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The Impact of Road Opening on Vegetation Damage in the Bukit Barisan Forest Park Protected Forest in Indonesia

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Abstract: Road opening on the Medan-Berastagi alternative route will begin in 2023 with a track length of approximately 55.87 km. The aim of this study was to analyze land cover in forest areas and recommend plants around the opening of the Medan-Berastagi alternative route, Kutalimbaru District. Data processing and retrieval was carried out in November 2023-January 2024. Calculation of the 2018 Sentinel image classification accuracy shows a Kappa Accuracy value of 86.20%. For the accuracy of the 2021 Sentinel image classification, the Kappa Accuracy value was 88.60%, it has 5 land cover classes, namely forest, bush, mixed gardens, built-up land, and open land. Vegetation density in the Bukit Barisan Forest Park, Kutalimbaru District, Deli Serdang Regency is divided into 5 classes, namely non-vegetation, sparse, medium, dense, and very dense. All land cover classes have different densities. There are 10 recommended plants that can be planted around the path, namely: Guava (*Psidium guajava*), durian (*Durio zibethinus*), petai (*Parkia speciosa)*, avocado (*Persea americana*), longan (*Dimocarpus longan*), simartelu (*Schima wallichii*), rasamala (*Altingia excelsa*), meranti (*Shorea leprosula*), ingul (*Toona sureni*), meang (*Alseodaphne* sp).

Keywords: Alternative Route, Bukit Barisan Forest Park, Sentinel 2, Kutalimbaru

Introduction

All living things depend on forests, which are renewable natural resources that will always exist. A forest is described as an ecosystem unit in the form of an expanse of land containing biological natural resources dominated by trees in the fellowship of its natural environment, which is inseparable from one another, according to the Law of the Republic of Indonesia.

Basic Forestry Law No. 41 of 1999 concerning Forestry. Protected forests are forest areas that have the main function of regulating water systems as part of a life support system, minimizing seawater intrusion, managing erosion, reducing flooding, and maintaining soil fertility (Susilawati *et al*., 2020).

Bukit Barisan Forest Park is the third forest park in Indonesia which was established by the President with Presidential Decree No. 48 of 1988 dated November 19, 1988. The development of this forest park is an effort to conserve natural resources and environmental utilization through increasing the function and role of forests. Bukit Barisan Forest Park is a management unit that consists of protected forest areas and conservation areas with a total area of 51,600 hectares. Most of it is protected forest in the form of natural mountain forests established since the Dutch era, including Sibayak I and Simancik I Protected Forests, Sibayak II and Simancik II Protected Forests, and Sinabung Protected Forest. Other parts of the Bukit Barisan Forest Park consist of the Sibolangit Nature Reserve (CA)/Tourist Park (TW), South Langkat Wildlife Reserve (SM), Lau Debuk-debuk TW and Sibolangit Scout Campground (Anugerah *et al*., 2016).

The purpose of road supervision is to ensure orderly growth, control, and direction of roads. The opening of the road on the Medan-Berastagi alternative route began in 2023 with a track length of approximately 55.87 km, the opening of this alternative road is expected to be usable in early 2024 So that people can use this road to avoid congestion along the Medan-Berastagi main road. However, in the current situation, this alternative route

cannot be used by the public. The opening of the route that crosses the Bukit Barisan Forest Park has two villages in it, namely Tanduk Benua and Sembaikan II.

At this time the opening of the Medan-Berastagi alternative route is almost complete. In 2025, paving and bridge construction will begin as well as bridge widening. After everything is completed, the road can be used by the community. This alternative is expected to have great benefits to the tourism sector and the economy in the local area.

The condition of vegetated land cover can be known through the vegetation index method, namely the Normalized Difference Vegetation Index (NDVI) which assumes that different surfaces will reflect different types of light waves (Solihin *et al*., 2020). NDVI analysis can provide information on the level of vegetation density in each land cover class in the Bukit Barisan Forest Park of Kutalimbaru District, Deli Serdang Regency. According to Nurul *et al*. (2021), the NDVI method can be used to classify vegetation. The more vegetation, the more influence it will have on the reflection results. The objectives of this research are as follows:

1. Analyzing land cover in forest areas located in the Bukit Barisan Forest Park of Kutalimbaru District, Deli Serdang Regency
2. Plant recommendations around the opening of the Medan- Berastagi alternative route in Kutalimbaru Sub-district

Materials and Methods

The tools used in this research consist of data collection tools and data analysis tools. Field data collection tools are digital cameras, stationery, phi band, Avenza Map, and GPS (Global Positioning System). The data analysis tools used are computers/laptops and their attachments as data processing tools, Sentinel- 2 images and ArcGis 10.8 for spatial analysis, Microsoft Excel, and Microsoft Word software for data processing. The data needed in this study are listed in Table (1).

This research was conducted on the Medan-Berastagi alternative road in the area of the Kutalimbaru District Forest Park, can be seen in Fig. (1). Processing and data collection were carried out in January- May 2024.

Image Data Management

1. Image band merging: Sentinel satellite photos with many bands, each different from the other, can be downloaded from Sentinel 2 Image Preprocessing. As a result, to categorize land cover, the bands from the satellite photos are combined. The ArcGIS 10.8 program is used to merge the photo bands
2. Cropping the image: Image cropping is carried out to get a more focused view of the research location. By using district vector data from the Forest Area Stabilization Center, ArcGis 10.8 software is used to crop the image
3. Unsupervised classification: The computer can classify photos using unsupervised classification based on a user-defined number of classes. Establishing a baseline for guided categorization and accuracy testing is another benefit of unsupervised classification
4. Field survey: Based on the observations made with the unguided classification, a field survey was conducted to confirm the land cover conditions in the area. Furthermore, the type of land cover present there was noted. With the help of the Global Positioning System (GPS), checks were made. Purposive sampling was used to identify observation points. At least four observation locations are set for each land cover type. After visiting each site, important information was observed, recorded, and data collected. Information collected includes GPS coordinates for the field observation locations and images depicting the surrounding land cover

Table 1: Types of primary and secondary data required in the research

No.	Data name	Data type	Source	Time
1	Data Field (ground check)	Primary	GPS and camera	2024
2	Sentinel-2A Tile Number Imagery T47NND	Secondary	https://scihub.copernicus.eu/dhus/#/home	2018
3	Sentinel-2A Imagery Tile Number T47NND	Secondary	https://scihub.copernicus.eu/dhus/#/home	2023
4	Google Images Earth	Secondary	Google Earth	2024
5	Map Bukit Barisan Forest Park Area Boundary	Secondary	Forest Area Consolidation and Environmental Management Agency Region 1 Medan	SK 8808 2018 and SK 6609 2021
6	Administrative e-map	Secondary	Forest Area Consolidation and Environmental Management Agency Region 1	SK 8808 2018 and SK 6609 2021

