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LAND COVER CHANGE IN PROTECTED FOREST, TANANTOVEA SUBDISTRICT DONGGALA REGENCY

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ABSTRACT

Protected forests play a vital role in maintaining ecosystem balance, such as regulating water systems, controlling floods, and preserving soil fertility. However, pressure from population growth and community activities around forest areas particularly land clearing for plantations has led to significant changes in land cover. This research was conducted from May to November 2023 and aimed to calculate the land cover area for the years 2013 and 2023, as well as analyze land cover changes in the Protected Forest area of Tanantovea District, Donggala, over the ten-year period. Land cover identification and its changes were assessed using Landsat 8 satellite imagery, classified through a supervised classification method. Image data processing identified five types of land cover: primary dryland forest, secondary dryland forest, plantations, shrubs, and bare land. The results showed that the primary dryland forest experienced a decrease of 522.20 hectares, while other land cover classes increased in area. These changes were driven by the socio-economic conditions of surrounding communities, such as low-income levels, limited employment opportunities, and small land ownership. The classification accuracy reached 82%, indicating that the image interpretation was reasonably representative of actual field conditions. These findings highlight the importance of utilizing remote sensing technology to monitor land cover dynamics and support sustainable forest management decision-making.

Keywords: *land cover change; landsat 8; protected forest; remote sensing; supervised classification*

INTRODUCTION

Protected forest areas serve as an essential component in protecting and sustaining life by maintaining water systems, preventing flooding, controlling erosion, protecting against seawater intrusion, and maintaining soil nutrient availability (Irkhamni *et al*., 2021). Forests also provide various ecosystem services that play a major role in the livelihoods of local communities. Communities depend on forests for ecosystem services such as house construction, firewood, honey production, edible wild fruits, and spices (Shiferaw *et al*., 2023).

Land cover change is the result of a complex interaction between natural drivers and anthropogenic factors. Rapid urbanization, population growth, and agriculture are the main drivers of land transformation (Machanda *et a*l., 2025). Rapid development also increases the demand for land to support the community's survival needs (Alfarizi *et al*., 2024). Land cover change occurs as a result of continuous population growth and rapid technological development, which has led to the conversion of areas into other forms to meet human needs, such as clothing, food, and especially land for settlements (Purnama *et al*., 2024).

Research in Thanh Hoa province, Vietnam, indicates a decline in the area of mixed forests, with a significant shift from forest areas to agricultural land (Nguyen *et al*., 2025). Similarly, research in the North Atwima Nwabiagya District shows that high-density forests are losing surface area, which is being converted into built-up and open land (Baidoo & Obeng, 2023). The lack of available land in an area is one of the factors driving the spread of land cover change to the outskirts of forest areas (Setyoko, 2025). Land constraints have led communities to seek alternatives for building new dwellings to meet their land needs, but these are still located in easily accessible areas on the outskirts of forest areas. Hamka *et al*. (2025) also revealed that land cover change occurs around protected forests due to limited land ownership per family and increasing needs, which are factors for some low-income communities to cultivate and convert land to expand their plantations.

The presence of villages on the edge of the protected forest area in Tanantovea Subdistrict, where the community generally has low incomes, lacks employment opportunities outside of plantations, has limited land ownership, and has low agricultural productivity, is a factor that drives the community to depend on the protected forest area by utilizing the potential of forest resources. In addition, the community's level of education, which has resulted in a weak understanding of sustainable forest management, has also contributed to the problem (Coronel-Chugden *et al*., 2025). The high rate of forest destruction can reduce the forest's ability to support its ecosystem functions. This condition has the potential to cause serious impacts on the environment, such as climate change, a decline in biodiversity, reduced availability of water resources, and increased soil erosion (Ahyar *et al*., 2024).

Furthermore, understanding the dynamics of land cover change in protected forest areas is crucial for formulating evidence-based management policies. Spatial–temporal analysis provides critical insights into the magnitude, direction, and patterns of landscape transformation over time. Without accurate monitoring, degradation processes may continue unnoticed and lead to irreversible ecological damage. In many developing regions, weak law enforcement and limited monitoring capacity further exacerbate uncontrolled land conversion around protected areas. Therefore, integrating satellite-based monitoring with socio-economic analysis is essential to capture both environmental and human-driven dimensions of land change. Such an approach enables policymakers to design targeted interventions that balance conservation objectives with community livelihood needs.

