

Evaluation and Prediction of Land Cover Changes in the Jangkok Watershed Using the Approach Ca-Ann

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Keywords	Abstract
Jangkok watershed, forest area, evaluation, Landsat-8 OLI, land cover change	This study addresses the increasing concern over deforestation and land cover changes in watershed areas, particularly in the Jangkok Watershed, West Nusa Tenggara, Indonesia. Rapid land conversion driven by population growth, agricultural expansion, and accessibility has contributed to forest degradation, potentially disrupting hydrological functions and ecosystem stability. Therefore, this research aims to evaluate land cover changes from 2019 to 2024 and to predict future changes until 2039 using an integrated modeling approach. The study employs remote sensing data derived from Landsat-8 OLI (2019) and Landsat-9 OLI-2 (2022 and 2024), processed through image pre-processing, classification, and accuracy assessment using ground checks, error matrix, and Kappa statistics. Furthermore, land cover change analysis is conducted using transition matrices, while the direction of change is evaluated using Curve Number (CN) and Soil Hydrology Group (KHT). Future predictions are generated using the Cellular Automata–Artificial Neural Network (CA–ANN) model based on driving factors such as distance to roads, rivers, and slope. The results indicate a significant decrease in primary and secondary dryland forests, accompanied by a substantial increase in mixed garden areas. Negative land cover changes dominate, leading to increased surface runoff and reduced infiltration capacity. The CA–ANN model demonstrates good predictive performance (Kappa = 0.78), projecting continued forest decline until 2039. In conclusion, land cover changes in the Jangkok Watershed are predominantly driven by human activities and pose risks to environmental sustainability. Strategic land management and conservation policies are essential to mitigate further degradation and preserve watershed functions.

INTRODUCTION

Forests play an important role in a River Basin Area (DAS), such as regulating the rate of air surface, preventing flooding, reducing flood peaks, purifying air quality, and regulating air runoff (Li et al., 2021). Massive forest utilization can reduce forest quality and cause forest degradation and deforestation. Other causes of forest degradation are unsustainable forest management and harvesting activities. In contrast, the cause of deforestation is the conversion of forests to non-forests, such as residential forests, agriculture, mining, and other use areas (Lindiani, 2024).

Deforestation and forest degradation can have a direct impact on climate change (Jagannathan & Divya, 2021) and be a driver of significant environmental change, increasing global temperatures, changing weather patterns, and reducing the level of biodiversity in an ecosystem (Reygadas et al., 2023). In addition, deforestation and forest degradation can affect

the quality of watersheds. According to Zhao et al., (2022), deforestation and forest degradation can cause changes in the hydrological response of watersheds, such as increasing surface flow (runoff) and sedimentation, erosion, and groundwater recharge.

Deforestation and forest degradation that have caused a decrease in forest area have occurred a lot in Indonesia. Data from the Ministry of Environment and Forestry (KLHK, 2018) shows that the forest area that experienced deforestation in Indonesia in 2017-2018 reached 439,439.1 ha. One of the cases of deforestation and forest degradation in Indonesia was in the Jangkok Watershed area. This statement is supported by the research results by Markum et al., (2012), which showed that the Jangkok Watershed area experienced significant changes from 1995 to 2009. Changes in area were seen in the natural forest area, which experienced a decrease of 1748 ha. The decrease occurred due to the mass logging of mahogany stands in 1999-2000.

Other studies show that the Jangkok Watershed, in the last two decades, has experienced changes in land cover in forest areas (Suhartanto et al., 2012). The rate of change in forest area to mixed gardens from 1995–2010 was 17.32%, with forest destruction per year reaching 1.08%. This is due to logging. In addition, changes are also caused by weak supervision, unclear sanctions, ineffective worker capacity and performance, encroachment for land expansion, illegal logging, minimal data on the area, high community dependence on the area and low community understanding regarding the function of the area (Mukhtar et al., 2010; Syaputra, 2019).

The magnitude of the negative impact of deforestation requires more accurate identification of land cover changes and predictions of the direction of these changes. This study offers an integrative approach based on CA–ANN, which is still rarely applied in Indonesia's tropical forest areas. In addition, accurate land cover information is one of the determining factors in improving the performance of ecosystem, hydrological, and atmospheric models (Derajat, 2020). Accurate land cover information is important in making land cover maps to provide information on the accurate value of the maps made, especially land cover maps obtained from remote sensing data (Tosiani, 2020).

