Land use change projection in Bonehau Watershed 2031

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Abstract. Through land use, humans have modified over 83% of the terrestrial surface. This research was aimed to identify land-use changes in 2001, 2008 dan 2016, and projected land-use changes in 2031 using Markov modelling in Bonehau Watershed. The study used Markov modelling to projected land-use change in 2031. The result indicates there were eight classes of land use in Bonehau watershed with accurate of interpretation 86.5 %. The classes consist of primary forest, secondary forest, brushwood, agriculture, rice fields, settlement, open land, and water areas. Validation of land use in 2016 using Markov modelling has an accuracy of 85,49 %. This is compatible with the percentage of equality area between actual and projected in 2016, 85.29 %. The result of projection land-use changes in 2031 showed the highest increasing areas occurred in the settlement class, 166.15 % or 320.54 hectares out of settlement area in 2016, whereas the highest decreasing areas occurred in the primary forest, 17.23 % or 7.397.05 hectare out of primary forest area in 2016. Projection of land-use change in 2031 showed all classes with natural characteristic was decreasing and all classes influenced by human activities were increasing.

1. Introduction
Population growth causes various problems in-country development [1]. Development has an impact on increasing the need for space for cultivation land, housing, industry, and other agricultural activities. Efforts to meet increasing needs impacted on space and natural resources, especially Indonesian economy very dependent on natural resources, including forest resources [2]. Through land use, humans have modified over 83 % of the terrestrial surface [3,4].

Land-use change can occur at any time naturally or impact human activities. Natural changes can be caused by natural disasters such as landslides, erosion, and flood. Another case human activity caused by land expansion for agricultural and industrial. As the impact of limited land, land-use change will occur. Land use describes human socio-economic activities on the land of the earth’s surface which is dynamic [5]. Land-use change is an increase in one type of land use to another followed by a reduction in other types of land use over time or it can be interpreted as a change in land use at different periods [6].

Land change due to human activities has an impact on ecosystem sustainability, for example, forest land cover will change its function and land degradation occurred. This has an impact on decreasing land productivity in the future [7,8] it will lead to erosion of soil or flooding in critical
water catchments. The rapid development with a large number of pavement areas causes an increase in temperature on the earth’s surface [9]. An increase in global temperature up to 1°C will cause the extinction of 30% of species, increase sea level temperatures to 27°C, and causing tropical storms. Greenhouse gas emissions caused by deforestation in 1990 reached 17% [10]. This data shows that land-use change becomes one major effect on climate, hydrologic regime, ecosystems, and human welfare [3,11].

Land-use change identifies in an area is a process of identifying differences existence of the object or phenomenon at different times [6]. The clearing of forests and forest conversion into other uses has separated compact and intact forests [8]. Conversion of forest to non-forest in the upstream area is a concern, not only because headwater regions contain critical habitats for biota [12], but also that land-use change in these regions can have cascading impacts on downstream ecosystem functioning [13,14]. The utilization of Geographic Information System (GIS) and satellite imagery data is an appropriate technology in managing spatial-temporal data on land-use change [8].

Bonehau watershed is part of the Karama Watershed. Bonehau watershed is located in two districts, Mamuju Regency and Mamasa Regency. Based on preliminary research, interpretation of land use/land cover 2014 and 2015 in Bonehau Watershed showed there has been a change in forest cover (primary forest and secondary forest), agriculture (dryland agriculture and rice fields), and settlement. Data from 2014 to 2015 showed forest cover in Bonehau Watershed decreased by 168,64 hectares (0.14% of the total watershed area), while agriculture increased by 557.24 hectares (0.48 %). The same thing happened in a settlement that expanded by 154,85 hectares (0.13 %). Land use/land cover between 2014 and 2015, if occur continuously can affect the condition of Bonehau Watershed.

Population growth encourages development in the economic sector and leads to increased land use requirements. This will have a direct impact on the condition of land cover (deforestation and land degradation) in the Bonehau Watershed. Based on this, it's necessary to identify the change that occurred in the future. Thus, to determine land use/land cover change in Bonehau Watershed 2031, this research was conducted.

