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Analysis of Land Cover Changes and Sustainable Reforestation in Sianjur Mula-Mula District, Samosir Regency, Indonesia

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Abstract: The increase in population and technological advances have had a significant impact on land use changes. there are changes in land cover 2017-2022 in the local ecosystem. there have been significant changes but can still be maintained. This is to prevent the extinction of species such as fish, land animals and other marine animals. Changes in land cover that are getting worse will reduce tourism activities in Lake Toba because the quality of the ecosystem decreases. This also happened in Sianjur Mula-Mula District, which consists of 12 villages. Even though most of the villages in this sub-district are located on hills and steep slopes, the need for new land forces the community to open and utilize these sloping lands into residential areas, agricultural land and community gardens which have an impact on dynamic changes in land cover. Therefore, this research aimed to analyze land cover changes in Sianjur Mula-Mula Subdistrict in 2017 and 2022 using Sentinel 2 imagery and a guided classification method to carry out reforestation of deforested land. The results showed that there were five distinct land cover classes in Samosir Regency: Forest land, settlements, shrubs, rice fields and mixed gardens. In 2017, shrubs dominated, covering an area of 4,689 Ha or 39.68% and a similar pattern persisted in 2022, with a coverage of 4,529 Ha or 38.32%. The most significant increase occurred in forest land, with change amounting to 182 Ha or 1.54%, while the smallest change was observed in rice fields, totally 33 Ha or 0.28%. The largest changes in land cover area occurred in forest with a decrease of 182 Ha or 1.54% and the largest increase was found in the built-up land with an area of 111 Ha or 0.95%. Reforestation must be carried out on 4,529 hectares of shrubs with a total of 5,032,222 seeds so that the water in Lake Toba remains maintained.

Keywords: Sentinel 2 Imagery, Sianjur Mula-Mula, Land Cover, Reforestation, Lake Toba

Introduction

Forests, comprising diverse flora and fauna, play essential roles in maintaining the balance of ecosystems, especially in tropical regions like Indonesia. Indonesian forests, classified as tropical. Play a crucial role in producing oxygen and absorbing CO_2, essentially serving as the lungs of the Earth. The ecological function of forests is to protect forest areas and their surroundings from erosion, protect the sustainability of endemic species, protect the sustainability of supporting species such as bird species. In addition, these expansive forests contribute significantly to global temperature stability and influence the amount of land cover (Stehman, 2009). Therefore, the extensive forested areas in the country, such as those in Sianjur Mula-Mula are essential for sustaining ecological equilibrium.

Sianjur Mula-Mula is a subdistrict in Samosir Regency. It consists of 12 villages, with some inhabitants residing on the slopes of the Sianjur Hill. This area is the coastal area of Lake Toba. Sustainability in this area is very important because if the area is sustainable then the water of Lake Toba will also be maintained. If the Sianjur Mula-Mula area is not sustainable, then it will have a negative impact on Lake Toba, one of which is a decrease in water discharge in Lake Toba. The region's topography, characterized by fairly incline and litosol soil types, predominantly supports shrubs, dryland agricultural plants and plantation. These plantations include essential crops like corn, coffee and Multi-Purpose Tree Species (MPTS) such as avocado, durian, rambutan, jackfruit and mango (DeWitt *et al*., 2017).

However, the region faces challenges stemming from a growing population, leading to increased land demand for agriculture, settlements and industry. This has resulted in relatively high demand for land, leading to diminished availability in Sianjur Mula-Mula Subdistrict, making it necessary to protect forests to maintain sustainability. According to Kennedy *et al*. (2010), an increasing population causes annual reductions in land use and changes in forested area for other purposes.

The Sianjur Mula-Mula area has been experiencing significant land changes due to the extended dry season, leading to widespread land fires. These fires are caused by a combination of natural factors and human activities such as land clearing by burning. Furthermore, land use has far-reaching impacts on climates, flora, fauna and human population. Both natural and human interventions such as deforestation, land conversion, coastal reclamation and city development affect land use changes. Consequently, these changes often require regular conservation, particularly in proximity to forested areas. In this context, assessing the conditions in the Sianjur Mula-Mula Subdistrict becomes imperative. Given the challenging hilly terrain and frequent fog, assessing its condition using remote sensing technology is essential. Sentinel image data and Geographic Information Systems (GIS) have proven to be invaluable tools for providing data, even though damages on forest lands have been noted (Wang *et al*., 2010). The gap in this research is that there is no research regarding land cover analysis in Sianjur Mula-mula. The research conducted research on the condition of land cover in Sianjur Mula-mula with the ultimate aim of calculating the total area of land that must be reforested. Against this backdrop, this research aimed to (1) Analyze land use changes in Sianjur Mula-Mula Subdistrict, Samosir Regency, comparing data from 2017-2022; and (2) Assess the factors contributing to these changes. This approach integrates remote sensing systems with field observations to provide a comprehensive understanding of current conditions, guide land use and protection strategies and carry out reforestation of deforested land.

