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Modeling land use/land cover change in Berau Pantai Forests, Berau Regency, East Kalimantan Province

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Abstract. *Land demands increase with the rise of population and regional development. This results in considerable pressure on forest resources, characterized by an increasing rate of deforestation. Deforestation occurred on the southern coast of Berau Regency due to the expansion of oil palm plantations and the optimization of tourist attractions. To further explore the impact of deforestation and forest management in the regional planning process, this study specifically aimed 1) to identify patterns of land use/land cover changes, 2) to analyze driving factors, and 3) to model future land use/land cover. This study employed Landsat imageries to construct land use/land cover maps and their variation across time. Driving factors were analyzed using binary logistic regression. Land use prediction was made through the Artificial Neural Network approach. Multitemporal analysis indicated that the research area experienced a decreasing trend of natural forests and shrubs, with substantial extension of existing plantation forests, plantations, agricultural lands, and settlements. Indicated driving factors included accessibility, slope class, soil type, forest permit, forest function, RTRW, and population density. A forecast in 2030 suggested that natural forests and built-up land would increase from current figures.*

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INTRODUCTION

The increasing population triggers substantial land demand for various activities. In addition, rapid development due to planning, regulations, or other factors, especially for expanding settlements and industry, would require additional pressure for this request (Li and Liu 2017). This demand puts considerable pressure on existing forest resources, characterized by an increasing deforestation rate. Experience with deforestation has been known throughout the world, especially in tropical, developing countries like Indonesia. Major islands like Sumatra and Kalimantan have known for being a frontline in tropical deforestation, while most likely, Papua would confront the same issue. The deforestation rate in Berau Regency, East Kalimantan Province, from 2000–2014 was 738,000 ha (15%) inside and outside forest areas (Pemerintah Kabupaten Berau 2016). More than 130,000 ha in 2014 planted oil palm plantations, and almost all (96%), were built in the period 2000 to 2014.

Beyond this, about half (51%) of them were developed through forest land use conversion (deforestation). Moreover, forest fires are also one of the main causes of deforestation and forest degradation. According to data from the Forestry Office of East Kalimantan Province, between 2016 and 2020. The province recorded

145,451 ha of forest and land fires. The development of Berau Regency has progressed but has not been evenly distributed in all areas, one of which is the coastal areas. This is probably due to the distance to the local government/business center is about 150 km with poor road conditions. Despite this, Berau coasts are developing, driven by the tourism and trade sectors. Nature-related tourism attracts domestic and foreign tourists. The trade sector relies on transactions with Sulawesi Island because it is more economical in transportation. With these two leading sectors, further development of Berau coastal areas would trigger migration. In general, land use/land cover change could be driven by physical and socio-economic aspects, for instance, the level of accessibility, soil type, slope, geological formation, policies, business permits, and spatial patterns.

Large-scale assessment of deforestation and land cover requires a specific monitoring scheme. Land use/land cover information can be obtained by analyzing satellite imagery. These images provide representative broad-coverage conditions, allowing rapid evaluation or serving as an input for spatial arrangement. The availability of multitemporal imageries, or perhaps time-series data, allows one to develop a series of land cover data. This leads to better land use/land cover modeling and future land use/land cover projections. While land use/land cover modeling has been developed thoroughly, its implementation in a diverse environmental setting is yet to be fully achieved. This includes the lack of research in forested lowlands and coastal zones in tropical developing countries. The study attempted to minimize the gap by using multitemporal remote sensing imageries combined with Artificial Neural Networks (ANN) to investigate characteristics and drivers of land use/land cover change. Specific goals of this research were (1) characterizing land use/land cover patterns and their changes; (2) investigating their driving factors, and (3) projecting future land use/land cover.

METHOD

Research Location and Time

This research was conducted in the southern coastal area of Berau Regency, East Kalimantan Province, consisting of 4 sub-districts, namely Talisayan, Biduk-biduk, Batu Putih, and Biatan is presented in Figure 1. The research period starts from August 2021 to January 2022.

