

LAND USE CHANGE MODELING ABOUT THE ARRANGEMENT OF THE MANAGEMENT BLOCK BUKIT BARISAN GREAT FOREST PARK, NORTH SUMATRA

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ABSTRACT

Bukit Barisan Great Forest Park (THRBB) is designated as the third TAHURA in Indonesia. TAHURA functions as a source of genetics and germplasm, erosion control, information and research center, education and conservation work, recreation and tourism services. Currently, the THRBB area is experiencing many land use changes that are not by the THRBB management block plan. Land use change modeling using the Land Change Modeler (LCM) instrument was carried out to predict land use change patterns by selecting a Multi-Layer Perceptron (MLP) to evaluate several variables that influence land use change. This research aims to analyze changes in land use in 2011-2018, factors influencing changes, predictions for 2033 and develop land use directions in the THRBB area. The results of the analysis show that during the 2011-2018 period, primary forest land decreased by 710 ha (2.19%), secondary forest by 1,185 ha (43.94%), and shrubs by 139 ha (7.58%). The decrease in forest land area was followed by an increase in open land area by 448 ha (59.74%) and dry land agriculture by 1,586 ha (57.46%). The pattern of land change in the THRBB area is from forest land to bushland, open land and dry land agriculture. The most significant driving factor for land use change is distance from roads. The prediction results for land cover in 2033 show that the area of primary forest will be 30,156 ha, secondary forest 1,236 ha, shrubs 2,833 ha, open land 1,375 ha and dry land agriculture 4,074 ha. The direction of land use policy in the THRBB area is forest restoration policy, increasing protection and security activities and law enforcement.

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1. INTRODUCTION

Bukit Barisan Great Forest Park (THRBB) was designated as a management unit with a core of protected forest areas and conservation areas by Presidential Decree Number 48 of 1988, then re-established based on Decree of the Minister of Environment and Forestry Number SK.95/Menlhk/Setjen/Pla.2/2/2018 Dated 20 February 2018 with an area of ± 39,678 Ha, located in North Sumatra Province and crossing four districts, namely Deli Serdang, Karo, Langkat and Simalungun. The THRBB area is an open area (open area) where the area borders directly on villages and there is road access that has been built across the area. The dependence of the people around the area and the people within the area on the potential of the area, both in the form of natural resources and the need for land, is very high. Various land use activities by communities in the THRBB area that are not by the THRBB management block plan (Indonesia, 2015) will disrupt the forest ecosystem, so it needs to be protected. (Maru et al, 2015) explained that changes in land use/cover continue to occur in line with population growth and regional development over time. The development of changes in land cover in an area can be analyzed by utilizing remote sensing data in the form of multi-temporal satellite imagery. According to (Petit & Lambin, 2001) the use of remote sensing technology is one way to quickly determine land conversion. It is very important to know the development of land cover changes so that patterns of land cover changes in the future can be predicted so that negative land cover changes can be prevented or reduced. Therefore, efforts are needed to determine the development of land cover changes in THRBB, so that the land cover changes that occur can be analyzed. Various modeling approaches have been widely used to analyze land cover changes. Land Change Modeler (LCM) in Terrset 2020 is a modeling tool designed on an ANN basis

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that uses a Markov transition matrix by default (Hasan et al, 2020; Leta et al, 2021). This research aims to analyze land cover changes in THRBB in 2011-2018, analyze the driving factors for land cover changes and predict land cover changes in 2033 in THRBB using the Markov Chain method based on modeling land cover changes in 2011-2018. By knowing the land cover change model and predictions of land cover change in 2033, it is hoped that it can be used as material for consideration in determining policies regarding land use planning in the THRBB area.