Remote sensing technology uses statistical and rule-based modelling to detect and predict land cover changes (Haque & Basak, 2017). Data and information on land cover conditions are obtained by digitally classifying a forest area identified as experiencing changes and damage. The forest damage rate in a particular area can be obtained from Landsat ETM-7+ time series satellite imagery (Tricahyono et al., 2016). Landsat TM data is obtained in seven spectral channels: three visible channels, one near-infrared channel, two mid-infrared channels, and one thermal infrared channel. (Ginting and Jadera, 2018). The objectives of this study include mapping land cover classes, evaluating land cover changes in 2019-2024 in the Jangkok Watershed Forest area, and predicting future land cover changes.

METHOD

Location and Time of Research

This research was conducted in February - March 2024 in the Jangkok Watershed Forest area, West Nusa Tenggara Province, which has an area of 13505.53 ha. Data processing and analysis were carried out at the Remote Sensing and GIS Laboratory, Department of Forest Management, Faculty of Forestry and Environment, IPB University.

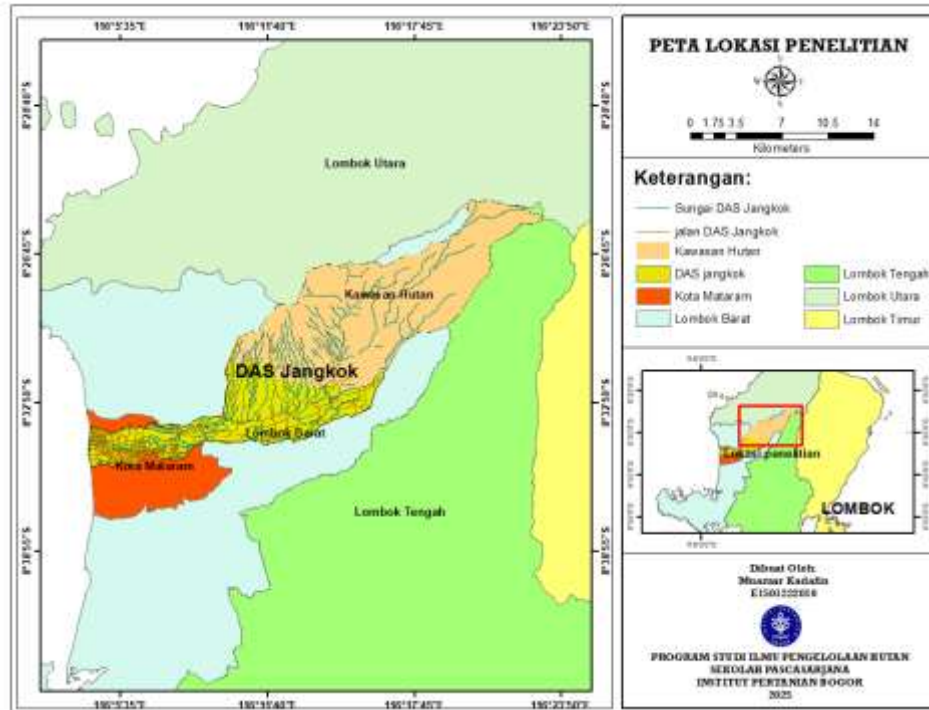


Figure 1. Research Location Map of the Jangkok Watershed (DAS Jangkok), West Nusa Tenggara, Indonesia

Method of collecting data

The data used in the research consists of primary data (observations and field data collection/ground checks) and secondary data (forest area boundaries and other supporting data obtained through literature studies). Pre-processing and image processing were carried out using QGIS 3.28.1 software. The data used in this study were Landsat-8 OLI (Operational Land Imager) in 2019 and Landsat-9 OLI-2 (Operational Land Imager 2) in 2022 and 2024 to identify land cover changes and predict land cover in the Jangkok watershed forest area located on path/row: 116/066. In addition, soil type and KHT (Soil Hydrology Group) data and CN values to evaluate land cover changes.

A. Data Analysis Stages

The data analysis stages consist of image pre-processing and image processing (land cover change analysis, evaluation of land cover changes in the Jangkok Watershed Forest area, and prediction of land cover changes).

