



Land Use Change Prediction Modelling in Nam Ha National Protected Area, Luangnamtha Province in 2025

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Abstract

This study investigates land use change trends within Nam Ha national protected area (NPA), Luang Namtha Province, objective of the research in this chapter is to predict land use change trends for the year 2025 using the CA-MARKOV model. Historical land use data were derived from Landsat 5 and Landsat 8 satellite imagery captured in 2005, 2010, and 2015. These datasets were systematically analyzed and classified to identify distinct land use categories, which were subsequently integrated into the CA-MARKOV model for predictive analysis. The findings reveal a projected reduction in forest area by 2,334 hectares and a decrease in shrubland area by 194 hectares. Conversely, non-forest area are anticipated to expand by 2,273 hectares, while plantations area are expected to increase by 254 hectares. These transitions exhibit complex and varied dynamics of land use gains and losses, underscoring the heterogeneous nature of landscape change in the region. The outcomes of this study provide critical insights for policymakers, land managers, and other stakeholders, offering a scientific basis for informed decision-making. These projections can guide land use planning, educational initiatives, and policy development aimed at safeguarding forest ecosystems and ensuring their sustainable management in alignment with broader developmental and environmental strategies.

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1. Introduction

Changes in resources have occurred rapidly from the past to the present due to population growth and the current global demand for economic expansion, leading to increased consumption of natural resources. Therefore, it is necessary to utilize the conditions of existing natural resources, especially the changes in forest resources, which are a crucial issue for development. At the same

time, sustainability must be maintained in accordance with the Party-State's plan, which aims to increase the forest cover rate to 70% by the year 2020 (Ministry of Agriculture and Forestry, 2005) and the target for 2035 is to allocate forest land to reach 70% of the country's total area, of which: 8.2 million hectares or 35% are Protection Forestland; 4.7 million hectares or 20% are Conservation Forestland; 3.1 million hectares or 13% are Production

Forestland; 0.5 million hectares or 2% is land for tree planting (Ministry of Agriculture and Forestry, 2024).

Luang Namtha Province is one province with valuable resources, especially forest resources, including the Nam Ha National Protected Area, which covers 24% of its total area and spans all districts within the province. It ranks 4th among National Protected Areas in Laos and 4th in the Indo-China region's north. Due to its regional biodiversity significance, the Nam Ha NPA was recognized as an ASEAN Natural Heritage site in 2003 (Schipani, 2008).

Prime Minister (1993) The Nam Ha National Protected Area was established by Prime Minister's Decree No. 164/NG, dated October 29, 1993, with an area of 69,000 hectares according to that decree. In 1999, the NPA was expanded to 222,400 hectares under the Prime Minister's Office Notification No. 1465/SNG, dated August 25, 1999. The Nam Ha NPA is located solely within Luang Namtha Province, covering the districts of Nalae, Viengphoukha, Sing, and Long. It is situated between 101°07' - 101°37' East longitude and 20°33' - 21°15' North latitude. It encompasses 27 villages located within the NPA (Figure 01).

In recent years, machine learning techniques have been employed in satellite image processing (Huang et al., 2002; Shao & Lunetta, 2012), forest type classification, and Artificial Neural Networks (ANNs) (Yuan et al., 2009; Song et al., 2011). Changes in forest cover and land use are among the most perceptible changes occurring globally. Such changes demonstrate the relationship between human activities and the transformation of the Earth's surface. Particularly, the increase in human activities is a key component driving environmental change, which has both direct and indirect impacts on land, water, and the atmosphere (Meyer & Turner, 1994; Roy & Roy, 2010; Phengvichith et al., 2024). Developing an understanding of past, present, and future conditions is essential for urban planners, land managers, and resource

managers in a rapidly changing environment (Meyer & Turner, 1994; Warner et al., 2009).

Analyzing land use change and predicting land use trends necessitates studying and monitoring the characteristics of past and present land use and land cover change, as well as conducting studies to predict future land use changes, in order to serve as a database for land use planning (Orwattan, 2012).

