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Analysis of Land Cover Changes in the Forest Area of Lindu Sub District Using Sentinel 2A Images

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ABSTRACT

Land cover change in forest areas are complex phenomena that have ecological, social, and economic impacts. Remote sensing is very useful for monitoring and mapping land cover changes because it can provide information about the earth's surface quickly, accurately, easily, and covers a wide area. Sentinel-2A imagery is a satellite remote sensing data with a high spatial resolution and has been widely used for land cover mapping. The study intends to analyze land cover changes in the forest area of Lindu District using Sentinel-2A imagery. The study was conducted in the forest region of Lindu Sub District, Central Sulawesi Province. The study found that the accuracy level of the classification output was 97.47% (Overall Accuracy) and 88.20% (Kappa Accuracy). The types of land cover produced consisted of forests, dryland agriculture, shrubs, grasslands, rice fields, swamp shrubs, and water bodies. Land cover that experienced changes were forests (decreased by 883.13 Ha), grasslands (decreased by 7.56 Ha), dryland agriculture (increased by 819.2 Ha), paddy field (decreased by 1.2 Ha), open land (increased by 36.31 Ha), and shrubs (increased by 28.23 Ha, swamp shrubs (increased by 9.51 Ha), water bodies (decreased by 1.36 Ha).

Keywords: *Land Cover Change, Object Based Classification, Forest Area, Lindu Sub District*

INTRODUCTION

Land cover includes biophysical attributes that cover the earth's surface. Land cover includes soil, water, rocks, road vegetation, buildings, and other construction elements that support human activities (LaGro, 2005). Land cover change is a fundamental process on the earth's surface and has a significant influence on humans, climate, biodiversity, hydrological cycles, ecosystems, biogeochemical cycles, and many other processes (Barati et al., 2023; Lin et al., 2018; Rahmawaty et al., 2022; Sunandar, 2016). Furthermore, Frimpong et al., (2023) explained that cover change is the transformation of the biophysical state of the earth's surface triggered by the interaction of anthropogenic activities and the natural environment that has an impact on the accumulated local environment into global climate change.

Law 41 of 1999 defines forest areas as specific areas designated by the government to be maintained as permanent forests. Land cover change in forest areas is a complex phenomenon and has an impact on ecology, social and economy. Forest land conversion can increase greenhouse gas emissions, disrupt the water cycle, dry out soil, and reduce the growth of crop products. This has a direct impact on the well-being of local communities whose livelihoods depend on forests and threaten biodiversity (Hallaj et al., 2024). According to Gamatara & Kusumawardani (2024), deforestation of 1%, it can produce CO2 emissions of 0.026%. Furthermore, changes in forest land cover to non-forest can also cause a decrease in the base flow of 104.99 mm and an increase in surface flow of 35.81 mm, as well as an increase in the maximum monthly discharge of 15.93 m^3/s (Pribadi et al., 2020).

The main drivers of land cover change in forest areas include population growth, changes in policies and institutions, poverty, and lack of awareness of the importance of natural resource conservation for sustainable livelihoods (Hailu et al., 2020). In addition, physical and accessibility factors such as slopes, distance of forests from roads and settlements also have an influence on changes in land cover in forest areas (Acheampong et al., 2019; Kumar et al., 2014).

Forest areas in Indonesia are divided into protected forest areas, conservation forest areas and production forest areas. Conservation areas include Nature Conservation Areas and Nature Reserve Areas. Lindu District is an area where most of the area is a nature conservation area

(Lore Lindu National Park). The forest area is directly adjacent to settlements and agricultural crop cultivation areas, this can trigger changes in land cover in the area.

