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SPATIAL-TEMPORAL ANALYSIS OF FOREST DEFORESTATION IN LORE-LINDU NATIONAL PARK

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ABSTRACT

Indonesia is listed as one of the countries with a high rate of deforestation. This deforestation occurs in almost all islands in Indonesia, including Sulawesi. Deforestation analysis needs to be carried out to determine the rate of change in forest cover and the factors that cause it, so that forms of forest management can be planned to achieve sustainable forest management This analysis is expected to fulfill the need for information on how the vulnerability of deforestation occurs spatially, where the locations of deforestation occur and what factors encourage deforestation and forest degradation. The study found that the rate of forest decrease from 1990 to 2020 was 328 hectares/year with the highest rate was from 1990 to 2000 with rate of forest decrease 690 hectares/year. The deforestation located in four area that has difference land cover change. Area 1 changed to settlement and dry land agriculture, area 2 changed to cocoa plantation by the local community planted in 2000s, area 3 changed to cocoa plantation by the local community planted in 2010s. Area 4 changed to open area/bareland indicated after ilegal logging occurred since 2000.

Keywords : Deforestation, Land Cover Change, Spatial Analysis, Temporal Analysis.

INTRODUCTION

The incidence of deforestation in developing countries such as Indonesia is influenced by various factors and is very complex. Nawir and Rumboko (2008) classify two factors that cause deforestation in Indonesia, namely direct and indirect factors. The direct causes are logging activities, illegal logging, and forest fires. Indirect causes, among others, are market failures, policy failures, and other socio-economic and political problems in general. There are about 10 variables that trigger deforestation, namely: (a) land sales, (b) settlement development, (c) clearing of fields/gardens, (d) search for firewood, (e) natural forest fires, (f) burning for land preparation, (g) illegal logging for commercial purposes, (h) illegal logging for local needs, (i) plantation development and (j) natural disasters (Sasaki et al. 2011). All of these things are inseparable from population density which is a fundamental explanation of the problem of deforestation in Indonesia (Sunderlin and Resosudarmo 1996).

Indonesia is listed as one of the countries with a high rate of deforestation. The Directorate General of Forestry Planning, Ministry of Forestry (2009) reported that the rate of deforestation in 1990–1996 was around 1.91 million ha per year, and then increased sharply to 3.5 million ha/yr in the period 1996–2000. In the period 2000–2003 the deforestation rate decreased sharply to 1.1 million ha/yr but then increased again to 1.2 million ha/yr in the 2003–2006 period from Indonesia's forest area of 120.1 million ha based on the results of the integration between TGHK and RTRWP.

This deforestation occurs in almost all islands in Indonesia, including Sulawesi. The annual rate of deforestation in Sulawesi is 2.7% of the total forest area in Sulawesi or in other words, deforestation is 331822 ha/year from a forest area of 12 million ha. These data make Sulawesi the 2 (two) largest deforestation after Kalimantan which has the largest annual deforestation rate (7%) during the period 2000-2009 (Directorate General of Planology 2009). Southeast Sulawesi experienced deforestation of around 63.7 thousand ha/year in the period 2000–2009 and the area of forested land was around 1.4 million ha (Directorate General of Planology 2009). If the rate of deforestation is not controlled, then in the future the existence of Central Sulawesi's forests will be threatened.

Studies on deforestation vary based on spatial distribution, area, pattern, and rate of occurrence (Kumar et al. 2014). Deforestation analysis needs to be carried out to determine the rate of change in forest cover and the factors that cause it, so that forms of forest management can be planned to achieve sustainable forest management (Strassburg et al. 2009). Monitoring changes in forest cover, especially deforestation and degradation, can be done or developed semi-automatically in the form of modeling, especially spatial modeling (Sulistiyono et al. 2015). Spatial analysis of deforestation using variables related to the factors causing deforestation and degradation has been widely carried out by (Prasetyo et al. 2013; Murray et al. 2015; Sulistiyono et al. 2015).

This analysis is expected to fulfill the need for information on how the vulnerability of deforestation occurs spatially, where the locations of deforestation occur and what factors encourage deforestation. This information can be used as material for recommendations and government considerations in formulating policies on forest management and regional planning in Lore Lindu National Park, Central Sulawesi Province.

RESEARCH METHODS

Location.