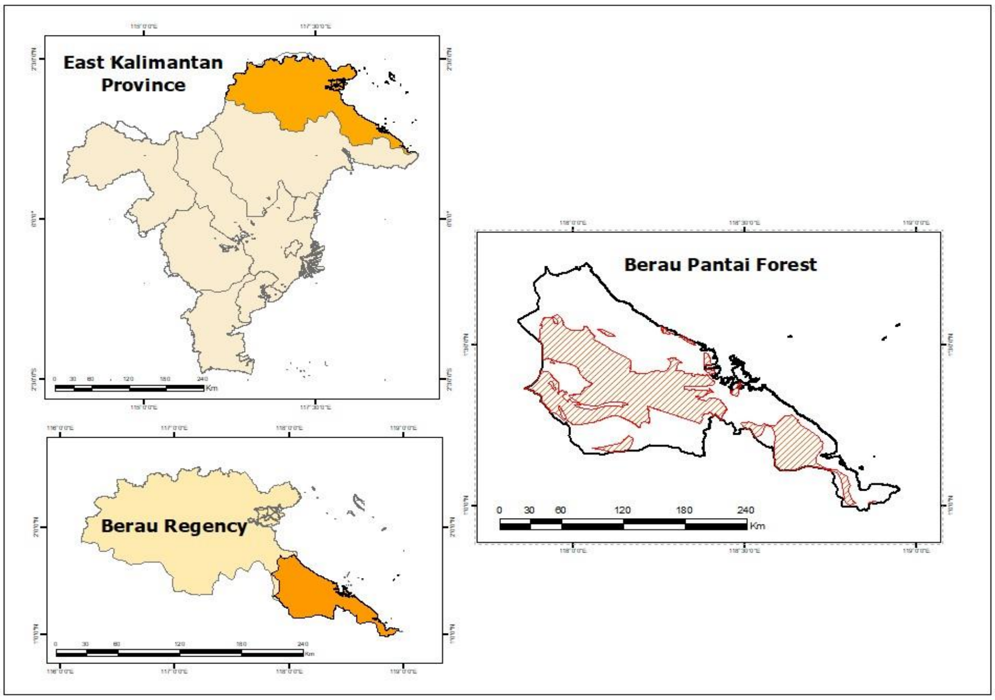

Figure 1 Study area ,Berau Pantai Forest, Berau Regency, East Kalimantan Province

Method of Collecting Data

The types of data used are secondary data, including Landsat Satellite Imagery coverage in 2000, 2005, 2010, 2015, and 2020, RBI Map 2016, Map of Forest Management Unit XVI Berau Beach, Map of Forest Area of East Kalimantan in 2018, Map of Distribution of Utilization Permits Forest in 2020, Map of Soil Types, Map of Spatial Plan and Region of Berau Regency for 2016–2036, reports on activities of the Forest Management Unit XVI Berau Beach. The tools used in this study are a set of computers equipped with ArcGIS 10.8, R-Studio, QGIS 2.18 software with MOLUSCE (Modules for Land Use Change Evaluation) plugins for data analysis, and Microsoft Office for reporting.

Data Analysis

Land Use/ Land Cover

The process of collecting and processing satellite imagery is accomplished by using the Google Earth Engine (GEE). This cloud computing-based platform allows users to perform satellite image processing that can be accessed online and free of charge (Novianti 2021; Ramdani et al. 2021). Interpretation of satellite imagery to obtain land use/land cover data for 2000, 2005, 2010, 2015, and 2020 is conducted visually. Visual image interpretation means an interactive (direct) relationship between the interpreter to the image, meaning that there is a tracing process from the interpreter to identify the object to the process of delineating the object boundary to define the object (Arifin and Hidayat 2014). Visual classification has better accuracy for classifying land cover than digital classification (Kosasih et al. 2019). This is because visual interpretation can distinguish between objects in an image based on human judgment, which can lead to better interpretation of complex objects, but visual interpretation is not efficient in terms of processing time (Fariz et al. 2020).

The interpretation results are then classified according to the type of land use/land cover in the research area. The land use/land cover in the research area consists of seven classes: Natural Forest, Plantation Forest, Shrub, Plantation, Agriculture, Built Land, and Water. Land use/land cover change analysis was performed by overlaying land-use classes at two points in the year. From this analysis, the land use/land cover change transition matrix is shown in Table 1.

Table1 Transition matrix of land use/land cover change

Land use/ land cover		**Year t_1**							**Sum**
		Nf	**Pf**	**Shr**	**Plt**	**Agr**	**Bl**	**W**	
Year t_0	Nf								Nf t_0
	Pf								Pf t_0
	Shr								Shr t_0
	Plt								Plt t_0
	Agr								Agr t_0
	Bl								Bl t_0
	W								W t_0
Sum		Nf t_1	Pf t_1	Shr t_1	Plt t_1	Agr t_1	Bl t_1	W t_1	Total

Description: : constantly; : changed

A nearest-neighbor analysis was used to determine the distribution pattern of land change. Nearest Neighbor Analysis is an analytical method that can be used to determine the distribution pattern, regardless of whether the distribution pattern is uniform, random, or clustered. Nearest Neighbor Analysis gives values in the range 0 to 2.15. Values 0 to 0.7 are values for clustered distribution patterns, values 0.71 to 1.4 are values for random distribution patterns, and values 1.41 to 2.15 are values for evenly distributed patterns (Riadhi et al. 2020).