Tools and Materials

The materials used were the location of protected forest areas in the Sianjur sub-district initially, land cover maps for 2017 and 2022, Sentinel-2A Tile Number T47NND and Tile Number T47NND maps While the tools are: GPS (Global Positioning System), compass and camera. The data analysis tool used is a laptop and several software, namely Microsoft Excel, ENVI 4.7, ERDAS Imagine 9.2 and ArcGis 10.3.

Methods

Study Area

The research was conducted in North Sumatra, specifically in the Sianjur Mula-Mula Subdistrict of Samosir Regency. The geographical coordinates and details of the study area are illustrated in Fig. 1.

Data collection and processing phase took place over three months, spanning from January to March 2022, while data analysis was performed at the Forest Cultivation Laboratory within the Faculty of Forestry at the Universitas Sumatera Utara. The research locations are shown in Fig. 1.

Data Collection

During the Field data collection phase, various tools were used, including Global Positioning System (GPS), compass and camera as documented by Malaviya *et al*. (2010). These tools facilitated the acquisition of primary data, specifically ground-truth data in the field, utilizing GPS and digital cameras. Table 1 presents a comprehensive overview of the types of primary and secondary data used in the research, along with their respective sources.

Image Data Processing

Merging of Citra Bands

Sentinel satellite imagery downloaded from the USGS had several bands and each was separate. Therefore, the satellite image bands were combined to carry out land cover classification. The process of merging image bands was performed using Erdas Imagine 9.2 software. The justification for selecting the sentinel-2 image was because the use of this image is an image that is good enough to be processed and separated into several types of land cover. The use of sentinel-2 imagery was taken an option because the satellite imagery obtained is also quite close. The size of 1 pixel on the map is equal to 10×10 m of the existing size in the field. Thus, the level of accuracy of the sentinel-2 image is also quite high. The sentinel-2 image has a confidence level of 85% so this map was considered good enough to be processed and shows differences in land cover in an area.

Radiometric Correction

Radiometric correction was carried out to eliminate interference in the image due to atmospheric influences. This was achieved through a contrast sharpening process or radiometric enhancement. The contrast sharpening process used the histogram Equalization model in the ERDAS Imagine 9.2 software.

Table 1: Data types and sources

No.	Data Name	Data type	Source of data	Year
1	Ground check data in the field	Primary data	GPS and Digital camera	2017
2	Sentinel-2A imagery Tile Number T47NND	Secondary data	www.earthexplorer.usgs.gov	2022
3	Sentinel-2A imagery Tile Number T47NND	Secondary data	www.earthexplorer.usgs.gov	2017
4	Administration map of Samosir Regency	Secondary data	Geospatial information agency	2022
5	Maps of Roads-network, Rivers, land use, and contours of samosir regency	Secondary data	Geospatial information agency	2022 2022

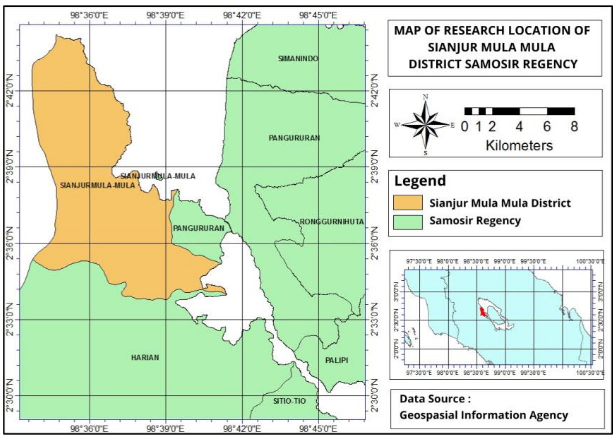

Fig. 1: Map of research location

Unsupervised Classification

Unsupervised classification allows the computer freedom to classify images based on the number of classes specified by the user. It also helped in determining ground checkpoints for guided classification and accuracy tests.

Image Cropping (Cropping)

Image cropping was carried out to obtain a more specific image of the research location. This was achieved with ArcGIS Software 10.3 using district vector data obtained from Balai Forest Area Consolidation (BPKH) Region I Medan.

Image Processing Techniques

The image processing process begins by downloading the sentinel 2 image which comes from the 2017 and 2021 images to see the changes over a period of 5 years. Furthermore, based on data taken in the field, the image map was corrected to equalize the parts of the map that have similar land cover. Then, after the map has been properly corrected, these land covers were classified into 5 types of land cover that have been determined based on previous field surveys. The results of the correction would show a land cover map for each year, namely 2017 and 2021. Next, the two maps were overlaid to see the changes that have occurred from 2017-2021. These changes were calculated and tabulated to describe the extent of land cover changes over a period of 5 year.