This research was conducted in Lore Lindu National Park, Central Sulawesi Province. Astronomically, the location of the study area is in the coordinate range of 103°40'00” east longitude 119°90' – 120°16'E and 1°8' – 1°3'LS. This study includes the stages of (1) preliminary study, (2) later data processing (3) ground check implementation is carried out by focusing on areas where degradation and deforestation occur (Figure 1). Data processing and analysis was carried out at the Faculty of Forestry, IPB University.

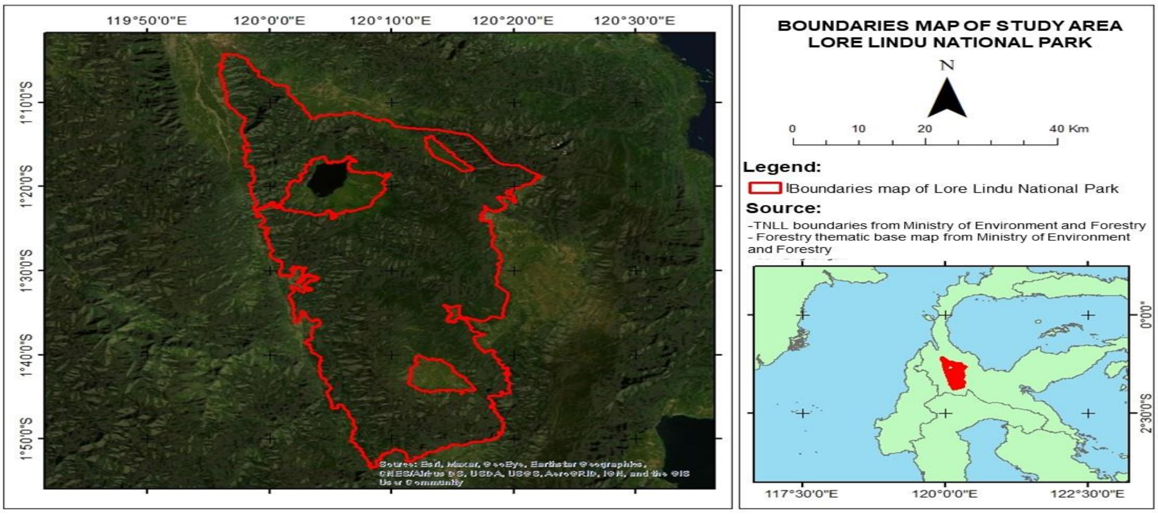

Figure 1 Study Area Map

Software dan Hardware

The data used in this study are medium resolution satellite images (Landsat) in 1990, 2000, 2010, and 2020 which were used for land cover analysis in those years. Landsat imagery is done because it has a complete spectral resolution, making it easier to make indexes. The research location is at path/row: 114/61. The main and supporting data can be seen in Table 1.

Table 1 Main and supporting data needed in this research

No	Main Data	Supporting Data
1	Landsat-5 TM image of 1990	Road data
2	Landsat-5 TM image of 2000	River data
3	Landsat-7 ETM image of 2010	Residential data
4	Landsat-8 OLI image of 2020	Map of the earth in 2020
5	Land Cover 1990, 2000,2010,2020	2020 Forest area boundaries
6	Groundcheck Data	

The hardware used in this research is a laptop, voice recorder, Global Positioning System (GPS), and a set of cameras. Pre-processing, image processing, and spatial analysis were performed using Erdas Imagine 2014 and ArcGIS 10.8. Data processing was carried out using Microsoft Excel software for data analysis and making land cover change matrices. All processes are carried out on computer devices that have an Intel (R) core (TM) i7-5600 processor specification, 8 Gb RAM, and 512 Gb SSD.

This research was conducted through several stages of activities as follows: pre-image processing, updating of land cover maps using visual interpretation techniques, detection of forest degradation and deforestation, and spatial analysis of the causes of degradation and deforestation. In simple terms, the stages of the research can be seen in Fig.

Image pre-processing.

Satellite images must go through the pre-image processing stage before visually classifying them, to produce accurate data before processing. The initial stage in image pre-processing used is geometric correction which is carried out to correct errors caused by the influence of sensors and satellite orbits (Handayani et al. 2017). The next step is to perform radiometric correction to reduce haze and noise in the image. The image coordinates used in the analysis are UTM coordinates so that the coordinates of all images are transformed to UTM (Universal Transverse Mercator) coordinates for zone 51S and datum WGS 84 (World Geographic System 84). Coordinate transformation is done using ArcGIS 10.8 software.