1) Pre-image processing stages

This stage consists of several work steps, including merging bands or layer stacking, image sharpening and image cropping.

2) Image processing stages

Visual Interpretation of Land Cover

Land cover classification uses visual interpretation that introduces the characteristics of objects spatially by paying attention to elements of colour, pattern shape, shadow, texture, size, and association.

Training Area

The spatial distribution of each land cover class determines the number and proportion. The more training areas in a class indicate the class's dominance and ease of identification in the study area. The determination refers to the principles of representation and distribution and is carried out through visual interpretation of Landsat imagery. The area is selected homogeneously based on the uniformity of colour tones representing each land cover class.

Separability Test

In this study, the method used to analyze separability is transformed divergence (TD), which measures the level of separation of each land cover class. The separation index is calculated using the formula (Jaya, 2015).

$$TD_{ij} = 2000 (1 - \exp [(-D_{ij})/8]) \quad (1)$$

Description: TD_{ij} : Separability between class i and class j ; \exp : -2.718; D_{ij} : Divergence of row i and column j ; i and j : Two classes being compared.

Land Cover Classification in 2024 Using MLC

The procedure of digital image classification procedure aims to categorize all image pixels into certain land cover classes automatically. This study uses the supervised classification method with the maximum likelihood classification algorithm. The class grouping criteria are determined based on the class signature obtained through the creation of a training area (Jaya, 2015).

Accuracy Test

The land cover classification results obtained will be tested for accuracy using the ground check method in the field and visual analysis of image data. The next step is to assess the land cover classification accuracy using the error matrix and kappa index (Keshtkar et al., 2017).

Table 1. Calculation of Kappa Index for accuracy assessment

Field	Interpretation table			Amount
	A1	A2	A3	
A1	X	A	B	X+a+b
A2	C	Y	D	c+Y+d
A3	E	F	Z	e+f+Z
	X+c+e	a+Y+f	b+d+Z	S

Source: Processed from field survey and classification validation results (2024)

Description: A1, A2, A3: classification results; a,b,c: number of sample points in one class from field testing results; X, Y, Z: number of sample points in the correct class from interpretation and field check results; S: number of rows in the error matrix $(X+c+e) + (a+Y+f) + (b+d+Z) = (e+f+Z) + (c+Y+d) + (X+a+b)$

The Kappa coefficient was calculated using the formula used by Congratlon and Green (2009):

$$\text{Kappa coefficient} = (2)$$

Description: I : class number; n : total number of classified pixels compared to the actual data; n_{II} : number of pixels included in the actual data of class I , which are classified with class I ; C_i : total number of classified pixels included in class I ; G_i : total number of pixels of the

actual data included in class. Furthermore, the analysis of land cover changes based on land cover data for the Jangkok Watershed Forest area uses a matrix table for 2019-2022 and 2022-2024, the satellite image data analysis results.

Stages of evaluating the direction and magnitude of land cover changes

Land cover changes are evaluated based on positive or negative directions using the Curve Number (CN) value with CN values ranging from 0 to 100 (Table 2) and KHT (Soil Hydrology Group) combined with soil type.

Table 2. CN and KHT values used

Land Cover	CN Value	KHT	Land Cover Type	Source
Primary Dryland Forest	77	D	Forest, good hydrology	Arsyad (2010)
Secondary Dryland Forest	79	D	Forest, temperate hydrology	Arsyad (2010)
Mixed Garden	91	D	Combination of wood, grass and agricultural crops, poor hydrology	Dharma et al., (2021)
Open Land	89	D	Open space, poor hydrology	Dharma et al., (2021)
Water Body	100	D	-	Arsyad (2010)

Source: Adapted from Arsyad (2010) and Dharma et al. (2021)

Land cover prediction modeling stages

ANN modelling was performed using QGIS 3.28.1 software with the MOLUSCE plugin. The stages include data input, Pearson correlation evaluation, area changes, Transition potential modelling, Cellular automata and Validation

RESULT AND DISCUSSION

Land cover of Jangkok watershed forest area

Based on the results of visual interpretation, five land cover classes were produced, namely primary dryland forest (HLKP), secondary dryland forest (HLKS), open land (LTK), mixed gardens (KB), and water bodies (BA). The weakness of optical imagery is its inability to penetrate clouds so that clouds do not identify or cover some areas. To avoid bias, the area and location of cloud-covered areas are the same in the analysis of changes and land cover predictions.