Field Survey

Field surveys were carried out to determine the condition of land cover in the field based on several points which had been made in an unsupervised manner and then land cover type found in the location was directly observed. Checking was performed with the Global Positioning System (GPS). The observation points were determined by purposive sampling with a minimum of four representing each land cover class. Each observation point was visited for data collection, observation and recording of important information. The data collection comprised coordinates of field observation points recorded from GPS and land cover conditions accompanied by images DeWitt *et al*. (2017). Field observations have been explained in the field survey. However, in general biophysics, the average slope was around 30-50%, the soil was shallow and the volcanic rocks in the lake were high, resulting in elevated levels of soil erosion in the rainy season. The research location also faced challenges in retaining groundwater, resulting in limited vegetation growth, with only weeds, ferns and grass surviving.

Field Data Collection

The data collection method begins with conducting a survey in the field. Surveys were carried out at locations representing various land covers. For each land cover, several field ground check sample points are taken, ranging from 4-10 samples depending on the conditions of the existing location. Determination of observation points was determined using the purposive sampling method. Each location point was marked with a GPS point taken to make it easier to overlay it later on the image map. Taking many samples was intended to minimize errors when processing data on the Sentinel 2 image map later. At each point visited, field data was then collected in the form of vegetation cover, open land,

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bushes or other forms of cover as well as recording other important information. Furthermore, based on these field samples, land cover was divided into 5 types, namely: Forest, mix garden, build up land, paddy field and shrub. At each sample location, images were taken in the form of field photos to illustrate the shape of the land cover. At each sample point that has been marked on the GPS, it was then inserted into the sentinel-2 image map to be processed and estimate the land cover image. Next, each different form of land cover was separated and its area was calculated. Each type of land cover was added up and tabulated in a conclusion table to describe the condition of land cover in the area studied.

Supervised Classification

Supervised classification was carried out based on the results of field surveys by creating polygon samples or training area in land cover classes. The maximum likelihood method was used in the ERDAS Imagine 9.2 software.

Accuracy Assessment of the Classificated Images

The level of accuracy in image classification was obtained by comparing the results with data collected from the field. The accuracy calculation played a role in determining whether the image classification result corresponded to conditions in the field. Accuracy assessment was done using a contingency matrix containing the number of pixels in the classification, often called an error or confusion matrix. Mathematically, the formula for calculating accuracy is as follows (Cui *et al*., 2018):

$$Overall\ Accuracy = \frac{Diagonal\ number\ in\ the\ matrix\,(Kkk)}{the\ total\ number\ of\ \ pixels\,(N)} \times 100\%$$

$$Kappa\ Accuracy = \frac{N'\sum^{n} Xkk - \sum^{n} Xkt\ \ Xtk}{N'2 - \sum^{n} Xkt\ \ Xk} \times 100\%$$

Remark:

N’ : Number of all pixels used for observation
N : The number of rows/columns in the error matrix (same as the number of classes)
Xkk: The number of correct pixels (diagonal number in the matrix)
Xkt : Number in row total
Xtk : Number in column total

Overlay

The map overlay was carried out after obtaining the land cover class based on the image classification results and field survey data. This was achieved using two land cover maps covering changes that occurred in different years. Change detection method was used to determine land cover in the coastal area of Samosir Regency from Sentinel imagery in 2011, 2016 and 2021. Analysis was carried out to determine the rate/level of land changes at any time using remote sensing technology (Raczko and Zagajewski, 2017). This process was followed by spatial analysis, a set of methods that could be used in processing GIS data. The spatial analysis steps are as follows:

1. Overlay land cover class at the time of initial observation (To) with land cover class at the next Time (T1)
2. Analyze objects that did not change (in To and T1) and changed (objects in To and T1 differ)
3. Perform area calculations on each object that changed

The next process was Tabular analysis, which described the characteristics, quality, or relationship between map appearance and geographic location. In other words, it explained the existence of various objects as spatial data. This analysis was conducted by:

1. Performing area calculations for each land cover class
2. Calculating changes in area within land cover class, using the following formula:

$$PTH = \frac{AI - Ao}{T1 - To}$$

PTH : Changes in land cover per year in a certain period, expressed in area per year (ha/year)
Ao : Land cover area at the time of initial observation, expressed in hectares (ha)
To : Initial observation Year T1: Final observation year

The image is a research flow chart, starting from downloading the Sentinel-2 image, then processing the data. So it can produce a map of land cover change 2017-2022.

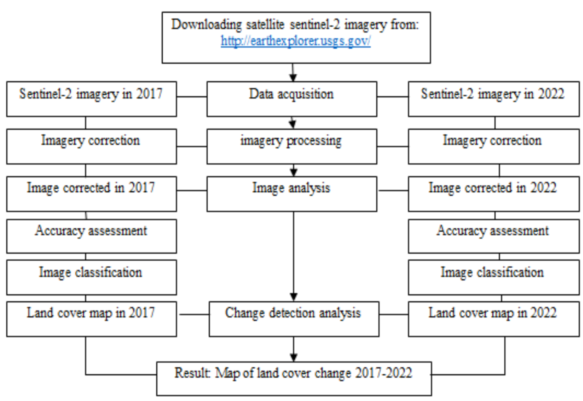

Fig. 2: Methodological flow chart

Results and Discussion

Land Cover Changes in Sianjur Mula-Mula Subdistrict, Samosir Regency in 2017 and 2022