Literature Review

The development of changes in land cover in an area can be analyzed by utilizing remote sensing data in the form of multi-temporal satellite imagery. According to (Petit & Lambin, 2001) the use of remote sensing technology is one way to quickly determine land conversion. It is very important to know the development of land cover changes so that patterns of land cover changes in the future can be predicted so that negative land cover changes can be prevented or reduced. Therefore, efforts are needed to determine the development of land cover changes in THRBB, so that the land cover changes that occur can be analyzed. Various modeling approaches have been widely used to analyze land cover changes. Land Change Modeler (LCM) in Terrset is a modeling tool designed on an ANN basis that uses a Markov transition matrix by default (Hasan et al, 2020; Leta et al, 2021). This research aims to analyze land cover changes in THRBB in 2011-2018, analyze the driving factors for land cover changes and predict land cover changes in 2033 in THRBB using the Markov Chain method based on modeling land cover changes in 2011-2018. By knowing the land cover change model and predictions of land cover change in 2033, it is hoped that it can be used as material for consideration in determining policies regarding land use planning in the THRBB area.

2. METHOD

The research was located in the Bukit Barisan Grand Forest Park (THRBB) area of North Sumatra Province. The THRBB area is administratively located in four districts, namely Langkat Regency, Karo Regency, Deli Serdang Regency and Simalungun Regency with an area of 39,678 Ha. This research was carried out from May to August 2023. The materials used in this research are Landsat 5 Thematic Mapper (TM) imagery in July 2011, Landsat 8 Operation Land Imager (OLI) imagery in February 2018, Landsat 9 Operation Land Imager (OLI) imagery in July 2023 downloaded from USGS Earth Explorer, Map of factors driving height and slope (slope) is made from DEM (Digital Elevation Model) data obtained from direct download from the page <https://www.indonesia-geospasial.com/>. Indonesian Earth Map (RBI) scale 1: 25,000, administrative map of North Sumatra province scale 1: 25,000, soil type map, rainfall map, road network map obtained from the Forest Area Stabilization Center (BPKH) Region I Medan. The THRBB Area Map and block map were obtained from the THRBB Management UPT. (Sk Rpjp Tahura Bukit Barisan.Pdf, n.d.).

The tools used are Microsoft Excel and Microsoft Word software for data recapitulation, GPS receiver taking Grounddeck field points, digital camera for research documentation, ArcGIS 10.8, and IDRISI TerrSet for data processing. Classification with visual interpretation is the interpretation of remote sensing data which is based on recognizing spectral and spatial features or characteristics of objects in image data (Mas et al., 2017). Image classification in this research uses visual interpretation which is carried out based on an approach to interpretation elements such as hue/color, texture, pattern, size, shape, shadow and site as a guide for delineating land use classes. Differences in the appearance of objects in the image can be identified by arranging the appropriate band composition in the RGB channel (red, green, blue). Interpretation uses a 5-4-3 band combination for Landsat 5 while Landsat 8 and 9 use a 6-5-4 band combination.

The land cover classification map was created using 6 land cover classes from the results of the land cover data approach published by the Ministry of Environment and Forestry (KLHK, 2015). The distance factor from roads and rivers is a factor that is often used in considering factors driving land cover change (Wang & Maduako, 2018). In their research in Balikpapan, (Hapsary et al., 2021) found that areas that use rivers as a means of transportation have a large influence on rivers in the process of land cover change, this is different from research locations that do not use rivers as transportation such as research in Semarang (Rahmah et al., 2019) and Salatiga (Kusniawati et al., 2019) river factors do not have a strong influence on the land cover changes that occur. Distance from settlements is another important factor used in predicting land cover change. Several previous studies used distance from

settlements as a driving factor in this analysis. (Pérez-Vega et al., 2012) in his research in Western Mexico used these driving factors to predict changes in tropical deciduous forest cover. In this research, the author uses the distance factor from the settlement considering that the settlement is close to the THRBB area. Slope is an important factor in several forms of land cover change, in line with elevation which is taken into consideration in clearing residential, agricultural and other built-up land (Reilly et al. 2009). Data on roads, settlements and rivers obtained from the 2016 Rupa Bumi Indonesia (RBI) map was processed spatially by creating straight distances from objects using the Euclidean Distance tool in ArcGIS, distances are calculated based on Euclidean, namely the distance from one object to another. The unit used for distance is meters. Spatial data from all factors driving land cover change are converted into raster form which has the same spatial resolution, namely 30x30 meters per pixel (Liu et al., 2020).