The Kappa Index accuracy test was conducted to assess the accuracy of the land cover maps in 2019, 2022, and 2024, with results of 70%, 80%, and 85%, respectively. These results indicate accuracy in the good to outstanding category by Noer and Wibowo (2024), who categorize the accuracy test as poor (<20%), relatively poor (21–40%), sufficient (41–60%), good (61–80%), and perfect (81–100%).

Table 3. The magnitude of changes in land cover in the Jangkok Watershed for the period 2019–2024

Land Cover	2019		2022		2024	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Covered in clouds	270.90	2.01	270.90	2.01	270.90	2.01

BA	41.72	0.31	30.11	0.22	37.66	0.28
HLKP	6380.71	47.25	6043.16	44.75	5440.57	40.28
HLKS	3813.40	28.24	2866.22	21.22	2682.81	19.86
LTK	230.41	1.71	247.78	1.83	269.74	2.00
KB	2768.41	20.50	4047.36	29.97	4803.85	35.57
Total luas	13505.53	100	13505.53	100	13505.53	100

Source: Processed Landsat 8 and Landsat 9 imagery (2019–2024)

Description: HLKP: Primary Dryland Forest; HLKS: Secondary Dryland Forest; Cloud Covered; LTK: Open Land; KB: Mixed Garden; BA: Water Body

Table 3 shows a decrease in the HLKP land cover class area from 6380.71 ha (47.25%) in 2019 to 2022 and 2024, with a decrease of around 2.5% and 4.47%, respectively. This trend is in line with the research of Markum et al. (2012b), which recorded a decrease of 1748 ha from 1995 to 2000. In addition, HLKS cover decreased from 28.24% to 21.22% in 2022, followed by KB cover increasing from 20.50% to 29.97% in 2022 and 35.57% in 2024.

Land cover changes in the Jangkok watershed forest area in 2019–2024 were influenced by population growth, livelihoods, accessibility, supporting facilities, and government policies. According to BPS (2024a), the population in West Lombok Regency and Central Lombok Regency increased. This growth has driven increased agricultural and mixed garden activities, and increased demand for land has contributed to the expansion of dryland agriculture (Suhartanto et al., 2012b).

Figure 1 illustrates the trend of land cover change, where HLKP and HLKS continue to decline while KB increases significantly. These changes are influenced by natural factors, such as forest fires, earthquakes, landslides, floods, erosion, and human factors, such as illegal logging, land grabbing, and forest fires (Tuakora et al., 2022

