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Analysis of Land Cover Change Across Land-Use Types in the Palolo Valley

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ABSTRACT

The progress of a region has several components, namely growth centers and the formation of a region. These components influence changes in the structure and diversity of a region or area, one of which is changes in land cover. Land cover itself is an object appearance on the earth's surface that shows that land cover reflects the relationship between natural processes and social processes. Land cover is also important information for the purposes of modeling and understanding natural phenomena that occur on the earth's surface through remote sensing techniques. Palolo Valley, Sigi Regency, experiences quite high land use pressure, so information on land cover changes is needed as a basis for sustainable regional management. The purpose of this study is to determine the extent and distribution of land cover changes in several types of land use and to determine what factors influence land cover changes in several types of land use in the Palolo Valley in 2016 to 2026. The study uses an integration method between making land cover maps in the Palolo Valley by utilizing Sentinel-2 images in 2016 and 2026 which are processed using Geographic Information Systems (GIS) using the ArcGIS 8.0 application. Data analysis in this study is by conducting a supervised classification method then taking the last sample point to test the accuracy of the land cover map using an error matrix. The results of this study indicate that the most significant changes in land cover in the 2016 to 2026 period in the Palolo Valley occurred in the plantation land cover category with a percentage of land cover change of 10.0%. Furthermore, shrub land cover experienced a change in area with a percentage change of 6.04%, the third land cover that experienced a change was rice fields with a percentage change of 3.52%, and finally forest land cover experienced a change of 0.44%, there were two land cover classes that did not experience a change in land cover, namely open land and settlements. Factors that influence land cover changes towards various types of land use in the Palolo Valley include biophysical factors and natural disasters, socio-demographic factors namely population growth and migration, accessibility and infrastructure factors in the form of road construction and residential construction, and the last factor is the economy and superior commodities, namely the expansion of cocoa and coffee plantations. The results of the accuracy test showed an overall accuracy of 90.3% in 2016 and 86.1% in 2026, so the classification results are considered reliable for land cover change analysis. The findings of this study can be a basis for formulating sustainable land management and conservation policies in the Palolo Valley.

Keywords: land cover change; Sentinel-2; Geographic Information System (GIS); Palolo Valley.

1. INTRODUCTION

The development of a region has several components, namely the growth center and the formation of a region. These components influence changes in the structure and diversity of a region or area, one of which is changes in land cover. Land cover itself is an object appearance on the earth's surface that shows that land cover reflects the relationship between natural processes and social processes. Land cover is also important information for the purposes of modeling and to understand natural phenomena that occur on the earth's surface through remote sensing techniques.

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Remote sensing itself is a science to obtain accurate information about land cover monitoring (Hansen et al., 2000; Thenkabail et al., 2009). In this study, land cover changes are permanent or temporary and are a condition of the emergence of growth and activity changes in the social and economic structure of a developing community in the Palolo Valley.

In Indonesia and the broader tropical Southeast Asia region, land cover change is driven by a complex interaction between biophysical and anthropogenic factors: Deforestation: The conversion of forests to agricultural land and plantations (especially oil palm and cocoa) is a major driving factor, resulting in changes in the hydrological cycle (Lestariningsih et al., 2018; Budi et al., 2019; Li et al., 2021). Agricultural Intensification: The expansion and intensification of agriculture, often leading to land cover change, erosion, and soil compaction (Widianto et al., 2023).

In recent decades, the Palolo Valley has experienced significant demographic and economic pressures. A large influx of migrants has led to shifts in land ownership, increased land loss among local residents, and increasingly uncontrolled land use intensification (Dechert et al., 2004; Acciaioli, 2021). Cocoa cultivation, the backbone of the local economy, has driven massive plantation expansion, which in turn has triggered deforestation, forest fragmentation, and extensive habitat conversion, with serious implications for the region's ecosystem services.