Given the increasingly alarming condition of forests, various conservation strategies and the involvement of all parties are needed to support and create an environment that remains preserved (Ahada & Zuhri, 2020). The rate of land cover change can be analyzed using geographic information systems (GIS) and remote sensing. Remote sensing and geographic information systems are useful approaches for surveying and tracking changes in land cover (Khan & Chen, 2025). Analysis of land use change using remote sensing can monitor land change patterns over time and provide information about the triggers that contribute to land cover change. This study aims to calculate the land cover area in 2013 and 2023 and identify land cover change in the protected forest area of Tanantovea subdistrict.

METHOD

Material and Methods

This study examines land cover changes over 10 years from 2013 to 2023 in the Protected Forest of Tanantovea Subdistrict, Donggala Regency. Identification and detection of land cover changes using descriptive data analysis, supervised classification, overlay, and accuracy testing of the matrix coefficient. The tools and materials used included a camera for documentation, writing instruments for recording data, a laptop with ArcGIS 10.8 software, a GPS device for collecting coordinates in the field, Landsat 8 imagery from 2013 and 2023 obtained from the USGS, Indonesian topographic map (RBI) scale 1:25,000 from the

Geospatial Information Agency (BIG), the Tanantovea District Administration Shp, and decree No. 6624 of 2021 on the Designation of Protected Forest Areas.

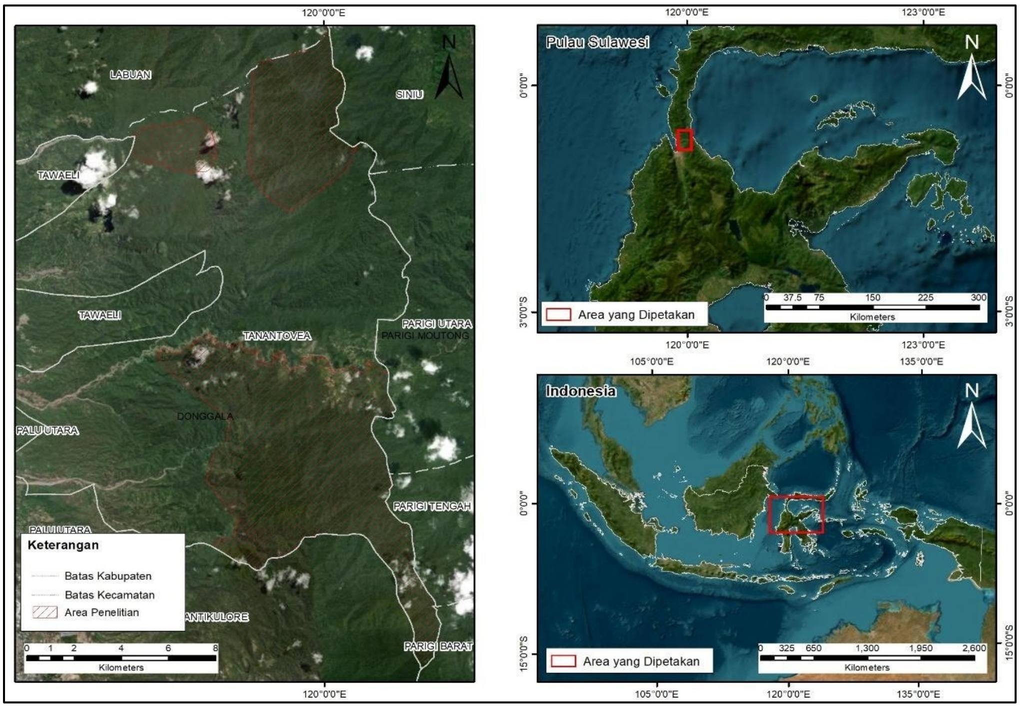

Figure 1. Research Location

Preparation Stage

The preparation stages include several steps, namely:

1. Image correction/image restoration: In the image restoration process, image quality is affected by various factors that cause a decline in image quality in various forms, such as blurring, loss of detail, and increased interference (Zhang *et a*l., 2024). At this stage, images with interference will be geometrically corrected to improve the image coordinate position in accordance with field conditions. Geometric transformation is the repositioning of pixel values in accordance with actual conditions, so that the image appearance matches the image of the earth's surface detected by the sensor (Andilla Aulia Arkham *et al.*, 2023). Meanwhile, radiometric correction aims to correct errors caused by electromagnetic radiation interference in the atmosphere and improve image quality by sharpening Landsat 8 images.