Driving Factor

Changes in land use/land cover are influenced by various factors in terms of socioeconomic, biophysical, and regional accessibility aspects. To determine the relationship of the driving factors to a land use/land cover analyzed by binary logistic regression. Binary logistic regression analysis is used to examine the relationship between the influence of the independent variable (X) on the dependent variable (Y), or it can be said that logistic regression analysis is a technique to explain the probability of certain events from the dependent variable category (Y). Variable Y is the change in land use/land cover, which is transformed into two dummy variables, namely a value of 1 for a change and a value of 0 for no change. Variable X used in this research is accessibility (road/river), slope class, soil type, presence of forest utilization permit, area function, the spatial pattern of Berau Regency in 2016–2036, population density, and livelihood choices of the population. The logistic regression equation model is formulated as follows:

$$g(x) = \left(\frac{exp\ (g(x))}{1 + exp\ \ (g(x))}\right)$$

$$g(x) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8$$

Description:

$g(x)$ = Land use/land cover change
X_1 = Accessibility
X_2 = Slope
X_3 = Soil Type
X_4 = Forestry utilization permit
X_5 = Area Function
X_6 = Spatial pattern of Berau Regency in 2016 - 2036
X_7 = Population density
X_8 = Livelihood Choices
β_0 = Constata
$\beta_1 \dots \beta_7$ = Coefficient of the variable

In the binary logistic regression analysis, several tests were undertaken: the Likelihood Test/estimation of model suitability, partial test/wald test, odds ratio, and goodness of fit test. The estimation of the suitability of the model is undertaken to determine whether the alleged model used is significant or not. Logistics model estimation can be done using the maximum likelihood estimator method. A partial test is used to test independent factors or variables that can independently have a real influence on the dependent variable. The odds ratio is used to interpret the coefficients of the resulting logit model. The interpretation of the logit model is the ratio of the probability of a successful event to an unsuccessful event of the variable. The goodness of fit test is used to see the model's accuracy, which is expected to have no difference between the data and the model.

Prediction of Land Use/Land Cover

Many researchers believe the ANN approach is more effective than linear regression, so we applied the ANN approach within the MOLUSCE plugin to transition potential modeling and future simulations (Rahman et al. 2017; El-Tantawi et al. 2019). Quantitatively, land use change can be predicted by including physical, social, economic, and policy factors (Alkaf et al. 2014). Based on the LULC data of 2010 and 2015, explanatory variables, and transition matrix, we projected the LULC for 2020. To validate the accuracy of the models and predictions, the MOLUSCE plugin provides a kappa validation method and a comparison of real and projected LULC images. In the ANN learning process, neighborhood 1 px, maximum iterations 1,000, hidden layer 10, momentum value 0.05, learning rate 0.1 (Dehingia et al. 2022). After obtaining satisfactory results from the model validation, we employed LULC data from 2010 and 2015 to forecast the LULC in 2030.

RESULTS AND DISCUSSION

Land Use/Land Cover

The combination of Landsat image bands in Red, Green, Blue (RGB) format used is 653 for Landsat 8 and 543 for Landsat 5. These bands combination is used because it has the best information in land use identification. The combination of band 653 gives a clear appearance of vegetation (forests, plantations, shrubs) and settlements (Khairussidqih and Wahid 2021). While the combination of band 543 on Landsat 5 provides information on vegetation health and contrast for open land (Papilaya 2013). The results of satellite image classification show that natural forest cover has the largest area each year. Natural forest cover covers more than 60% of the total research area. Despite having the largest area, the natural forest has decreased in each year of observation by 74,238 ha in the period 2000–2020.

The decline in natural forest generally occurs in production forest areas due to changes in function and land management for agricultural land. The use of land for plantations and agricultural land is the cause of the decline in the area of shrubs. In addition to a decrease in the natural forest and shrubs classes, there was an increase in the area of plantation cover, agriculture, natural forest, and built-up land classes. The increase in plantation class by 47,617 ha is an activity of plantation location permit holders, which started in 2005 and has continued to increase until now to 21 permits. In the plantation forest class, an additional 11,847 ha occurred due to the development or opening of new planting blocks in the business permit area. In agricultural cover, there was an increase from 2000 to 2020, which was 26,366 ha. The Land use/land cover is presented in Figure 2 and Table 2.