Accurate and up to date data and information are indispensable in mapping and monitoring land cover changes. The ability of remote sensing to present earth surface information that is fast, accurate, easy, and covers a large area makes the technology a source of data and information in mapping and monitoring land cover. The Sentinel-2A image is a digital image resulting from satellite remote sensing provided by the European Space Agency (ESA), has a wide spatial resolution (10 m x 10 m, 20 m x 20 m, 60 m x 60 m), as well as a wide spectral coverage (13 bands), and is classified as an image with a radiometric resolution of 12 bits (Suhet, 2013). The image has been widely used as a source of data in making land cover maps and producing maps with a good and excellent level of accuracy (Awaliyan & Sulistyoadi, 2018; Putri et al., 2018). The purpose of the study was to analyze land cover changes in the forest area of Lindu sub-district using 2A sentinel imagery.

METHOD

The location of the research was carried out in Lindu District, Sigi Regency, Centeral Sulawesi Province. The map of the research location can be seen in figure 1.

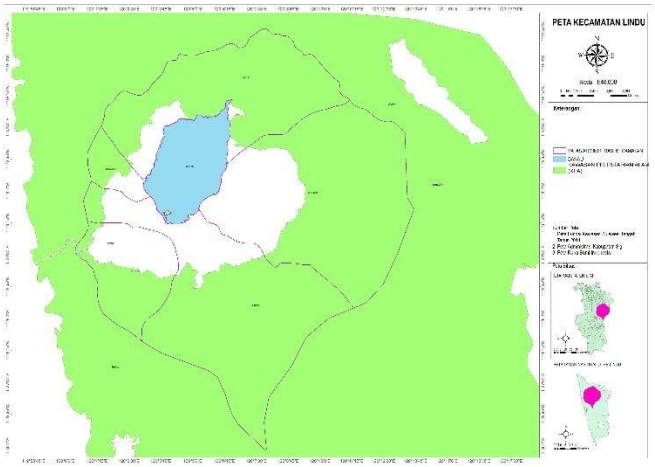

Figure 1. Map of Lindu District

Tools and Materials

The tools used in this study consist of Computers and software (ArcGis 10.7, Microsoft Excel, Microsoft Word), GPS Receivers (*Global Positioning System*), cameras, and writing stationery. Furthermore, the materials used are 2A sentinel images recorded in 2016 and 2024, Forest Area Function Maps, and District Administration Maps. Sentinel 2A image downloaded at https://dataspace.copernicus.eu/, Forest Area Function Map (SK.6624/MENLHK-PKTL/KUH/PLA.2/10/2021) comes from BPKH region XVI Palu, Regency Administration Map sourced from the Geospatial Information Agency.

Stages of research

The research stages include a) Composite Band to improve visual imagery. The composite used is 432 (*Natural colour*). (b) Sharpening to obtain images with higher contrast, c) Image cutting to obtain an image of the study area is carried out using the map of the lindu sub-district and the functional map of the forest area. (d) Image classification, the classification method used is *Object-Based Classification* which begins with the segmentation stage and then classification. The segmentation process is carried out using *the Multiresolution Segmentation* algorithm. The results of segmentation that have formed segments in the image are then classified using the *Nearest Neighbour method*. **e**) Location survey. **f)** Accuracy Test,

testing the accuracy of classification results is carried out using an error matrix table (*Confusion Matrix*). The accuracy values assessed include producer *accuracy*, *user accuracy*, *overall accuracy and kappa* accuracy

Table 1. Confusion *Matrix*

Reference data (Training area)	**Classify reference data into classes (class data in image)**				**Total line Xk+**	**Manufacturer Accuracy Xkk/X k+**
	1.	**2.**	**3.**	**Dst.**		
1.	XII					
2.						
3.						
Dst				Xkk		
Total Column X+k					N	
User Accuracy Xkk						

Source: Danoedoro, 2012

The calculation of the accuracy value is carried out by referring to table 1. The types and formulas for calculating each measured accuracy are as follows:

1. User Accuracy = (Xkk/X+k) x 100%
2. Manufacturer Accuracy = (Xkk/Xk+) x 100%
3. Overall Accuracy = (∑Xkk) / N x 100%
4. Kappa Accuracy = ((N∑Xkk) - (∑Xk+ ∑X+k) / N2 - (∑Xk + ∑Xk+)) x 100%