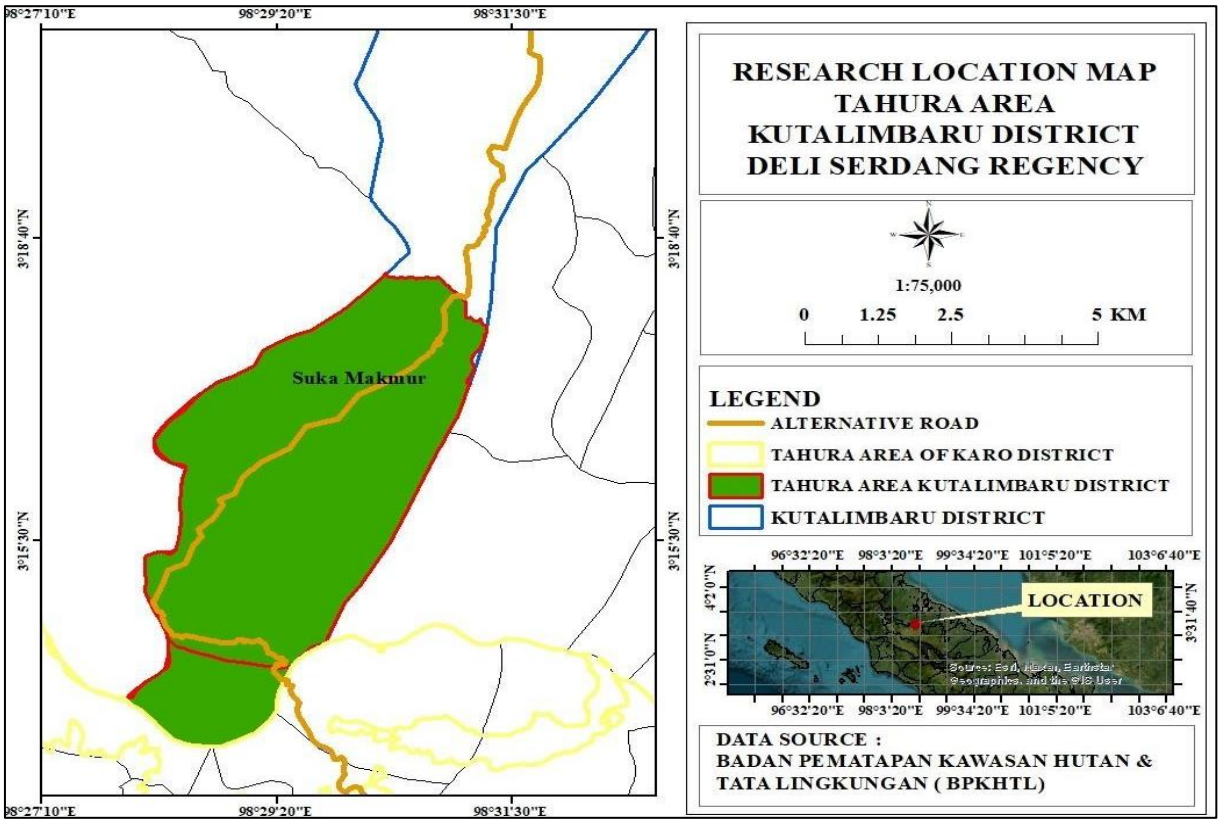


Fig. 1: Map of the research location

5. Supervised classification: Guided classification is done by creating polygon samples or land cover class areas based on field survey findings. The method used is the maximum likelihood method found in ArcGis 10.8 software.
6. Accuracy calculation: Image classification By comparing the image classification results with the collected field data, we can determine the accuracy of the process. The stage that determines whether or not the image categorization results match the field conditions is the accuracy calculation. The contingency matrix, also known as the error matrix or confusion matrix, is a square matrix that includes the number of pixels in the classification and is commonly used to analyze accuracy. The following formula can be used to mathematically calculate accuracy:

$$KappaAccuracy = \frac{N \sum_{i=1}^{n} Xkk - \sum_{i=1}^{n} Xkt \;\; Xtk}{N2 - \sum_{i=1}^{n} Xkt \;\; Xtk} \times 100\%$$

Remark:
N: Number of all pixels used for observation
N: Number of rows in the error matrix (equal to the number of classes)
Xkk: Number of correct pixels (diagonal number in the matrix)
Xkt: Number in row total
Xtk: Number in column total

7. Overlay: After obtaining the results of the analysis in the form of land cover maps in 2018 and 2023, the next stage is map overlay. The overlay is the merging of two land cover maps with different year periods to produce a land cover change map between the two years.
8. Normalized difference vegetation index analysis: Normalized Difference Vegetation Index (NDVI) is the greenness of plants, as an indication of the presence or state of vegetation. NDVI has a range of values from -1 to +1, where a minus (-) value indicates a lower vegetation density in an area and a plus (+) value indicates a higher vegetation density in an area

The classification of NDVI values into vegetation density classes is stated in several previous studies, namely Bolton *et al*. (2020); Zaitunah *et al.* (2019), the classification can be seen in Tables (2-3).

Table 2: Object division based on NDVI value according to Bolton *et al*. (2020)

No	Land cover type	NDVI value
1.	Water	<0
2.	Vacant land	0-0.1
3.	Medium vegetation	0.2-0.3
4.	Thick vegetation	0.4-0.8

Table 3: NDVI value levels and its classification according to Zaitunah *et al*. (2019)

No	Land cover type/classification	NDVI value	NDVI range
1.	Non-vegetation	<0	<0
2	Rare/sparse density	0-0.18	0.1-0.2
3	Medium density	0.18-0.36	0.2-0.4
4	Dense density	0.36-0.54	0.4-0.5
5	Very dense	>0.54	>0.5

Based on several references above, the classification of vegetation density classes based on NDVI values is divided into 5 classes, namely non-vegetation density classes, sparse density classes, medium density classes, dense density classes, and very dense density classes.