This intensive land-use pressure has resulted in significant and measurable land cover changes. Hansen et al. (2013) noted that Sulawesi experienced significant forest cover loss during the 2000–2012 period, with the most extensive deforestation occurring in fertile valleys cleared for agricultural and plantation expansion. Consequently, the Palolo Valley faces a series of interconnected land cover changes, including increased soil erosion, decreased organic matter content, silting of the Palolo River due to high sedimentation, and increased frequency and intensity of downstream flooding during the rainy season (Taufik et al., 2017). This situation was further exacerbated by the earthquake, liquefaction, and flash floods that struck Sigi Regency in 2018, which directly weakened the resilience of land ecosystems and accelerated the already ongoing degradation process (BNPB, 2019).

Facing this escalating risk, systematic and scientifically based land management efforts are urgently needed. Assessing the level of land criticality through an integrated analysis of key determinants, both natural biophysical attributes and anthropogenic factors such as land use and management practices, is a fundamental step that must be prioritized as a basis for formulating sustainable and adaptive landscape management strategies (Dale et al., 2005; Deteix et al., 2023). Based on these conditions and scientific gaps, research on land cover change across several land

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use types in the Palolo Valley is crucial and urgent. Land cover change is identified through the development of a simple spatial model representing the real-world system supported by remote sensing and Geographic Information Systems (GIS) (Gabriele et al., 2023). Accurate and precise data presentation is crucial for delivering reliable information. Therefore, this study aims to assess the extent of land cover change across several land use types in the Palolo Valley.

2. RESEARCH METHODS

Place and Time

This research was conducted in Palolo District, Sigi Regency, Central Sulawesi Province, located at coordinates approximately 1°08′25″ N and 120°03′30″ E. With an area of 626.09 km², this area borders Lore Lindu National Park (TNLL) and has an altitude of between 700 and 1,700 meters above sea level. Palolo has developed as a transmigration area, with coffee, cocoa, and onions as its main commodities. This research is planned to be conducted from May to June 2026.