2. Material and methods

2.1. Research site
This research was conducted for five months, starting in November 2016 – April 2017, through two stages of activities, data collection and data analysis. Data collection was carried out in January in research locations, Bonehau Watershed (119°09’00” – 119°28’20” E and 2°24’31” – 2°53’10” S). Data analysis was carried out in February at Planning and Information System of Forestry Laboratory, Faculty of Forestry, Hasanuddin University.
The required tools included computer, Geographic Information System (GIS) software, Global Positioning System (GPS) receivers, camera, and writing instruments. The materials in this study consist of Landsat 7 Enhanced Thematic Mapper (ETM+) imagery recorded in 2001, 2008, Landsat 8 Enhanced Thematic Mapper (ETM+) imagery recorded in 2016 located on path 115 rows 62, Aster DEM (Digital Elevation Model) resolution 30 meter, administrative maps of Mamuju and Mamasa Regency.

2.2. Methods

This research consists of image downloading processing, geometric and radiometric correction, layer stacking, and cropping. The next step is to interpret 2001, 2008 Landsat 7 ETM+ imagery and 2016 Landsat 8 ETM+ imagery, projection of land use/land cover change, and probability of change in land use/land cover projections. Interpretation of satellite imagery produces land use/land cover maps for 2001, 2008, and 2016 data. Land use/land cover projection will produce a land use/land cover projection map in 2031.

2.2.1. Determination of research boundary. Determination of research boundary carried out using GIS software with Aster DEM. Then all satellite imagery was clipped to focus on our study area.

2.2.2. Image pre-processing. A first step in the pre-processing is to check all images of any defects such as striping. After that, all images were corrected geometrically and radiometrically. At last, all images were stacked and classified. Image processing has been implemented using GIS software.
Geometric correction of the different satellite images is of great importance for change detection since the potential exists for registration errors to be interpreted as land use/land cover change, leading to an overestimation of actual change [15].

Radiometric correction is implemented by combines the sun and view angle effects, and the sensor calibration with the atmospheric correction. It's necessary to correct the atmospheric scattering caused by haze, dust, or smoke [16].

Layer stacking of Landsat band carried out to make it easier to interpret land use/land cover of the study area. The merging of Landsat 7 ETM+ imagery band for 2001 and 2008 carried out by combining band 5, band 4, and band 3 (RGB) and for Landsat 8 ETM+ imagery band for 2016 combined band 6, band 5, and band 4 (RGB).

2.2.3. **Image classification.** Generally, the classification process includes supervised classification and unsupervised classification [17]. The overall objective of the image classification procedure is to automatically categorize all pixels in an image into land use/land cover classes or themes. One of the most important applications of satellite remote sensing is to detect changes in land use to discern those areas on digital images that change features of interest between two or more dates [18]. Supervised classification emphasizes the ability to categorize the spectrum of objects based on the visual interpretation performed by the analyst. Meanwhile, unsupervised classification leads to the classification process by software based on the digital value of each image pixel. Interpretation of Landsat imagery 2001, 2008, and 2016 used unsupervised classification bay visually-manually. Land use/land cover maps are obtained from interpretations determined based on patterns and characteristics (hue, color, shape, and texture) of the image. Supervised classification is not carried out because Landsat Imagery in this research has a medium resolution (30 meters × 30 meters).

The result of interpretation produced land use/land cover maps of 2001, 2008, and 2016. The basis for determining the class or theme of land use/land cover is based on the land cover class from Badan Standarisasi Nasional (BSNI) 7645:2010.

2.3. **Ground check**

Land use/land cover in Bonehau Watershed consists of primary forest, secondary forest, brushwood, agriculture, rice fields, settlement, open land, and water areas. Representative coordinate determined by purposive sampling which each class of land use/land cover, also considering accessibility and area every class.

Ground check aims to correct the result of land use/land cover interpretation. This is done to compare the actual condition of land use/land cover with an interpretation of Landsat imagery. Ground checks were carried out by looking at the visual appearance (hue, color, texture, and shape) of each type of land cover/use. Apart from taking the coordinates, it is also carried out taking pictures and other information related to each type of land cover/use in the field. The coordinates of the GPS then become a reference for testing the accuracy of image interpretation. The total sample points to be observed are 185 points.

2.4. **Image interpretation accuracy**

An image interpretation accuracy test is used to determine the accuracy of the image interpretation that has been done. The accuracy test is a comparison between the data interpreted by the image and the actual conditions. The model used to test the accuracy is overall accuracy [8,19,20]. Image
interpretation accuracy calculation is done by using the confusion matrix method. The confusion matrix is used as a first step in describing differences and statistical analysis techniques to assess the accuracy of the map [3]. On the confusion matrix, data from image interpretation results and actual checking data are arranged in a percentage comparison table. The acceptable level of accuracy in image interpretation is 85% [21]. This means that 85 out of 100 sample points have been determined according to field conditions.