9. Vegetation density analysis on land cover: To be able to see the density of vegetation that occurs in each land cover class, the vegetation density map of 2023 was analyzed. So that the results of the vegetation density map on land cover in 2023 are obtained
10. Vegetation observation: To collect data on vegetation types in the field can be done in two ways, namely:

- Directly

A direct observation approach, often known as the descriptive survey method, was used in this study. Semi-structured data collection was conducted using the results of interviews with respondents. Descriptive samples were collected to identify plant species found in the Bukit Barisan Forest Park. A descriptive analysis was conducted on the interview results (Larasati *et al*., 2019). Statistics known as "descriptive analysis" are used to assess data by characterizing the data obtained as it is, without trying to draw broad conclusions or generalizations (Colwell and Grimes, 1984).

Without the need for measurements, inventory techniques can be completed quickly and simply with the aim of morphologically identifying species. One way to complete this inventory is by exploring the area. Species found can either be recorded immediately for those that have been identified by species name, or taken into captivity with the help of an identifiable herbarium or plant atlas book. This approach does not provide a complete and comprehensive picture of how each species has mastered its environment as it is used with a limited purpose or for a first introduction. As a result, this approach is only used for observational studies or preliminary research to help future research stabilize (Ludwig and Reynolds, 2018).

- Indirect

The indirect way is done by looking at and reading journals related to plants that can grow in the area. Using literature about plants that can grow in the forest area of Bukit Barisan Forest Park, Kutalimbaru District (Clerici *et al*., 2017). The results obtained were then analyzed using descriptive analysis.

Results and Discussion

Land Cover Analysis of the Bukit Barisan Forest Park in Kutalimbaru District, Deli Serdang Regency 2018 - 2023

Based on research in the area of the Bukit Barisan Forest Park, Kutalimbaru District, Deli Serdang Regency, 5 land cover classes were obtained, namely: Forest, shrubs, built-up land, mixed gardens, and open land. The results of the Sentinel image classification accuracy calculation in 2018 showed a Kappa Accuracy value of 86.20%. For the classification accuracy of Sentinel imagery in 2021, the Kappa Accuracy value is 88.60%. The results of sampling training areas in the land cover class in Arcgis 10.8 are validated using ground checks directly to the field with the help of high-resolution interpretation on Google Earth and using Avenza maps to determine ground checkpoints in the field. The number of samples from the image classification results on land cover is 146 samples.

The interpretation of the image categorization results meets the minimum standards set by the US Geological Survey (USGS) based on this accuracy figure. The USGS criteria state that the interpretation of land use or land cover should have an accuracy of at least 85%. Therefore, it can be said that the land cover map produced from the Sentinel image interpretation in this study contains data with a fairly good level of accuracy. You can use this reliable interpretation data for additional analysis.

Based on the results of the analysis, the total area of the Bukit Barisan Forest Park, Kutalimbaru District, Deli Serdang Regency in 2023 is 2,960.26 Ha. Land cover classification using Sentinel 2 imagery in 2018 shows that the largest land cover is forest and the smallest land cover is open land. Classification of Sentinel 2 imagery in 2023 shows that the largest land cover is forest and the smallest land cover is open land. Data on the area of land cover classes in the Bukit Barisan Forest Park of Kutalimbaru District, Deli Serdang Regency in 2018 can be seen in Table (4).

Based on Table (4), it can be seen that in 2018 the largest land cover was in forests with an area of 2,876.3 Ha or 96% and the smallest land cover was open land with an area of 0.77 Ha or 0.02%. The next largest land cover is bushland with an area of 74.71 Ha or 2.49%, followed by mixed gardens with an area of 36.62 Ha or 1.22%, and built-up land with an area of 7.56 Ha or 0.25%.

The data on the land area of the Bukit Barisan Forest Park in Kutalimbaru District, Deli Serdang Regency in 2023 can be seen in Table (5).

Table 4: Land cover area of Bukit Barisan Forest Park in Kutalimbaru Sub-district, Deli Serdang Regency in 2018

No.	Land cover	Area (Ha)	Area (%)
1	Forest	2,876.3	96.00
2	Bushes	74.71	2.49
3	Mixed garden	36.62	1.22
4	Built-up Land	7.56	0.25
5	Open Land	0.77	0.02
	Total:	2,995.96	100.00

Table 5: Land cover area of Bukit Barisan Forest Park in Kutalimbaru District, Deli Serdang Regency in 2023

No.	Land Cover	Area (Ha)	Area (%)
1	Forest	2,122.88	71.71
2	Bushes	345.21	11.66
3	Mixed garden	234.64	7.92
4	Built-up Land	155.73	5.26
5	Open Land	101.80	3.43
	Total	2,960.26	100.00

Based on Table (5) the results of the classification of land cover in the Bukit Barisan Forest Park, Kutalimbaru sub-district, Deli Serdang Regency shows that the dominating land cover is forest with an area of 2,122.88 Ha or around 71.71% after that there are shrubs with an area of 345.21 Ha or around 11.66% and mixed gardens covering 234.64 Ha or around 7.92%. Meanwhile, the open land that has been cleared in the Bukit Barisan Forest Park has an area of 101.8 Ha or around 3.43% and the built-up land has an area of 155.73 Ha or around 5.26%.

In Fig. (2) (left) it can be seen that the land cover map of Bukit Barisan Forest Park, Kutalimbaru sub-district in 2018 is dominated by the dark green color of the forest and the red color of very minimal open land, in the yellow color of mixed gardens in the light green color of shrubs, in the brown color of built-up land. The following is a map of the Land Cover of the Bukit Barisan Forest Park in Kutalimbaru District in 2023.

In Fig. (2) (right) it can be seen that the land cover map above is dominated by dark green with a description of the forest in the Bukit Barisan Forest Park, as for the land built up in the brown Bukit Barisan Forest Park and the red open land which causes the forest area to decrease. An increase in population leads to an increase in settlements in a place which causes this to increase the threat to forest ecosystems ranging from animals to flora in the forest area.