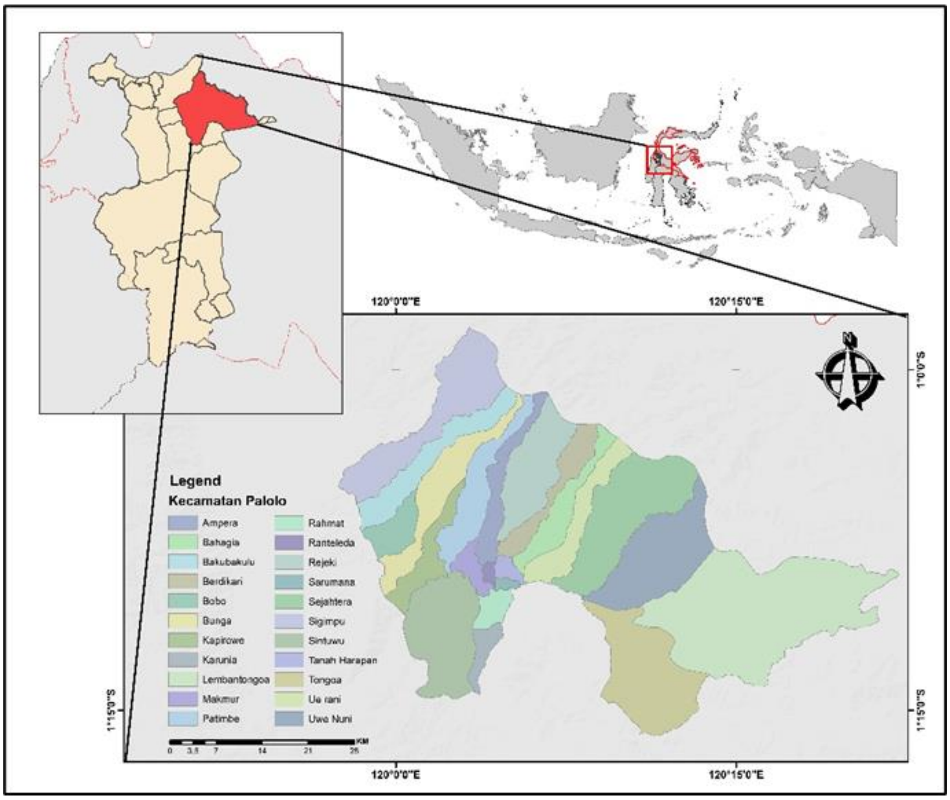

Figure 1. Land Use Map of Palolo Valley, Sigi Regency, 2026

Tools and Materials

The equipment used in this research included a digital camera to record and document research activities, a Global Positioning System to obtain field point coordinates, a computer for

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data processing, and writing instruments to record information or important matters supporting the research.

The materials used included an Administrative Map of Sigi Regency and Sentinel-2 imagery from 2016 and 2026.

Research Method

Preparation Stage

This stage includes reviewing literature and collecting image data about the research location from the USGS website. The literature study itself is conducted to obtain and acquire supporting information sources for or during the implementation of the research.

Data Types and Sources

The types of data to be collected in this study include:

1. Primary data, which is data obtained directly in the field, results of survey activities, such as taking coordinates using the Global Positioning System, and data from satellite imagery, namely Sentinel-2 imagery from 2016 and 2026, obtained from the USGS website.
2. Secondary data, needed to complement the primary data, in this study includes administrative maps of Sigi Regency and rainfall data taken from the CHIRPS website for 2025.

Research Implementation Stage

This study analyzed land cover in the Palolo Valley area. Subsequently, a classification of land cover types within the area was conducted through several stages: image processing, field data collection, data analysis, and confusion matrix accuracy testing.

Image Processing

Compositing Sentinel-2 Images

Image composite is a combination of three channels (bands) to highlight the strengths of each channel comprehensively in a single display, making it easier for users to visually interpret the image. Based on the analysis to be conducted, the band used is band 432, or natural color.

Image Cropping

Image cropping is performed to obtain the focus area of the research. The image is separated using a map of Sigi Regency.

Field data collection

Field inspections were conducted to collect data, including data on actual land cover conditions in the field, and to identify key coordinate points to verify the accuracy of image classification results. These coordinates can then be used as sample areas for digital image classification. The

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sample coordinate points were collected using a Global Positioning System (GPS) device. A total of 12 observation points were selected through purposive sampling for each land cover type.

Data analysis

Supervised Clasification

The analytical method applied in this study is supervised classification analysis. This method essentially considers various aspects, such as the likelihood of a pixel being classified into a particular class or category. This analysis encompasses multiple dimensions, thus categorizing land cover types applied to various land use types in the Palolo Valley with similar pixel values in the classified images (Purwadhi, 2001).

Guided classification is based on the input of object samples (in the form of spectral values) by the operator. To perform supervised classification, a false-color composite of the combined image was created, consisting of bands 4, 3, and 2. Bands 4, 3, and 2 were chosen because these bands are sensitive and have high reflectance values for vegetation (Opa, 2010).

Sample Point

The sample area determination was carried out to identify areas representing each desired land cover type and to compile a numerical description of the spectrum of each type of land cover. Sampling and determination were carried out based on data from field inspections, followed by the determination and selection of training area locations for the collection of statistical data on various types of land cover. Statistical data collection was carried out by taking pixel samples from each land cover class and determining their positions on the composite image. Statistical data from each land cover class were used to implement the accuracy function.

Map Accuracy Test

Accuracy test evaluation serves to measure the level of error that occurs in the classification of sample areas, so that the percentage of mapping accuracy can be determined. This evaluation measures the extent of accuracy in the supervised classification. According to Sutanto (1986), the accuracy results criteria for ranking are as follows: >80% is in the Very Good category and 60%-70% is in the Good category. Therefore, the level of mapping accuracy is evaluated in this study by compiling a contingency matrix or error matrix as shown in Table 1.

