

Analysis and Prediction of Land Use Change in Bima Regency, West Nusa Tenggara, from 2006 to 2016 with a Projection for 2026

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Abstract. Land use change is closely linked to population growth and human activities. Bima Regency is one of the regions that has experienced a significant population increase over the past decade. This growth has led to a corresponding rise in land demand. This pilot project aims to (1) quantify the percentage of land use change in West Bima Regency between 2006 and 2016, and (2) identify the extent of land conversion in both positive and negative directions during the same period. The method employed in this study is spatial change detection analysis. Based on land use maps from 2006 and 2016, several land cover types have shown a decrease in area, including primary dryland forest, which declined from 61,858.78 hectares (18.72%) in 2006 to 34,084.62 hectares (10.69%) in 2016. Similarly, savannas/grasslands decreased from 153,618.02 hectares (46.5%) to 115,427 hectares (36.21%), and open land declined from 11,708.81 hectares (3.54%) to 10,989.35 hectares (3.45%). Conversely, dryland agriculture experienced the most significant increase, rising by 9.83%. Secondary dryland forests also expanded by 7.23%. Additionally, settlements increased by 3,461.12 hectares (1.09%). The relatively high public awareness of forest conservation is reflected in the net land change: the total area of negative land use change (191,604.47 hectares) is considerably smaller than the total area of positive land use change (2,220,729.15 hectares).

Keywords: Land use, land use change, spatial analysis, Bima regency

INTRODUCTION

Humans have always relied on land as a fundamental medium to support survival. Various activities carried out by humans always involve land use (Long et al., 2021; Suharyanto et al., 2022; Xie et al., 2020). According to Arsyad (1989), land use itself is divided into two main types of use, namely agricultural and non-agricultural land use. The use of agricultural land consists of moors, rice fields, plantations, production forests, protected forests, grasslands and reeds, including land for livestock and fisheries (Nabuurs et al., 2022; Sharma, 2022). In addition to these uses, it can be categorized as land use for non-agriculture.

Land use is closely related to the human population on earth. This is one of the causes of land use problems. As the human population increases, the need for land is also increasing (Hossain et al., 2020; Molotoks et al., 2021; Roy et al., 2022). The increase in population is not balanced by the land area that always remains constant, causing inevitable changes in land use. This change in land use has both positive and negative impacts on life. Positive impacts due to land use changes in the form of development and progress of a region. The negative impact of land use change is the reduction of green area so that it can cause natural disasters such as floods, landslides, and so on (Agarwal et al., 2023; Ghalehtimouri et al., 2024; Kato & Huang, 2021; Pacheco Quevedo et al., 2023).

Land use change has occurred a lot in Indonesia. One of the areas that has experienced an increase in land use change is West Nusa Tenggara Province, especially Bima Regency. This is because the number of people in the district is increasing every year. According to Nurmi et

al. (2020), the average population growth of Bima Regency in 2016 reached 6.3%. In addition, data from the Central Statistics Agency (2022) shows that the number of people in Bima Regency in 2020–2022 increased by 13,840 people. The increasing number of people causes the need for settlements to also be high, which will certainly affect land use patterns in the area.

The land use pattern that is greatly affected by the increase in population is forests. Many forests in Bima Regency have been damaged due to changes in land use. In addition to the conversion of forests for settlements, forests in Bima Regency are also undergoing conversion for agricultural purposes. According to Rahmat (2021), several forests in West Nusa Tenggara Province have been damaged to the point of being classified as critical and very critical land. One of the forests that has a critical land category is located in Bima Regency. The critical land is located in a conservation forest area with an area of 4483 ha.

An increase in the number of people will definitely occur every year. In addition, the land use process carried out by humans from time to time continues to change along with the development of civilization and human needs. The higher the human need, the higher the demand for land (Yunanto and Susetyo, 2016). Therefore, activities that cause changes in land use patterns will definitely continue to occur in the future. Through Geographic Information System (GIS) technology, the pattern of land use changes over time can be known and predicted for the future. *This pilot project* was made to find out how much and how the pattern of land use change occurred in Bima Regency during the period 2006–2016. In addition, through *this pilot project*, a model can be made to predict the pattern of land use change in the future.

Population growth is expected to continue each year. Additionally, patterns of land use evolve continuously in response to the development of civilization and increasing human needs. As these needs expand, so too does the demand for land. Consequently, activities that lead to changes in land use patterns are likely to persist. However, the use of Geographic Information System (GIS) technology allows researchers to monitor and predict land use changes over time.

This pilot project aims to analyze the extent and patterns of land use change in Bima Regency during the 2006–2016 period. Furthermore, the study seeks to develop a model for predicting future land use changes in the region.

RESEARCH METHODS

Research Time and Location

The pilot project was conducted from January–May 2023 at IPB University. The case study used in this pilot project took place in Bima Regency, West Nusa Tenggara in 2006 and 2016.

Tools and Materials

The tools used in making this pilot project include a laptop equipped with several software programs used listed in Table 1 and the materials used are listed in Table 2.