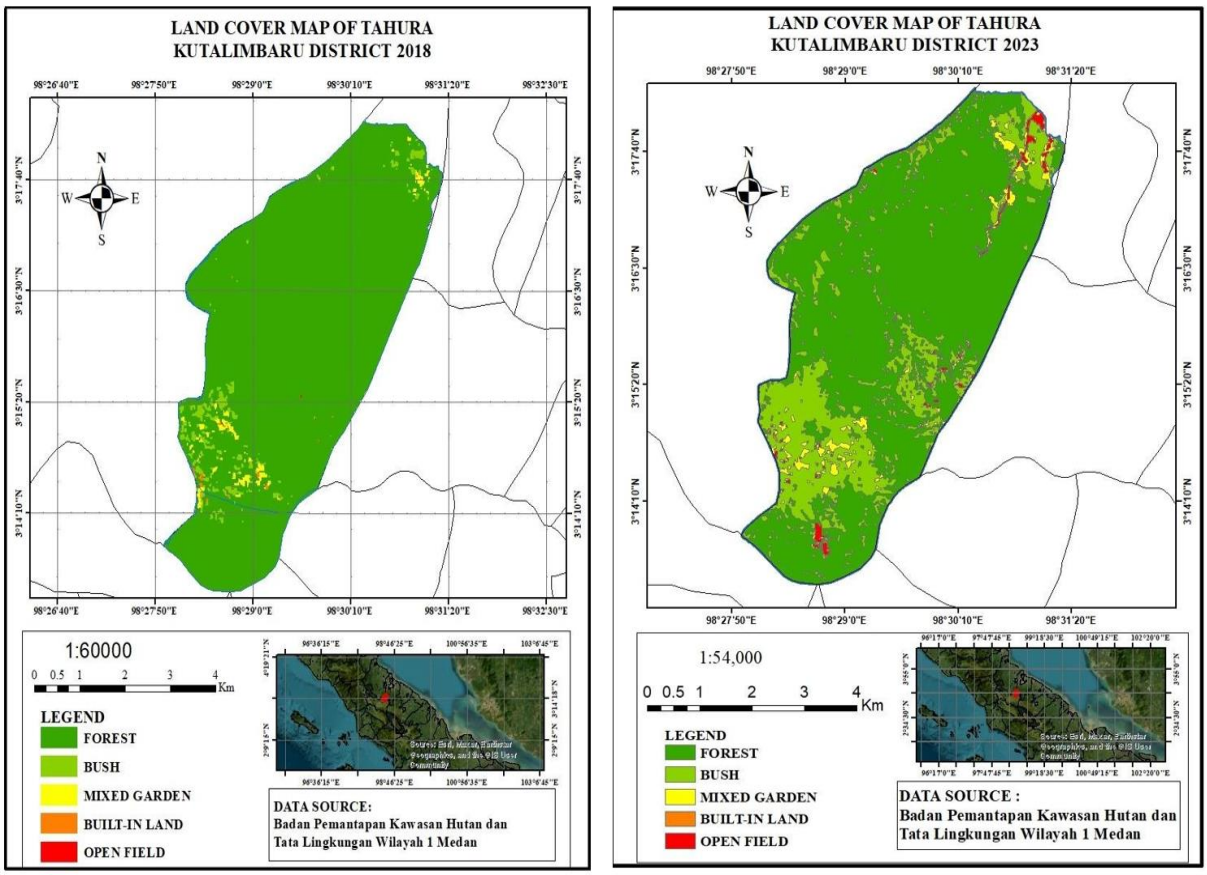


Fig. 2: Land cover map of Bukit Barisan Forest Park, Kutalimbaru District in 2018 and 2023

Visual Appearance of Land Cover Classes in RGB 4-3-2 Composite Bands

Analysis of the appearance of land cover classes in Sentinel 2 imagery was carried out using a combination of Red, Green, and Blue (RGB) bands 4-3-2 for all land cover classes. Bands 4, 3, and 2 were chosen because they are sensitive and have high reflectance values for vegetation. The following are the characteristics of each land cover visually in the RGB 4-3-2 composite band. This is also in accordance with the statement of Opa (2010), which is a band that is sensitive to the reflectance value of each vegetated land cover. The following visual display of sentinel 2 imagery can be seen in Table (6).

In Table (6) the Bukit Barisan Forest Park in Kutalimbaru Sub-district, Deli Serdang Regency, has a land cover class that includes various types of plants. Annuals include corn (Zea mays), banana (Musa paradisiaca), cassava (Manihot esculenta), and pineapple (Ananas comosus). Some MPTS plants are planted in mixed gardens such as coffee (Coffea arabica), guava (Psidium guajava), Rambutan (Nephelium lappaceum), and avocado (Persea americana). Bukit Barisan Forest Park also has a dominant forest land cover, with tree species simertelu (Schima wallichii), tusam (Pinus merkusii), and ingul (Toona sureni).

Table 6: Characteristics of land cover in the Bukit Barisan Forest Park, Kutalimbaru District

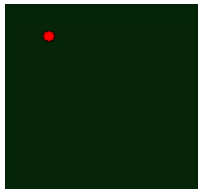
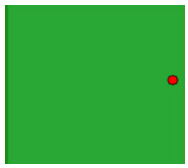
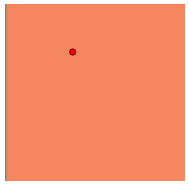
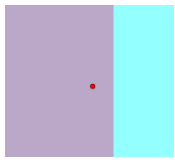
No	Land cover class	Sentinel 2 imagery	Citra Google Earth	Field photograph	Remark
1	Forest				
2	Bushes				
3	Mixed garden				
4	Built up land				
5	Open land				

Table 7: Kappa accuracy test results

Land cover	Forest	Open land	Built-up land	Mixed garden	Bushes	Total	PA %
Forest	37	1	0	0	1	39	0.25
Open Land	0	25	2	0	2	29	0.17
Built-up Land	0	2	12	0	0	14	0.08
Mixed Garden	0	1	0	24	0	25	0.16
Bushes	1	0	1	2	35	39	0.24
Total	38	29	15	26	38	146	0.91
UA	1.02	0.86	0.81	0.92	1.08		133.00
Overall Accusation							91.09
Kappa Accusation							88.60

Table 8: Area and percentage of land cover change in the Bukit Barisan Forest Park of Kutalimbaru District, Deli Serdang Regency

No	Land cover	Area in 2018		Area in 2023		Year Change 2018-2023	
		Ha	%	Ha	%	Ha	%
1	Forest	2,876.3	96.00	2,122.88	71.71	753.42	24.29
2	Bushes	74.71	2.49	345.21	11.66	270.5	9.16
3	Mixed garden	36.62	1.22	234.64	7.92	198.02	6.70
4	Built-up Land	7.56	0.25	155.73	5.26	148.17	5.00
5	Open Land	0.77	0.025	101.8	3.43	101.03	3.41
	Total	2,995.96	100	2,960.26	100		

The accuracy test was conducted to determine the percentage level of accuracy of a study using the kappa accuracy and overall accuracy tests. If the mapping has been done correctly and meets the accuracy requirements for using satellite imagery, which is more than 85%, then the level of accuracy in classifying land cover is considered good and practical. In the Bukit Barisan Forest Park of Kutalimbaru District, Deli Serdang Regency, the total kappa accuracy value obtained in the land cover classification in 2023 was 88.60, and the total accuracy value obtained was 91.09%. In the Bukit Barisan Forest Park of Kutalimbaru District, Deli Serdang Regency, the amount of kappa accuracy value obtained in the land cover classification in 2023 is 88.60, and the total accuracy value obtained is 91.09%.