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Tabel 1. Confusion Matrix

Data	Dikelompokan ke dalam kategori (data kelas pada peta)				Jumlah Baris	Producer's accuracy
	A	B	C	D	X_{i+}	X_{ii}/X_{i+}
A	X_{ii}					
B						
C						
D				X_{ii}		
Jumlah Kolom	X_{+i}				N	
User's accuracy	X_{ii}/X_{+i}					

Accuracy that can be calculated from the table above includes User Accuracy, Producer Accuracy, and Overall Accuracy. In a mathematical context, these accuracy levels can be expressed as follows:

$$user's\ accuracy = \frac{X_{ii}}{X_{+i}} x\ 100\%$$

$$Producer's\ accuracy = \frac{X_{ii}}{X_{i+}} x\ 100\%$$

$$Overall\ accuracy = \sum_{i}^{r} X_{ii}\ x\ 100\%$$

Description:

Xii = diagonal value of the contingency matrix in row i and column i

Xi+ = number of pixels in row i

X+i = number of pixels in column i

Accuracy level assessment is carried out by comparing data obtained from field inspections with the obtained classification.

3. RESULT AND DISCUSSION

Land Cover Area in Palolo Valley in 2016

After classification was carried out on the 2016 Sentinel-2 image in the Palolo Valley, 6 land cover classes were obtained, the following land cover classifications and their areas can be seen in Table 2.

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Table 2. Land cover area in Palolo Valley in 2016.

No	Land Cover in 2016	Area (Ha)	Persentase %
1	Forest	3646,86	93,19
2	Open Land	3,31	0,08
3	Settlements	1,21	0,03
4	Plantations	24,17	0,62
5	Rice Fields	25,62	0,65
6	Shrubland	212,16	5,42
Total		3913,33	100

The table above shows that the results of the analysis of the sentinel-2 image in 2016 show that the classification of land cover in the form of forests has an area of 3646.86 ha or (93.19%), open land has an area of 3.31 ha or (0.08%), settlements have an area of 1.21 ha (0.03%), plantations have an area of 24.17 ha or (0.62%), rice fields have an area of 25.62 ha (0.65%), shrubs have an area of 212.16 ha (5.42%). In the table, the largest land cover area is Forest, while the lowest land cover area is Residential land can be seen or observed on the land cover map in the Palolo Valley, Sigi Regency, Central Sulawesi in 2016 below.

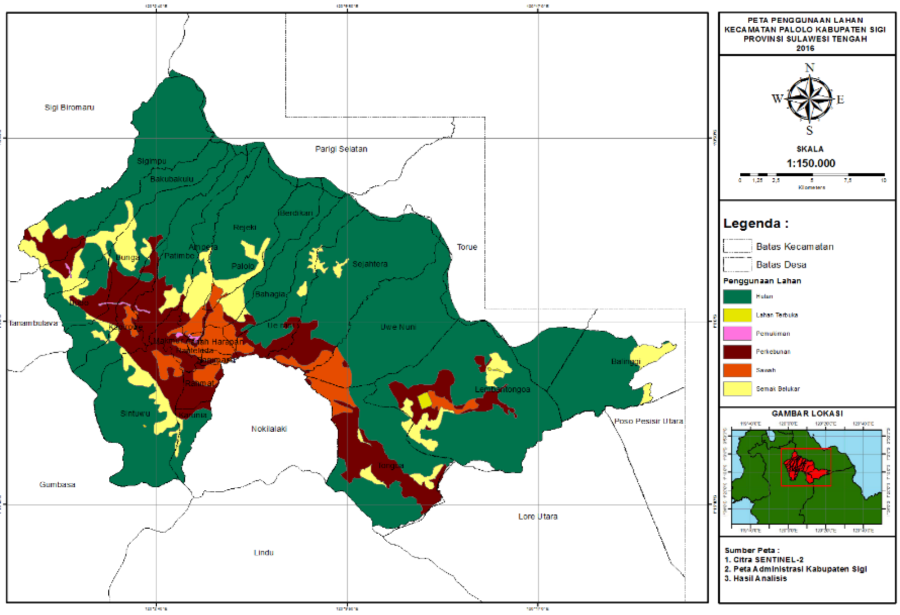

Figure 2. Land Cover Map in Palolo Valley in 2016

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Land Cover Area in Palolo Valley in 2026

After land cover classification was carried out on the 2026 Sentinel-2 image in the Palolo Valley, 6 (six) land cover classes were obtained, the following land cover classifications and their areas can be seen in Table 3.