Land use change models are popular tools used in studies to predict trends in land use change. Currently, there are two main groups of models: land use change models that can predict the rate of land use change, and land use change models that can show the location of change as well as the rate of land use change. Currently, the Cellular Automata model is widely used in studying land use and land cover change. It has been developed into the CA-MARKOV (Cellular Automata – Markov Chain) modeling program. This model has the capability to predict land use and land cover change in both spatial and quantitative terms (Orwattan, 2012).

Eastman (2006) explained the methodology for using the CA-MARKOV model in the user manual for the IDRISI Andes Edition 15 software, summarizing it as follows: The CA-MARKOV model is a model used for decision-making, operating through the integration of the Markov Chain model and the Cellular Automata model. It is used to analyze the quantity of land use and land cover change. It employs the quantitative predictions of land use and land cover obtained from the Markov Chain model and performs an analysis of the relationship of neighboring cells that influence the state of the central cell, using the Cellular Automata model to describe the spatial data.

The Markov Chain model is a popular theory used in studies to predict changes in data that will occur in the future (Watcharakitti, 1978). Pontius (2000) stated that Cellular Automata refers to cells that exist independently and can change their state based on factors causing change, specifically the surrounding environmental cells

according to the "Game of Life" rule created by John Conway in 1970. CA-Markov is the application of the principles of Cellular Automata and Markov Chain together to predict land use patterns using geographic information system processing software. The pattern of change in each cell is determined by considering the proportion of land use (Pontius, 2000).

This research utilizes data from remote sensing to classify land use types for each time period and employs a Geographic Information System (GIS) to analyze land use change. This approach enables accurate comparison of spatial data. The results are then integrated with the CA-MARKOV model to predict future land use trends.

Modeling to observe future change trends based on current conditions is essential for use as a database for management planning and sustainable utilization, responding to the targeted goals of increasing forest cover rates in the future.

The overall objective of the research in this chapter is to predict land use change trends for the year 2025 using the CA-MARKOV model.

2. Materials and Methods

2.1 Materials

- This research was utilized Landsat 5 and Landsat 8 satellite imagery to classify forest cover types and analyze land use change for each time period (years 2005, 2010, 2015). (Details on the differences between the spectral bands of Landsat 5 and Landsat 8 can be found in Table 1).

- Arc Map 10.2 Desktop software was used to process and analyze satellite imagery, analyze land use change, and create maps.

- The CA-MARKOV model was used with IDRISI Selva 17 software to analyze land use change trends for the year 2025.

2.2 Research Methodology

- Landsat 5 and Landsat 8 satellite imagery with path/row designations 129/45, 129/46, 130/45, 130/46 from the years 2005, 2010, and 2015 was used. The

images were corrected, layer stacked, mosaicked into a single image, and then subset to the specific study area. Land use types was classified. Subsequently, the classified images was overlaid to analyze changes between each time period (Figure 2).

- Following this, the land use types and land use change data was analyzed to determine transition probabilities and transition areas in order to predict change trends for the year 2025 (Figure 3).

2.3 Classification of Forest Cover and Land Use Types

The selection of sample areas used land use type point data from the field as the basis for creating training areas on the image, which were then used to calculate statistics or reflectance values for each land use type. If land classification is determined according to the Land Law 2003 (Article 11), it might be complex for the study area and the model predicting future change trends. Therefore, a new land use classification was applied, categorized into 4 main land use types:

- Areas with forest cover level > 20%, average area greater than 0.5 hectares, classified as Forest Area.
- Areas with cover level < 20% (areas with potential for natural regeneration), average area greater than 0.5 hectares, and subject to disturbance (e.g., clearing for production, excavation, ...) classified as Shrubland Area.
- Plantation forest areas, specifically rubber tree plantations, were distinctly classified as Plantation Area.
- Areas not forested, such as agricultural areas, upland fields, paddy fields, grasslands, roads, residential areas, water bodies, classified as Non-Forest Area.