Band merging is intended to obtain multispectral image data consisting of bands that will be used in later processing, in this study the bands used are blue, green, red, NIR and SWIR. Jaya (2010) explained that by using only one band (channel) which is generally displayed in grayscale, object identification in an image is generally more difficult than interpretation in a color image. The different types of images used in this study certainly cause differences in the combination of bands used in the interpretation process. This study uses several composite bands to get a good visual interpretation, the main composite used is true color, and false color composites to get a firm definition of the existing class differences. For Landsat 5 TM Bands used are band 1, band 2, band 3, band 4, and band 5 where the true color composite image uses band 321, and false color uses band 4-3-2 and band 5-4-3 (Sampurno and Thoriq 2016).

Land Cover Classification.

Land cover classification is carried out as the first step to obtain a land cover map. Land cover maps were made using visual interpretation methods on Landsat 5 TM 1990 (T1), and 2000 (T2), Landsat 7 ETM 2010 (T3), and Landsat 8 OLI 2020 (T4) images. The land cover classification map was created using the results of a data approach published by the Ministry of Environment and Forestry.

Classification with visual interpretation is the interpretation of remote sensing data based on the introduction of spectral and spatial characteristics or characteristics of objects in image data (Mas et al. 2017). Visual interpretation is carried out before making observations in the field by delineating boundaries between land cover classes by digitizing directly on a computer screen (digitation on screen) on a Landsat image with an RGB composite display (Liu et al. 2020), this process is carried out using ArcMap 10.8 software.

Land cover classification is done by delineating each land cover class based on interpretation elements, and tested for accuracy with field observation data (ground check). The method of determining the number of field observations used was purposive sampling considering the accessibility and representativeness of each land cover class with the number of samples representing of every change class of deforestation and degradation. The calculation of the accuracy test is carried out to see the accuracy or accuracy of the results of the classification of objects in the image. The interpretation accuracy test is only carried out on the results of the 2020 image classification, while the results of the 1990, 2000 and 2010 image classifications are not accurate, but the interpretation method uses the interpretation key from the 2020 image. The accuracy test of the visual interpretation results with actual data is carried out using values user's accuracy (UA), Producer's accuracy (PA), Overall accuracy (OA), and Kappa accuracy (KA) (Viera and Garrett 2005).

Table 2 Confusion Matrix

Reference data	Classified to class PL1	PL2	PL3	PL4	PLn	Total	UA
PL1	X_{11}	X_{12}	X_{13}	X_{14}	X_{1n}	X_{1+}	X_{11}/ X_{1+}
PL2	X_{21}	X_{22}	X_{23}	X_{24}	X_{2n}	X_{2+}	X_{22}/ X_{2+}
PL3	...					...	...
PL4	..					...	...
PLn	X_{n1}	X_{n2}	X_{n3}	X_{n4}	X_{nn}	X_{5+}	X_{55}/ X_{+5}
Total	X_{+1}	X_{+2}	X_{+3}	X_{+4}	X_{+5}	X_{ii}	
PA	X_{11}/ X_{+1}	X_{22}/ X_{+2}	X_{33}/ X_{+3}	X_{44}/ X_{+4}	X_{55}/ X_{+5}		

PL (Land Cover); PA (*Producer's accuracy*); UA (*User's accuracy*)
Modified from (Jaya 2010)

$$Overall\ accuracy = \frac{\sum X_{ii}}{N}$$

$$Kappa\ Accuracy = \frac{N \sum X_{ii} - \sum X_{i+} X_{+i}}{N^2 - \sum X_{i+} X_{+i}}$$

Description:

N : The number of values in the matrix

X_{ii} : The diagonal values of the i-th row and i-th column contingency matrices

X_{i+} : The number of values in the j-th column

X_{+i} : The number of values in the i-th line

N : Number of observations

Analysis of Land Cover Change 1990-2020.

The analysis of land cover changes was carried out by making a matrix of changes that occurred from 1990 to 2020. The data used in making the matrix were land cover maps for 2014 and 2016. The land cover maps issued by the Ministry of Environment and Forestry with the classification standard SNI 7645-2010 are those used in This research has been updated. Errors are minimized by updating the classification using Landsat imagery in the same year as the land cover map. Some of the classes that experienced changes in the research location can be illustrated as in Fig.