2. Image cropping: Image cropping aims to extract part of the data set to maintain the boundaries of the research area (Al-Aarajy, *et al*. 2024). At this stage, the 2013 Landsat 8 image and the 2023 Landsat 8 image were overlaid with the area designation map and the Tanantovea subdistrict administrative map, resulting in an image cutout of the Tanantovea Subdistrict Protected Forest area.

3. Image Composite: The channel composition used is RGB 432 and RGB 654, which serve to detect vegetation.

Image identification and classification

The image identification and classification process is carried out using the supervised classification method. The stages begin with determining the training area, which shows the level of each class, using the maximum likelihood algorithm (Reham Riyadh Mahmoud *et al* 2019). This algorithm estimates that the statistical distribution in each class follows a normal distribution, then calculates the probability value for each pixel. Each pixel is then classified into the class with the highest probability (Aurellia *et al*., 2023).

Analysis of Land Cover Change

Changes in land cover can generally be observed over different time periods (Bairwa *et al*., 2025). Changes in land cover are identified by overlaying image processing results, then analyzed using image comparisons from 2013 and 2023 to measure the extent of change in land cover area during that period. The results of the analysis are then displayed in a land cover change matrix.

Field Check or Survey

Field checks are used to review the results of land cover interpretation (Foody, 2024). Land cover observations are made by referring to available land cover maps (ground checks) and matching them with conditions in the field using coordinate points. Coordinates are taken using the Global Positioning System in the study area.

Accuracy Analysis

Accuracy analysis is the result of image data processing that serves to provide information about the conformity with actual conditions. This process is carried out to identify potential errors that may have occurred in the previous stage, which could cause the information to be inaccurate (*Suni et al*., 2023). The accuracy level is analyzed using a contingency matrix, often referred to as an error matrix or confusion matrix.

Table 1. Confusion Matrix Accuracy Calculation

<table>
<tr><td colspan="3"></td><td colspan="2">Field Data</td><td>Total Classes</td></tr>
<tr><td rowspan="3">Classification data</td><td colspan="4">Class</td><td rowspan="3"></td></tr>
<tr><td rowspan="2">Class</td><td></td><td>1</td><td>2</td></tr>
<tr><td>1
2</td><td>Main Class</td><td>Primary Class</td></tr>
<tr><td colspan="2">Total Rows</td><td colspan="4"></td></tr>
</table>

RESULTS AND DISCUSSION

Land Cover in 2013

In this study, Landsat 8 image data were processed through several stages to classify land cover. This process applied a supervised classification method. Image classification resulted in primary dryland forest, secondary dryland forest, gardens, shrubs, and open areas. For further clarification, see the table below.

Table 2. Land Cover in 2013

Class	Area (Ha)	Percentage
Primary Dryland Forest	2,223.37	22.29
Secondary Dryland Forest	7,129.81	71.49
Plantations	328.36	3.29
Scrub	216.80	2.17
Open Land	75.15	0.75

Total	9,973.49	100

Source: Landsat 8 image analysis 2013

The results in the table above show that secondary forest land cover has the largest area compared to other land cover types, namely 7,129.81 ha or 71.49%, which is marked in light green. Next is the primary dry forest land cover, which has an area of 2,223.37 ha or 22.29% and is marked in dark green. The appearance of forests in the image can be recognized by looking at various visual characteristics. Forests are generally green in color, depending on the type of vegetation and its condition.

Plantations on the image are marked in yellow, covering an area of 328.36 ha or 3.19%. Furthermore, shrubs are marked in orange with an area of 216.80 ha or 2.17%, and open land is marked in purple with an area of 75.15 ha or 0.75%. To provide a clearer picture, the classification results are displayed as follows.