Based on the research results, it was found that there are five classes of land cover in Sianjur Mula-Mula District, namely forest, built-up land, paddy fields, mixed gardens and shrubs. Based on the 2017 land cover map, from 191 samples tested and corrected, a kappa accuracy value of 88% was obtained. Meanwhile, in testing the land cover map in 2022, from the 156 samples tested, a kappa accuracy value of 92% was obtained. From the test results, the criteria for the kappa accuracy test have been met, which requires a minimum accuracy value of 85% (Pal, 2005), thereby ensuring confidence in the accuracy of the land cover change map obtained from the results of this image interpretation.

The total area under analysis in Sianjur Subdistrict of Samosir Regency was 10,125 ha in 2017, which increased to 11,818 ha in 2022. The 2017 Sentinel image classification showed that the dominant land cover was bushes, while the smallest was rice fields and a pattern was also observed in 2022. Changes observed in land cover classes for residential area, mixed gardens and rice fields were relatively modest.

In the forest plant types, Casuarina Junghuhniana, Pinus merkusii, Anthocepalus cadamba and Eucalyptus were found. Although there were several Toona sinensis present, Pinus merkusii and Casuarina Junghuhniana were the most commonly encountered species in the entire Samosir mainland, including Sianjur Mula-Mula Subdistrict. In plantation crops, numerous types of MPTS plants were found, such as Mangifera indica, Persea americana, Durio zibethinus, Arthocarpus integra, Nephelium lappaceum and Psidium guajava.

Many of these plants were combined with agricultural crops such as cassava, sweet potatoes, corn, sorghum and cereal. Data on land cover classes in Sianjur Mula-Mula Subdistrict in 2017 and 2022 are shown in Table 2.

Table 2 presenting the data for 2017 showed that shrubs (4,689 ha or 39.68%) had the largest land cover followed by forest (4,380 Ha or 37.07%), gardens (1,775 Ha or 15.02%, built-up land (606 Ha or 5.12%) and rice fields (367 Ha or 3.10%). On the other hand, in 2022, the largest land cover was occupied by shrubs (4529 Ha or 38.32%), followed by forest (4,198 ha or 35.52%) mixed gardens (1,826 ha or 15.45%), built-up land (717 Ha or 6.07%) and rice fields (399 Ha or 3.38%). This was based on the size of the research area according to the ground check. In both years, the shrub class remained the largest and rice fields were found as the smallest. The 2017 and 2022 Sianjur Mula-Mula Subdistrict land cover map is shown in Fig. 3.

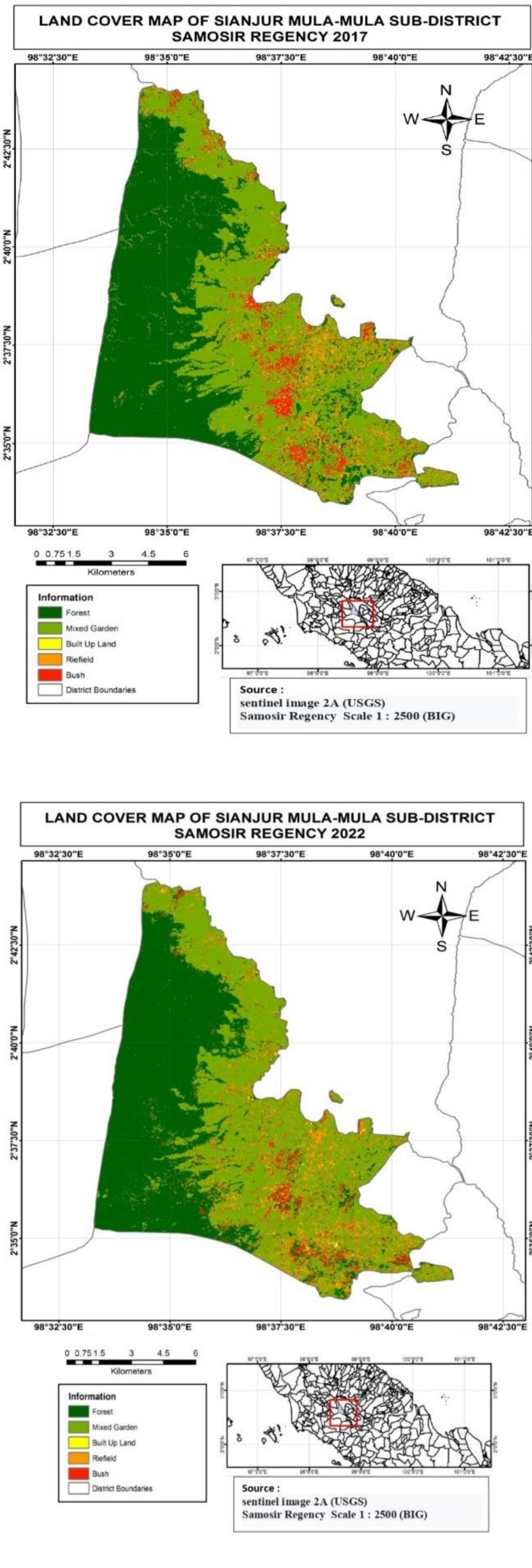

Fig. 3: Land cover map 2017 and 2022

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Table 2: Land Cover Area of Sianjur Mula-Mula Subdistrict, Samosir Regency in 2017 and 2022