Table 1. Software used in manufacturing Pilot Project

No	Software	Function
1.	ArcGIS 10.8	Spatial data processing
2.	Microsoft Excel 2016	Processing attribute data from land use maps
3.	Microsoft Word 2016	Pilot project report creation

Table 2. Materials used in the preparation of the pilot project

No	Material	Scale	Source
1.	Bima Regency sub-district boundaries	1:50.000	indonesia-geospasial.com
2.	Map of land use in Indonesia in 2006 and 2016	1:50.000	Practicum data

Working Procedure

Preparation Stages

The preparation stage involved conducting a literature review relevant to the topic of the pilot project, as well as collecting the necessary data. The data used in this pilot project included administrative boundary data of Bima Regency, land use maps of Indonesia for the years 2006 and 2016, and supporting materials such as scientific literature and journal articles.

Stages of Data Processing

The data processing in this pilot project employed the change detection method, a spatial analysis technique used to identify land use changes over time. This method utilizes Geographic Information System (GIS) tools to detect changes in specific study areas across two or more time periods (Pramono, 2020). The data processing workflow was divided into several key stages, including the creation of land use maps for the years 2006 and 2016, as well as the generation of a land use change map comparing these two periods. The mapping process consisted of the following steps:

Land Use Map Preparation in 2006 and 2016

1) Data input

The data input stage is the process of entering all the data needed to work on the *pilot project* into *ArcGIS 10.3*.

2) Dissolve and clip

The *dissolve* process is carried out to combine several sub-districts that have more than one polygon, while *clipping* is carried out on the sub-district boundary data that has been *dissolved with land use maps*.

3) Separating land use in 2006 and 2016

The available land use map is a land use map from 1990-2016, so it is necessary to separate it to select the data to be used only, namely 2006 and 2016. This separation is carried out by exporting data.

4) Classify the land use class to be used

In making this land use change map, not all land use classes are used. Some of the classes selected based on the social and economic conditions of the people of Bima Regency are listed in Table 3.

Table 3. Land use classes

Land Class	Code
Primary Dryland Forests	HLKP
Secondary Dryland Forest	HLKS
Dryland Agriculture	PLK
Savannah/Grassland	SA
Bushes	SB
Settlements	PM
Open Ground	TB

The classification of land use classes is carried out by exporting data back to each of the 2006 and 2016 land use maps.

5) Calculating area and *layouting*

Calculating the area was carried out on the table of attributes of each land use map in 2006 and 2016. This calculation aims to determine the area of land use in each class. Before doing the calculation, the geographical coordinates of the map need to be changed to UTM 50S. After the area is known, then change the color symbol and do *layout* to get a land use map in each year.

Land Use Change Map 2006-2016

1) Perform overlays

Overlays were carried out on both land use maps in 2006 and 2016. This aims to find out how much changes have occurred in the use of the land.

2) Classifying land use change

The classification of land use change is carried out to group changes in land use that are positive (land use for forests becomes wider) and negative (land use for forests becomes less).

3) Modeling predictions using the Terrset 2020 application to see land use changes in 2026 using the changing factors that are happening today. The application of land change modeler In this stage, land cover data in 2006 and 2016 will be analyzed to predict land use in 2026 using a land change modeler. These changes are represented in the next steps, namely change analysis, potential transition, and change prediction. Change Analysis at this stage, land changes in 2006 and 2016 will be used as the basis for modeling land closure in 2026. The resulting land changes in the form of rasters and graphs according to the classes contained in the raster data as input. Then an accuracy test was carried out on the results of the prediction of land closure in 2026. Calibration of land change modeler In this stage, the results of validation tests that are declared valid must be modeled again to obtain the results of land use prediction in 2026 through the 2006-2016 change model by MLP and the markove chain

4) Calculating area and layouting

Calculating the area was carried out on the attribute table of the land use change map in 2006-2016. This calculation aims to determine the area of land use in each class. Before doing the calculation, the geographical coordinates of the map need to be changed to UTM 50S. After the area is known, then change the color symbol and do layout to get a land use map in each year.