3. Results

From the study, it was found that in the Nam Ha National Protected Area, the forest area in 2005 was 156,128 hectares, covering 70% of the area; in 2010 it was 154,067 hectares, covering 69% of the area; and in 2015 it was 150,626 hectares, covering 67% of the area. For shrubland area, in 2005 it was 62,198 hectares, covering 28 % of the area; in 2010 it was 61,839 hectares,

covering 28% of the area; and in 2015 it was 64,591 hectares, covering 29% of the area. For plantation area, in 2005 it was 493 hectares, covering 0 % of the area; in 2010 it was 3,723 hectares, covering 2% of the area; and in 2015 it was 4,856 hectares, covering 3% of the area. For non-forest area, in 2005 it was 3,581 hectares, covering 2% of the area; in 2010 it was 2,771 hectares, covering 1% of the area; and in 2015 it was 2,327 hectares, covering 1% of the area (Table 2).

The prediction of land use trends in the Nam Ha National Protected Area for the next 10 years using the Markov Chain model, based on land use and forest data from 2005 and 2015 as baseline information, yielded the following analysis results: transition probability values (Table 5) and transition area values (Table 6). The transition area values for land use and forest change obtained from the analysis were used to create a CA-Markov model, resulting in a predictive model for land use and forest cover trends for 2025. The results show that in 2025, forest area was 148,292 hectares, equivalent to 66.48 %; shrubland area was 64,397 hectares, equivalent to 29.14%; non-forest area will be 4,600 hectares, equivalent to 2.10 %; and plantation area will be 5,111 hectares, equivalent to 2.28 % of the total area of the National Protected Area (Table 7).

Regarding the characteristics of land use change during the projected period of 2015–2025 from the model: Forest area in 2025, when compared to 2015, is projected to change into shrubland (1,803 ha), plantation area (1,460 ha), and non-forest area (409 ha). Shrubland area in 2025, compared to 2015, is projected to change into forest area (1,928 ha), non-forest area (1,039 ha), and plantation area (153 ha). Plantation area in 2025, compared to 2015, is projected to change into non-forest area (1 ha). Non-forest area in 2025, compared to 2015, is projected to change into shrubland (727 ha) and plantation area (19 ha) (Table 9).

4. Discussion

Predicting land use change trends using the CA-MARKOV model proved suitable for the study area, with an accuracy validation of 82.04%. This finding is consistent with Thanit (2005), who studied land use change in the coastal area of Ban Laem District, Phetchaburi Province, by applying GIS, remote sensing data, and GPS with the CA-Markov model to examine land use change patterns during 1997–2003 and predict changes for the next 15 years (2015). The study found that land use change predictions from the CA-Markov model had an overall accuracy of 73.59% compared to actual land use areas. Tonsiri et al. (2018) applied CA-Markov to predict land use change in 2023 within the Khao Soi Dao Wildlife Sanctuary, Chanthaburi Province, finding that forest areas showed a continuous decreasing trend. This is consistent with Butkho (2020), who used the model to study land use change and analyze participatory land suitability for industrial town planning in the case study of Si Maha Phot District, Prachinburi Province. The study revealed that urban and built-up areas tended to expand into areas with high potential across various dimensions, while also encroaching into important natural resource areas and expanding into areas lacking potential. Furthermore, this finding is consistent with Khunrattanasiri et al. (2024), who applied the CA-Markov model to predict land use in the Thale Noi Non-Hunting Area, revealing that agricultural land, forest areas, and water body areas show a continuous decreasing trend, while residential and built-up land use types show a continuous increasing trend, with an accuracy of 89%.

Therefore, the application of the CA-MARKOV model together with Geographic Information Systems and remote sensing data constitutes an important tool and one of the key options for predicting land use and land cover change. It can effectively produce results in both spatial and temporal dimensions of change, enabling the identification of the direction, magnitude, location, and timing of land use change.

5. Conclusion

This research demonstrates that the predicted land use change trends in the Nam Ha National Protected Area, Luang Namtha Province, for the year 2025, when compared to 2015, show that forest area is projected to decrease by 2,334 hectares, shrubland area to decrease by 194 hectares, non-forest area to increase by 2,273 hectares, and plantation area to increase by 254 hectares within the study area boundary. However, when examining the transitions between individual land use types, it is evident that changes involve both increases and decreases in varying patterns. This assessment can serve as a reference for relevant stakeholders in land use planning, research, and policy formulation to maintain and increase forest cover in the future, thereby supporting development strategies.