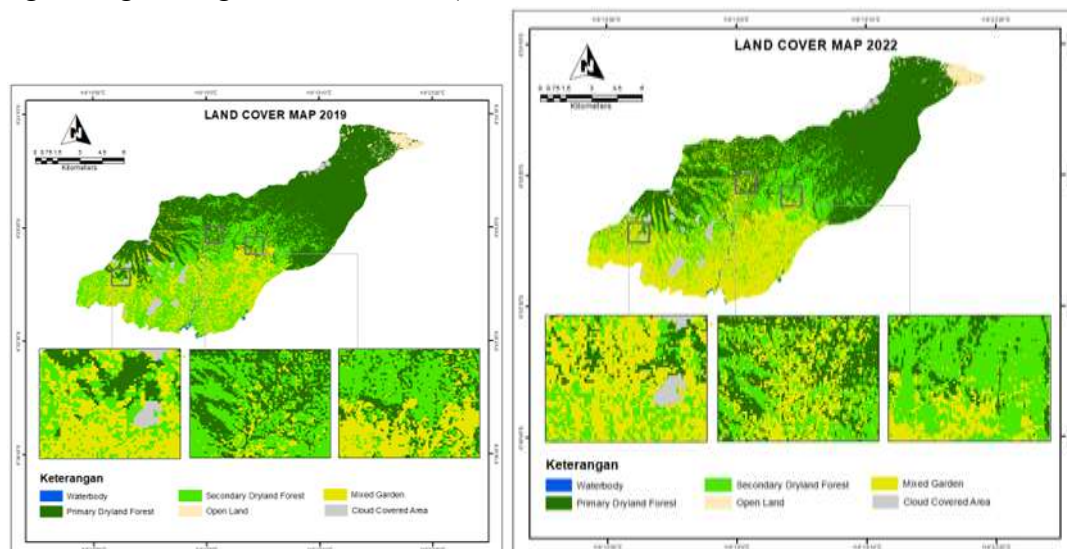
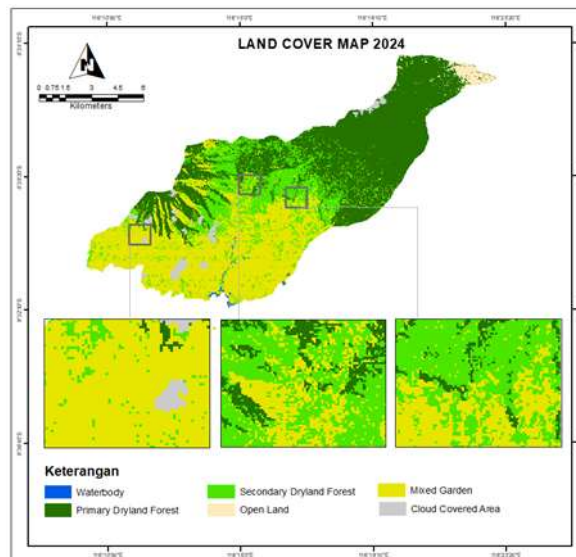
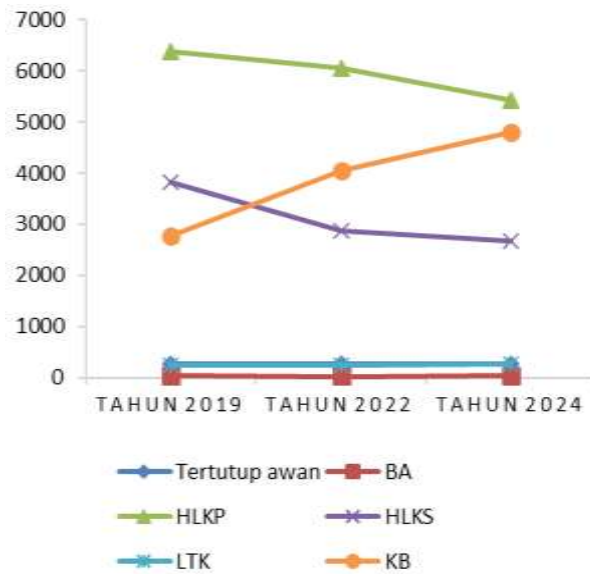


Figure 2. Land cover of the Jangkok DAS forest area in (a) tahun 2019, (b) 2022, (c) 2024 and (d) land cover change trends



The magnitude of land cover changes in the Jangkok watershed forest area

Table 4 shows the 2019–2022 change matrix, where most of the land cover experienced changes. HLKS experienced the largest conversion to KB, covering an area of 1,668.10 ha, while HLKP changed to HLKS, KB, and LTK. The results of this study are in line with Markum et al., (2013a), which stated that from 1995–2010, HLKP experienced a decline due to the logging of mahogany (*Swietenia macrophylla*) by the community, changing it to HLKS with a loss rate of 125 ha/year. The implementation of an agroforestry system triggered this change. Markum et al., (2013b) also stated that 19% of agroforestry land is in the Jangkok Watershed Forest area.

Table 4. Land cover change matrix for the period 2019–2022

Land Cover	Land cover change 2019–2022 (ha)						Total area
	Covered in clouds	BA	HLKP	HLKS	LTK	KB	
Covered in clouds	270.90						270.90
BA		15.67		0.87	0.08	25.10	41.71
HLKP		0.08	6043.16	100.15	17.55	219.77	6380.71

HLKS		5.35	2139.78	0.17	1668.10	3813.40
LTK				229.53	0.87	230.41
KB		9.01	625.43	0.45	2133.52	2768.41
Total	270.90	30.11	6043.16	2866.22	247.78	4047.36

Source: Processed land cover change matrix from Landsat data (2019–2022)

Description: HLKP: Primary Dryland Forest; HLKS: Secondary Dryland Forest; Cloud Covered; LTK: Open Land; KB: Mixed Garden; BA: Water Body

Although the change from HLKS to KB was quite significant, KB also changed to HLKS by 625.43 ha. This was influenced by the National Forest and Land Rehabilitation Movement (GNRHL) initiated by the Ministry of Forestry in 2003 and strengthened by Presidential Regulation No. 89 of 2007. Data from the NTB DLHK (2017) noted that in 2014, land rehabilitation in West Lombok Regency, Central Lombok, and Bima City reached 2,067 ha, 1,083 ha, and 100 ha, respectively.