Where N is the sum of all pixels used for analysis; k1+ = ∑XII is the sum of all columns in row i; k+1 = ∑XII is the sum of all columns in column I (Sutanto., 1994; Lillesand et al., 2008; Tso and Mather, 2009 *in* Danoedoro, 2012). The accuracy results criteria in the rankings are as follows ≥80% (Excellent) and 60-70% (Good). (Akhbar et al., 2017)

RESULTS AND DISCUSSION

Geographically, Lindu sub-district is located at 1013'37"-1030'15" LS and 120000'43"-120017'17" E, with an area of 45,355.64 Ha and consists of 5 villages. About 70.39% (31,924.65 ha) of the area is forest. The forest area is part of the nature conservation area (Lore Lindu National Park). The results of image analysis and field surveys show that the land cover in the forest area of Lindu District includes water bodies, swamp bushes, forests, grasslands, dryland agriculture, shrubs, and open land. In the image analysis stage, the band composites used were band 4 (red), band 3 (green), and band 2 (blue). The combination of band 432 produces natural color imagery (the color of the object in the image corresponds to the color of the object seen by humans). The appearance of the land cover object on the composite image of band 432 and the actual conditions in the field are as follows:

1. Water Body

Water bodies include lakes and rivers. The appearance of the river in the image is light gray with an elongated shape and has an irregular pattern, while the lake has an irregular polygon shape with a blue color.

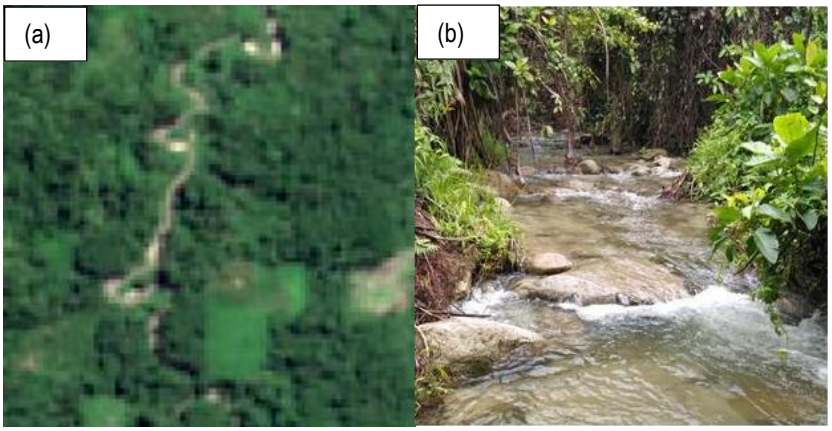

Figure 2. Appearance of Water Bodies in Images (a) and Water Bodies in the Field (b)

2. Swamp Bushes
   In composite image 432, the swamp bush is green, smooth in texture and has an irregular pattern. The results of the field survey showed that the swamp bush was composed of various types of swamp vegetation such as Lembang, Purun Lake, Longkida, Rasau, water hyacinth, Mensiang, Perumpung and several other woody and cascading plants. The appearance of the swamp bush in the image and the results of the field survey can be seen in the following image:

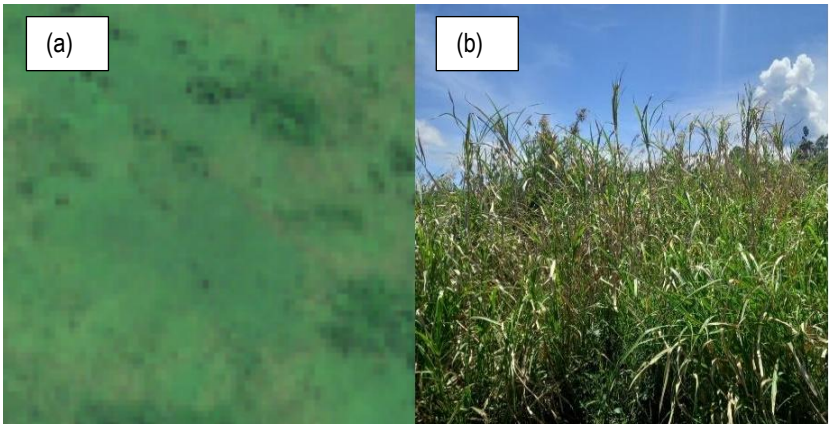

Figure 3. Display of Swamp Bushes in Image (a) and Swamp Bushes in the Field (b)

