur, many rice field had been converted into settlement, in this area there is a famous of the housing that development by Sumarecon. From the table 1 we can see when area settlement is calculated from the data 1990 to 2017, there is a significant increase occurred, from the table 1 and figure 7 can be seen that the increase is about 3.196 ha, but when we see the prediction of the settlement area in 2031 is not too much change, only increase about 435 ha. This can be caused by fewer and fewer land that can be turned into settlements, it is seen that from 1990 to 2017 settlements had increased by 19 percent from the initial conditions.
Table 1. Settlement area for 1990 to 2017.

| Existing (Ha) | Prediction (Ha) |
|--------------|-----------------|
| 1990         | 2010            | 2017 | 2031 |
| 5,011.99     | 6,826.05        | 8,208.46 | 8,644.16 |

Figure 7. Growth of settlement from 1990 to 2031.

From the results of this study, it can be compared two land cover maps, namely the existing land cover in 2017 and the land cover predicted by the 2031 model that can be seen in Figure 7, it can be seen that there is a massive change in the northern part of Bandung city namely from the forest (green) to a settlement (yellow). There are three sub-districts that have seen massive changes from forests to settlements, namely Cidadap sub-district, Ujung Berung sub-district and Cibiru sub-district. This is in line with the quantitative calculation of predictions of land change into residential classes, namely as much as 435 ha.

Figure 8. Land cover year 2017(existing) and result of prediction Landcover year 2031.

Seeing one of the driving factors for land cover change is the road network, it can be seen that the existing road network in the northern city of Bandung has grown a lot, this is thought to be one of the strong factors in driving land change into a settlement in Bandung city. With the large number of road access built in the northern Bandung area, it will result in many new settlements growing and resulting in many land changes becoming residential land cover.

This landuse change is very contrary to the development plan of the city of Bandung which is listed on the Bandung city spatial plan. In the northern part of Bandung, planned as a conservation area whose land cover is forest, with the prediction of this model, which shows that in the north of Bandung in the
future it will turn into many settlements, so this will be an important input and challenge for Bandung city government in the supervision of spatial planning in the area.

4. Conclusion
This study show that there have been many change to settlement form year 1990 to 2017, but when the model predict the settlement area in 2031 there is not too much change, this can be caused by fewer land areas that can be converted, or the model must be added the new parameter of the driving force and in this research one influential driving factor is road network data. Model of the cellular automata is successful in capturing complexity with simple rules, but the cellular automata is having many uncertainties in the technique, and more research is needed to improve the result of the model.

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