Land Change Modeler (LCM) in Terrset is a modeling tool designed on an ANN basis that uses a Markov transition matrix by default (Hasan et al., 2020; Leta et al., 2021). The stages used are change analysis, land cover change modeling (Transition Potential), and land cover projections (Change Prediction). This modeling is quite accurate because of the ability to project dynamic conditions, measurable calibration and the ability to simulate several land covers at once (Regmi et al., 2020).

The validation test was carried out by comparing the 2023 land use prediction model with the actual 2023 land use. Validation is carried out with the validated instrument on the Change/Time series tab in Idrisi Terrset. The Kappa value or correspondence value between the number of columns and rows has a maximum value of 1.00. According to (Altman, 1991) (Kubangun, 2015) a Kappa value of 0.81–1.00 indicates very good suitability, a Kappa value of 0.61–0.80 is good, 0.41–0.60 is moderate, 0.21–0.40 is less than moderate, and values <0.21 are considered poor. The kappa value determines whether the simulation results can be said to be suitable in terms of area and spatial distribution or not. Once deemed appropriate, modeling to predict land use in 2033 can be carried out.

3. RESULT AND DISCUSSION

Land Cover Classification

The results of the interpretation of land use in the THRBB area in 2011, 2018 and 2023 produced six land use classes, namely: (1) primary forest, (2) secondary forest, (3) shrubs, (4) open land, (5) water bodies and (6) dry land farming (Figure 1). The land use classification accuracy test shows that the Overall Accuracy and Kappa Accuracy values of land use interpretation results in 2023 are 91% and 88% respectively. The accuracy value is included in the very good category (very good agreement) so that the results of land use classification can be continued for analysis of land use changes.

Table 1. Land Cover Area in 2011, 2018 and 2023

Land Use	Year of Change					
	2011		2018		2023	
	ha	%	ha	%	ha	%
Primary Forest	32.333	81,49	31.624	79,70	31.167	78,55
Secondary Forest	3.882	9,78	2.697	6,80	2.294	5,78
Shrubs	1.983	5,00	1.844	4,65	2.046	5,16
Open field	302	0,76	750	1,89	819	2,07
Body of Water	4	0,01	4	0,01	4	0,01
	1.174	2,96	2.760	6,96	3.348	8,44
Total	39.678	100	39.678	100	39.678	100