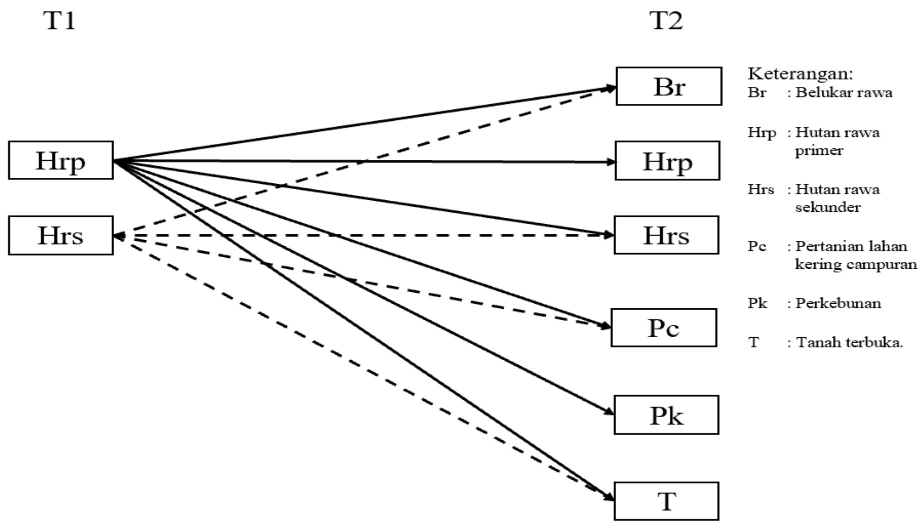

Figure 2 Illustration of land cover change from T1 to T2

Spatial Analysis of Driving Factors.

The distribution of the occurrence of degradation and deforestation is overlaid with spatial data to find out what factors can encourage the occurrence of degradation and deforestation. The spatial data used are the distance from the road, the distance from the settlement, and the pattern of settlement distribution (cluster, uniform, random). This analysis was conducted to determine the trend of the occurrence of degradation and deforestation on human activities. The distance used in this analysis has an interval of 500m for the three variables. The trend can be seen from the R2 value of each variable according to the following formula.

$$R^2 = \frac{\sum\left(Y_{Prediction} - Y_{Average}\right)}{\sum\left(Y_{Actual} - Y_{Average}\right)}$$

Prediction Y value is obtained from testing of several algorithms such as the following:

Exponential Model : $Y = a.X^b$
Power Model : $Y = a.e^{(bx)}$
Linear Model : $Y = aX + b$
Logarithmic Model: $Y = a\text{Log } X + b$

Ground check.

After obtaining the driving factors that influence the occurrence of degradation and deforestation, the results must then be overlaid with administrative boundaries to determine the distribution of land use changes in each district. This data will be combined with data from depth interviews conducted at predetermined locations to find out non-spatial causes. The results obtained from the spatial analysis will be combined with the results of the depth interview to find out the facts on the ground regarding the causes of the forest transition. Depth interview was conducted using purposive and snowball sampling method.

Results and Discussion.

Deforestation is the conversion of forest to an alternative permanent non-forested land use such as agriculture, grazing or urban development (Van Kooten 2020). Deforestation is primarily a concern for the developing countries of the tropics (Myers *et al.* 2000) as it is shrinking areas of the tropical forests (Ghimire and Barraclough 2013) causing loss of biodiversity and enhancing the greenhouse effect(Angelsen *et al.* 1999).