Land Cover Change in the Bukit Barisan Forest Park Area of Kutalimbaru Subdistrict Between 2018 and 2023

Based on Table (7), the Bukit Barisan Forest Park of Kutalimbaru District, Deli Serdang Regency has 5 types of land cover with different proportions of area in the two-year periods. The largest increase in the area occurred in shrubland, with a change of 270.5 Ha or 9.16%. Based on ground check data in the field, this is due to the fact that at the time of taking images of some land such as in newly planted mixed gardens, there are shrubs or grass that are almost the same height as the height of the plants. The next increase in land cover occurred in mixed gardens with a change of 198.02 Ha or 6.70%, built-up land with a change of 148.17 Ha or 0.80%, and open land with a change of 101.03 or 3.41%. At the same time, forests decreased by 753.42 Ha or 24.29%. Changes in land resource utilization and the occurrence of shifts in certain functions to other forms of functions of both productive and unproductive land (Umar *et al*., 2019).

Based on Tabel (8), the largest land cover changes are shown in the shrub land cover class, changes in the shrub class increased the most, reaching 270.5 Ha. The second largest change occurred in mixed gardens, based on field conditions and the results of the analysis obtained, in 2018 The Bukit Barisan Forest Park was dominated by forest plants, and in 2023 the Bukit Barisan Forest Park was dominated by open land that had been overgrown with bushes. From the area of the Bukit Barisan Forest Park, changes in forest and bushes have become very extensive, this is in accordance with the statement of Donya *et al*. (2020) who stated that of the diversity in the forest, undergrowth has a diverse whose distribution can be random. Other factors, differences in height, temperature, and humidity will support the existence of undergrowth vegetation.

Based on Tabel (9), in 2016 the settlement area amounted to 7.56 Ha or 0.25%, then increased to 155.73 Ha or 5.26% in 2021. The Bukit Barisan Forest Park has settlements in the Kutalimbaru sub-district area, specifically Lau Gedang village. The existence of increasing settlements makes the increase in built-up land in the area, this is one of the factors for opening roads in forest areas, apart from being an alternative route to the Berastagi field, the opening of this alternative route is also made as a means of transportation for the community in Lau Gedang village. This is in accordance with Sarihi *et al*. (2020) which states that increasing population, employment, easy access, and life support facilities and government policies are factors that cause land cover change. However, the opening of this alternative route has an impact on damage to the forest ecosystem around the Bukit Barisan Forest Park.

Table 9: Land cover change matrix sentinel 2 images 2018 and 2023

	2023						
	Land of class cover	Forest	Bushes	Mixed garden	Built-up Land	Open land	Total
2018	Forest	2,200.46	562.42	76.17	5.08	29.94	2,874.07
	Bushes	0.27	64.05	6.42	0.34	3.55	74.063
	Mixed garden	0.32	27.71	7.1	0.24	1.29	36.66
	Built-up land	0.046	4.99	1.7	0.05	0.76	7.54
	Open land	0	0	0.48	0.18	0.1	0.76
Total		2,201.096	659.17	91.87	5.89	35.64	2,993.666

The opening of paths in forest areas into open land can be seen in the table that open land increased to 101.03 Ha. This is due to forest encroachment around the road opening carried out by the community, most of the communities around the forest area earn a living as farmers. In this case, the forest cleared for road opening was utilized by the community on the side of the road to make a mixed garden. The community still considers the protected forest in the Bukit Barisan Forest Park as a legacy of the ancestors, Ritonga (2014) states that the community still lacks education about the importance of protecting the forest, so there are still many people who consider the forest private property and manage the forest carelessly.

The need for land in farming as well as development from both the community and the government requires cooperation in improving the economy (Umar *et al*., 2019). In an effort to continue life, humans are very dependent on land as a home for protection and need land as a place to produce food. Nature has provided extensive land for us to carry out various activities, but there are still some humans who do not know how to manage land properly. As a result, various land damages. It is undeniable that humans are very much tied to land use. The existence of mixed gardens planted with forestry-type mixed gardens of MPTS (multi-purpose tree species) such as mango, and durian.

The Bukit Barisan Forest Park in Kutalimbaru Subdistrict is seen to be decreasing over a period of five years in 2018 the forest area was 2,876.3 Ha in 2023 to 2,122.88 Ha, and the change in area to the forest class is 753.42 Ha. This decline has many factors, one of which is road clearing, and land clearing which is the biggest factor in reducing the forest area in the Bukit Barisan Forest Park. This is in accordance with the statement of Fariz *et al*. (2023) which states that the North Sumatra region is an area that is visited and famous for natural tourism, especially in the Bukit Barisan Forest Park, so there is a lot of land clearing to be used as tourism by the community.

Vegetation Density Analysis of Land Cover Classes in 2023

Based on the analysis of the Normalized Difference Vegetation Index (NDVI) in 2023, the NDVI value is obtained from 0.00-0.71. The distribution area of vegetation density classes in the Bukit Barisan Forest Park of the Kutalimbaru sub-district can be seen in Table (10) and Fig. (3).

From Table (10) and Fig. (3) it can be seen that the distribution of vegetation density in the Bukit Barisan Forest Park in Kutalimbaru sub-district, Deli Serdang Regency in 2023 is divided into 5 classes. The widest vegetation density class is in the very dense vegetation density class which has an area of 1,424.51 Ha or 47.56%. Of the total area of the Bukit Barisan Forest Park in Kutalimbaru sub-district, Deli Serdang Regency, Based on conditions in the field there are several forest areas dominated by simertelu (*Schima wallichii)* and tusam *(Pinus merkusii)*, ingul *(Toona sureni)*.