Table 3. Land cover area in Palolo Valley in 2026.

No	Land Cover in 2026	Area (Ha)	Persentase %
1	Forest	3646,42	93,18
2	Open Land	3,31	0,08
3	Settlements	1,21	0,03
4	Plantations	34,17	0,87
5	Rice Fields	22,1	0,56
6	Shrubland	206,12	5,27
Total		3913,33	100

The table above shows that the classification results on the Sentinel-2 image in 2026 show that the land cover classification, namely forests, has an area of 3646.42 ha or (93.18%) and is the largest land cover, can be seen on the classification results map, open land has an area of 3.31 ha or (0.08%), settlements have an area of 1.21 ha or (0.03%) and is the lowest land cover, plantations have an area of 34.17 ha or (0.87%), rice fields have an area of 22.1 ha or (0.56%), and shrubs have an area of 206.12 ha or (5.27%).

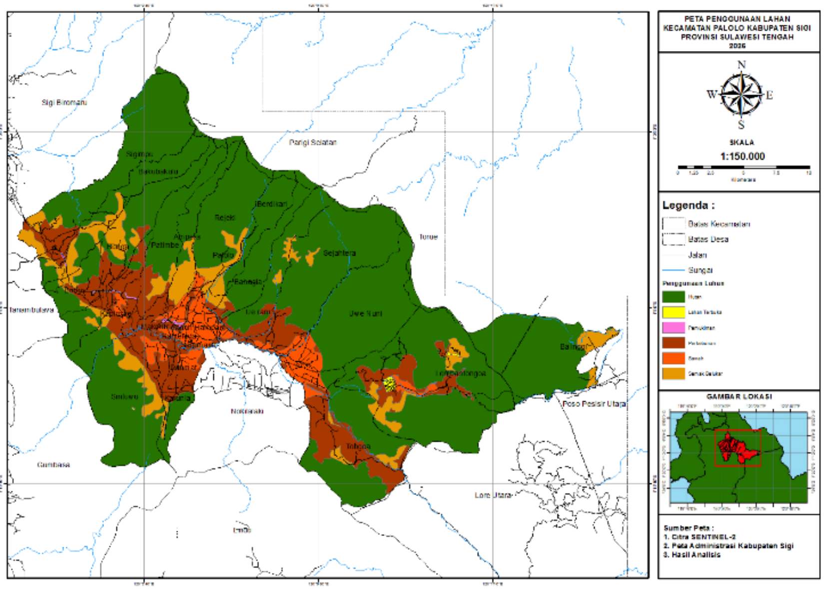

Figure 3. Land Cover Map in Palolo Valley in 2026

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Land Cover Change in Palolo Valley

Land cover changes in the Palolo Valley were analyzed to determine the extent of land cover changes in the area. To identify land cover changes, the classified 2016 Sentinel-2 imagery was overlaid with the 2026 Sentinel-2 imagery. The overlay yielded land cover changes and their extent, as presented in Table 4.