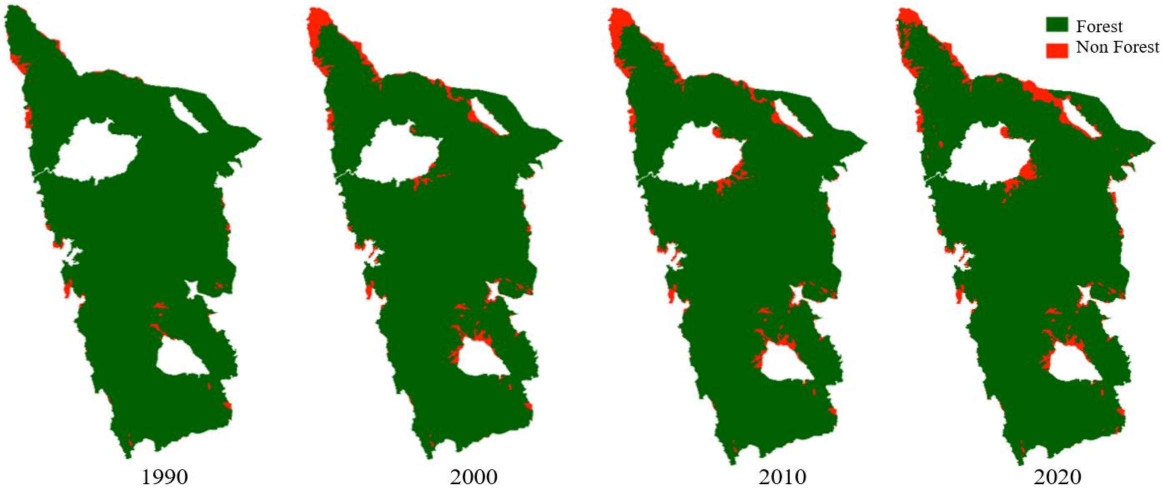

Figure 3 Deforestation trend from 1990 to 2020

Changes in forest cover that occurred from the 1990s have a downward trend. The decline in forest area in the Lore Lindu National Park area is caused by various factors that affect the decline in forest area in the conservation area. Analysis of forest cover change is carried out ten years to obtain historical information before the national park was established. Changes can be seen from figure 3 which is shown in red.

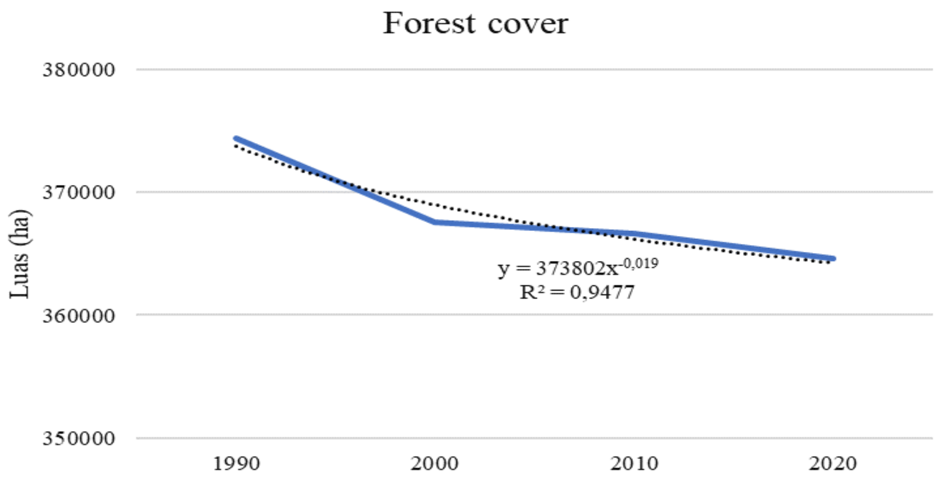

Figure 4 Forest lost from 1990 to 2020

In 1990 the forest area in the national park area had an area of 374 thousand hectares and decreased with a decreasing rate of forest area of 690 hectares / year so that the forest area was reduced to 368 thousand hectares. The rate of decline decreased to 89 hectares/year from 2000 to 2010, bringing the forest area to 367,000 hectares. Meanwhile, the rate of forest decline increased from 2010 to 2020 by 203 hectares/year. The remaining 365 thousand hectares of forest area in the national park area or about 97% of the total national park area. The overall rate of forest decline from 1990 to 2020 was 328 hectares/year.

Forest loss was distinguished based on the range of years of change (ten years). Forest change in 1990-2000 was represented by using light green color, forest change from 2000-2010 was represented by using orange color, and changes from 2010-2020 was represented by red color. Meanwhile, no change forest from 1990 to 2020 are represented in dark green.

