Indonesian Journal of Environmental Management and Sustainability
e-ISSN:2598-6279 p-ISSN:2598-6260

IJEMS

Research Paper

Fragmentation Typology of Sumatran Tropical Lowland Forest, Labuhanbatu Selatan - Indonesia

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Abstract
Forest land cover experienced changes caused by various factors. Deforestation and forest degradation decreased forest structure and size that produce forest fragmentation. This study aimed to determine spatial distribution patterns and typology of forest fragmentation in the Labuhanbatu Selatan district. The study uses land cover image analysis, forest fragmentation analysis, correlation analysis, and typology analysis. Forest fragmentation is determined based on patch area (CA), patch density (PD), contiguity index (CONTIG), and proximity index (PROX). The study analyzes the correlation between variable factors and the degrees of forest fragmentation to develop a typology of fragmentation forest. The variables used to construct the typology of forest fragmentation are population density, productive age ratio, income, and slope. The classification of forest fragmentation has been completed to create a forest fragmentation typology. To determine the typology of forest fragmentation, the K-Means Cluster analysis method is used. Typology of forests fragmentation of Labuhanbatu Selatan district is three typologies. Typology 1 is the low forest fragmentation of Torgamba, Silangkitang, and Kota Pinang sub-district, typology 2 is moderate forest fragmentation are the Kampung Rakyat, and Typology 3 is high forest fragmentation of Sungai Kanan sub-district.

Keywords
Correlation Analysis, Cluster Analysis, Fragmentation, Landcover, Typology Analysis

Received: 04 June 2021, Accepted: 23 August 2021
https://doi.org/10.26554/ijems.2021.5.3.105-112

1. INTRODUCTION

The growing population has resulted in a reduction in forest land cover and land use. According to the Ministry of Environment and Forestry KLHK (2017), the conversion of forest areas to non-forest areas was done to meet the community's needs. On the other hand, changes occur to support national development while remaining focused on the functions and benefits of forest areas. This is done to ensure the forest's survival.

The increased population has increased the demand for land and food. To meet the high demand for land and food has prompted clearing forest land for crops or settlements (Samsuri, 2014). The conversion of forests to agricultural land or settlements causes the forest to be divided into a small patch of forest. It is known as forest fragmentation. Forest fragmentation is defined as forest area blocks due to road construction, housing development, agriculture, urbanization, and other developments (Gunawan et al., 2010). Forest fragmentation can cause extinction for animals because animals experience loss of their natural habitat; fragmentation also reduces forest biodiversity loss.

Forests have various functions that can provide various benefits for the life and welfare of the community. Changes in forest management need to be made to support the forest to be maintained. However, the community around the forest can be prosperous changes in forest management which initially focused on timber management towards forest landscape ecosystem management, including social forestry and community-based forest management. The combination of better forest management and land use represents a strategic reorientation toward more prudent forest management while taking traditional values and social forestry into account. It is hoped that this policy change will significantly influence the community to continue conserving forests while also using them optimally, reducing deforestation and forest degradation, and increasing forest area.

It is necessary to analyze the components that ensure sustainability in an area plan or management unit. The

planning is expected to be specific by considering the characteristics of each area to be managed. The area analysis is completed first, followed by the planning to carry out the area analysis. The areas with the same characteristics will be grouped first. Typology refers to this characteristic of the regional grouping. Typology is also expected to help map the distribution of not yet known forests and have not been carried out in a comprehensive inventory (Lastini et al., 2011). This grouping aims to provide an overview of the areas and policies the government will carry out towards those areas. The government is expected to provide policies that can help the community. These policies are also expected to get support from the community so that people want to participate in implementing policies carried out by the government.

Labuhanbatu Selatan district is the result of division because it is considered to have a fast regional development stage. One of the impacts of this development is changes in land use and cover. These changes can have an impact on potential disturbance to forested areas. The threat of deforestation that triggers fragmentation needs to be controlled. Classifying the remaining forest into fragmentation degrees prompts which rehabilitation, utilization, and protected areas are prioritized. Based on their social and biophysical characteristics, the degree of fragmentation must be classified into several typologies. Forest managers require information on the typology of forest landscape fragmentation to manage forest areas effectively. This study aims to (1) identify spatial distribution patterns and typology of forest landscape fragmentation and (2) determine the degrees of forest landscape fragmentation in the Labuhanbatu Selatan district.

2. EXPERIMENTAL SECTION

2.1 Time and Location

The research was conducted in August-October 2020. The research was conducted in Labuhanbatu Selatan district, North Sumatra (Figure 1). Data processing and analysis were carried out at the Forest Management Laboratory, Forestry Study Program, Faculty of Forestry, Universitas Sumatera Utara.

2.2 Tools and materials

Several tools used in this research are GPS (Global Positioning System) and digital camera for field surveys. The study also uses hardware (personal computer) as a data processing tool, ArcGis software (ArcMap 10.3) for spatial analysis, Fragstat, SPSS, Microsoft Excel, and Microsoft Word software. GPS was used to mark and record coordinates of point checked; ArcMap 10.3 was used on spatial analysis, i.e., inputting data, editing, and overlay analysis. Fragstat ver 4.0 was used for getting landscape metrics, i.e., CA, PROX, CONTIG (McGarigal, 1995; McGarigal, 2002). SPPS was used to conducted typology analysis, and EXCEL was used for inputting and tabular analysis.