Table 4. Clasification results and extent of land cover changes in the Palolo Valley from 2016 to 2026

No	Tuplah Clasification	Tuplah Area 2016 (Ha)	Tuplah Area 2026 (Ha)	Percentage of Area Chenge in Tuplah from 2016 to 2026 (%)	Note/ Change
1	Forest	3646,86	3646,42	0,44	Plantation
2	Open Land	3,31	3,31	0	Do not change
3	Settlement	1,21	1,21	0	Do not change
4	Plantation	24,17	34,17	10,0	Plantation
5	Rice Field	25,62	22,1	3,52	Ricefield
6	Shrubland	212,16	206,12	6,04	Ricefield
Total		3913,33	3913,33	20,00	

`Source : Analysis Results, 2026

Based on the results of the table above, it shows that the land cover in the Palolo Valley has changed, with the largest area in 2016 being in the forest class, namely 3646.86 ha and in 2026 the forest area became 3646.42 ha, the area changed with a percentage of 0.44% change, then followed by shrubs in 2016 with an area reaching 212.16 ha in 2026 to 206.12 there was an increase in area with a percentage of 6.04%, then the rice field cover with an area of 25.62 ha in 2016 in 2026 the area changed to 22.1 ha with a percentage change of 3.52 ha, the next land cover is plantations with an area of 24.17 ha in 2016 in 2026 the area increased or changed to 34.17 ha with a percentage of (10.0%), and what did not experience any change was open land and settlements from the total area of the Palolo Valley area.

Factors Causing Land Cover Changes in Several Land Use Types in the Palolo Valley

Land cover change is a dynamic issue influenced by the interaction of various social, economic, and physical factors in an environment or region. Based on this information, the following are the main factors that influence land cover change in various types of land use (such as from forest to mixed gardens, agroforestry areas, or conversion to agricultural land and plantations).

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Changes in land use occur due to various factors, including:

1. Biophysical Factors and Natural Disasters

The physical characteristics of the Palolo Valley area also limit or influence the types of land use available, such as topography and slope. Most of the Palolo area has a fairly steep slope. Land on steep slopes often becomes mixed-use plantations due to the limited availability of flat land for agriculture. Topography is a limiting factor for regional development because its characteristics are difficult to change. However, humans have made various efforts to alter the topography, such as digging the ground or building embankments to address the issue of topographic elevation.

2. Socio-Demographic Factors (Population Growth and Migration).

Population growth results in an increased need for residential land to meet housing needs, which ultimately drives demand for suitable areas for settlements or for supporting facilities and infrastructure. The Palolo Valley has historically been known as a highly dense transmigration and spontaneous migration destination in Central Sulawesi. Population pressure, resulting from increasing population, increases the demand for living space and food crops. This pressure, coupled with the conversion of forest land, drives the conversion of forest areas into open agricultural land or mixed-use plantations to meet these needs.

3. Accessibility and Infrastructure (Roads and Settlements)

Road construction and the proximity of land to settlement centers facilitate land cover changes. The distance to main roads is one factor; the closer a forest area is to the Palu-Palolo highway network, the greater the likelihood that the land will be accessed, encroached upon, and converted into built-up or plantation land. Furthermore, settlement expansion, as villages in the Palolo Valley develop, and the need for public facilities and housing drives the shift of land from agricultural to built-up areas. Land accessibility will influence its economic value. Land with efficient transportation access will have a higher economic value because it can reduce travel costs and time.

4. Economic Factors and Leading Commodities (Cocoa and Coffee Expansion)

Economic factors are also often the strongest driving force for local land cover changes. The surge in cocoa crops, or the cocoa boom, from the 1990s to the present has significantly increased the economic appeal of cocoa cultivation in the Palolo Valley region. Many farmers are converting forest or scrubland areas into cocoa agroforestry systems or mixed monoculture gardens. Furthermore, the need for household income is a supporting factor, as local communities' economic dependence on agricultural products forces them to expand mixed dryland farming areas

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toward hillside slopes. Land prices are also important, as land is a tradable commodity, so its use is determined by supply and demand. The high cost of land logically supports its utilization to achieve optimal productivity, providing the best and highest utilization.

Discussion

Land cover change results for various land use types show a wide variation in the values of change in the Palolo Valley, likely caused by variations in the characteristics of each soil area within the Palolo Valley. One factor contributing to regional characteristics is weather, which in this context is related to water flow from precipitation. Rainfall itself is one of the natural elements that causes changes in land cover. This occurs due to the impact of rain and soil erosion (Notohadiprawira, 1998). The amount of rainfall per unit area in the Palolo Valley reaches 6051.53 mm^2.