3. Forest
   The appearance of the forest in the composite image of 432 is dark green, with a rough texture. The forest object in the field is in the form of natural forests with vegetation conditions in the form of trees of various sizes, undergrowth, and liana.

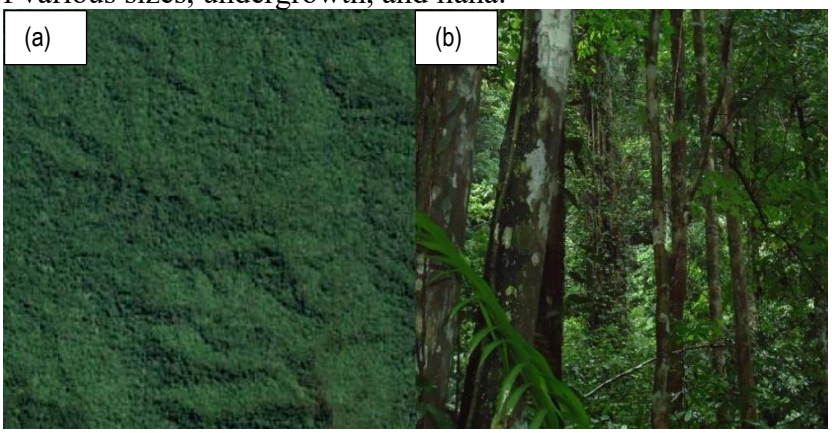

Figure 4. Forest View in Image (a) and Forest in Field (b)

4.

5. Meadow
   Padang is seen bright green in composite image 432, a smooth texture with irregular patterns. The types of grass that grow are Jarun and Bahia grass

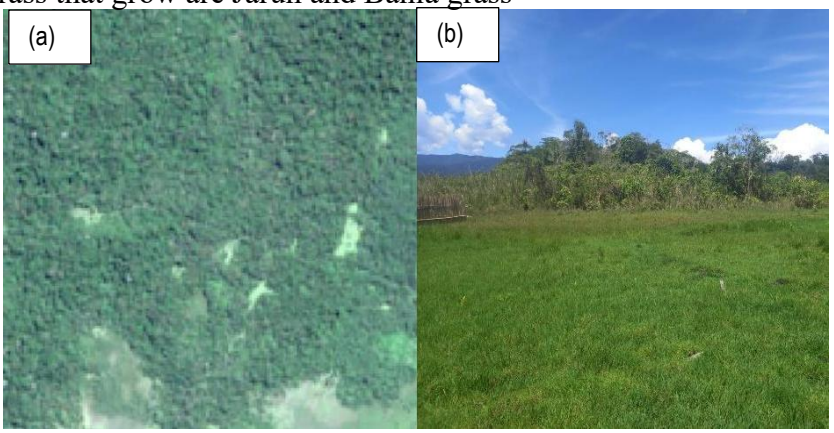

Figure 5. Grassland View in Image (a) and Grassland in Field (b)

6. Dryland Agriculture
   Dryland agriculture in the composite image of 432 appears to be brownish-green in color with a regular pattern. The results of the field survey showed that the crops that populate dryland agriculture were in the form of chocolate, coffee and corn plants.