No.	Land Cover	Area (2017)	Percentage % (2017)	Area (2022)	Percentage % (2022)
1	Forest	4,380	37.07	4,198	35.52
2	Mix garden	1,775	15.02	1,826	15.45
3	Build up land	606	5.13	717	6.07
4	Paddy field	367	3.11	399	3.38
5	Shrub	4,689	39.68	4,529	38.32
	Total	11,816	100.00	11,818	100.00

Table 3: Image

No.	Land cover class	Visual in sentinel 2 imagery	Field picture	Remark
1	Paddy field			Area where water is flooded rice plants
2	Agriculture land			Area where there are annual crops and some annual plants
3	Shrub			Dry area where there is vegetation
4	Forest			Area dominated by trees and woody
5	Build up land			Area dominated by buildings and open land

As shown in Fig. 3, on the 2017 map, the green color of the forest was predominant with a fairly large bush (grey), followed by mixed gardens (light brown), rice fields (light green) and settlement area (purple-blue) (Jorgenson *et al*., 2018a). On this map, there were clouds and shadows obscuring part of the land, making it necessary to focus on area under the clouds, despite not being clearly visible.

In the 2022 land cover map, the green color remained dominant, but the forest had reduced to shrubs, resulting in an increased presence of grey-shaded shrubs. This was followed by built-up land (purple), mixed gardens (brown light green), rice fields (light green) almost similar to that of 2017 and white boundaries. The 2022 sentinel imagery showed no clouds, showing that land in Sianjur Mula-Mula Subdistrict was clear. This is very helpful in the Ground check process for land cover class adjustments (Stehman, 2009).

Visual appearance analysis used sentinel imagery 2 A by identifying conditions in images and objects using (RGB) 2,3,4 and 8 namely red, green and blue covering all land cover classes. Sentinel imagery used for this analysis had area and resolution of 10 meters, in line with (Mohamed *et al*., 2018) which related the sensitivity of these bands to the reflectivity values of each vegetated land cover.

The visual images of Sentinel 2 are shown in Table 3.

Land cover classes in Sianjur Mula-Mula Subdistrict, Samosir Regency included several annual plants such as corn (Zea mays), banana (Musa paradisiaca), cassava (Manihot ecuslenta), papaya (Carica papaya), rice (Oryza sativa) and other class. The forest land cover in Sianjur area was dominated by Casuarina junghuhniana and Pinus merkusii.

Sentinel 2 imagery for 2017 and 2022 showed several changes in the classification of land cover classes, presented in the column (by ha and percentage) in Table 4.

Table 4 showed that Sianjur Mula-Mula Subdistrict had five land cover classifications with different broad coverage between 2017 and 2022. The most extensive changes in land cover class occurred in forest with a reduction of 4,380 Ha or 37.07% in 2017, which decreased to 4,198 or 35.52% in 2022, marking a decline of -182 Ha or -1.54%. Field observations showed that this changes were primarily due to extensive land burning and the absence of direct intervention from the community and government. Consequently, the forest land cover diminished and newly harvested plantations left by landowners allowed for shrub growth on the community land. Shrubbery can proliferate rapidly, particularly given the steep hills predominant in Samosir Regency, which incur higher land management costs (Wang *et al*., 2017).

Table 4: Changes in Land Cover Class in Sianjur Mula-Mula Subdistrict, Samosir regency based on area and percentage

		Land cover area in 2017		Land cover area in 2022		Land cover changes in 2017-2022	
No.	Land cover	Ha	%	Ha	%	Ha	%
1	Forest	04,380	037.07	04,198	035.52	-182	-1,54
2	Mix garden	01,775	015.02	01,826	015.45	051	0.43
3	Build up land	00,606	005.12	00,717	006.07	111	- 0,95
4	Paddy field	00,367	003.10	00,399	003.38	033	0.28
5	Shrub	04,689	039.68	04,529	038.32	-160	-1,36
	Total	11,816	100.00	11,816	100.00		

Another significant land change occurred in the shrub class, namely a decrease amounting to -160 Ha or -1.36%. On the other hand, mixed gardens, built-up land and rice fields increased by 51 Ha or 0.43%, 111 ha or 0.95% and 32 ha or 0.28% respectively.

Based on the results, land cover in the research location initially experienced changes into a very large area of forest and shrubs. This was consistent with (Jorgenson *et al*., 2018b) stating that understory forests can have random or clustered distribution. Factors such as altitude, temperature and humidity, also play roles in supporting the diversity of understorey vegetation.