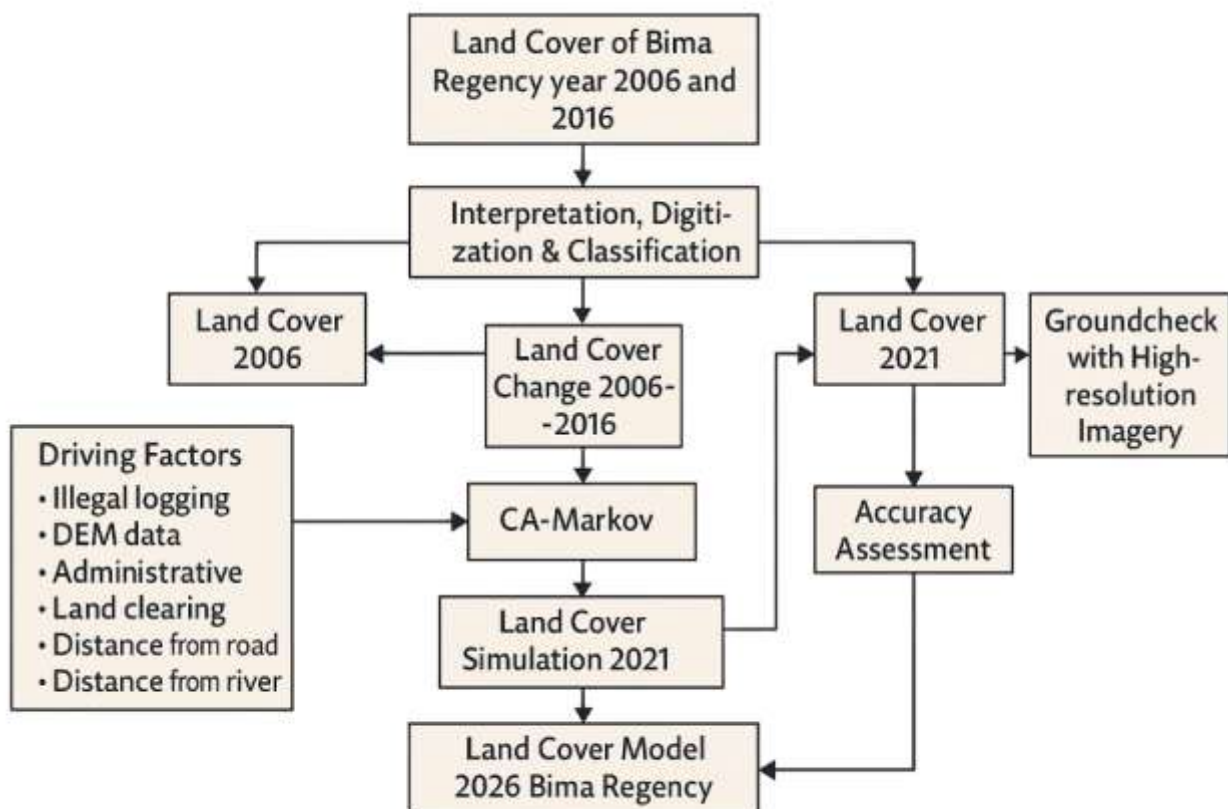


Figure 1. Diagram of land use change prediction method

RESULTS AND DISCUSSION

Land Use of Bima Regency in 2006 and 2016

Land use in Bima Regency is categorized into several classes, including Primary Dryland Forest (HLKP), Secondary Dryland Forest (HLKS), Dryland Agriculture (PLK), Shrub (SB), Savanna (SA), Settlement (PM), and Open Land (TB). These land use categories reflect the diversity of land cover types present in the region and serve as the basis for spatial analysis in detecting land use changes between the years 2006 and 2016.