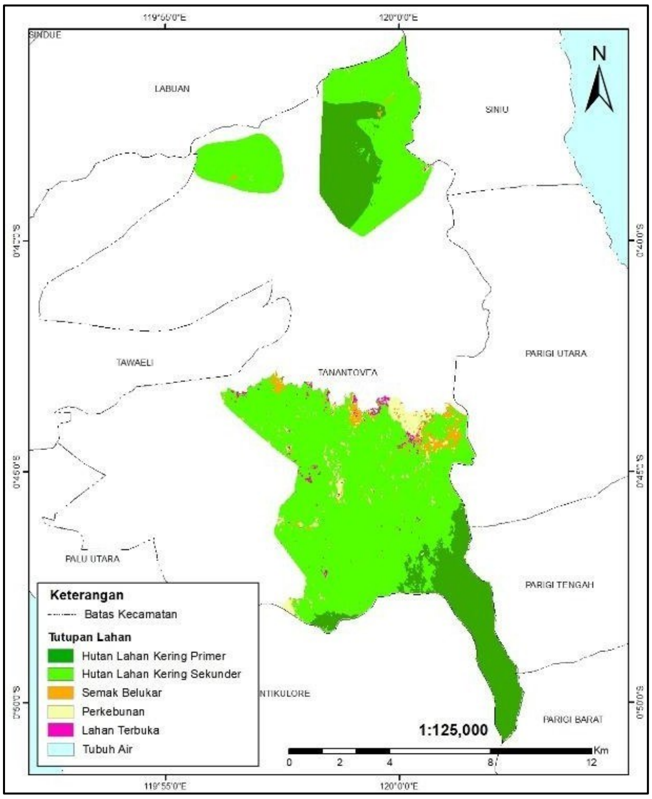

Figure 2. Land Cover Map for 2013

Land Cover in 2023

Interpretation of Landsat 8 imagery from 2023 in the protected forest area of Tanantovea subdistrict, Donggala, was carried out by classifying land cover based on references that took into account the characteristics of the identified objects. Objects were determined by considering their shape, size, pattern, shadow, texture, and position. Image analysis was carried out through various steps, starting from image cropping to the classification process. The results of image interpretation produced several classes, which are presented in the following table 3.

Table 3. Land Cover 2023

Class	Area (Ha)	Percentage
Primary Dryland Forest	1,701.17	17.06

Secondary Dryland Forest	7,479.06	74.99
Plantations	463.62	4.65
Scrubland	237.26	2.38
Open Land	92.39	0.93
Total	9,973.49	100.00

Source: Landsat image analysis 2023

The interpretation and classification results from Landsat 8 imagery in 2023 show five classes, including 1,701.17 ha or 17.06% of primary dryland forest, 479.06 ha or 4.09% of secondary dryland forest, plantations covering an area of 463.62 ha or 4.56%, shrubs covering an area of 237.26 ha or 2.38%, and open land covering an area of 92.39 ha or 0.93%. The Landsat image data in this study was processed through several stages to classify land cover. The final step was to classify the images through interpretation using a supervised classification method. The supervised method requires samples of land cover classes whose classes are already known (Moraes *et al*., 2024). This stage includes the detection and grouping of pixels using the training location. The results of land use classification are then refined based on a survey of the research location conditions, producing the following map.

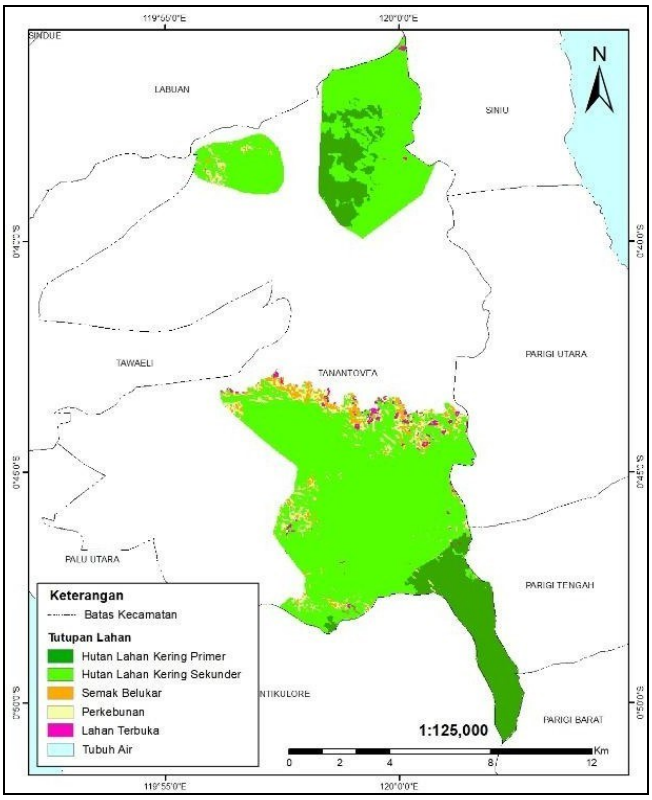

Figure 3. Land Cover Map 2023

Land Cover Changes from 2013 to 2023

Land use change refers to a condition in which the function of land is transformed from one type to another. The results of the overlay of Landsat images from 2013 and 2023 indicate changes in land cover area in the protected forest area in Tanantovea District, Donggala. Based on calculations of land cover area changes in the area over a ten-year period (2013-2023), there are land cover classes that have decreased and increased in area. Land cover change detection was obtained by *overlaying* the 2013 and 2023 classification maps. Next, the changes were calculated and exported to Ms. Excel to then calculate the area of change using *Pivot Table* (Matrix Table). To provide a more detailed overview, the changes in land cover area for the 2013-2023 period are presented in the following table.