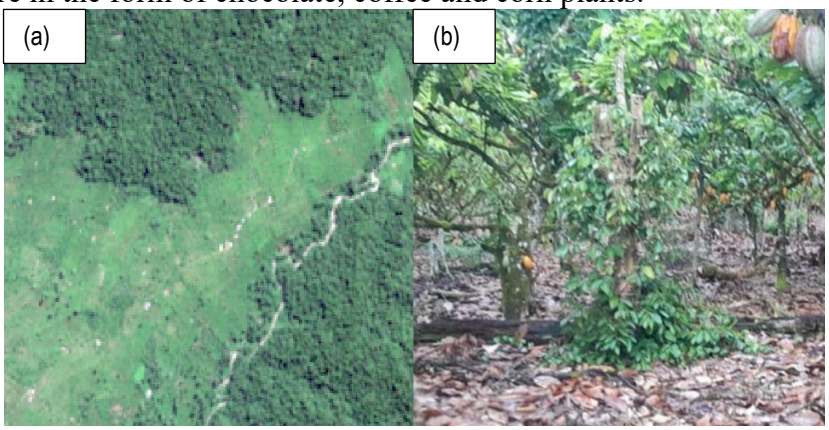

Figure 6. Display of Dryland Agriculture in Image (a) and Dryland Agriculture in the Field (b)

7. Bushes
   The bush in the image is green with an irregular pattern. Based on the results of field surveys, shrubs consist of saplings, shrubs, vines, bamboo saplings, Kasimpo, Kecombrang and others.

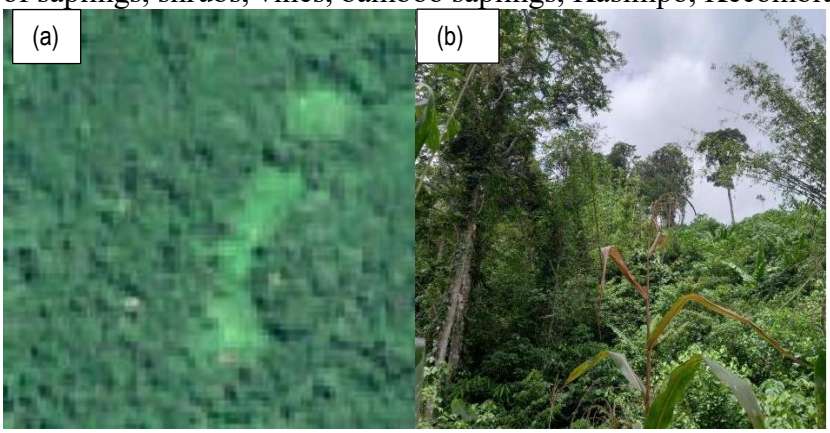

Figure 7. Display of Shrubs in Image (a) and Dry Land Agriculture in the Field (b)

8. Open ground.
   The open ground appears to be light brown in composite image 432. Based on the results of field surveys and observations on high-resolution Google Earth images, it shows that open land consists of former avalanches and new planting land.

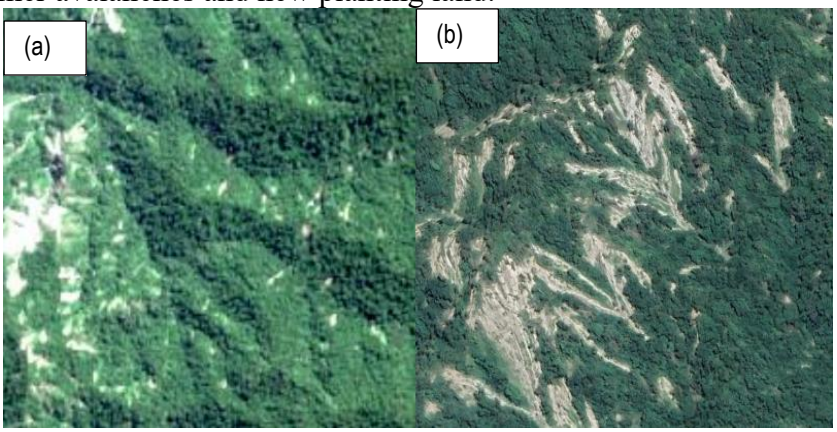

Figure 8. Display of Open Land in Image (a) and Open Land in the Field (b)