Recommendation: This research employed CA-Markov model analyzes spatial change trends based primarily on the proportional factors of past changes (time series) as the main determinant, without incorporating socio-economic factors as determinants, which may reduce the model's accuracy. Therefore, in future applications, socio-economic indicators should be added to make the prediction results more precise.

6. Conflicts of Interest

I as a scientific researcher, hereby declare that all the data contained in this academic article has no conflicts of interest with any party and does not provide undue advantage to any particular party. In the event of any form of violation, I am willing to accept full responsibility alone.

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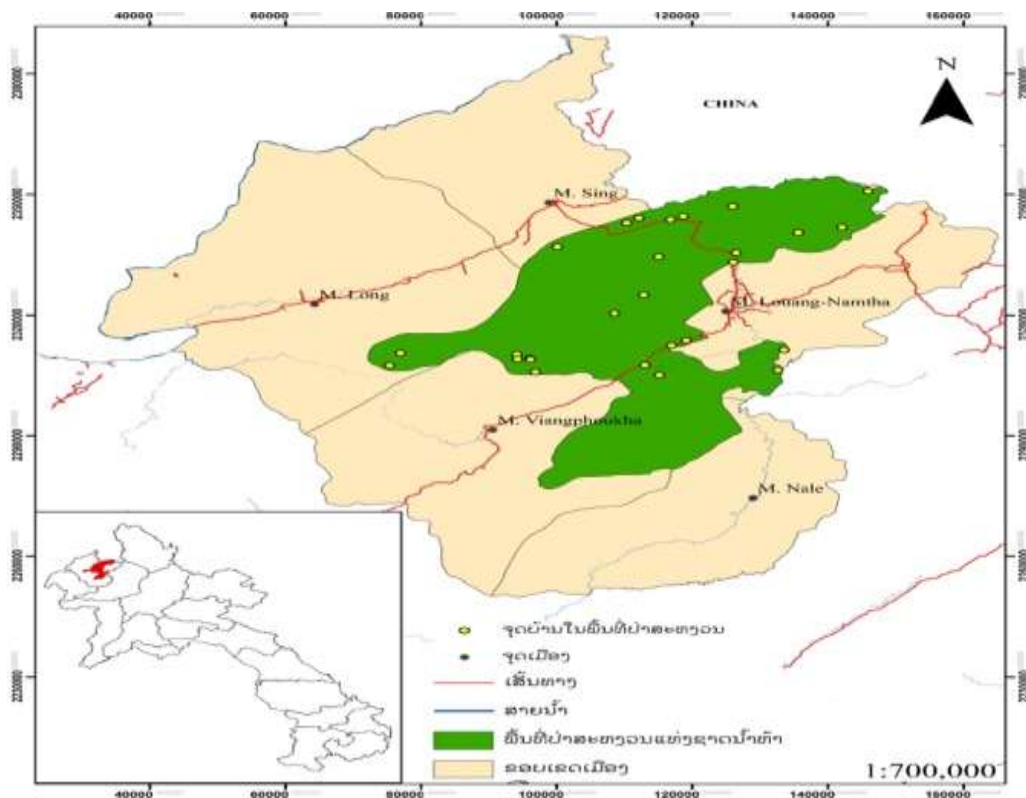


Figure 1: Map of the Nam Ha National Protected Area, Luang Namtha Province.

Table 1: Comparison of the Differences Between the Spectral Bands of Landsat 5 and Landsat 8 Satellites

Landsat 5 TM		Landsat 8 OLI/TIRS	
Band	Wavelength (Micrometers)	Band	Wavelength (Micrometers)
1	0.45-0.52	1	0.43-0.45
2	0.52-0.60	2	0.45-0.51
3	0.60-0.69	3	0.53-0.59
4	0.77-0.90	4	0.64-0.67
5	1.55-1.75	5	0.85-0.88
6	10.40-12.50	6	1.57-1.65
7	2.08-2.35	7	2.11-2.29
		8	0.50-0.68
		9	1.36-1.38
		10	10.60-11.19
		11	11.50-12.51

Source: (Agricultural Information Center, 2014)