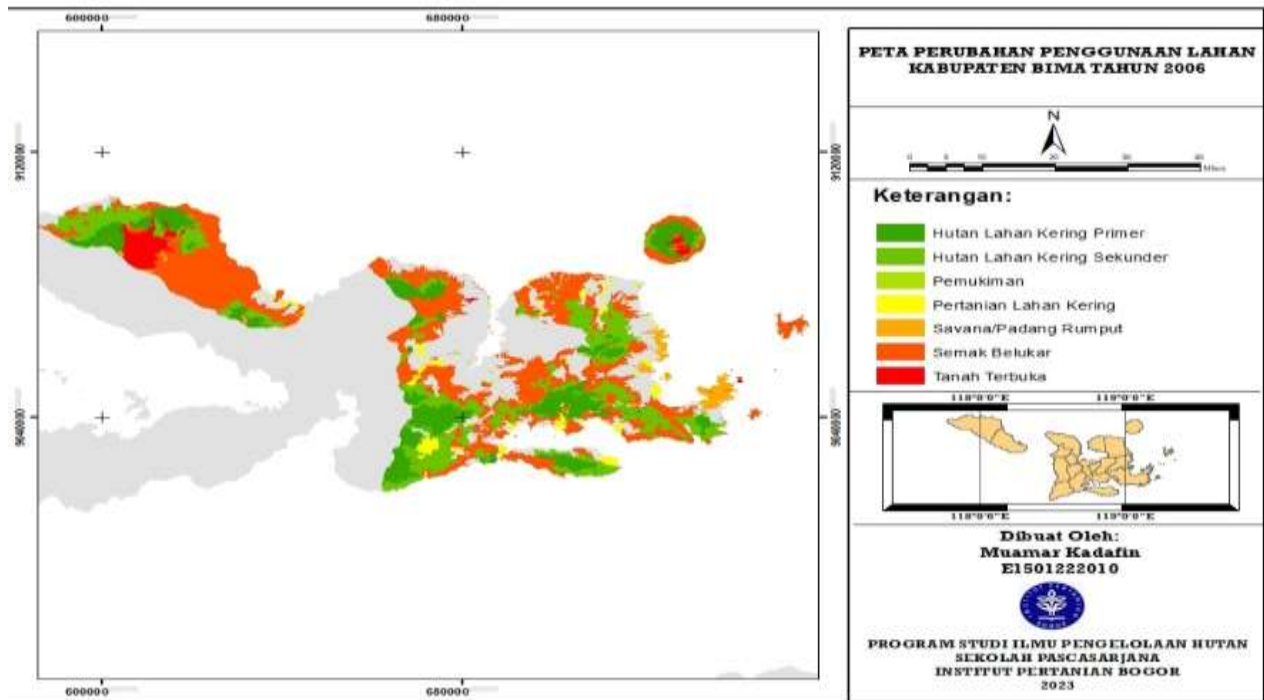


Figure 2. Land use map in Bima Regency in 2006

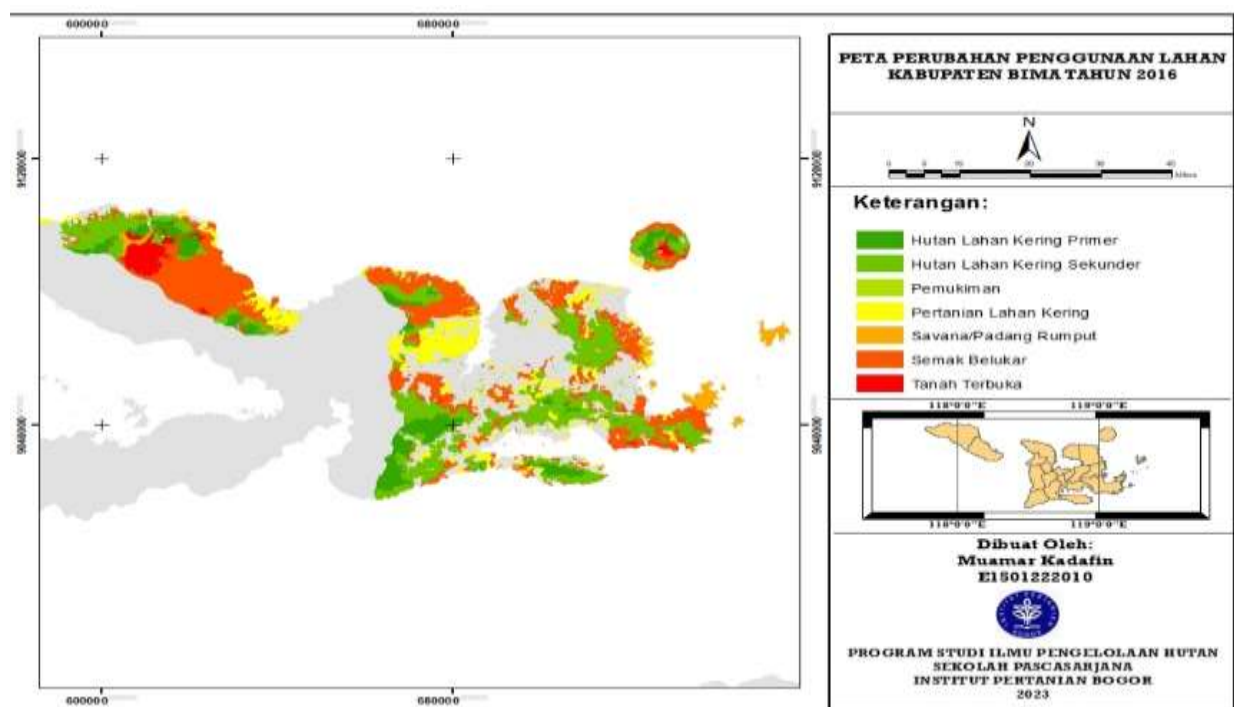


Figure 3. Map of land use in Bima Regency in 2016

Based on the land use maps from 2006 and 2016, noticeable differences in land use distribution can be observed. These differences are identified through the use of distinct color symbols representing each land use category. For instance, plantations, represented by the yellow color, show a visible expansion in area on the 2016 map. Similarly, the extent of primary dryland forest, symbolized by dark green, also demonstrates a change in spatial distribution compared to its coverage in 2006. These observed changes in land use patterns, particularly in plantation areas and primary dryland forests, are consistent with the quantitative data presented in Table 4, which details the changes in land use area over the two periods.

Table 4. Land use area in 2006 and 2016

Land Use	2006		2016	
	Ha	%	Ha	%
Primary Dryland Forests	61858.78	18.72	34084.62	10.69
Secondary Dryland Forest	81953.42	24.81	102150.91	32.04
Dryland Agriculture	11341.76	3.43	42276.23	13.26
Bushes	8651.45	2.62	10408.33	3.26
Savanna	153618.02	46.50	115427	36.21
Open Ground	11708.81	3.54	10989.35	3.45
Settlement	1230.44	0.37	3461.12	1.09