In the vegetation density class, the non-vegetation class is 4.23 hectares or 0.14%. The image used in this study was on July 15, 2023, when the opening of the path had not been completed so the highest land cover is in the medium class. The opening of the alternative route Medan-Berastagi via Kutalimbaru is as far as 55.7 km. The opening of this route caused some forest area vegetation to disappear due to logging. The tight canopy condition makes the land cover open land. The medium-density class has an area of 182.98 Ha or 6.11%. The meeting density class has an area of 1370.20 Ha or 45.75%. The sparse density class has an area of 13.01 Ha or 0.43%.

In Fig. (3) it can be seen that the very tight class is dark green, the tight class is light green, the medium class is yellow, the sparse class is brown, and the non-vegetation class is red. The dominating class is the very dense dark green class and the last class is the red non-vegetation class.

Plant Recommendations in the Bukit Barisan Forest Park of Kutalimbaru District, Deli Serdang Regency

In the research, recommendations were made to reclaim forest areas that had been cleared. There are also recommendations based on existing conditions, which can be seen in Fig. (4). Marked with a blue line is a road shoulder area that needs to be planted. In this forest area, there is also a village, namely Seimbaiken II village, this is what strengthens the clearing of forest areas to assist in the activities of the existing village community and it is hoped that later with the opening of this road it can improve the economy of the surrounding community. The recipient of this road opening is Jaranguda Berastagi village.

Table 10: Distribution of vegetation classes in the Bukit Barisan forest park of Kutalimbaru district, deli Serdang regency

No	NDVI	Vegetation density class	Area (Ha)	Area (%)
1	<0	Non-vegetation	4.23	0.14
2	0-1	Rare	13.01	0.43
3	0.2-0.4	Medium	182.98	6.11
4	0.4-0.5	Dense	1,370.20	45.75
5	>0.5	Very dense	1,424.51	47.56
	Total		2,994.95	100

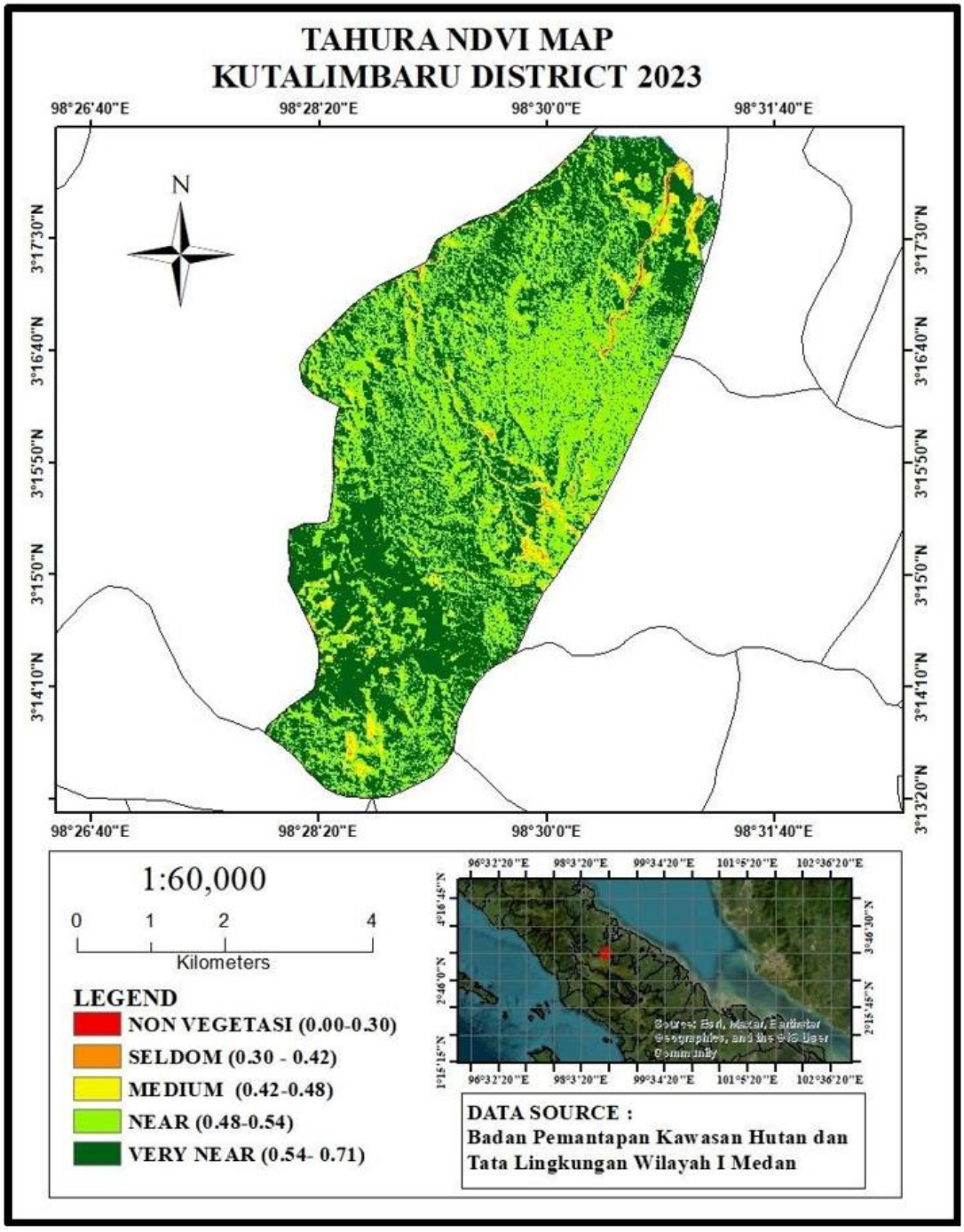


Fig. 3: NDVI map of the Bukit Barisan Forest Park, Kutalimbaru sub-district in 2023

Recommendations need to be made so that open forest areas on the shoulder of the road can be replanted to minimize the occurrence of natural disasters. With the appropriate planting distance so that plants can grow well, according to Lindgren *et al*. (1985) which states that the determination of a planting distance of 3×3 meters produces optimal plant growth. This spacing is key in increasing crop yields. If the spacing is too tight, it will increase the rate of evaporation of water from the soil, disrupting the process of plant growth and development. Conversely, if the spacing is too tight, there will be competition between plants to obtain sufficient water, nutrients, and sunlight. Therefore, it is important to adjust the planting distance so that plants can grow optimally and produce maximum yields. So that it can be made according to the formula of seedling needs equal to the land area divided by the planting distance.