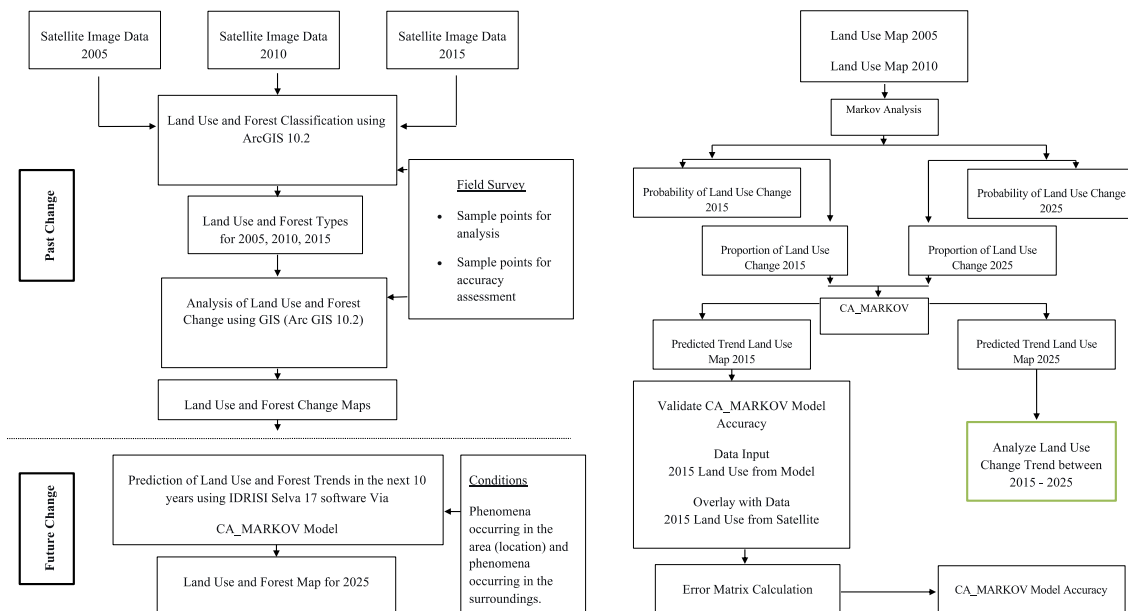


Figure 2: Methodological framework of the study Figure 3: Predicting land use change trends using the CA_MARKOV model

Table 2: Forest Cover and Land Use Change 2005-2015

Land Use and Forest Type	2005		2010		2015	
	Ha	(%)	Ha	(%)	Ha	%
Forest Area	156,128	70	154,067	69	150,626	67
Shrubland Area	62,198	28	61,839	28	64,591	29
Plantation Area	493	0	3,723	2	4,856	2
Non-Forest Area	3,581	2	2,771	1	2,327	1.04
Total	222,400	100	222,400	100	222,400	100

Table

3: Differences between Modeled Land Use/Forest Data and Data from 2015 Image Classification.

Land Use and Forest Type	Classification Data		Modeled Data		Difference	
	Ha	(%)	Ha	(%)	Ha	%
Forest Area	150,626	67.48	150,728	67.47	102.49	0.01
Shrubland Area	64,591	29.07	64,030	28.76	560.21	0.31
Plantation Area	4,856.2	2.16	4,305	2.10	550.98	0.07
Non-Forest Area	2,326.8	1.04	3,335	1.67	1,008.7	-0.39
Total	222,400	100	222,400	100		