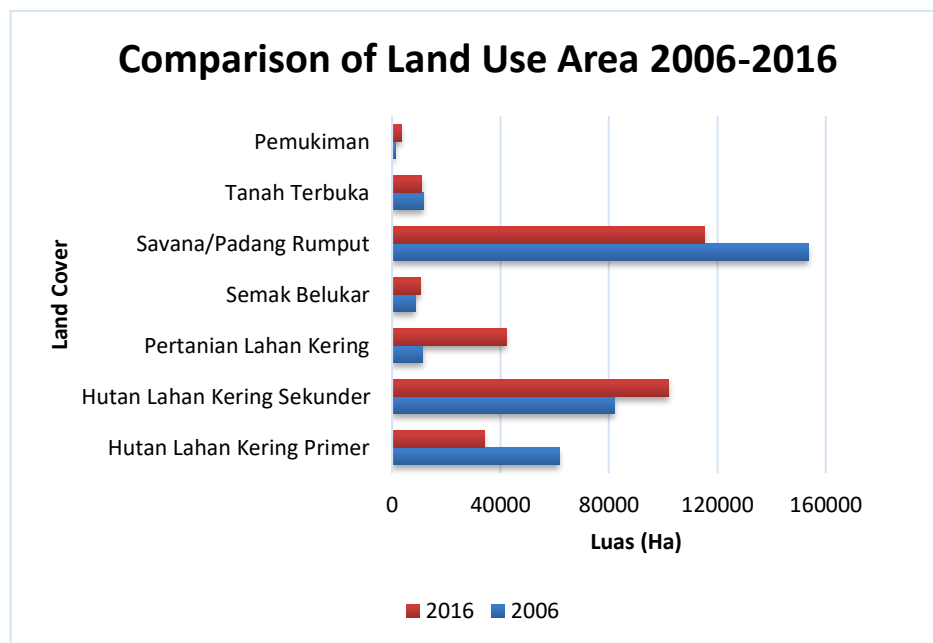


Figure 4. Comparison Chart of Land Cover Area 2006-2016

The largest land use category in Bima Regency in both 2006 and 2016 was Savanna. In 2006, the area of savanna covered 153,618.02 Ha (46.50%) of the total land area, while in 2016, the area of savanna decreased to 115,427 Ha (36.21%). Despite this decrease, the savanna area remained the largest compared to other land use categories. However, this was followed by an increase in the area of secondary dryland forest (HLKS), which grew from 81,953.42 Ha in 2006 to 102,150.91 Ha in 2016. The expansion of secondary dryland forests can be attributed to planting or rehabilitation efforts, often related to land use conversion for agriculture.

The decline in the savanna area is likely due to the increasing human activity around the savanna, which has led to a higher demand for land to accommodate various human activities. Similarly, the area of primary dryland forests decreased from 61,858.78 Ha (18.72%) in 2006 to 34,084.62 Ha (10.69%) in 2016.

Additionally, dryland agriculture experienced the highest increase, with a growth of 9.28%. The area of plantations expanded from 11,341.76 Ha to 42,276.23 Ha, while the area of bushland also increased by 0.64%. These changes are consistent with the livelihoods of the surrounding communities, the majority of whom rely on agriculture and gardening.

Settlements also saw an increase in land area by 0.72%, which correlates with the population growth in Bima Regency. According to Sihombing (2017), the increase in population directly affects the demand for space, particularly for residential areas, infrastructure, and other facilities.

Positive and Negative Land Use Changes

Land use changes are inevitably associated with both positive and negative impacts. These changes are closely linked to the area of the surrounding forest. This is due to a fixed land area, while the need for land for activities is increasing, resulting in a change in land use from less profitable activities to more profitable activities that cause land that is still productive to change its function into a residence or for various kinds of business activities (Ahmadi et al., 2016).