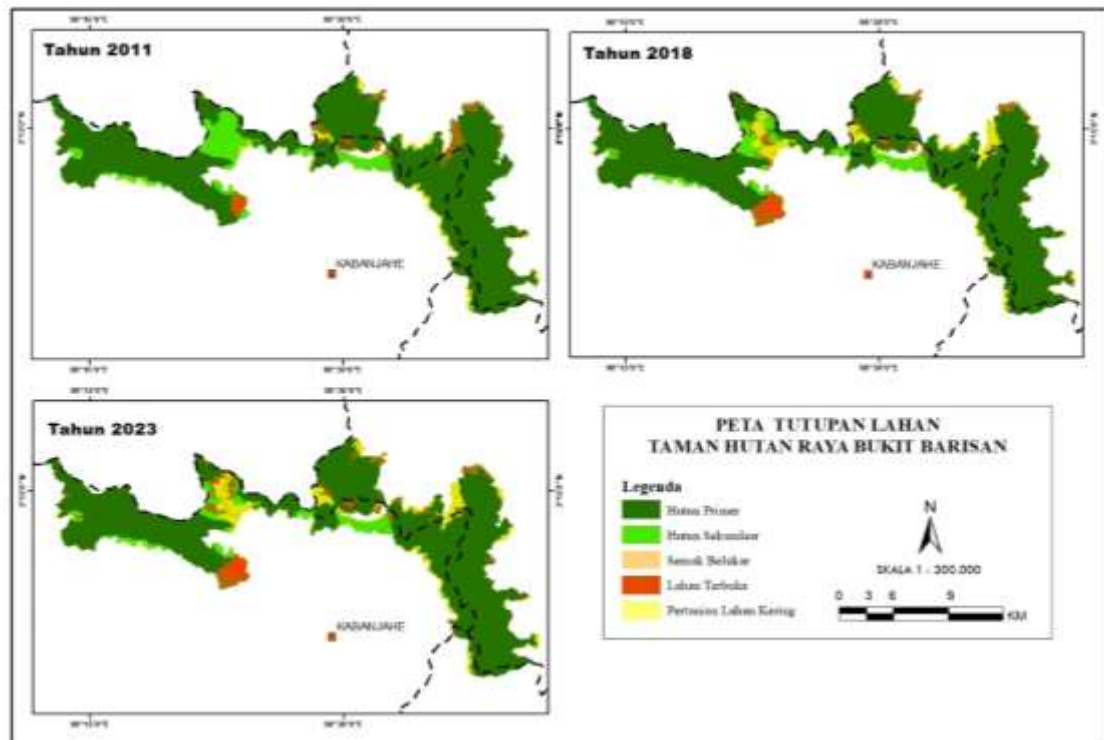


Figure 1. Land Cover Map Interpretation Results for 2011, 2018 and 2023 THRBB Area
Changes in Land Use 2011-2018

Changes in land use in the THRBB area for the 2011-2018 period as shown in Table 2 occurred on an area of 4,068 hectares (10.25%). In 2011, the forest class dominated overall land use followed by shrubs, while in 2018 the forest class experienced a reduction of 1,895 hectares (46.13%), while dry land agriculture increased by 1,586 (57.46%) this was because in 2011 to 2018 forest land experienced shrinkage due to illegal clearing of forest land for agricultural and farming activities.

Table 2. Extent of land use changes in 2011 and 2018 in the THRBB Area

Land use	Year				Change Area	
	2011		2018		ha	%
	ha	%	ha	%		
Primary forest	32.333	81,49	31.624	79,70	-710	2,19
Secondary forest	3.882	9,78	2.697	6,80	-1.185	43,94
Shrubs	1.983	5,00	1.844	4,65	-139	7,58
Open land	302	0,76	750	1,89	448	59,74
Water bodies	4	0,01	4	0,01	0	0
Dry land agriculture	1.174	2,96	2.760	6,96	1.586	57,46
Total	39.678	100	39.678	100	4.068	10,25

Table 3. Transition Matrix of Land Use Changes in 2011 and 2018 in the THRBB Area

Land use in 2011 (ha)	Land use in 2018 (ha)						Amount
	Hp	Hs	B	T	A	Pt	
Hp	31.624	9	446	223	0	32	32.333
Hs	0	2.674	347	112	0	748	3.882
B	0	11	1.025	136	0	811	1.983
T	0	0	26	276	0	0	302
A	0	0	0	0	4	0	4
Pt	0	3	0	2	0	1.169	1.174
Total	31.624	2.697	1.844	750	4	2.760	39.678

Land Cover Class: Hp = Primary forest, Hs = Secondary forest, B = Shrubs, T = Open land, A = Water bodies, Pt = Dry land agriculture

Factors Influencing Changes in Land Use

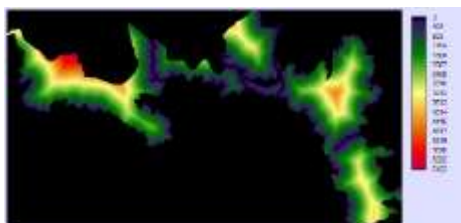
Land cover changes are influenced by driving factors. The magnitude of the influence of driving factors on land cover change has a value of 1 – 5, where the value 1 has the highest level of influence and the value 5 the lowest. The recapitulation carried out on data on the relationship between changes in land cover that occurred and the driving factors that influenced them, revealed that the driving factor of distance from the road had a dominant influence (1). Of the total of 13 sub-models formed, 7 sub-models of land cover changes were identified that occurred due to the influence of distance from the road. This is because areas with lots of roads make access in and out easy, in addition to the existence of the sub-district city center, infrastructure development occurs in the surrounding area. The closer an area is to roads and the city center, the more land use changes will occur (Kubangun et al., 2016). The magnitude of the driving factors that influence land cover changes in full can be seen in Table 4.