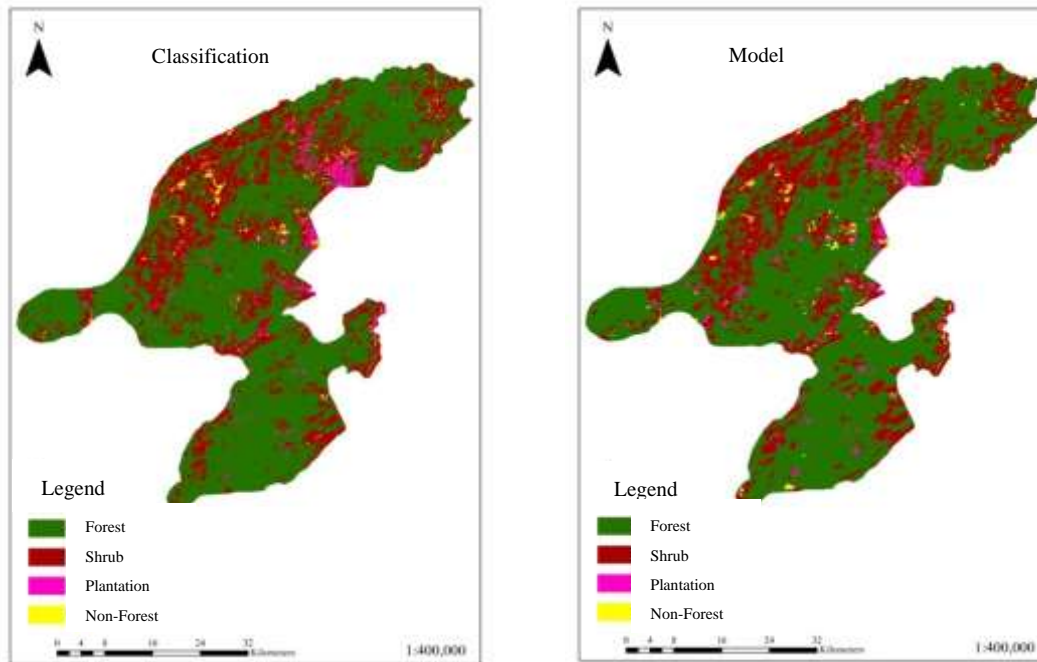


Figure 4: Comparison of Forest Cover and Land Use Change maps of the Nam Ha National Protected Area for the year 2015 from classification (left) and from modeling (right).

Model Accuracy

The accuracy of the 2015 land use and forest model was checked using an overlay technique between the map from satellite image classification and the modeled map. The results were used to create an error matrix. The model has an Overall Accuracy of 82.04%, calculated as follows:

$$\text{Overall Accuracy} = \frac{\sum_{i=1}^k n_{ii}}{n}$$

$$\text{Accuracy} = ((133,106.6 + 2,451.05 + 3,138.3 + 45,080.19) / 222,400) * 100 = 82.04\%$$

Table 4: Model Accuracy (Error Matrix in Hectares).

Land Use and Forest Type	From Model				
	Forest Area	Non-Forest Area	Plantation Area	Shrubland Area	Total
Forest Area	133,106.6	277.2	258.48	17,645.64	151,287.92
Non-Forest Area	37.72	2,451.05	152.64	1,069.46	3,710.87
Plantation Area	531.66	3.06	3,138.3	270.09	3,943.11
Shrubland Area	16,518.24	946.08	913.59	45,080.19	63,458.1
Total	150,194.22	3,677.39	4,463.01	64,065.38	222,400

Source: Calculation formula adapted from (Congalton, R. G. & Green, K. 2008)

Table 5: Probability of Forest Cover and Land Use Change for 2025

Land Use and Forest Type	2025			
	Forest Area	Non-Forest Area	Plantation Area	Shrubland Area
Forest Area	0.8063	0.0055	0.0131	0.1750
Non-Forest Area	0.1358	0.1105	0.0861	0.6676
Plantation Area	0.1102	0.0483	0.1883	0.6532
Shrubland Area	0.4132	0.0246	0.0326	0.5296

Table 6: Proportion of Forest Cover and Land Use Change for 2025 (Hectares)

Land Use and Forest Type	2025			
	Forest Area	Non-Forest Area	Plantation Area	Shrubland Area
Forest Area	122,185.98	835.38	1,989.36	26,522.28
Non-Forest Area	382.41	311.22	242.55	1,879.92
Plantation Area	491.85	215.46	840.6	2,915.19
Shrubland Area	25,862.58	1,542.51	2,037.69	33,151.41

Table 7: Forest Cover and Land Use Change for 2025

Land Use and Forest Type	2025	
	Area (Ha)	Percentage (%)
Forest Area	148,292	66.48
Shrubland Area	64,397	29.14
Plantation Forest Area	5,111	2.28
Non-Forest Area	4,600	2.10
Total	222,400	100