**Overall accuracy (OA):** \( \frac{X}{N} \times 100\% \)  

\( X \) : Number of diagonals of the matrix  
\( N \) : Number of matrix samples

2.5. **Land use/land cover projection**

Projection of land use/land cover change in this study used Markov modeling. The main product in Markov modeling is the transition matrix, which explains the opportunities for changes in land use/land cover based on observations of certain years (in this study, 2001 and 2016). The pattern of land cover/land-use change that occurred between 2001 and 2016 is a variable for projecting land use/land cover in 2031.

2.5. **Analysis**

Land use/land cover in 2031 is obtained by comparing the changes between 2001 and 2016. The results of the analysis are the input for determining land use in the projection year. The Markov chain model will produce a transitional/probability area matrix, which is a transition matrix for changes from the previous year to the projection year. The Markov equation is built using the distribution of land use at the beginning and at the end of the observation which is interpreted in a vector (one column matrix) and a transition matrix [22].

The data validation process is carried out to test the performance of Markov modeling in GIS software in projecting land use/land cover 2031. Validation is needed to determine how accurate the data projection carried out can be recognized as true. The level of data validity is not less than 85% (Standard ≥ 0.85). Data validation was carried out by taking the preceding 7 years, using land use/land cover maps in 2001 and 2008. With the input of land use/land cover in 2001 and 2008, projections of land use/land cover were carried out 8 years later. This aims to obtain a projection map that will be used in validating the data.

The next step is to run the Cellular Automata model to obtain projections of land use in 2031. The data entered is in the form of a land use/land cover transition matrix from 2001 to 2016 which is assumed not to be influenced by other factors that affect land-use change. The projection results of land use in 2031 are then overlaid with land use in 2031. This is done to see changes in the area of each land use/land cover class.
3. Result and Discussion

3.1. Land use/land cover
The result of Landsat imagery interpretation and observation indicate there eight classes of land use of Bonehau watershed. The classes consist of primary forest, secondary forest, brushwood, agriculture, rice fields, settlement, open land, and water areas. The total area for each type of land use/land cover at the Bonehau watershed in 2001 and 2016 can be seen in Table 1.

Table 1. Total area for each type of land use/land cover at Bonehau watershed in 2001 and 2016

| Type of Land Use/Land Cover | Area (ha) | 2001       | 2016       |
|-----------------------------|----------|------------|------------|
| Primary Forest              |          | 45,921.10  | 42,93.00   |
| Secondary Forest            |          | 51,462.25  | 50,030.00  |
| Brushwood                   |          | 15,758.38  | 16,680.00  |
| Agriculture                 |          | 2,957.39   | 6,038.55   |
| Rice Fields                 |          | 66.77      | 435.14     |
Table 1 showed land use/land cover from 2001 to 2016 changed significantly, change that occurred due to decreasing or increasing area in each type of land use/land cover. Land use/land cover that has decreased are primary forest, secondary forest, open land, and water area, while land use/land cover that’s has increased are brushwood, agriculture, rice fields, and settlements.

Land use/land cover change in Bonehau watershed changes in certain land use/land cover conditions unto different land use/land cover in 15 year periods. Land use/land cover change from 2001 to 2016 is presented in Figure 3.

Validation of Landsat 8 ETM+ 2016 interpretation carried out through an accuracy test. The accuracy test is to determine the accuracy of the image interpretation that has been done. The test was carried out by comparing the data between the result of Landsat 8 ETM+ 2016 interpretation with direct observation data in Bonehau Watershed. The number of sample points taken was 185 points. Based on the result of the ground check, the number of points that were proven correct was 160. From these data, an overall accuracy test was performed to determine the percentage level of confidence in each class of land use/land cover in the Bonehau watershed.

![Figure 3. Maps of land use/land cover change from 2001 to 2016](image-url)
Overall accuracy showed the level of confidence in the overall interpretation of Landsat imagery. By looking at the diversity of land use/land cover classes in the Bonehau watershed and the overall accuracy calculation, which is 86.5%, this shows that the interpretation of Landsat imagery is acceptable.

3.2. *Markov model data validation*

Data validation process carried out to test the performance of Markov modeling at projecting land use/land cover in 2031. Validation is needed to determine how accurate the data projection can be recognized as true. The level of data validity not less than 85 % (Kstandard ≥ 0.85). Projections are carried out using 2001 and 2008 land use/land cover data. The total area for each type of land use/land cover at Bonehau watershed in 2001 and 2018 can be seen in Table 2. The results of the Markov projection will produce land use/land cover in 2016.