Table 5. Land cover matrix for the period 2022–2024

Land Cover	Land cover change 2022–2024 (ha)						Total area
	Covered in clouds	BA	HLKP	HLKS	LTK	KB	
Covered in clouds	270.90						270.90
BA		16.86		3.60		9.64	30.11
HLKP		0.05	5440.57	413.07	22.30	167.17	6043.16
HLKS		1.16		1680.13	0.88	1184.06	2866.22
LTK		0.55			246.56	0.68	247.78
KB		19.04		586.02		3442.31	4047.36
Total	270.90	37.66	5440.57	2682.81	269.74	4803.85	13505.53

Source: Processed land cover change matrix from Landsat data (2022–2024)

Description: HLKP: Primary Dryland Forest; HLKS: Secondary Dryland Forest; Cloud Covered; LTK: Open Land; KB: Mixed Garden; BA: Water Body

Land cover changes also occurred during 2022-2024 (Table 4). HLKS is still the land cover with the largest area of change to KB compared to other land covers of 1184.06 ha. HLKP in 2022-2024 experienced a greater decrease in area, namely 602.54 ha, with details of 22.30 ha to LTK, 167.17 ha to KB, and 413.07 ha to HLKS. This increase was influenced by easy access to forests and population growth around the Jangkok Watershed, especially in West Lombok Regency, Central Lombok, and Mataram City.

Direction of land cover change in Jangkok watershed forest area based on CN and KHT values

The results of the overlay of soil type and Soil Hydrology Group (KHT) data show that KHT D. dominates the Jangkok Watershed Forest area. This category includes soil that expands when wet, heavy clay, plastic, and certain saline soils, with a minimum infiltration rate of 0–1 mm/hour. Vitric Andosol and Eutric Andosol soil types dominate around 80% of the area, formed from volcanic activity with a blackish colour, high organic content, and high humidity

(Masinambow et al., 2021). This soil has a base saturation of <50% at a depth of 25–100 cm and is spread at an altitude of 750–3,000 mdpl.

Evaluation of land cover changes 2019–2024 using the Curve Number (CN) value in this study ranged from 77–100; the CN value is often used because it is the most sensitive parameter in assessing the level of surface flow (Enriquez, 2025), where high CN indicates large surface flow and low land absorption capacity, while low CN indicates small surface flow and higher soil absorption (Table 1). In 2019–2024, land cover changes were unchanged, positive, and negative. Most were negative, marked by an increase in the Curve Number (CN) value (Table 6).

Table 6. Direction of land cover change for the period 2019–2024

	Direction of land cover change for the period 2019–2024											
	Land cover 2019-2022				Land cover 2022-2024							
	Positive		Negative		Still		Positive		Negative		Still	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
HLKP-HLKP					6043.2	45%					5440.6	40%
HLKP-HLKS			100.2	1%					413.1	3%		
HLKP-LTK			17.6	0.1%					22.3	0.2%		
HLKP-KB			219.8	2%					167.2	1%		
HLKS-HLKS					2139.8	16%					1680.1	12%
HLKS-LTK			0.2	0.001%					0.9	0.01%		
HLKS-KB			1668.1	12%					1184.1	9%		
LTK-LTK					229.5	2%					246.6	2%
LTK-KB	0.87	0.01%					0.7	0.01%				
KB-KB					2133.5	16%					3442.3	25%
KB-LTK			0.5	0.003%								
KB-HLKS	625.4	4.6%					586	4.3%				
Total	626.3	5%	2006.2	15%	10546	78%	586.7	4%	1787.5	13%	10809.5	80%

Source: Processed from CN and KHT analysis results (2019–2024)

Description: HLKP: Primary Dryland Forest; HLKS: Secondary Dryland Forest; Cloud Covered; TK: Open Land; KB: Mixed Garden; BA: Water Body This shows that rainfall or surface flow is difficult to absorb into the soil, thus increasing the risk of flooding (Thiruchelva et al., 2024), surface water runoff, which causes sedimentation and decreases water availability during the dry season (Venkatesh & Ramesh 2018 and Pribadi et al., 2020).