The community forest land cover in Sianjur Mula-Mula Subdistrict has declined over the past five years, with area decreasing from 4,380 Ha in 2017 to 4,198 ha in 2022 showing a decline of -182 ha. This decline was attributed to several factors, including the forest fire. According to Liu *et al*. (2017), the North Sumatra region is prone to fires, with the incidence increasing almost every year in Samosir Regency. This is because the vegetation in area is mostly grass, such as Imperata cylindrical, which is very flammable and makes the fire spread even faster.

Built-up land also experienced an increase in land cover, although the additional rate was not significant. In 2017, build-up land covered 606 hectares, expanding to 717 hectares in 2022 showing an increase of 122 hectares. This was supported by data from the population and civil registration service 2019, stating that in 2018, the population in Samosir Regency was 143,499 people with a total number of 35,990 households. The population increased in 2019 to 159,958 people with a total number of 36,613 households primarily due to the rising birth rates.

The data observation showed that mixed gardens also experienced an increase in land cover estimated at 51 hectares or 0.43%. This was supported by the regional BPS report stating that Samosir Regency relied significantly on secondary crops including rice, cassava and sweet potatoes.

The increase in the mixed garden class in 2017 and 2022 was relatively small, reflecting the widespread presence in the Sianjur Mula-Mula area. This prevalence was due to the hilly and undulating terrain, considered less fertile for other types of land use. The mixed gardens were found to be vulnerable to natural disasters such as landslides and fires, according to data from (Curatola Fernández *et al*., 2015). Furthermore, the topographic diversity in Samosir Regency included 10% flat, 15% sloping, 20% sloping and 55% steep. The soil structure was also less fertile for agricultural land due to its composition of sand, clay, lime and rocky layers, resulting in the classification as Toba tufo soil. This type of soil originates from active volcanic eruptions on Lake Toba and Samosir.

The shrub area remained relatively constant, with 4,689 Ha in 2017 and a slight changes to 4,529 ha in 2022. Addressing this stability requires massive reforestation efforts to convert the shrubland into forested area. Given the predominantly bare topography of Lake Toba catchment area, reforestation is essential at a distance of 3×3 m, meaning 10,000/9 = 1,111 plants. Therefore, for the entire 4,529 ha area, 5,032,222 plant seeds would be required for planting. The success of this initiative requires participation from the surrounding community and local government to allocate necessary efforts and resources.

Natural disasters in Samosir Regency, such as landslides, fires and land clearing have become increasingly widespread, occurring almost yearly. Land clearing through burning, including unused crop residues such as leaves, rice and coffee were common practices in the community. This led to uncontrollable fires, because dry bushes acted as fuel for the flames, while wind and other environmental conditions worsened the situation.

Román-Dañobeytia *et al*. (2015), climatic conditions play a significant role in creating a fire-prone environment. Weather factors influence forest fires, with dry conditions, strong winds, storms and lightning increasing the risks. The frequent occurrence was associated with prolonged long dry season weather. Climate and weather determine the occurrence number, duration, direction and influence of the fire. Furthermore, the traditional practice of burning biomass for clearing land remains deeply ingrained in the culture.

Table 5 shows the largest area of land cover changes in 2017 and 2022.

Table 5: Villages with the largest area of land cover changes

No.	Land Cover in 2017	Land Cover in 2022	Area (Ha)	Name of Village
1.	Shrub	Mix Garden	730	Boho, Siamarihit, Huta Ginjang, Bonan Dolok, Huta Gurgur, Hasinggan, Habean Naburahan, Siboro, Ginolat, Singkam, Aek Siputudai, Simarihit, Sianjur Mula-Mula,
2.	Mix garden	Shrub	559	Siamarihit, Boho, Habean Naburahan, Bonan dolok, Huta Ginjang, Siboro Naburahan, Hasinggan, Ginolat, Singkam, Huta Gurgur
3	Forest	Mix garden	422	Simarihit, Ginolat, Boho, Huta Ginjang, Bonan Dolok, Singkam, Huta Gurgur, Siboro, Hasinggan, Habean Naburahan, Singkam, Siajur Mula-Mula,
4	Shrub	Built-up land	170	Sianjur Mula-Mula, Singkam, Boho, Huta Ginjang, Bonan dolok, Hasinggan, Aek siputudai, Singkam, Huta gurgur, Simarihit
5	Forest	Shrub	182	Huta Ginjang, Huta Gurgur, Hasinggan, Singkam, Sianjur Mula-Mula, Siboro, Aek siputudai, Bonan dolok
6	Forest	Built-up land	126	Bonan dolok, Huta Ginjang, Aek siputudai, Singkam, Huta Gugur, Sianjur Mula-Mula, Siboro, Simarihit, Hasinggan