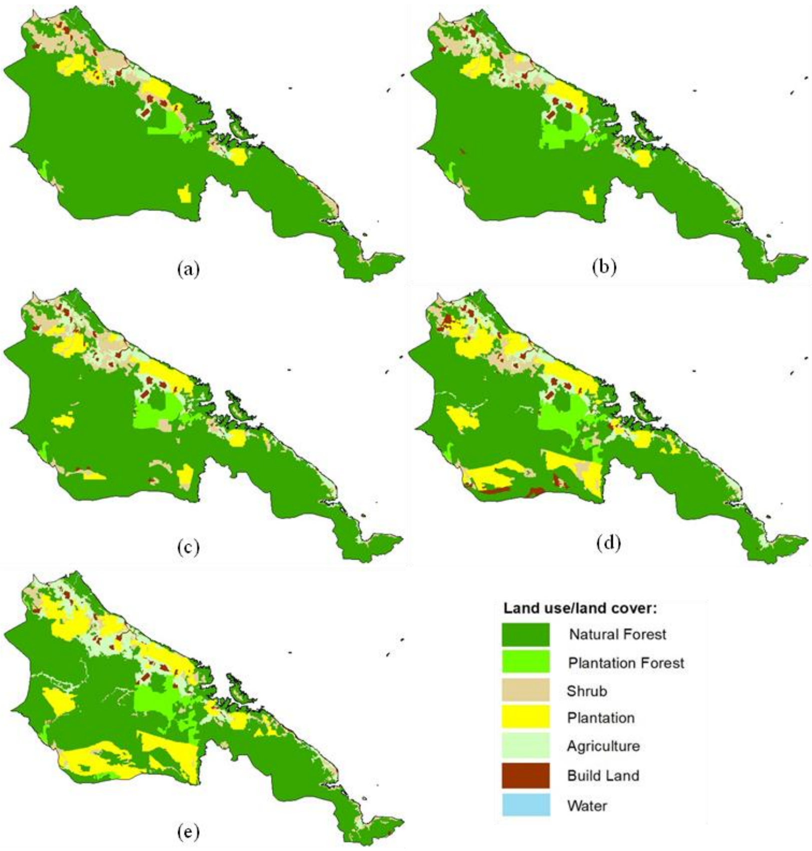

Figure 2 Land use/land cover in Berau Pantai Forest maps (a) 2000, (b) 2005, (c) 2010, (d) 2015, and (e) 2020

Table 2 Recapitulation of land use/land cover in the research area in the period 2000–2020

Land use/land cover	**Year**					**Change**
	2000	**2005**	**2010**	**2015**	**2020**	
Natural Forest (NF)	301,335	291,881	274,244	243,130	227,097	–74,238
Plantation Forest (PF)	6,534	11,463	11,759	16,591	18,381	11,847
Shrub (Sh)	28,721	20,678	27,953	21,343	16,607	–12,114
Plantation (Pl)	14,451	14,430	22,448	48,891	62,068	47,617
Agriculture (Agr)	5,937	18,397	19,869	22,325	32,304	26,366
Built land (BL)	4,011	4,139	4,716	8,797	4,620	609
Water (W)	344	344	344	256	256	–87

Table 3 Matrix of land use/land cover changes in the period 2000–2005

Land use/ land cover		**Year 2005 (ha)**							**Total**	**Change**
		NF	**PF**	**Sh**	**Pl**	**Agr**	**BL**	**W**		
Year 2,000 (ha)	NF	291,881	4,929	1,138	2,105	1,154	128		301,335	–9,453
	PF		6,534						6,534	4,929
	Sh			19,540	458	8,722			28,721	–8,043
	Pl				11,867	2,584			14,451	–21
	Agr					5,937			5,937	12,460
	BL						4,011		4,011	128
	W							344	344	0
Total		291,881	11,463	20,678	14,430	18,397	4,139	344	361,333	

The largest change in land use/land cover occurred from 2000–2005 are shown in Table 3, significantly in the category of natural forest and agricultural land. This change is referred to as deforestation, where the forested land is converted to no-forested land. There is also an increase in the conversion of plantation forests due to the company's operational activities, usually through natural forest logging for industrial plantations. Changes in land use/land cover for the 2005–2010 period are shown in Table 4. During this period, land use/land cover changed from natural forest classes to other classes (deforestation). The biggest change is natural forests into scrub and plantations. This change is caused by land clearing for oil palm plantations. Cultivating oil palm plantations has a long and complex licensing procedure. Although the licensing process with the government is finished and land clearing begins, sometimes there is still a problem with community claims on the ground.