Land Cover Change Prediction Model for Jangkok Watershed Forest Area

The land cover prediction model uses the 2019 map as the initial and the 2022 map as the final. Driving factors include distance to road, distance to river, slope, and elevation. The strength of the relationship between factors is analyzed using the Pearson correlation test (Table 7).

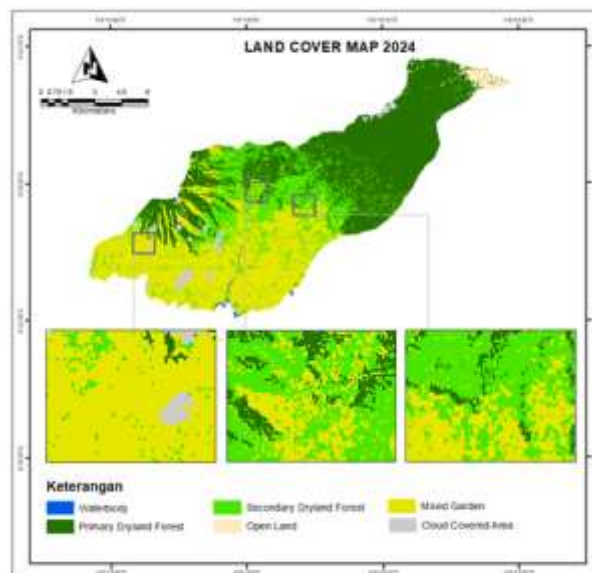
Table 7. Correlation between variables

	X1	X2	X3	X4
X1	--	0,38	0,85	0,33
X2		--	0,43	0,05
X3			--	0,12
X4				--

Source: Processed from Pearson correlation analysis using research variables (2024)

Description: X1 (Elevation), X2 (Distance from River), X3 (Distance from Road), X4 (Slope)

Table 7 shows a strong correlation between distance from the road and elevation (0.85), while the correlation between other variables is relatively small. To avoid multicollinearity, only one of the two variables is used: the distance from the road. The land cover prediction model uses the ANN method with a 4-3-2 structured Multi-Layer Perceptron (MLP). The input layer consists of 4 nodes (distance from the road, slope, distance from the river), the hidden layer has three nodes to analyze the relationship between driving factors and land cover, and the output layer with two nodes produces a land cover prediction map for 2024 (Figure 4a). Validation was carried out using the Landsat 9 OLI visual classification map (Figure 4b), producing a Kappa value of 0.78 (78%), in line with Supriatna et al., (2016).



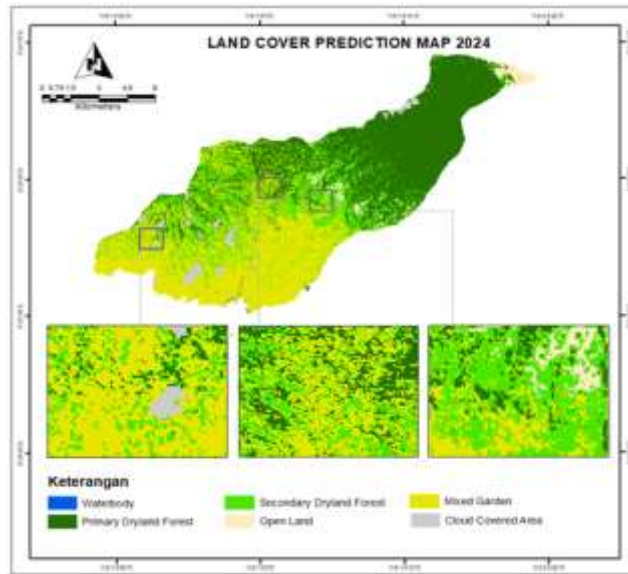


Figure 3. Comparison of land cover maps (a) 2024 visual classification (b) 2024 prediction