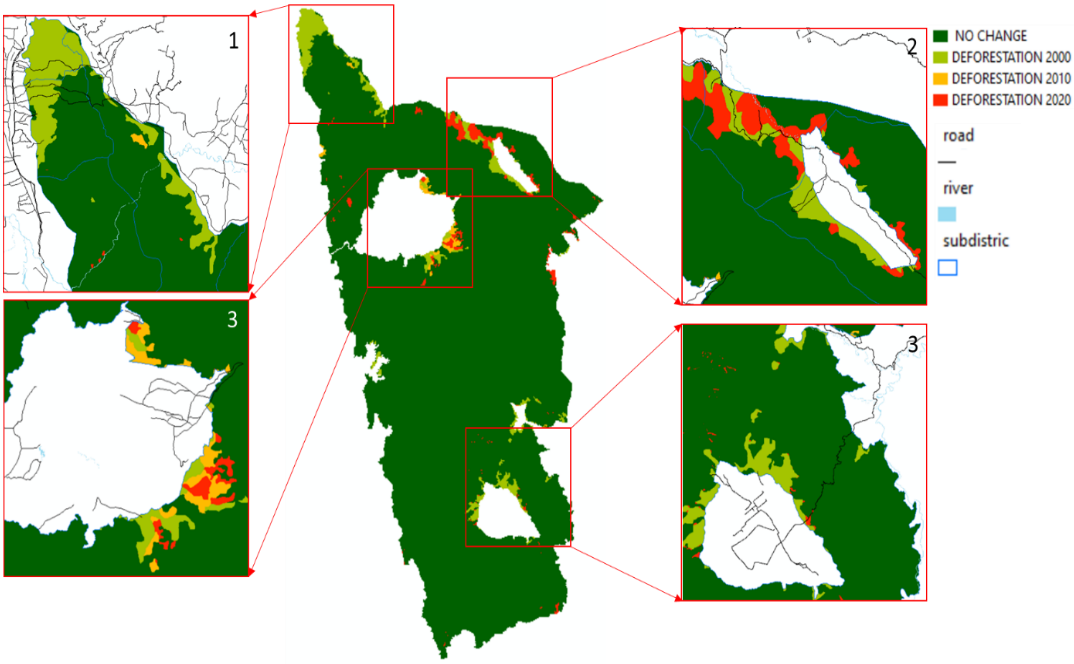

Figure 5 Deforestation trend from 1990 to 2020

Brown (1994) identified two main forces affecting deforestation. They are (1) Competition between humans and other species for the remaining ecological niches on land and in coastal regions. This factor is substantially demonstrated by the conversion of forest land to other uses such as agriculture, infrastructure, urban development, industry and others. (2) Failure in the working of the economic systems to reflect the true value of the environment. Basically, many of the functions of tropical forests are not marketed and as such are ignored in decision making. Additionally, decisions to convert tropical forests are themselves encouraged by fiscal and other incentives. The former can be regarded as the direct and latter as indirect cause of deforestation

Spatially, it can be seen that the location of deforestation is in four main areas. The first area is located in an area directly adjacent to community settlements and agriculture. Area 1 is dominated by the expansion of community-owned agricultural land that extends to the national park area. The commodities grown by the community are corn, soybeans, bananas, and moringa as barriers between community plots. About 60 per cent of the clearing of tropical moist forests is for agricultural settlement

Myers *et al.* (2000) with logging and other reasons like roads, urbanization and Fuelwood accounting for the rest. Tropical forests are one of the last frontiers in the search for subsistence land for the most vulnerable people worldwide. Millions of people live on the tropical forest with less than a dollar a day where a third of a billion are estimated to be foreign settlers. However, as the land degrades people are forced to migrate, exploring new forest frontiers increasing deforestation (Amor and Pfaff 2008). Deforestation is proxied by the expansion of agricultural land. This is because agricultural land expansion is generally viewed as the main source of deforestation contributing around 60 per cent of total tropical deforestation

Area 2 was dominated by community-owned cocoa plantations in areas close to roads and dry land farming with corn as a commodity in other locations. Cocoa planted in early 2000s difference as seen in area 3 that planted in 2010. Area 3 located in nearby lindu lake that has difficult accesibility from the city. Area 4 changed to open area/bareland indicated after ilegal logging occurred since 2000. Logging does not necessarily cause deforestation. However, logging can seriously degrade forests (Putz *et al.* 2001). Logging in Southeast Asia is more intensive and can be quite destructive. However, logging provides access roads to follow-on settlers and log scales can help finance the cost of clearing remaining trees and preparing land for planting of crops or pasture. Logging thus catalyzes deforestation (Chomitz *et al.* 1996).

Table 3 Comparation between imagery and field in every area of interest

Area	Imagery	Field
Area 1 Commodity : Dryland agriculture mixed with shrub		
Area 2 Commodity : Cocoa plantation mixed with dryland agriculture		
Area 3 Commodity : dryland agriculture		

Area 4 Commodity : Open area/ bareland		

CONCLUSION

The study found that the rate of forest decrease from 1990 to 2020 was 328 hectares/year with the highest rate was from 1990 to 2000 with rate of forest decrease 690 hectares/year. The deforestation located in four area that has difference land cover change. Area 1 changed to settlement and dry land agriculture, area 2 changed to cocoa plantation by the local community planted in 2000s, area 3 changed to cocoa plantation by the local community planted in 2010s. Area 4 changed to open area/bareland indicated after ilegal logging occurred since 2000.

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