Table 4 Matrix of land use/land cover changes in the period 2005–2010

Land use/ land cover		**Year 2010 (ha)**							**Total**	**Change**
		NF	**PF**	**Sh**	**Pl**	**Agr**	**BL**	**W**		
Year 2005 (ha)	NF	274,244	296	9,475	6,188	974	704		291,881	–17,638
	PF		11,463						11,463	296
	Sh			18,350	1,830	498			20,678	7,275
	Pl				14,430				14,430	8,018
	Agr					18,397			18,397	1,472
	BL			128			4,011		4,139	577
	W							344	344	0
Total		274,244	11,759	27,953	22,448	19,869	4,716	344	361,333	

Due to the settlement of this problem, the land-clearing process can be delayed for many years. As a result, this long process causes the land that has been cleared to become shrubs. Land use/land cover changes for 2010–2015 are presented in Table 5. The largest changes occurred in the natural forest and plantation category in this period. The natural forest decreased by 31,114 ha. On the other hand, the plantation category increased by 26,444 ha. Changes in these two categories are caused by changes in the function of the area from production forest (HP) to other use areas (APL). This change is explained in the Minister of Forestry Decree Number SK.718/Menhut-II/2014 concerning Forest Areas of East Kalimantan Province and North Kalimantan Province. Changes in the function of the area mentioned in this regulation are about 46,744 ha in the Berau Pantai Forest.

Table 5 Matrix of land use/land cover changes in the period 2010–2015

	Land use/ land cover	**Year 2015 (ha)**							**Total**	**Change**
		NF	**PF**	**Sh**	**Pl**	**Agr**	**BL**	**W**		
Year 2010 (ha)	NF	243,130	3,446	5,743	15,767	2,723	3,436		274,244	–31,114
	PF		11,740				19		11,759	4,832
	Sh		1,405	13,807	10,078	1,498	1,166		27,953	–6,640
	Pl				22,448				22,448	26,444
	Agr			1,769	101	17,999			19,869	2,485
	BL			24	497	18	4,177		4,716	4,081
	W					87		256	344	–87
	Total	243,130	16,591	21,343	48,891	22,325	8,797	256	361,333	

This change impacts the changes in the function of forest areas where the conversion of forests to oil palm plantations is increasingly widespread. By comparing with the previous period, the changes in the natural forests are very large due to the changes in the function of forest area. The water conversion into agricultural land became an example of the change from a water body category to agricultural land of 87 ha. This appearance is seen because of a change from the previous dark hue, the blue-black color as a feature of the body of water, to a slightly lighter hue, pink with green spots, which are characteristics of agricultural land. The decline in pond production, pest and disease attacks, and environmental conditions are the causes of the conversion of pond land to agricultural land (Kasturiyah et al. 2021).

Table 6 Matrix of land use/land cover changes in the period 2015–2020

	Land use/ land cover	**Year 2020 (ha)**							**Total**	**Change**
		NF	**PF**	**Sh**	**Pl**	**Agr**	**BL**	**W**		
Year 2015 (ha)	NF	227,097	1,775	5,031	5,261	3,759	207		243,130	–16,032
	PF		15,532	13	44	729	272		16,591	1,790
	Sh		1,019	7,921	4,555	7,667	180		21,343	–4,736
	Pl			601	47,709	546	35		48,891	13,176
	Agr			2,543	518	18,782	481		22,325	9,979
	BL		56	496	3,980	820	3,445		8,797	–4,177
	W							256	256	0
	Total	227,097	18,381	16,607	62,068	32,304	4,620	256	361,333	

Changes in land use/land cover for the 2015–2020 period are shown in Table 6. In this period, the biggest changes were in the natural forest class and plantation class. The natural forest was reduced by 16,032 ha and plantations by 13,176 ha. In addition, there was an addition to the agricultural land class, namely 9,979 ha, plantation forest 1,790 ha. As in the previous period, the biggest changes in the two classes resulted from changes in the area's function. After the issuance of the decision of the minister of forestry number

SK.718/Menhut-II/2014 concerning to forest areas of East and North Kalimantan Provinces, there was a change in the function of the forest area through the decision of the Minister of Environment and Forestry Decree Number SK. 278/MENLHK/SETJEN/PLA.2/6/2017 concerning to amendment to the decree of the minister of forestry number SK.718/Menhut-II/2014 dated August 29, 2014 concerning forest areas in the provinces of East and North Kalimantan especially in Berau Regency. The issuance of this decision resulted in a change in the function of the area from production forest to another use area of 12,349 ha. It increases the clearing of new land for oil palm plantations.