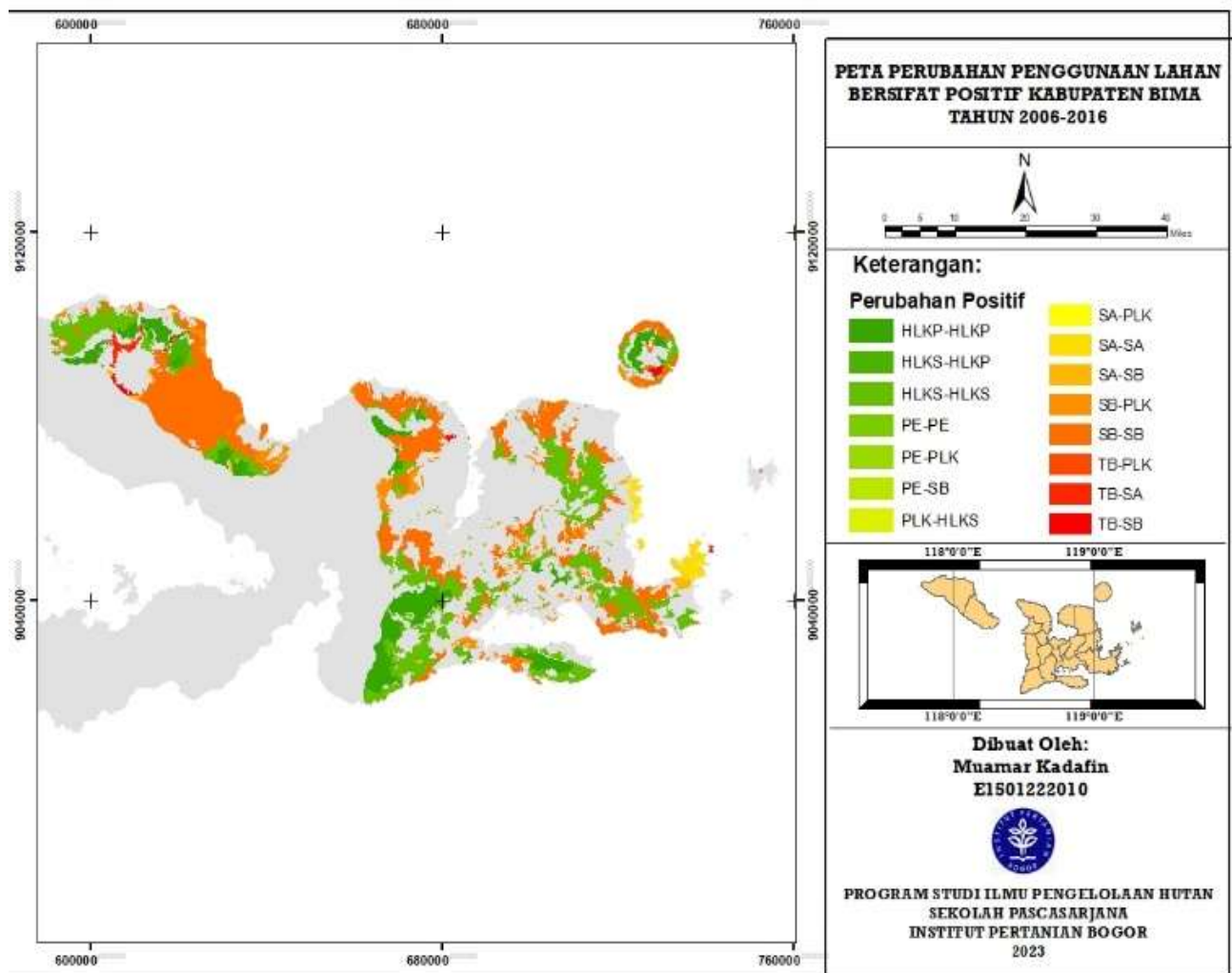


Figure 5. Map of positive land use change

Based on the map in Figure 7, the area that has experienced a change in land use in a positive direction is quite large. The size of the area that has experienced a change in land use in a positive direction can be seen in Table 5.

Table 5. Area of positive land use change

No.	Land Use Change	Land Use Change Code	Land Use Change Area (Ha)
1	Primary Dryland Forests - Primary Dryland Forests	Hp - Hp	828500,53
2	Secondary Dryland Forest - Primary Dryland Forest	Hs - Hp	111498,85
3	Secondary Dryland Forests - Secondary Dryland Forests	Hs - Hs	1067856,57
4	Plantation Forest - Secondary Dryland Forest	Ht - Hs	8364,96
5	Plantation Forest - Plantation Forest	Ht - Ht	196347,84
6	Plantations - Secondary Dryland Forests	HP - Hs	0,01
7	Plantation - Plantation Forest	HP - Ht	144,97
8	Settlements - Plantation Forests	Pm - Ht	0
9	Mining - Secondary Dryland Forest	Tm - Hs	0
10	Mining - Plantation Forest	Tm - Ht	0
11	Dryland + Shrub Agriculture - Secondary Dryland Forest	Pc - Hs	22,31
12	Dryland Agriculture + Shrubs - Plantation Forest	Pc - Ht	1197,95
13	Open Land - Secondary Dryland Forest	T - Hs	0,26
14	Open Ground - Plantation Forest	T - Ht	6794,9
Total Changes			2220729,15