Table 4. Sub Models of Land Cover Change in THRBB

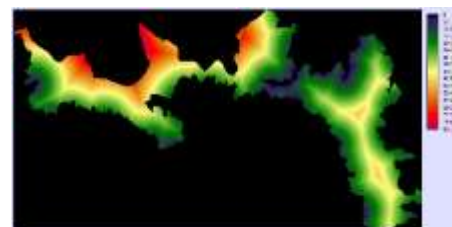
Land Cover Change Sub Model		Faktor Pendorong				
		Distance from Road (1)	Distance from Settlements(2)	Distance from Rive(3)	Height/ Elevation(4)	Slope (5)
Hp	Hs	1	2	3	4	5
	B	1	5	4	3	2
	T	5	2	1	4	3
	Pt	1	2	3	4	5
Hs	B	2	1	4	3	5
	T	2	3	1	4	5
	Pt	1	2	3	4	5
B	Hs	2	5	3	4	1
	T	2	3	1	5	4
	Pt	1	5	3	4	2
T	B	1	2	5	3	4
Pt	Hs	2	5	3	4	1
	T	1	2	3	4	5
A	-	-	-	-	-	-

Description: Hp (Primary Forest), Hs (Secondary Forest), B (Shrubs), T (Open Land), Pt (Dry land agriculture)

The slope factor is a factor that slightly influences changes in land use in terms of the physical condition of the land. Meanwhile, the elevation factor does not influence land cover changes that occur in the THRBB area. There are 9 values of 4 which indicate a weak connection between the factors driving elevation and the 6 types of land cover changes that occur (Table 4). No sub-model of land cover change has the greatest relationship (value 1) with the elevation factor. It is assumed that all land cover changes that occurred in the THRBB area during the research period were not greatly influenced by existing elevation differences.



(a)



(b)

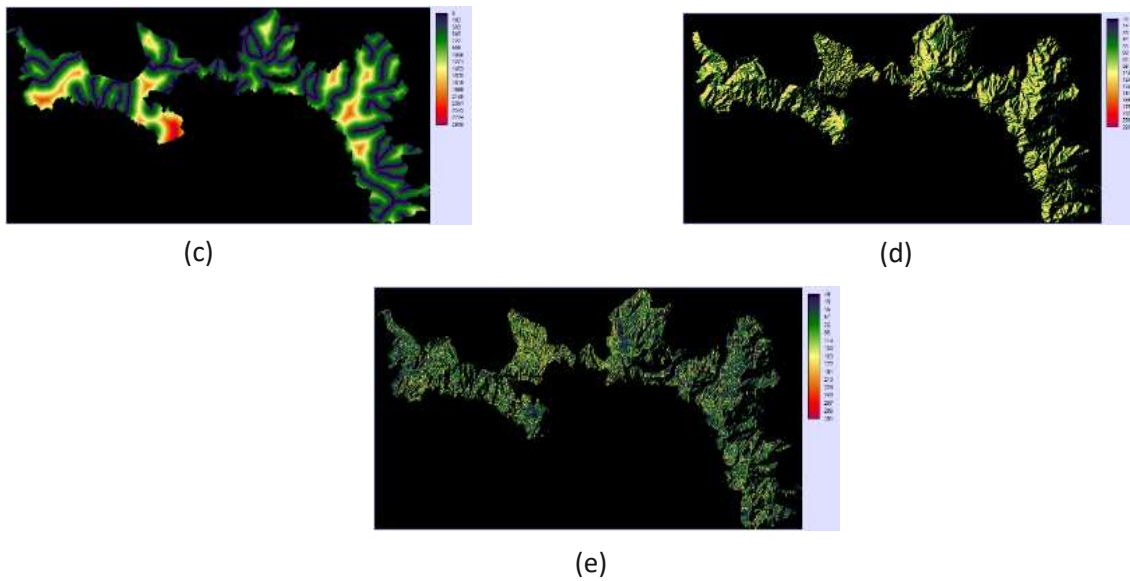


Figure 2. Driving factors

Information :

- a) Distance from road
- b) distance from settlements
- c) Distance from River
- d) Elevation
- e) Slope (Slope)

Based on the Cramer's V test, the five driving factors received their respective values as presented in Table 3.