In addition, forest and land fires occurred in the Berau Regency area in the 2016–2020. According to data from the Ministry of Environment and Forestry, there were 10,346 ha of forest and land fires in the Berau Regency area during that period. These two occurrences led to increased land conversion to plantations and agricultural land. Table 7 is a matrix of land use/land cover changes from 2000 to 2020. In general, there is a change in the natural forest class into another class, especially the plantation class. The plantation forest class experienced an operational expansion, which decreased the natural forest area. The class change to agricultural land comes from the natural forest and bush classes. The opening of new land for agriculture and plantations is the impact of increasing population to meet needs. The built-up land class consists of land with buildings and land clearing. So that there was a change in the class of land built into plantations and agricultural land because, in the early years, it was still open land. Changes in water class to agricultural land due to the use of former ponds into rice fields around large rivers.

Table 7 Matrix of land use/land cover changes in the period 2000–2020

Land use/ land cover		**Year 2020 (ha)**							**Total**	**Change**
		NF	**PF**	**Sh**	**Pl**	**Agr**	**BL**	**W**		
Year 2000 (ha)	NF	227,097	12,806	9,628	41,019	10,435	351		301,335	–74,238
	PF		5,576	13	44	729	172		6,534	11,847
	Sh			6,966	9,203	12,440	112		28,721	–12,143
	Pl				11,747	2,310	394		14,451	47,617
	Agr					5,791	146		5,937	26,396
	BL				55	511	3,445		4,011	609
	W					87		256	344	–87
Total		227,097	18,381	16,607	62,068	32,304	4,620	256	361,333	

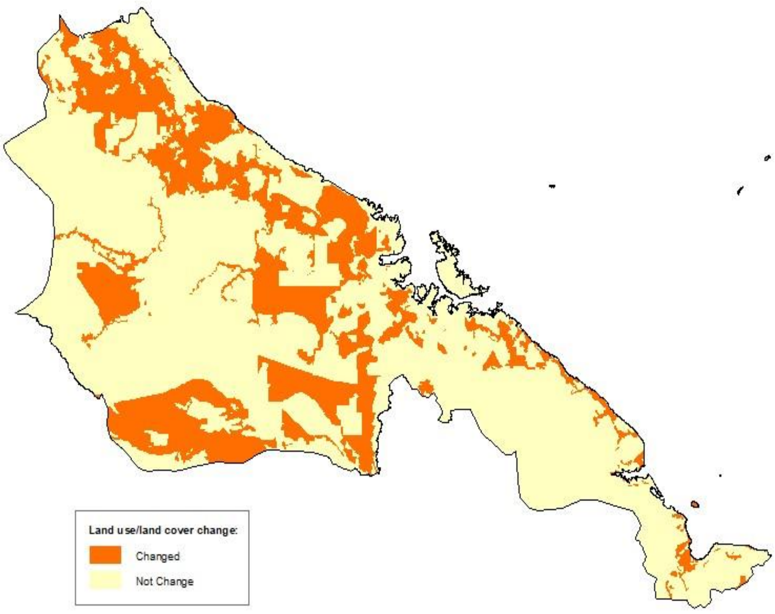

Figure 3 Distribution of land use/land cover changes

Figure 3 shows the distribution of land use/land cover changes in the research area from 2000–2020, which are generally grouped in certain areas. The results of the nearest neighbor analysis show that the z-score is –74.36 and the Nearest Neighbor Ratio is 0.37, which means < 1, indicating that the distribution of changes is clustered. Changes are spread throughout the region, but there are still areas where land use/land cover remains. Land use/ land cover that does not change is an area that is difficult to use due to severe physical conditions (geology, soil type, slope).

The distribution of land use/land cover changes is generally an interconnected and interrelated area. Changes to land clearing are increasingly widespread when plantation activities and plantation forest management activities open access points. In addition, the pattern of land use/land cover by the community is usually close to each other, so the production stage is easier.