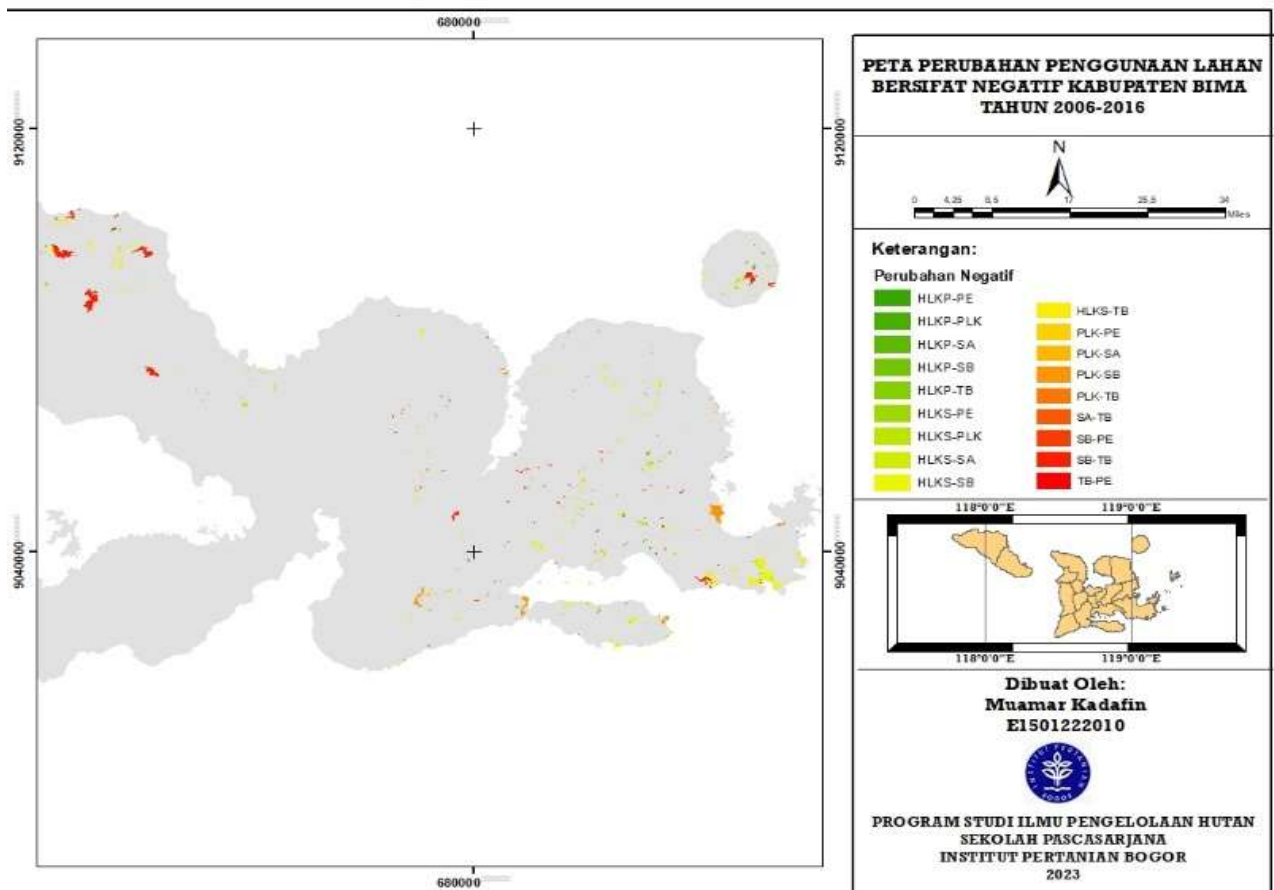


Figure 6. Map of negative land use change

The total area of positive land use change is 2,220,729.15 Ha. A land use change is considered positive if it involves the conversion of non-forest land or forest land that is not primary forest or primary dryland forest. According to Table 5, the largest area of land use change occurred in secondary dryland forest, which did not undergo conversion, covering 1,067,856.57 Ha. This was followed by the secondary dryland forest area, which also remained unchanged, covering 828,500.53 Ha.

This data indicates that the local community is still aware of the crucial role of forests in sustaining life, as they continue to preserve these areas. The community's concern is further reflected in Figure 8, where the map shows that negative land use changes are less extensive than positive land use changes. The details of these changes are outlined in Table 6.

Table 6. Area of negative land use change

No	Land Use Change	Land Use Change Code	Land Use Change Area (Ha)
1	Primary Dryland Forest - Secondary Dryland Forest	Hp - Hs	22682,18
2	Primary Dryland Forests - Plantation Forests	Hp - Ht	17,03
3	Primary Dryland Forest - Plantations	Hp - Pk	1790,68
4	Primary Dryland Forests - Settlements	Hp - Pm	0
5	Primary Dryland Forest - Dryland Agriculture + Shrubs	Hp - Pc	201,94
6	Primary Dryland Forest - Open Land	Hp - T	1015,39
7	Secondary Dryland Forest - Plantation Forest	Hs - Ht	32190,51
8	Secondary Dryland Forests - Plantations	Hs - HP	71559,34
9	Secondary Dryland Forests - Settlements	Hs - Pm	104,24
10	Secondary Dryland Forests - Mining	Hs - Tm	6862,9
11	Secondary Dryland Forest - Dryland Agriculture + Shrub	Hs - Pc	25991,44
12	Secondary Dryland Forest - Open Land	Hs - T	8660,12
13	Plantation Forest - Plantation	Ht - HP	5903,18
14	Plantation Forest - Settlement	Ht - Pm	0
15	Plantation Forest - Mining	Ht - Tm	6799,97
16	Plantation Forest - Dryland Agriculture + Shrub	Ht - Pc	556,12
17	Plantation Forest - Open Land	Ht - T	7269,43
Total Changes			191604,47

The area that has undergone negative land use changes is significantly smaller than the area experiencing positive changes, with a total of only 191,604.47 Ha. The largest change occurred in secondary dryland forest, which was converted into plantations, covering an area of 71,559.34 Ha. This was followed by the conversion of secondary dryland forests into plantation forests, which amounted to 32,190.51 Ha. Interestingly, there were areas that did not experience any change, with a 0 Ha conversion recorded. These areas include the conversion of secondary dryland forests and plantation forests into settlements.