Table 4. Matrix of Land Cover Area Changes from 2013 to 2023

Class		**2023**					
		Pdf	**Sdf**	**P**	**S**	**Ol**	**Total Area (Ha)**
2013	**Pdf**	1,627.06	583.12	10.65	0.84	1.69	2,223.37
	Sdf	70.54	6,540.37	342.04	132.84	44.03	7,129.81
	P	0.72	212.68	57.23	39.21	18.51	328.36
	S	2.86	108.28	38.74	52.40	14.53	216.80
	Ol		34.61	14.96	11.97	13.62	75.15
Total Area (Ha)		1,701.17	7,479.06	463.62	237.26	92.39	9,973.49

Source: Overlay of 2013 and 2023 maps
Description:
Pdf : Primary Dry Forest;
Sdf : Secondary Dry Forest;
P : Plantation;
S : Scrub;
Ol : Open Land.

In 2013, the area of primary dryland forest reached 2,223.37 ha, while in 2023 it had shrunk to 1,701.17 ha. Primary dryland forest experienced a decrease in area of 522.20 ha. Primary dryland forests were converted into secondary dryland forests (583.12 ha), plantations (10.65 ha), shrubs (0.84 ha), and open areas (1.69 ha). However, during the same period, there was also an increase in the area covered by primary dryland forests due to changes in secondary dryland forests and open areas. These changes were caused by community activities in an effort to meet their daily needs. Various activities carried out by the community to meet their daily needs include clearing agricultural land and utilizing forest products, both timber and non-timber, by cutting down trees in forest areas.

Over a ten-year period, the area covered by secondary dryland forest increased. In 2013, secondary dryland forest covered an area of 7,129.81 ha, and in 2023, it covered an area of 7,479.06 ha. During this period, secondary dryland forest increased in area by 349.24 ha. The increase in the area of secondary dryland forest was due to changes in the classification of other types of forest cover, such as shrubs/scrub (108.28 ha), primary dryland forest (583.12 ha), open land (34.61 ha), and plantations (212.68 ha). Despite the increase in area, primary dryland forest cover also experienced the largest change, becoming plantations covering an area of 212.68 ha. This change was caused by an increase in population supported by the gardening skills of the community living around the protected forest area of Tanantovea subdistrict, which resulted in land conversion for gardening.

Plantation cover, which in 2013 had an area of 328.36 ha according to the classification results, has increased to 463.62 ha. The increase in plantation area was due to population pressure, low income, and a lack of skills other than farming, which were the main factors in the change in land cover. One example found in the field was the existence of community gardens in a fairly large area.

The classification of scrubland cover in 2013 covered an area of 216.80 ha, and in 2023 it covered an area of 237.26 ha. The classification of scrubland increased in area by 20.46 ha. The classification of scrubland cover changed to primary dryland forest (2.86 ha), secondary dryland forest (108.28 ha), and open areas (14.53 ha). The area of open land cover also increased. In 2013, it covered an area of 75.15 ha, and in 2023 it covered an area of 92.39 ha. The open land classification occurred due to changes from secondary dryland forest (26.91 ha), primary dryland forest (123.02 ha), and shrubs/scrub (263.88 ha).

Increased community activity has led to unavoidable land clearing and changes in land use. Increased clearing of land for settlements and plantations is caused by population density. Rhamdhani *et al*., 2020) states that based on several studies, changes in land cover that cause deforestation are increasing due to population growth. Another factor contributing to increased land conversion is the distance between protected forests and settlements (Dwiyanda *et al*., 2022). Furthermore, socioeconomic factors within communities that are closely related to human needs, especially for people living near forests (Sabar *et al*., 2024), have led to an increasing demand for land.