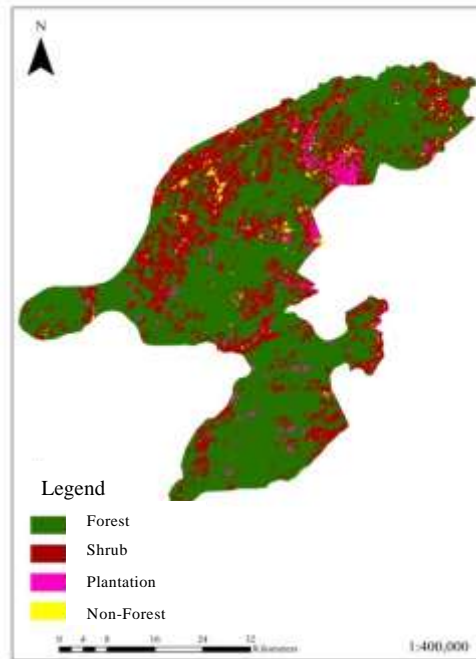


Figure 5: Predicted Forest Cover and Land Use Map for The Year 2025

Table 8: Forest Cover and Land Use Change between 2015 - 2025.

Land Use and Forest Type	2015		2025		Change (Ha)
	Area (Ha)	%	Area (Ha)	%	
Forest Area	150,626	67.48	148,292	66.48	-2,334
Shrubland Area	64,591	29.07	64,397	29.14	-194
Plantation Area	4,856.2	2.16	5,111	2.28	254.8
Non-Forest Area	2,326.8	1.04	4,600	2.10	2,273.2
Total	222,400	100	222,400	100	

Table 9: Characteristics of Forest Cover and Land Use Change, 2015-2025

Land Use and Forest Type	2025				
	Forest Area	Non-Forest Area	Plantation Area	Shrubland Area	Total
Forest Area	147,858.8	409.77	1,460.61	1,803.69	151,532.87
Non-Forest Area		2,316.87	19.89	727.81	3,064.57
Plantation Area		1.89	3,477.33		3,479.22
Shrubland Area	1,928.69	1,039.49	153.18	61,201.98	64,323.34
Total	149,787.49	3,768.02	5,111.01	63,733.48	222,400

2015

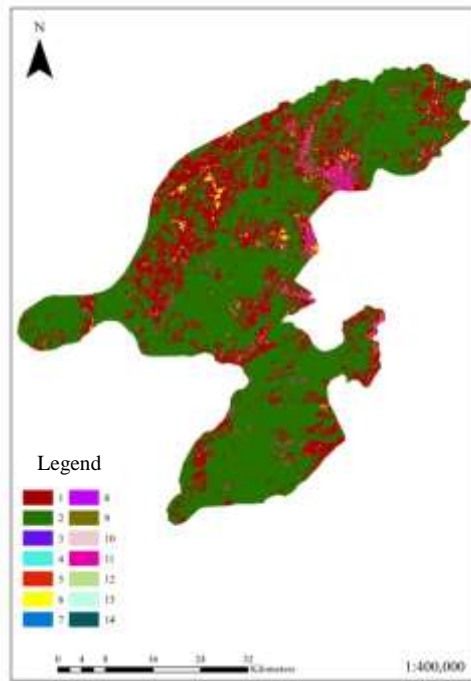


Figure 6: Map of Forest Cover and Land Use Change characteristics, 2015-2025

Table 10: Characteristics of Forest Cover and Land Use Change, 2015-2025

Symbol	Change	
	2015	2025
1	Shrubland	Shrubland
2	Forest	Forest
3	Shrubland	Forest
4	Forest	Shrubland
5	Forest	Non-Forest
6	Non-Forest	Non-Forest
7	Shrubland	Non-Forest
8	Non-Forest	Shrubland
9	Forest	Plantation
10	Plantation	Shrubland
11	Plantation	Plantation
12	Shrubland	Plantation
13	Plantation	Non-Forest
14	Non-Forest	Plantation