In addition to natural factors, the influence of land cover changes on several types of land use in the Palolo Valley plays a significant role. Forest land use in the Palolo Valley is quite extensive, covering almost half the area of the Palolo Valley. Forest areas continue to expand (be utilized) by the community, resulting in potential changes in land cover, in this case conversion to agricultural land and plantations. Therefore, this area requires protection efforts. Furthermore, changes in land use, such as settlements and open areas, require recommended soil conservation efforts for this area, namely through planting perennials, planting multi-functional trees, and mixed gardens. Hardwood enrichment is an effort to increase the variety of vegetation in open areas, consisting of permanent plants with strong root systems. This step aims to regulate surface runoff and strengthen roots to prevent land use changes. Multifunctional tree planting is the activity of planting hardwood or annual trees with high economic value. These multifunctional trees consist of various types such as durian, mango, mangosteen, and others. These plants can also provide economic benefits to the community because they have high value.

The scrubland in the Palolo Valley is considered moderately distributed compared to forests, open areas, and residential areas. Scrubland is characterized by areas surrounded by weeds and other shrubs, as well as a few randomly growing trees. The characteristics of scrubland indicate that this type of land cover does not offer significant utility compared to other areas such as fields and secondary forests. Therefore, conservation measures are needed to enhance the benefits of this land cover.

However, land use for agriculture and rice paddies shows a more pronounced distribution compared to forests, open areas, and residential areas. Gardens and rice paddies, as secondary forest land cover in areas with very high land cover change, essentially receive land treatment more

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or less equivalent to those in the moderate and high land cover change categories. The only difference is the slope of the area, which is quite steep. One example is planting that follows the contour. This is done considering the topography in this location, which varies in slope, from gentle to very steep, ranging from 8-15% to over 45%. The steep slope gradient and land use for plantations and agriculture are the main factors causing frequent changes in land cover in the area, so it is necessary to take preventive measures by planting along the contour.

Map Classification Accuracy Test

The accuracy test of land cover classification results on Sentinel 2 imagery from Palolo District in 2016 demonstrated a user accuracy of 100% for three land cover classes: forest, open land, and rice fields. The residential land cover class achieved a score of 92%, and two land cover classes each received scores of 75%: plantations and shrubs. The producer's accuracy of 100% was achieved for three land cover classes: forest, residential, and rice fields. The open land land cover class achieved a score of 92%, and two land cover classes each received scores of 75%: plantations and shrubs.

The overall accuracy was 90.3%. This indicates that the pixels in the sample area were classified very well, with an accuracy level of 90.3%.

The accuracy test for land cover classification results on Sentinel 2 imagery of Palolo District in 2026 demonstrated a user accuracy of 100% for three land cover classes: open land, residential areas, and rice paddies. Forest and plantation land cover scored 83%, and shrubland land cover scored 50%. Producer accuracy of 100% was achieved for three land cover classes: open land, residential areas, and shrubland. Forest and plantation land cover scored 83%, and rice paddy land cover scored 67%.The overall accuracy was 86.1%. This indicates that the pixels in the sample area were classified very well, with an accuracy level of 86.1%.

4. CONCLUSION

The research results show that land cover change in the Palolo Valley during the 2016–2026 period was dominated by an increase in plantation area, followed by changes in shrubland, rice fields, and forests, while open land and settlements remained relatively unchanged. This finding indicates a shift in land use toward cultivation activities, particularly plantations. This land cover change is influenced by the interaction of various factors, including biophysical factors (topography, rainfall, and natural disasters), socio-demographic factors (population growth and migration), accessibility and infrastructure factors (road and settlement development), and

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economic factors, particularly the expansion of cocoa and coffee plantations, which are the primary drivers of land conversion.

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