Driving Factors of Land Use/Land Cover Change

Based on the results of the binary logistic regression analysis the overall test results obtained the value of G2 (1,055.41) > chi-square table, which means that at least one independent variable has an effect on the independent variable. Based on the results of the partial test, it was found that most of the independent variables (X) had a significant effect on changes in land use/land cover, as indicated by the p-value < alpha 5% (0.05). Accessibility variables (X1), slope class (X2), the existence of permits (X4), and area functions (X5) for each category have a significant influence on changes in land use/land cover. In the soil type variable, only the district regosol category (X3e) has no significant effect because the p-value is > 0.05. The categories of spatial pattern variables (X6) that have a significant effect are protected forests (X6a), permanent production forests (X6e), territorial seas (X6h), marine tourism (X6j), plantations (X6k), rural settlements (X6l), land agriculture. wet (X6n), coastal (X6p), river (X6q) and river (X6r) boundaries. The high category population density variable (X7c) has no significant effect because the p-value > 0.05.

The livelihood variable (X8) does not have a significant effect on changes in land use/land cover because the p-value is > alpha 5% (0.05). Most of the settled population generally own agricultural land in the form of gardens or fields, although the main livelihood is not farmers. The Hosmer and Lemeshow Goodness of Fit test results obtained a p-value of 0.13 > 0.05, so it failed to reject H0, which means that the model is correct and appropriate. In addition, the chi-square 12.61 < chi-square table (15.51) confirms that the model formed following the observations and possible outcomes. Furthermore, the coefficient of determination test on this model resulted in a Nagelkerke R Square value of 0.22 or 22.11%. This means that it means that the variability of the dependent variable that can be explained by the independent variable is 22.11%, while the remaining 77.89% is explained by other variables outside the research model. From the model and coefficient estimator, the logistic regression model is obtained as follows:

$$g(x) = \left(\frac{exp\ (g(x))}{1+exp\ (g(x))}\right) \quad (3)$$

Where

$$g(x) = -1.36 - 0.32X1_b - 0.68X1_c - 0.99X1_d + 0.15X2_b - 0.31X2_c + 0.24X3_b + 0.6453_c + 0.42X3_d + 0.25X4_b + 0.89X5_b + 0.70X6_e - 1.87X6_h - 1.31X6_j + 0.63X6_k + 0.54X6_l + 1.06X6_n - 1.00X6_p - 0.84X6_q - 1.47X6_r - 0.49X7_b$$

Table 8 is the odds ratio value used to describe how much the response variable changes if there is a change in the independent variable. An odds ratio value of more than one means that the independent variable positively affects the opportunity for land use/land cover change. On the other hand, the odds ratio is zero to one, meaning that the independent variable has a negative effect on the opportunity for land use/land cover change.

Table 8 Odds ratio value

Category	Odds ratio	Kategori	Odds ratio	Kategori	Odds ratio
Intercept	0.26	X6b	0.00	X6n	2.88
X1b	0.72	X6c	1.26	X6o	1.50
X1c	0.51	X6d	0.00	X6p	0.37
X1d	0.37	X6e	2.01	X6q	0.43
X2b	1.16	X6f	6.05	X6r	0.23
X2c	0.73	X6g	1.67	X6s	1.67
X3b	1.27	X6h	0.15	X7b	0.61
X3c	1.91	X6i	0.79	X7c	0.71
X3d	1.53	X6j	0.27	X8b	1.10
X3e	1.12	X6k	1.87	X8c	0.00
X4b	1.29	X6l	1.71		
X5b	2.45	X6m	0.88		

Land Use/Land Cover Change Model

The prediction of land use/land cover in this study uses the results of the 2010 and 2015 classifications with validation based on the results of the 2020 classification. With the ANN method in this simulation, the overall accuracy is 88.68%, and the kappa coefficient is 0.79022. According to (Rwanga and Ndambuki 2017), the kappa coefficient level with a value of 0.61–0.80 is said to be in a good category. In the prediction of land use/land cover in 2030 is presented in Figure 4, it is found that natural forest has the largest area of 242,862 ha (67.21%). While the water body has the smallest area of 0.05% (185 ha). In addition to natural forests, plantations are also predicted to have an area of 59,134 ha (16.37%) in 2030.