Table 6: Smallest Regional changes in land cover class

No.	Land Cover in 2017	Land Cover in 2022	Area (Ha)	Name of Village
1	Forest	Paddy field	25	Ginolat, Boho,Huta Gimjang; Aek siputudai, Singkam
2	Paddy field	Shrub	36	Hasinggan, Sianjur Mula-Mula, Huta Gurrgur, Siboro

Table 5 shows the 12 villages/subdistricts in Sianjur Mula-Mula District, namely Boho, Aek Sipitudai, Singkam, Sarimarihit, Sianjur Mula-mula, Giolat, Huta Ginjang, Siboto, Hutagugur, Bonandolok, Hasinggan and Habean. According to data from BPS presented in Sianjur Mula-Mula District figures for 2022, built-up land increased by 20 ha due to several factors. These included the Development of the Elementary schools between 2018 and 2020, as well as a corresponding increase in Junior high schools with the construction of six new buildings. Furthermore, the Habean Naburhan and Simarihit villages experienced significant growth in senior high schools, with an increase of three schools in Sarimarihit Village. Additional four health facilities between 2018 and 2021 were constructed in the villages of Sari Marihit and Aek Saputudai (Yang *et al*., 2018).

Land use changes in 2017 and 2022 occurred in all villages, with the largest occurring in shrubs to mixed gardens at 730 (Ha) and mixed gardens to shrubs at 559 (Ha) (Berhane *et al.*, 2018). In Sianjur Mula Mula Village, the most significant changes was forest into mixed gardens at 442 (Ha). The forest to shrub changes was estimated at 182 (Ha) and occurred in all villages, along with shrubs to built-up land at 170 (Ha). The smallest land use changes observed was forest to built-up land at 126 (Ha) and this did not occur throughout the villages.

Table 6 showed that the smallest land cover class occurred in the forest to rice fields, accounting for only 25 (Ha) and changes in rice fields to shrubs accounted for 36 (Ha). This minimal changes in land cover class could be attributed to the unique topography of Sianjur Mula-Mula, a plateau requiring more energy, making it more suitable for rice fields.

Land cover classes observed in this research included shrubs, forests, mixed gardens, built-up land and rice fields. The most substantial changes was observed in the shift from shrubs to mixed gardens, reflecting the continued economic activity of the community through farming. The second-largest changes occurred in the conversion of forest land to mixed gardens, showing that the practice of clearing forest for land remains prevalent (Wang *et al*., 2001).

These results were consistent with the conditions of the field and imagery from 2017 and 2022. Local communities in Sianjur Mula-Mula engage in activities such as harvesting and clearing agricultural land by burning, which was not always monitored. Farmers often intercrop mango, jackfruit and durian together with corn and cassava in the same field.

This pattern of land cover changes reflects a conscious effort by the community to sustain their way of life and preserve their ancestral culture. Sianjur region has many cultural and natural attractions, leading to land development. The construction carried out when collecting field data included roads, bridges, schools and places of worship. According to Cui *et al*. (2018), government programs have accelerated the pace of development by developing essential facilities required for social, economic and health services in the region.