In this research, the road opening that uses the Bukit Barisan Forest Park in Kutalimbaru District is 16.19 km long. The existence of this road opening makes the density situation in the forest area open. This research will recommend plant species for forest areas that are open due to road opening. The following is a picture of the area that needs to be planted. It can be seen in the picture marked in blue is the land that needs to be planted along 12.15 km in the Bukit Barisan Forest Park.

Based on Fig. (4) it can be seen that on some of the routes, there are planting areas, the planting area starts from the Bukit Barisan Forest Park boundary of Kutalimbaru sub-district to Sembaikan II village. According to Tsujino *et al*. (2016), the minimum recommended distance for planting plants is 9 m from the edge of the pavement in areas outside urban areas. This is done to consider the growth of plant roots so as not to interfere with the structure of the road pavement. Therefore, in plant arrangements, it is recommended to maintain a planting distance of 10 m from the edge of the pavement to ensure the safety and welfare of both plants and road infrastructure. Therefore, in the arrangement of plants, it is recommended to maintain a planting distance of 10 m from the edge of the pavement to ensure the safety and well-being of both the plants and the road infrastructure.

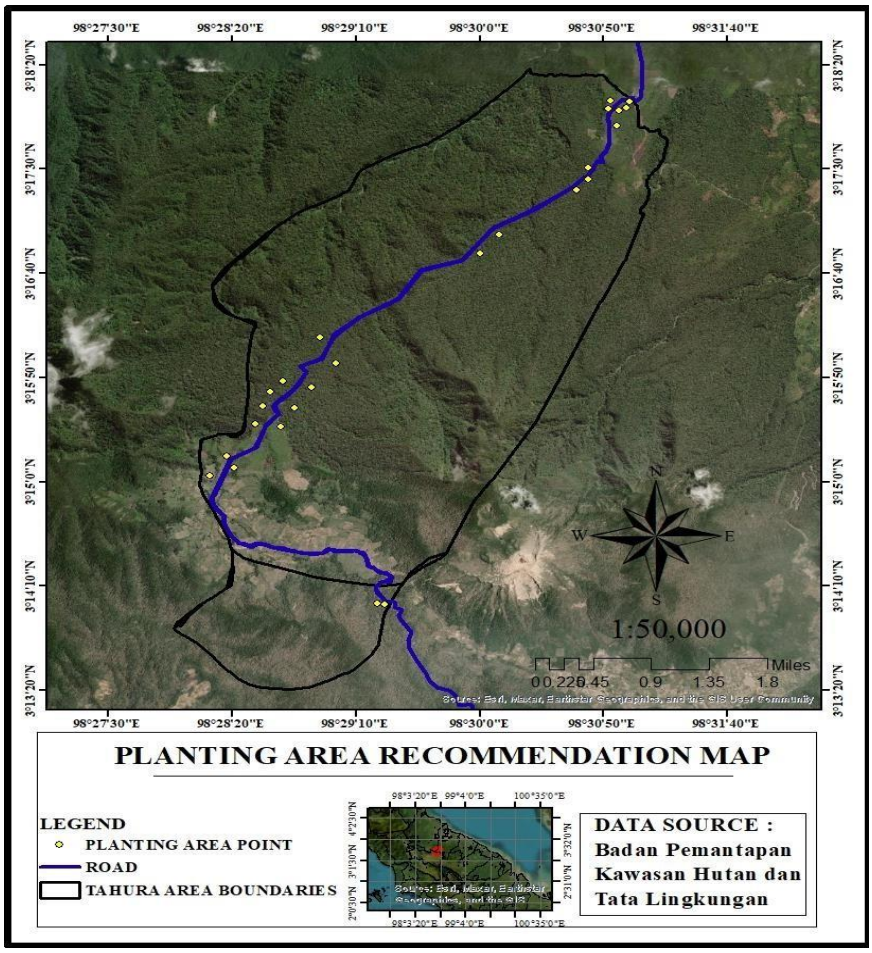


Fig. 4: Map of planting area recommendations on the Medan Berastagi alternative route, Kutalimbaru district

The opening of this alternative road, the opening of this road body with a width of approximately 9 m and coupled with right and left shoulders with a width of half a meter. This classification sets minimum standards to ensure the safety of land transportation using roads and to ensure transportation infrastructure meets the requirements set out in the law, in accordance with Law No. 38/2004 on Roads, PP No. 34/2006 on Roads, Law No. 14/1993 on Road Traffic and Transportation, and PP No. 43/1993 on Infrastructure and Road Traffic and Transportation. One of the minimum standards set is a minimum width for collector roads of 2.5 m with a minimum length of 120 m. This is important to ensure that these roads can meet the needs of vehicles and road users safely and efficiently. As for some plant species in the Bukit Barisan Forest Park of Kutalimbaru District, Deli Serdang Regency as follows.

Based on Table (11) the data was obtained based on direct methods with descriptive surveys and indirect with simple interviews with residents around the Bukit Barisan Forest Park. Table (11) shows that woody plants are found with a total of 30 species as well as 8 types of MPTS plants and 4 types of NTFP plants. In the Bukit Barisan Forest Park, there are so many diverse types of plants that this is a pride of the surrounding community and government to have such a rich nature. According to Erwin *et al*. (2017), Bukit Barisan Grand Forest Park is the pride of the people of North Sumatra, with the aim of protecting natural resources, encouraging environmental utilization, and increasing the role of forests in supporting human life. The following are plant recommendations for the Bukit Barisan Forest Park of Kutalimbaru District, Deli Serdang Regency.

Based on Table (12), plants can be planted around the Medan - Berastagi alternative road via Kutalimbaru Sub-district, Deli Serdang Regency. In selecting plant species for planting, it is important to consider the various benefits that these plants can provide. In addition to aesthetic benefits, it is also necessary to consider the benefits in terms of ecology, safety, and comfort. When using plant organs, it is important to consider their stage of development as well as the characteristics of stems, leaves, fruits, flowers, and roots. By choosing native or exotic species that can only grow and develop specifically in a place, street tree planting can also serve as a mascot or characteristic of an area (Viswanath *et al*., 2020).