Table 5. Cramer's V test

Variable	Cramer's V	P Value
Distance from road	0.2317	0.0000
Distance from settlements	0.1897	0.0000
Distance from the river	0.2288	0.0000
Elevation	0.0389	0.0000
Slope	0.0666	0.0000

The results of the Cramer's V analysis in the table above show that the V value range is 0.0389 to 0.2317, this shows that not all of the independent variables used affect the dependent variable. The distance variable from the road has the highest degree of relationship, with a V value of 0.2317, while the lowest degree of relationship is the elevation variable, which is 0.0389 and the slope variable is 0.0666, so that the driving factors of elevation and slope do not influence significantly.

Analysis of Land Cover Change Prediction Model

Predictions of land use changes are carried out using the Land Change Modeler (LCM) model with the Change Analysis instrument. Analysis of land use changes produces graphs of additions and reductions in land area. Based on the graph of area additions and reductions, it can be seen clearly that generally land use classes experience an increase in area as a result of conversion to other land uses and experience a reduction in area due to conversion to other land uses.

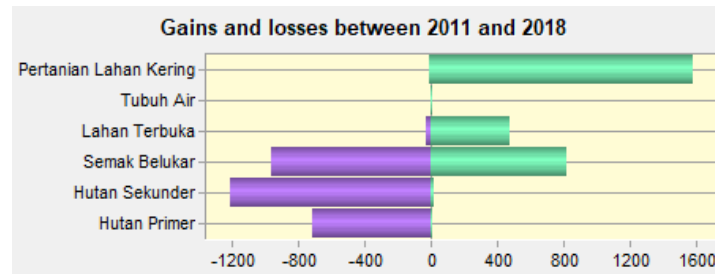


Figure 3. Graph of Additions and Reductions in Land Use Area in the THRBB Area in 2011 and 2018

Land uses that experienced increases and decreases in area were primary forest, secondary forest, shrubs, open land and dry land agriculture. Land uses that are converted to other land uses but do not receive an increase in area are primary forests. Land use of water bodies tends to be fixed and does not change. The potential for change (Transitions Potential) comes from the analysis of land use changes in the Change Analysis instrument into one sub-model and explores the influence of each variable that can be added. Starting by entering land use changes into one sub-model which is done on the Transition Sub-Models: Status tab. This tab contains all the transitions that occur between the 2 land uses. In this study, 13 land use transitions were used resulting from the analysis of land use changes in 2011-2018 which were then evaluated in LCM with several input variables in the form of distance from roads, distance from settlements, distance from rivers, elevation, slope slope and the likelihood of use transitions. land. This stage produces a map of potential land use change locations which are then entered into the land use change model.

Changes in land use during the period 2011 to 2018 have been calculated for potential transition changes, then modeling was carried out using the Markov Chain method in Terrset software to predict land cover in 2023 and produce a transition probability matrix which can be seen in Figure 4. The data in the figure shows the values in the transition probability matrix starting from 0 to 1. The transition probability with a value close to 1 in the diagonal matrix is a type of land cover that is very difficult to change to another type of land cover (Rimal et al., 2017). Probabilities that have a value close to 1 occur in the land cover types of primary forest, open land and dry land agriculture. The transition probability number in the diagonal matrix that is close to 0 indicates that the chance of changing to another land cover is increasing.

Transition Probabilities Grid						
Given :	Probability of changing to :					
	Hutan Primer	Hutan Sekur	Semak Beluk	Lahan Terbu	Tubuh Air	Pertanian La
Hutan Primer	0.9843	0.0002	0.0105	0.0049	0.0000	0.0001
Hutan Sekunder	0.0000	0.7678	0.0709	0.0212	0.0000	0.1401
Semak Belukar	0.0000	0.0044	0.6303	0.0529	0.0000	0.3125
Lahan Terbuka	0.0000	0.0000	0.0618	0.9382	0.0000	0.0000
Tubuh Air	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
Pertanian Lahan Kering	0.0000	0.0019	0.0000	0.0015	0.0000	0.9966

Figure 4. Transition Probability Matrix

The transition probability value outside the diagonal matrix shows the opportunity for one land cover to change to another land cover. The closer it is to 1, the greater the opportunity to change to another land cover. Shrubs are the type of land cover most likely to change. The possibility of changing scrubland to dry land farming is a change between classes that has the greatest opportunity value in the THRBB area.