Land cover predictions for 2029, 2034, and 2039

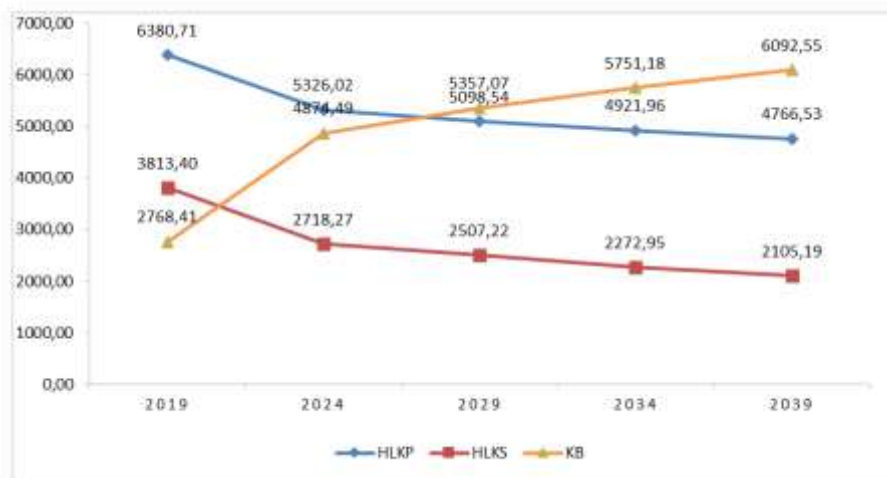
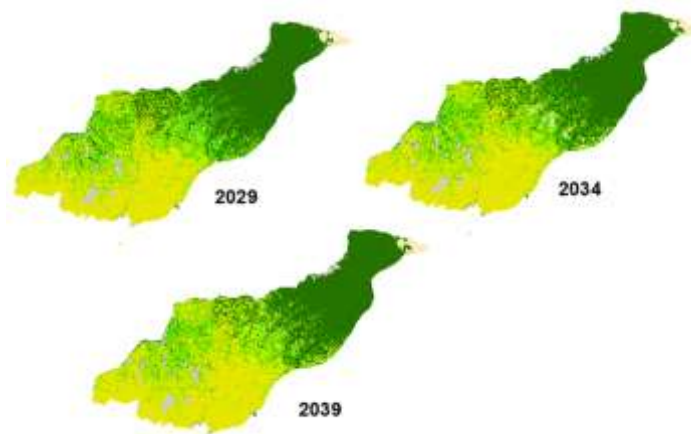


Figure 4. Prediction graph of land cover in 2029, 2034 and 2039 for the Jangkok DAS forest area.

This change could hamper the target of reducing greenhouse gas emissions by 94.88%, making land cover predictions crucial in climate mitigation strategies and low-carbon development in NTB. Unplanned development risks damaging forest ecosystems, reducing water quality, and increasing the potential for disasters such as floods and landslides, especially on Lombok Island (Margono, 2014). This is related to the function of the Jangkok DAS forest area as a provider of ecosystem services, such as clean water, flood control, and climate mitigation, so land cover predictions until 2039 allow for identifying potential threats to forest areas due to agricultural land expansion.

CONCLUSION

Based on the findings presented in the manuscript, the research concludes that the Jangkok Watershed forest area has undergone significant land cover changes during the 2019–2024 period, characterized by a continuous decline in primary and secondary dryland forests (HLKP and HLKS) and a substantial increase in mixed garden areas (KB). The transition matrix and Curve Number (CN) evaluation indicate that negative changes (28%) dominate over positive changes (9%), reflecting worsening hydrological conditions such as increased surface runoff and reduced water absorption capacity. Furthermore, the CA–ANN modeling approach demonstrates a relatively high predictive accuracy (Kappa value of 0.78), confirming that the trend of forest degradation is likely to persist until 2039, accompanied by the expansion of mixed gardens. These findings highlight that land cover dynamics in the Jangkok Watershed are strongly influenced by anthropogenic pressures such as land conversion, accessibility, and population growth, which ultimately threaten ecosystem stability and watershed sustainability.

For future research, it is recommended to incorporate more comprehensive driving variables, such as socio-economic factors, land ownership patterns, and policy interventions, to improve the robustness and explanatory power of land cover prediction models. Additionally, the integration of higher-resolution satellite imagery and advanced machine learning techniques could enhance classification accuracy and spatial detail. Longitudinal studies combining environmental, economic, and institutional perspectives are also needed to better understand the complex interactions influencing land use change. Moreover, future studies should explore scenario-based simulations to assess the effectiveness of sustainable land management policies and conservation strategies, thereby providing more practical and policy-relevant recommendations for mitigating deforestation and maintaining the ecological and hydrological functions of the watershed.

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