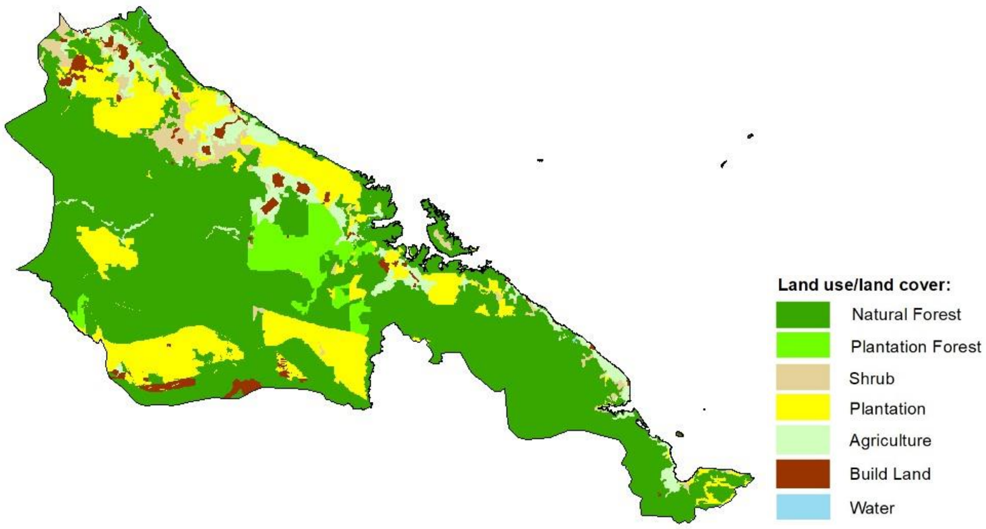

Figure 4 Land use/land cover prediction of 2030

Table 9 shows that the classes of land use/land cover that have increased in 2030 are the natural forest class and the built up land class. The increase in the natural forest class is the result of natural succession to other classes that are not managed due to access cuts. Changes in land use/land cover are smaller in 2030 due to the driving factors that become obstacles. The driving factor that has the potential to hinder is limited accessibility. The increase in the natural forest category is the result of natural succession to other classes that are not managed. The scrub category is a stage of natural succession before becoming natural forest. Unmanaged plantations and agricultural land due to loss of access will turn into shrubs. Naturally, forests that have been disturbed will return to secondary forests after going through successional stages (Thamrin et al. 2022).

Limitations of biophysical factors, especially slope class, soil type, and accessibility are factors that are considered in agricultural management, especially by the community. Biophysical barriers in the use of natural forest land require large capital and high technology for land use/land cover that is difficult to reach by the community. Areas with this barrier are generally a stretch of natural forest that spans almost the entire area. Road access in the field is generally a road built by the company to support operational activities. However, the company's operational activities have shifted, so road maintenance is lacking and even abandoned. This has resulted in the destruction of community access roads on managed land. In the long term, land without natural succession will return to the forest. The next factor is land with a very steep slope class becomes an obstacle in management, so there is little opportunity for land use/land cover to change.

In addition, the shifting cultivation method, which has become the culture of the surrounding community, has resulted in changes to the use category over a long period. Meanwhile, land management by corporations/companies is limited by policies, including the status of area functions and regional spatial patterns. In addition, almost all areas already have permit holders in forest areas and other use areas. The thing that allows changes to occur is the addition of built-up land due to residential development, both local and transmigration. Population density is a factor that affects the addition of built-up land for settlements because of the increased need for housing.

Table 9 Recapitulation of land use/land cover 2010–2030

Land use/land cover	**2010**		**2015**		**2020**		**2030**	
	Ha	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**
Natural Forest	274,244	75.90	243,130	67.29	227,097	62.85	242,862	67.21
Plantation Forest	11,759	3.25	16,591	4.59	18,381	5.09	16,156	4.47
Shrub	27,953	7.74	21,343	5.91	16,607	4.60	11,380	3.15
Plantation	22,448	6.21	48,891	13.53	62,068	17.18	59,134	16.37
Agriculture	19,869	5.50	22,325	6.18	32,304	8.94	23,290	6.45
Built land	4,716	1.31	8,797	2.43	4,620	1.28	8,327	2.30
Water	344	0.10	256	0.07	256	0.07	185	0.05
Total	361,333	100	361,333	100	361,333	100	361,333	100

CONCLUSION

During 2000-2020, land use/land cover of natural forest has a coverage of 60%. The pattern of changes in land use/land cover that occurred in the period 2000–2020 is the reduction of natural forests and shrubs and the increase in the area of plantations, agricultural land, and plantation forests. The pattern of distribution of changes that occur is in groups in areas where previous land clearing has occurred. The driving factors for changes in land use/land cover in the research area are accessibility conditions, slope class, soil type, the existence of permits, forest area functions, spatial patterns, and population density. The results of the prediction of land use/land cover in 2030 are an increase in the area of natural forests and built-up land and a decrease in plantation forests, shrubs, and agricultural land. In addition to the existence of roads as a driving factor, road quality is considered more important as a driving factor for changes in LULC.

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