Validation

The resulting model is validated first to see whether the model is good for predicting land cover in the coming year. Validation was carried out by comparing the predicted results of land cover in 2023 with the actual land cover map in 2023 obtained from the results of image interpretation processing.

Validation is carried out with the Validate instrument on the Change/Time series tab in Idrisi Terrset. Based on the Kappa Index of Agreement, the validation results show an Overall Kappa value: of 0.9552. The Kappa value from the validation results for this projection shows a "very good" suitability to the actual conditions of land cover in the actual year, so this model can then be used to predict the distribution pattern and extent of land use changes in 2033.



Figure 5. Map of Actual Land Use (a) and Predictions for 2023 (b)

Land Use Prediction Results for 2033

Land use changes in 2023 and 2033 are predicted as shown in Table 5.

Table 6. Changes in Land Use in the THRBB Area in 2023-2033 in Various Management Blocks

Blok THRBB	Penggunaan Lahan												Jumlah
	Hutan Primer		Hutan Sekunder		Semak belukar		Lahan Terbuka		Tubuh Air		Pertanian lahan kering		
	2023	2033	2023	2033	2023	2033	2023	2033	2023	2033	2023	2033	
Perlindungan	26,383	25,326	1,204	696	1,234	1,454	699	1,100	4	4	541	1,485	30,065
Pemanfaatan	3,268	3,344	837	441	405	556	49	158	-	-	407	467	4,967
Tradisional	1,321	1,302	137	77	163	266	-	31	-	-	626	571	2,246
Rehabilitasi	133	113	21	7	217	475	-	4	-	-	1,721	1,494	2,092
Khusus	61	70	41	16	26	27	70	81	-	-	53	57	251
Koleksi	-	-	55	-	-	55	1	1	-	-	-	-	56
Jumlah	31,166	30,156	2,295	1,236	2,045	2,833	819	1,374	4	4	3,348	4,074	39,678

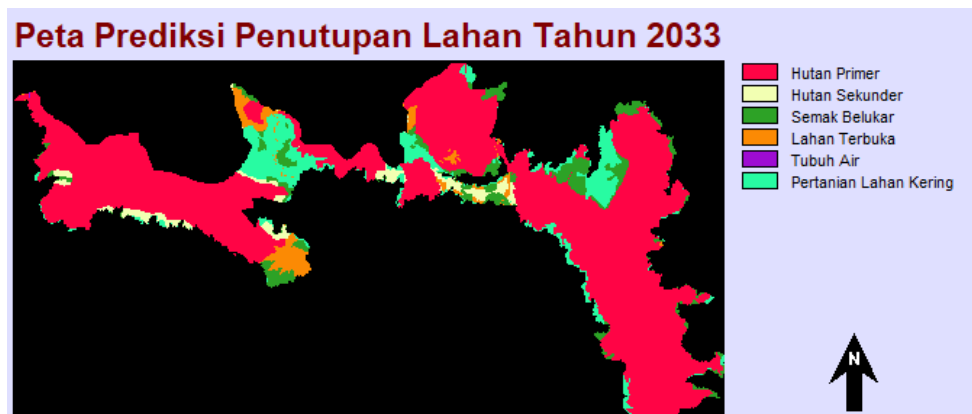


Figure 6. Predicted Land Use Map for 2033

Based on the table above, it can be seen that changes in land use in the THRBB area during the period 2023 and 2033 are predicted to occur in all blocks. However, changes in land use in protection blocks and rehabilitation blocks are not by their function. Especially the change of forests into agricultural

land, open land and bushes. Reducing forest area to other land uses in protection blocks, collection blocks and utilization blocks as well as rehabilitation blocks needs attention from THRBB Management so that the condition does not become further damaged. Efforts to secure the area and educate the community will restore the function of the forest area as a life support. Changes in land use in the THRBB area during the 2023-2033 period will occur in all blocks as follows:

- a. Protection Block. Land cover in the protection block in 2023 is dominated by Primary Forest covering an area of 26,383 Ha and will decrease in 2033 to 25,326 Ha. The same thing also happens to secondary forests which experience land changes from the previous area of 1,204 ha in 2023 to 696 ha in 2033. Much of the forest changes to open land and dry land farming in 2033 to 2 times that of 2023. It will be, However, the protection blocks in the THRBB area are relatively safe from changes in land use. This is because the topography of the area is mountainous and there is no road access to this protection block.
- b. Utilization Block. In 2023, the land cover that dominates the utilization blocks will be primary forest covering an area of 3,268 ha and secondary forest covering 837 ha. During the 2023-2033 period, there was an increase in the area of primary forest in the utilization block by 76 ha, while secondary forest experienced a 50% decrease from 2023-2033 to 441 ha. Changes in scrubland, open land and dry land farming have increased in the area. Overall, the utilization block only experienced minor discrepancies.
- c. Traditional blocks are areas where residents traditionally use non-timber forest products and use land for agriculture and this has been done for generations to meet the community's living needs, even before the THRBB was established. During the 2023-2033 period, land use that experienced a decline in traditional blocks was forest land at 79 ha and dry land agriculture at 55 ha. Land use that has increased includes 103 ha of bushes and 31 ha of open land.
- d. The rehabilitation block in the THRBB area is an important ecosystem and is a habitat for important species that have been degraded. In 2023, the land cover that dominates the rehabilitation zone will be primary forest 133 ha, secondary forest 21 ha, shrubs 217 ha and dry land agriculture 1,721 ha. And in 2033 the land cover will be 113 primary forests, secondary forests reduced to 7 ha, shrubs increased to 475 ha, open land 4 ha and dry land agriculture reduced to 1,494 ha.
- e. Special blocks in the THRBB area are areas where community groups already reside before being designated and there are facilities/infrastructure such as telecommunications towers, road networks, electricity networks and so on. In 2023, the land cover that dominates the special block will be primary forest 61 ha, secondary forest 41 ha, shrubs 27 ha, open land 70 ha and dry land agriculture 53 ha. During the 2023-2033 period, there will not be too many changes to this particular block.
- f. The collection block is located around the UPT THRBB office where there are several types of collection plants and natural tourism infrastructure. Changes in land use in the THRBB area collection block from secondary forest in 2023 to shrubs in 2033 covering an area of 55 ha and 1 ha remaining.

4. CONCLUSION

Based on the research results, several conclusions were obtained as follows: The largest change in use in the THRBB area for the 2011-2018 period occurred in secondary forest areas which experienced a reduction of 1,185 ha (43.94%), in primary forests of 710 ha (2.19%) and shrubs of 139 ha (7, 58%). The decrease in secondary forest area was followed by an increase in open land area by 59.74% and dry land agriculture by 57.46%. The largest pattern of land change in the THRBB area is from forest land to bushland, open land and dry land agriculture. Factors that influence changes in land use in the THRBB area, especially from forest to non-forest, are distance from roads, distance from settlements and distance from rivers, while the driving factors of elevation and slope do not have a significant effect. Land use change modeling using the Markov-Chain (MC) method with a kappa value accuracy of 95.52% can be used well, using T1 and T2 land cover data, as well as driving factors in the form of distance from roads, distance from settlements, distance from river, elevation and slope. The direction of land use policy in the THRBB area is a forest restoration policy in protection blocks, utilization blocks, rehabilitation blocks and collection blocks as well as increasing activities for protecting and securing the THRBB area together with the community through the Forestry Police Partner Community program as well as law enforcement

actions against perpetrators of encroachment and illegal logging. . This policy can reduce land use mismatches in each management block by 2033.

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