Object-based classification includes segmentation and classification. The grouping of objects in the form of segments uses the parameters of scale, shape, and *compactness*. Scale is the determination of the average size of the formed segment, and the shape is the determination of how far the segment can deviate from the most compact shape (square or circle), as well as compactness which is the determination of how compact the segment is formed. Segmentation in this study was carried out using the parameters of Scale 65, shape 0.1 and compactness 0.9. Segmentation in the 2024 image produces 2,103 segments and the 2016 image produces 1,751 segments. These segments are then classified and produce 8 classes in the 2024 image and 6 classes in the 2016 image. The land cover classes classified include Water Bodies, Swamp Bushes, Forests, Grassland Dry Land Agriculture, Rice Fields, Shrubs, and Open Land.

The results of the accuracy test obtained an Overall Accuracy level *of 97.47%, the accuracy of* Producer's and User's ranges from 80-100%, and the Kappa Accuracy (*Kappa*) of 88.20%. This figure indicates that the results of the classification are in the category of very good. The accuracy level calculation was done using 84 sample pixels. Reference data is in the form of field survey results and high-resolution images (Google Earth). A comparison of the classification results on the image and the full reference data is presented in the following error matrix table (*Confusion Matrix*):

Table 2. Confusion *Matrix* in Land Cover Classification in Lindu District Forest Area

Land cover		Reference Data								
		Water Body	Swamp Bushes	Forest	Meadow	Dryland Agriculture	Paddy	Bushes	Open Ground	Sum
Classification Results	Water Body	5	0	0	0	0	0	0	0	5
	Swamp Bushes	0	12	0	0	2	1	0	0	15
	Forest		1	21	0	0	0	0	0	22
	Meadow	0	0	0	3	0	0	0	0	3
	Dryland Agriculture	0	2	0	0	20	0	2	0	24
	Paddy	0	0	0	0	0	4	0	0	4
	Bushes	0	0	0	0	0	0	8	0	8
	Open Ground	0	0	0	0	0	0	0	3	3
Sum		5	15	21	3	22	5	10	3	84

Source: Results of Image Data Analysis and Location Survey, 2024

Furthermore, the accuracy value of the Producer's and User's results of the complete classification can be seen in the following table 3:

Table 3. The accuracy value of producers and users of the cover classification results in the forest area of Lindu sub-district

Yes	Land Cover	Manufacturer	User
1.	Water Body	100,00	100,00
2.	Swamp Bushes	80,00	80,00
3.	Forest	100,00	95,45
4.	Meadow	100,00	100,00
5.	Dryland Agriculture	95,24	83,33
6.	Paddy	80,00	100,00
7.	Bushes	80,00	100,00
8.	Open Ground	100,00	100,00

Source: Results of Image Data Analysis and Location Survey, 2024

Land cover in 2016

The results of the land cover classification in 2016 were obtained in 6 classes. The types of land cover produced include water bodies, swamp bushes, forests, dryland agriculture, and rice fields. The area of each land cover can be seen in the following table 4:

Table 4. Land Cover in 2016

Yes	Land Cover	Area (Ha)	Percentage (%)
1	Water Body	38,06	0,12
2	Swamp Bushes	217,48	0,68
3	Forest	30.210,62	94,63
4	Meadow	23,36	0,07
5	Dryland Agriculture	1.428,87	4,48
6	Paddy	6,26	0,02
Sum		31.924,65	100,00

Source: Results of Image Data Analysis and Location Survey, 2024

Referring to table 4, it can be seen that in 2016, forest areas in Lindu sub-district had a forest cover of 94.63% and 5.37% non-forest. The distribution of land cover in 2016 is presented in Figure 9.