**Table 2.** Total area for each type of land use/land cover at Bonehau watershed in 2001 and 2008

| Type of Land Use/Land Cover | Area (ha) | 2001   | 2008   |
|----------------------------|----------|--------|--------|
| Primary Forest             |          | 45,921.10 | 45,846.79 |
| Secondary Forest           |          | 51,462.25 | 51,196.23 |
| Brushwood                  |          | 15,758.38 | 7,927.86  |
| Agriculture                |          | 2,957.39  | 10,980.98 |
| Rice Fields                |          | 66.77    | 215.6    |
| Open Land                  |          | 75.70    | 75.71    |
| Settlement                 |          | 128.92   | 128.92   |
| Water Area                 |          | 520.77   | 519.19   |
| **Total Area (ha)**        |          | **116,891.28** | **116,891.28** |

Land use/land cover data validation was carried out by overlaying land use/land cover data by Markov model and land use/land cover actual in 2016. The overlay result showed an accuracy value of 0.8549. This accuracy value showed land use/land cover data between projection and actual is correspond to 85.49 both in terms of area and spatial distribution. If calculated manually using comparison data of land use/land cover actual and projected, the corresponding area is 85.29. There is a difference of 0.20 with the results of the Markov modeling. Comparison of land use/land cover 2016 between actual and projection are shown in Table 3.

**Table 3.** Comparison of each type of land use/land cover 2016 between actual and projection

| Type of Land Use/Land Cover | Area (ha) | Actual  | Projection |
|----------------------------|----------|---------|------------|
| Primary Forest             |          | 42,930.00 | 44,264.03 |
| Secondary Forest           |          | 50,030.00 | 45,890.00 |
| Brushwood                  |          | 16,680.00 | 23,940.00 |
| Agriculture                |          | 6,038.55  | 1,700.82  |
| Rice Fields                |          | 435.14   | 430.79    |
This data showed data validation of Markov projection results has a balanced kappa accuracy value. It concluded that the projection results of land use/land cover in 2031 are quite good and acceptable.

### 3.3. Land use/land cover projection

Projections of land use/land cover 2031 are carried out using Markov modeling in GIS software. The projection results are obtained by multiplying the Markov transition matrix period 2001 - 2016 with the vector (one column matrix) each class of land use/land cover in 2016. The Markov transition matrix is obtained from the calculation of change in land use/land cover matrix using the equation Markov.

Table 4. Comparison area for each type of land use/land cover at Bonehau watershed in 2016 and 2031

| Type of Land Use/Land Cover | Area (ha) | 2016  | 2031  |
|----------------------------|----------|-------|-------|
| Primary Forest             |          | 42,930.00 | 35,532.95 |
| Secondary Forest           |          | 50,030.00 | 41,543.79 |
| Brushwood                  |          | 16,680.00 | 26,851.46 |
| Agriculture                |          | 6,038.55  | 1,132.50  |
| Rice Fields                |          | 435.14    | 1,132.50  |
| Open Land                  |          | 75.52     | 64.46    |
| Settlement                 |          | 192.92    | 513.46   |
| Water Area                 |          | 509.15    | 510.28   |
| Total Area (ha)            |          | 116,891.28 | 116,891.28 |

Projection result of land use/land cover in Bonehau Watershed 2031 showed natural land use/land cover type significantly decreased. It's inversely proportional with land use/land cover which is influenced by human activity. Land use/land cover type that has decreased is primary forest and secondary forest, while land use/land cover type that has increased are agriculture, brushwood, rice fields, settlement, open land, and water area. Land use/land cover projection maps on 2031 shown been Figure 4. Land use/land cover change period 2016 to 2031 presented in Figur 5.
Figure 4. Maps of land use/land cover projection 2031
4. Conclusion
This study showed Bonehau Watershed experienced changes in land use/land cover during periods 2001–2016. Type of land use/land cover which increased in the area was brushwood (5.85%), agriculture (104.18%), rice fields (551.70%), and settlements (49.65%). While the type of land use/land cover which decreased in the area were primary forest (6.51%), secondary forest (2.78%), open area (0.25%), water area (2.23%).

Projection results of land use/land cover of Bonehau watershed in 2031 showed the type of land use/land cover which increased in the area is brushwood, agriculture, rice fields, open land, settlement and water area with the highest addition occurring in settlement type, 166.15 % or 320.54 ha from total settlements area in 2016. While the type of land use/land cover which decreased were primary forest and secondary forest. The highest reduction occurred in primary forest type, 17.23 % or 7,397.05 ha from a total primary forest area in 2016.

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