Predicted Land Use Change in 2026

The land use prediction for 2026 was derived from a Markov Chain analysis, utilizing land use data from 2006 as the baseline and land use data from 2016 as the second reference point. The results of this land use prediction for 2026 were then compared with the land use map of 2016 through a crosstabulation method. Based on the validated land use map of 2016, a

simulated land use prediction map for 2026 was generated. The 2026 land use change map was constructed by analyzing transition potentials between 2006 and 2016 using the Markov Chain model. The results of the Markov probability analysis and the 2026 land use prediction map are shown in the figure below:

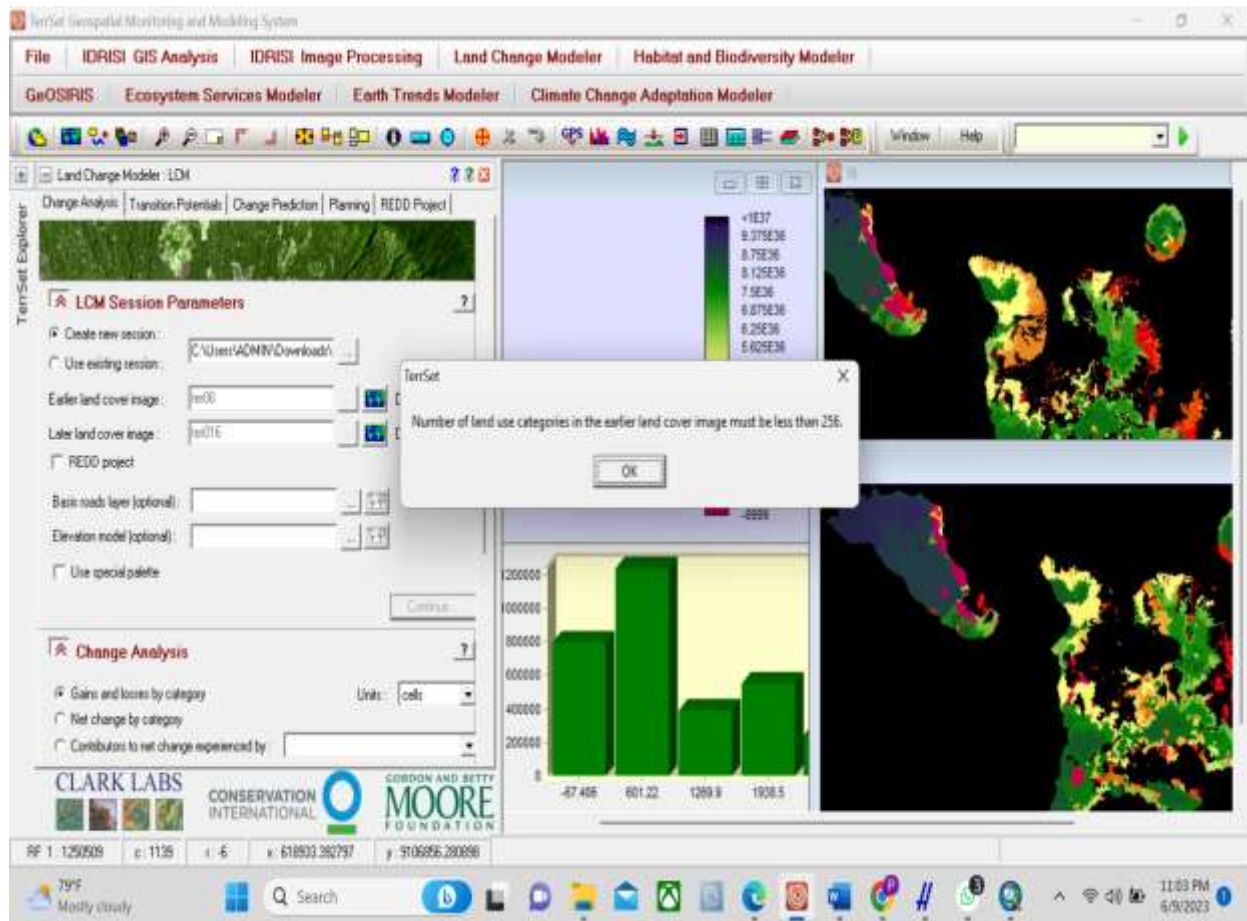


Figure 7. Modeling process using terrset

This prediction is based on the historical patterns observed between 2006 and 2016. However, challenges arose during the Markov analysis, particularly related to technical issues that are common when using applications such as this. Specifically, there was a need to align and ensure the integrity of the metadata for the 2006 and 2016 land cover data. Without proper alignment, the prediction model could not proceed, as the potential probability values failed to appear.

CONCLUSIONS

Savannah dominates land use in Bima Regency experiencing a decrease in area from the Savannah Area in 2006 of 153618.02 Ha (46.50%) 115427 Ha (36.21%) in 2016. In addition to savannas, other land uses that have experienced a decrease in area are primary dryland forests and open land. The land use that has increased in area is secondary dryland forests, dryland agriculture, shrubs, and settlements. The people of Bima Regency still have concern for the surrounding forests. This is evident from the total area of negative land use change of 191604.47 Ha , which is much smaller than the area of positive land use change of 2220729.15 Ha. The data used in this practicum is in the form of secondary data obtained from various sources, so there may be biases or errors in the results obtained. Therefore, it is necessary to conduct further research and adjust the data to the field in order to get maximum results.

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