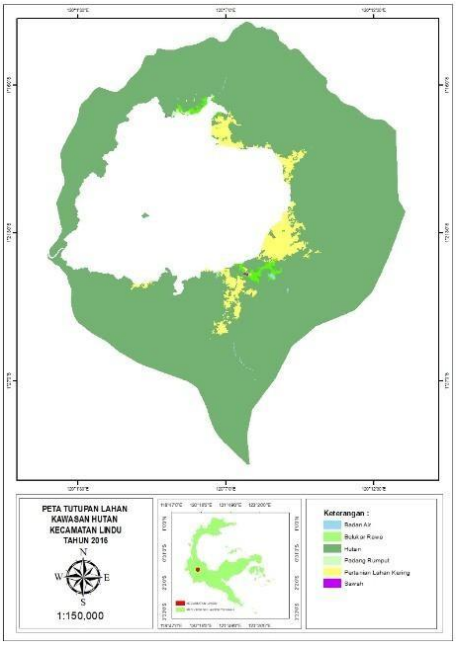

Figure 9. 2016 Land Cover Map

Land Cover in 2024

The land cover classification in the 2024 image produces 8 types of land cover consisting of water bodies, swamp bushes, forests, grasslands, dryland agriculture, rice fields, shrubs, and open land. The area of each land cover class in 2024 can be seen in table 5.

Table 5. Types and Areas of Land Cover in 2024

Yes	Land Cover	Area (Ha)	Percentage (%)
1	Water Body	36,70	0,11
2	Swamp Bushes	226,99	0,71
3	Forest	29.327,49	91,86
4	Meadow	15,80	0,05
5	Dryland Agriculture	2.248,07	7,04
6	Paddy	5,06	0,02
7	Bushes	28,23	0,09
8	Open Ground	36,31	0,11
Sum		31.924,65	100,00

Source: Results of Image Data Analysis and Location Survey, 2024

Table 5 shows that the forest area of Lindu District in 2024 will still be dominated by land cover in the form of forest, which is 91.86% of the total forest area and 8.14% is non-forest land cover. Furthermore, the distribution of land cover in 2024 is shown in the following figure 10:

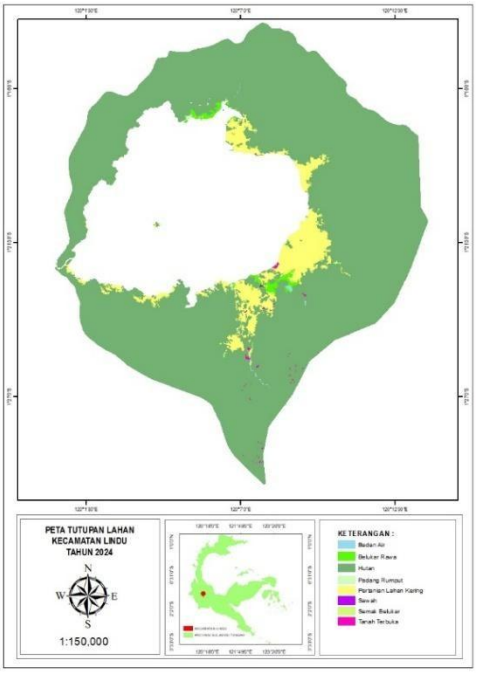

Figure 10. Land Cover Map in 2024

Land cover change

Information on land cover changes in the forest area of Lindu District was analyzed from land cover data in 2024 and 2016. Data analysis was carried out using a change matrix table. Data on land cover change over 7 years in the Lindu District Forest Area is presented in table 6.