Table 11: Plant species in the Bukit Barisan Forest Park

No	Scientific Name	Local Name	Family	Shape of plant	Remark
1	*Pinus merkusii*	Tusam	Pinaceae	Woody plant	*
2	*Schima wallichii*	Simartelu	Theaceae	Woody plant	**
3	*Altingia excelsa*	Rasamala	Alseodaphne	Woody plant	*
4	*Alseodaphne*	Meang	Lauraceae	Woody plant	*
5	*Toona sureni*	Ingul	Meliaceae	Woody plant	*
6	*Shorea*	Meranti	Dipterocarpaceae	Woody plant	**
7	*Pinus caribaea*	Pinus karabia	Pinaceae	Woody plant	**
8	*Cupresusv*	Cemara	Casuarinaceae	Woody plant	**
9	*Agathis* sp	Damar	Araucariaceae	Woody plant	*
10	*Ficus* spp	Rube samba	Moraceae	Woody plant	**
11	*Ilex pleurobrachia*	Monis-monis	Aquifoliaceae	Woody plant	**
12	*Eucalyptus*	Ekaliptu	Myrtaceae	Woody plant	**
13	*Saurania* spp	Pirdot	Actinidiaceae	Woody plant	*
14	*Erythrina variegata*	Dadap	Fabaceae	Woody plant	*
15	*Styrax* sp	Ndelip putih	Styracaceae	Woody plant	*
16	*Styrax* sp	Ndelip merah	Styracaceae	Woody plant	*
17	*Actinodaphne*	Sengketen	Lauraceae	Woody plant	*
18	*Evodia*	Telubulung	Rutaceae	Woody plant	*
20	*Diplopterys cabrerana*	Tualah tualah	Malpighiaceae	Woody plant	*
21	*Proteaceae*	Macadamia	Macadamia	Woody plant	*
22	*Calliandra calothyrsus*	Kaliandra	Haematocephala	Woody plant	*
23	*Shorea bracteolata* dyer	Beras- beras	Dipterocarpaceae	Woody plant	*
24	*Ficus benjamina*	beringin	Moraceae Genus	Woody plant	**
25	*Melastoma* sp	Senduduk	Melastomataceae	Woody plant	*
26	*Manglietia glauca*	Jatuh	Magnoliaceae	Woody plant	*
27	*Strombosia javanica*	Gersap	Olacaceae	Woody plant	*
28	*Quercus subsericea*	Kecing	Fagaceae	Woody plant	*
29	*Aucuba chinensis*	Mei-mei	Garryaceae	Woody plant	*
30	*Artocarpus elasticus*	Torop	Moraceae	Woody plant	*
31	*Arenga pinnata*	Aren	Arecaceae	NTFP	**
32	*Calamus rotang*	Rotan	Arecaceae	NTFP	**
33	*Bambusoideae*	Bambu	Poaceae	NTFP	**
34	*Olibanum*	Kemenyan	Styracaceae	NTFP	**

35	*Coffea arabica*	Kopi arabika	Rubiaceae	NTFP	*
36	*Dimocarpus longan*	Kelengkeng	Sapindaceae	MPTS	**
37	*Nephelium lappaceum*	Rambutan	Sapindaceae	MPTS	*
38	*Parkia speciosa*	Petai hutan	Fabaceae	MPTS	*
39	*Duriozibetinus*	Durian	Malvaceae	MPTS	**
40	*Persea americana*	alpukat	Lauraceae	MPTS	**
41	*Psidium guajava*	Jambu	Myrtaceae	MPTS	**
42	*Archidendron clypearia*	Jengkol	Fabaceae	MPTS	*

Table 12: Recommended plant

No.	Scientific name	Local name	Family	caption
1	*Psidium guajava*	Guava	Myrtaceae	Mpts
2	*Duriozibetinus*	Durian	Malvaceae	Mpts
3	*Parkia speciosa*	Petai	Fabaceae	Mpts
4	*Persea americana*	avocado	Lauraceae	Mpts
5	*Dimocarpus longan*	Longan	Sapindaceae	Mpts
6	*Schima wallichii*	Simartelu	Theaceae	Woody
7	*Altingia excelsa*	Rasamala	Alseodaphne	Woody
8	*Alseodaphne sp*	Meang	Lauraceae	Woody
9	*Toona sureni*	Ingul	Meliaceae	Woody
10	*Shorea*	Meranti	Dipterocarpaceae	Woody

Simartelu, Rasamala, meang, ingul, and meranti are woody plants. Often found growing in abundance in lowland to montane primary forests, these trees are also common in secondary forests and disturbed areas. Simartelu can live up to 3900 m above sea level, Meranti can grow at altitudes between 0-700 m above sea level in lowland dipterocarpaceae forest formations.

Petai, avocado, guava, longan, and durian are tropical plants and can grow in sub-tropical areas with rainfall intensity ranging from 1,000-2000 mm/year and can grow and bear fruit optimally at temperatures (23-28)ºC. Durian and petai grow in lowland areas up to a maximum altitude of 800 m (above sea level), with rainfall between 1500-2500 mm per year and evenly distributed throughout the year. Guava trees have good endurance. It usually grows in areas with altitudes between 5 m above sea level to 1000 m above sea level, covering flat or steep land with terraces. Ohon Avocado can grow from lowlands to highlands. However, fruit production is optimal at planting altitudes of 200-1000 MASL.

Conclusion

The Bukit Barisan Forest Park of Kutalimbaru District, Deli Serdang Regency has 5 land cover classes, namely forest, shrubs, mixed gardens, developed land, and open land. In the change of forest area, namely forest with an area of 753.42 Ha or around 24.29%. Vegetation density in the Bukit Barisan Forest Park of Kutalimbaru Sub-district, Deli Serdang Regency is divided into 5 classes, namely non-vegetation, sparse, medium, dense, and very dense. All land cover classes have different densities.

There are 10 plant recommendations that can be planted around the path, namely: *Guava* (*Psidium guajava),* Durian (*Durio zibetinus),* Petai (*Parkia speciosa),* avocado (*Persea americana),* longan (*Dimocarpus longan*), Simartelu (*Schima wallichii*), Rasamala (*Altingia excelsa),* Meranti (*Shorea),* Ingul *(Toona sureni),* Meang *(Alseodaphne* sp*).*

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Author's Contributions

Budi Utomo: Create concept and designed, monitor the progress of research from start to finished and ensure that the entire research process goes according to planed, analysis and interpretation of data.

Bungaran Johanes Tambunan: Mad a mayor contribution to the conduct of the research and data acquisition.

Rizky Wahyudi: Coordinate the data analysis and contributed to written of the manuscript.

Yunasfi: Contributed in drafted the article or reviewed it critically for significant intellectual content.

Afifuddin Dalimunthe: Assisted in map process and calculate the area of each map area.

Mohammad Basyuni: Gave final approval of the version to be submitted and revised version.

Ethics

The author is solely liable for any consequences that may arise from the publication of this journal manuscript.

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