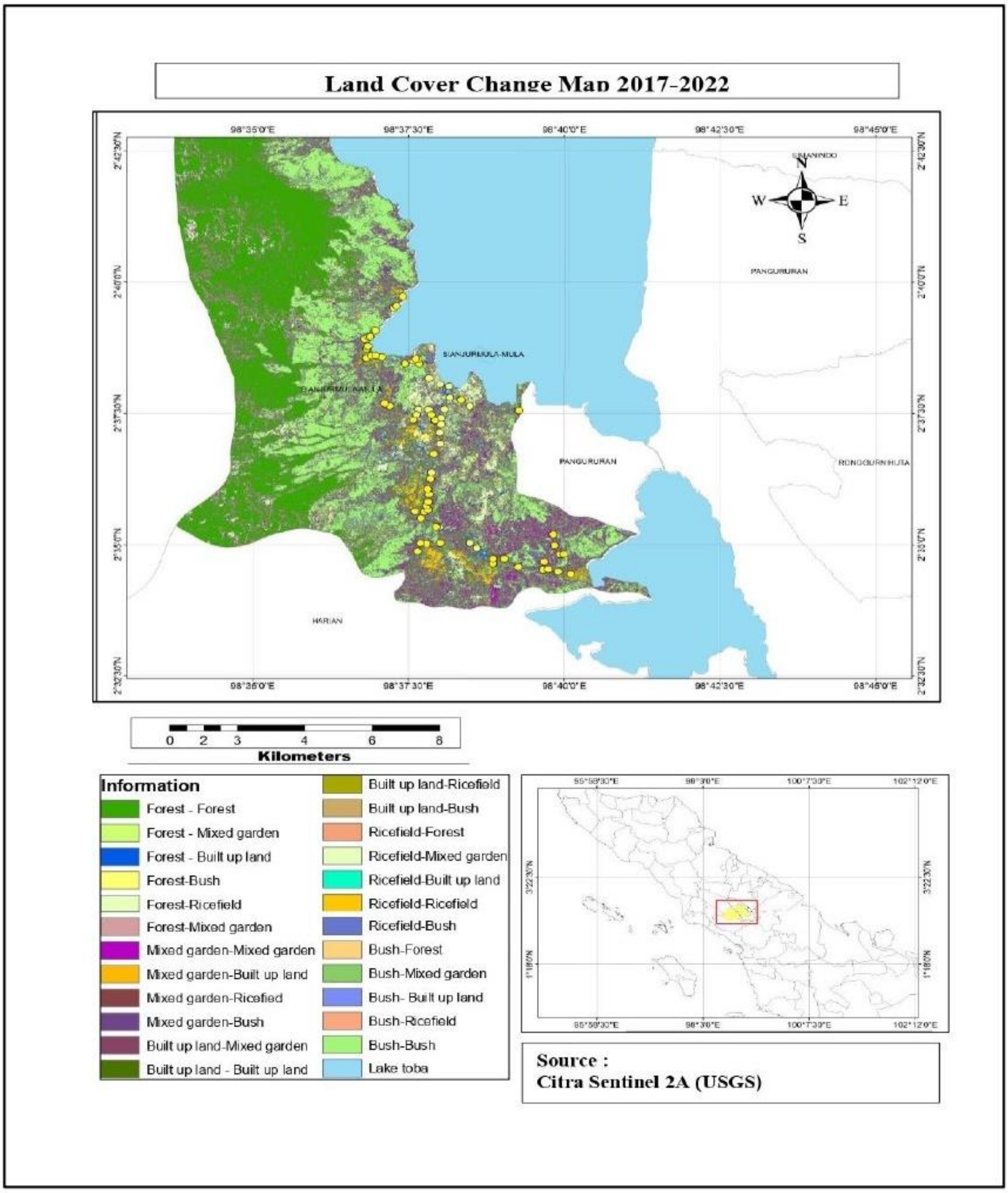

Fig. 4: Land cover changes map 2017-2022

The increasing need for land both for farming and development purposes, requires collaboration between the community and the government to improve the economy (D'Almeida *et al*., 2007). Land serves as a vital resource for human livelihood and food production, showing the need for proper management to prevent degradation.

The shrub class included vegetation resulting from the residues of forest and plantation product harvesting, as well as burnt land overgrown with grass. During the ground check, many large and small areas of burnt land were observed from the topography in the area. The presence of even a small amount of fuel could lead to large-scale fires, potentially extending to a significant portion of the hills in Sianjur Mula-Mula area.

To restore these shrub sites, it is essential to implement planting measures for preservation, reforestation and research purposes. Creating planting location maps becomes crucial to access research sites and serve as a reference for selecting appropriate plant types and identifying planting area. The management by PT. Toba Pulp Lestari has several types operating in the Industrial Forest. However, the raw material for HTI is the Eucalyptus type, which remains prevalent in Samosir area, reaching an average tree age of 12. In 2018, 10,000 seedlings were planted along the hilly slopes in Harian Village. In addition, the Department of Forestry cultivated MPTS types of Toba mango in 2022, better known as shrimp mango (Evans *et al*., 2013).

Damage from natural disasters also resulted in the loss of plantation land, forests, agriculture and settlements, making land empty. The government, together with the community often plant and distribute trees to solve this problem and provide plant benefits. Settlements lost due to natural disasters were old buildings that had begun to decay and were located on slopes. Moreover, the roads were often damaged due to moving soil landslides, high rainfall and strong winds (Ji *et al*., 2015).

Encouraging active participation in reforestation and plantation activities on vacant land is vital to prevent further damage. Proper management of forested area and changes in land use requires direction maps, which are very helpful in conducting rehabilitation, reforestation, determining suitable locations and assisting the community in constructing settlements, roads and services such as health and education posts. Given the steep terrain in Sianjur Mula-Mula area, it is crucial to adapt development, land use and plant selection to the local conditions and requirements (Skaloš and Kašparová *et al*., 2012). The limitation of the study is this research uses image data, the results of which may be covered by clouds and this cannot be avoided.

Conclusion

Land cover in Sianjur Mula-mula Subdistrict, Samosir Regency comprised five classes including forest, built-up land, rice fields, mixed gardens and shrubs. In 2017 the most extensive land cover classification was forest, with an area of 4,380 Ha or 37.07% and the smallest was rice fields, with 367 Ha or 31.0%. In 2022, the most extensive class was shrubs, with area of 4,198 Ha or 35.25%, while the smallest was rice fields, with 399 Ha or 3.38%. The largest changes in land cover area occurred in forest with a decrease of 182 Ha or 1.54% and the largest increase was found in the built-up land with an area of 111 Ha or 0.95%. Reforestation must be carried out in the shrubs amounting to an area of 4,529 Ha with a total of 5,032,222 seedlings. In the future, this research can be carried out in the following year to determine changes in land cover after reforestation.

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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.

Rezky Nizar: 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.

Samsuri: 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

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and that no ethical issues are involved.

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