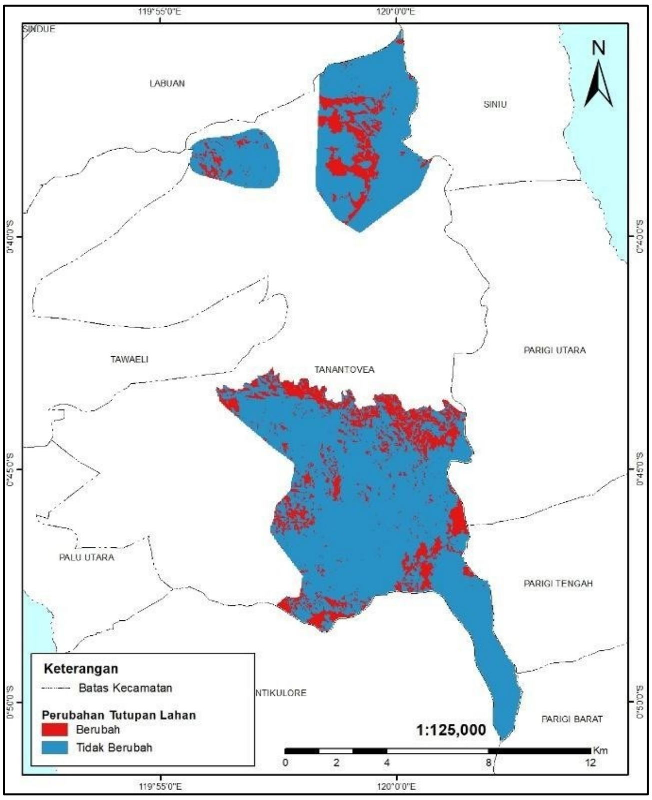

Figure 4. Map of Land Cover Change 2013-2023

Accuracy Testing

Land cover is one of the vital elements in the vegetation structure of a forest area. An increase in land cover can provide an overview of the flora and fauna in a forest area. Measuring the accuracy of land use is a method of assessing the accuracy of the classification results obtained through remote sensing.

Table 5. Results of Confusion Matrix Accuracy Test

Land Cover Class	Pdf	Sdf	P	S	Ol	Total Column	Prosedur Accuracy	User Accuracy	Overall Accuracy
Pdf	8	1	0	1	0	10	80	80	82
Sdf	2	8	0	0	0	10	89	80	
P	0	0	8	1	1	10	75	80	
S	0	0	1	9	0	10	75	90	
Total Rows	10	9	10	12	9	50			

Description:
Pdf : Primary Dry Forest;
Sdf : Secondary Dry Forest;
P : Plantation;
S : Scrub;
Ol : Open Land.

Referring to the standards of (Akhbar *et al.*, 2022). and calculations from the confusion matrix, the accuracy rate of land cover shows satisfactory results. The results of the land cover area calculations in the Tanantovea Donggala Subdistrict Protected Forest show an overall accuracy rate of 82%, which indicates that the interpretation of the map based on the accuracy calculation results is very good, because the land cover classification is almost in accordance with the actual conditions in the field. If the accuracy limit of the interpretation results is less than 80%, then it cannot be used as a reference for assessing the percentage of land cover suitability.

CONCLUSION

This study demonstrates that significant land cover changes occurred in the Protected Forest area of Tanantovea Subdistrict, Donggala, between 2013 and 2023. In 2013, the area was predominantly covered by secondary dryland forest 7,129.81 ha (71.49%) and primary dryland forest 2,223.37 ha (22.29%). Over the ten-year period, primary dryland forest declined by 522.20 ha, while secondary dryland forest increased by 349.24 ha. Plantation areas also expanded from 328.36 ha to 463.62 ha, accompanied by slight increases in shrub and open land areas.

The reduction in primary forest and expansion of plantation and transitional land cover classes indicate ongoing land conversion processes within the protected forest landscape. These changes are closely associated with socioeconomic pressures, including population growth, limited land ownership, agricultural dependence, and the utilization of forest resources by surrounding communities. The transformation of primary forest into secondary forest and plantations reflects both degradation and vegetation succession dynamics.

The overall classification accuracy of 82% confirms that the supervised classification of Landsat 8 imagery provides reliable results for assessing land cover dynamics. This study highlights the effectiveness of remote sensing and GIS in monitoring spatio-temporal land cover change and provides essential baseline information to support evidence-based forest management and conservation strategies in the Protected Forest area of Tanantovea Subdistrict.

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