Table 6. Land Cover Change Matrix in Lindu District Forest Area

Land Cover		Year 2024								
		Water Body	Swamp Bushes	Forest	Meadow	Dryland Agriculture	Paddy	Bushes	Open Ground	Sum
Year2016	Water Body	36,7	1,36							38,06
	Swamp Bushes		217,12				0,36			217,48
	Forest			29.327,49		831,16		22,54	29,43	30.210,62
	Meadow		8,51		14,85					23,36
	Dryland Agriculture					1.416,30		5,69	6,88	1.428,87
	Paddy				0,95	0,61	4,7			6,26
	Sum	36,7	226,99	29.327,49	15,8	2.248,07	5,06	28,23	36,31	31.924,65

Source: Results of Image Data Analysis and Location Survey, 2024

Table 6 illustrates that land cover in 2016 consists of 6 types, namely water bodies, swamp bushes, forests, grasslands, dryland agriculture, and rice fields. Furthermore, in 2024 there will be 8 types of land cover, namely water bodies, swamp bushes, forests, grasslands, dryland agriculture, rice fields, shrubs, and open land. There are 2 types of new land cover in 2024,

namely shrubs with an area of 28.23 hectares and open land with an area of 36.31 hectares. Open land and shrubs are a change from forest land cover and dryland agriculture. The existence of open land is caused by landslides and clearing for crop replacement on agricultural land. 81.05% of open land occurred due to avalanches and was located in areas with steep and very steep slopes. Based on observations on high-resolution images (Google Earth), the change of forests to open land occurred in 2018. Some of the open land has been overgrown with vegetation and will subsequently become a shrub in 2024. The forest area in 2016 was 30,210.62 Ha or 94.63% of the total forest area, but in 2024 there will be 29,327.49 Ha or 91.86% of the total area, this shows that the forest has experienced a reduction in area by 2.766% (883.13 Ha). The reduction includes the change of forest to shrub covering an area of 22.54 Ha, forest to dryland agriculture covering an area of 831.16 Ha and forest to open land of 29.43 Ha. Forests have only decreased in area and have not increased, as well as water bodies, which have only decreased in area by 0.004% (1.36 ha). The reduction occurred due to the growth of vegetation that makes up the swamp bush which resulted in the closure of the water surface. This change occurs in water bodies in the form of lakes. In addition to forests and water bodies, other types of land cover have decreased and increased area. These types of cover include dryland agriculture, swamp bushes, grasslands, and rice fields. The area of dryland agriculture in 2016 was 1,428.87 Ha or 4.48% of the forest area and in 2024 it will increase by 819.20 Ha or 2.57% so that the area of dryland agriculture in 2024 will be 2,248.07
Ha or 7.04%. The increase in area comes from the change of forests to dryland and rice fields to dryland agriculture covering an area of 0.61 hectares. However, dryland agriculture has also experienced a reduction of 6.88 hectares, namely changes to shrubs. Furthermore, land cover in the form of grasslands has decreased by 7.56 Ha or 0.024%. The area of grassland in 2016 was 23.36 Ha, then in 2024 it amounted to 15.8 Ha. The meadow turned into a swamp bush covering an area of 8.51 Ha. Then the rice field land cover has decreased by 1.20 Ha or 0.004%. 0.95 Ha turned into pasture and 0.61 Ha turned into dryland farming.

CONCLUSION

This study concludes that significant changes in land cover have occurred in the forest area of Lindu District between 2016 and 2024. In 2024, the land cover types include water bodies, swamp bushes, forests, grasslands, dryland agriculture, rice fields, shrubs, and open land, while in 2016, the classifications were limited to water bodies, swamp bushes, forests, grasslands, dryland agriculture, and rice fields. The analysis revealed a substantial decrease in forest area by 883.13 hectares and reductions in water bodies (1.36 ha), grasslands (7.56 ha), and rice fields (1.2 ha). Conversely, there were notable increases in dryland agriculture (819.2 ha), swamp bushes (9.51 ha), shrubs (28.23 ha), and open land (36.31 ha). These findings indicate a shift toward agricultural expansion and land degradation, likely driven by anthropogenic pressures and changing land use demands.

For future research, it is recommended to investigate the socio-economic and environmental drivers behind these land cover changes through a mixed-method approach, combining remote sensing analysis with ground validation and community-based surveys. Further studies should also assess the ecological impacts of deforestation and the effectiveness of conservation policies in protected areas, especially given the proximity of human activities to conservation zones such as Lore Lindu National Park.

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