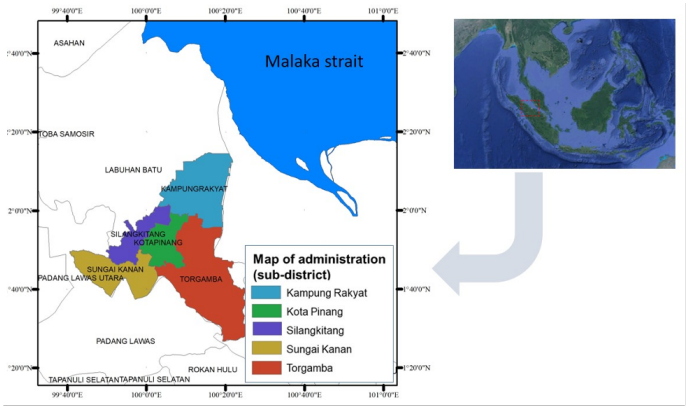

Figure 1. Research Location, Labuhanbatu Selatan District – Sumatera Utara, Indonesia

The materials used are maps of lands cover area of Labuhanbatu Selatan district in 2018; Landsat image obtained from www.earthexplorer.usgs.gov, administration maps of Labuhanbatu Selatan district, contour maps, and maps of road networks.

2.3 Methods

2.3.1 Data Collection

Secondary data were obtained from publications from government agencies such as the Forest Area Consolidation Center and the Central Statistics Agency (CSA), research institutes, universities, as well as other scientific publications literature. Data and information on the results of the spatial processing analysis of the digital map of the research location are assisted by several supporting layers, namely contour maps, road network maps, state forest area maps, land maps, and administrative boundary maps, and fragmentation analysis to determine changes in parameter values-fragmentation on a landscape scale. The community's social and economic data collection was obtained from interviews with the community and questionnaires given to the community in Labuhanbatu Selatan district.

2.3.2 Data analysis

Image analysis

The primary data used in this study were Landsat imageries from 2018, which were used to derive land covers and land uses. The images were obtained from http://glovis.usgs.gov. Landsat OLI 2018 images were used. Erdas Imagine 9.1 was used for image pre-processing and processing. After that, the satellite images were analyzed to generate a map of land cover use. The land-use classes (categories) referred to the Ministry of Environment and Forestry category.

Fragmentation Analysis

The fragstat analyzes the landcover layer to generate the landscape metrics. The landscape metrics were used in determining the degree of forest landscape fragmentation. Its are patch area (AREA), patch density (PD), proximity

(PROX), and contiguity index (CONTIG). The fragmentation score was calculated according to Samsuri (2014), the total forest fragmentation score will be calculated based on the score of each fragmentation sub-factor (proximity, density, isolation, and area). The score of each sub-factor uses a Likert scale.

Typology Analysis

According to Lastini et al. (2011), the biophysical and socio-economic factors that make up the forest typology are slope ratio, population density, productive ratio, and income. A critical area with slopes and valleys is one of the areas targeted for forestry development. The variable that needs to be considered is the ratio (ratio) between the land area with the slope class, which is greater, equal to 15% of the total village area. Population density is defined as the ratio between the total population in each village (people) and the administrative area of the village. For income data, it is carried out with an approach to the community. The ratio of productive age is the ratio between the total population of productive age (15-64 years) and the village's total area. Forest management is still considered a side activity that is not intensive, so it is suspected that several areas developed when the number of productive ages was small and dominated by non-productive ages. Based on the Central Statistics Agency (BPS) of Labuhanbatu Selatan district, the age ratio is categorized as workers, namely those aged 15-60 years and over.

2.3.3 Correlation analysis

Correlation analysis serves to see the relationship of a variable with other variables. In this study, the correlation analysis used was the Spearman correlation analysis. The Spearman correlation analysis aims to see the relationship between biophysical-socio-economic factors and the degrees of fragmentation. The correlation coefficient determines the level of connection (correlation) between variables. According to Khusnul (2017), the correlation coefficient is a coefficient that describes the degree of the linear relationship between two or more variables. According to Safitri (2016) the correlation coefficient is used to determine the relationship between variables. The correlation coefficient value is between -1 < 0 <1, namely:

- If r = -1 perfect negative correlation, the influence of variable X on variable Y is very strong, and the correlation is inversely proportional
- If r = 1 perfect positive correlation, the influence of variable X on variable Y is very strong, and the correlation is directly proportional.
- If the correlation coefficient shows the number 0, then there is no relationship between the two variables studied, or the correlation that occurs is very weak.

The strength of correlation between variables will be accepted if the value is <0.05 or 0.01. The relationship is considered significant, and if the value is >0.05 or 0.01, then the relationship is considered insignificant.

2.3.4 Cluster Analysis for Fragmentation Typology

Cluster analysis is used to group variables with similar characteristics so that the diversity within a group is smaller than the diversity between groups (Sitepu et al., 2011). The cluster analysis used in this study is K-Means Cluster Analysis (Ediyanto et al., 2013). This non-hierarchical cluster analysis method seeks to partition existing objects into one or more clusters or groups of objects based on their characteristics. K-means cluster analysis is used to classify variables in demographic and biophysical data that affect forest fragmentation with similar characteristics in an area. Grouping based on the similarity of demographic and biophysical factors that affect forest fragmentation in Labuhanbatu Selatan district will make it easier to determine the following policy.

3. RESULTS AND DISCUSSION

3.1 Land Cover

Lands cover types of Labuhanbatu Selatan district comprised six land covers: water bodies, forests, settlements, oil palm plantations, mixed gardens, and bare land. The distribution of land cover area in Labuhanbatu Selatan district is listed in Table 1; meanwhile, the land cover type of Labuhanbatu Selatan district is illustrated on a map in Figure 2.

Table 1. Area Distribution of Landcover, Labuhanbatu Selatan the Year 2018

No	Landcover types	Area (hectare)
1	Waterbody	3,670.61
2	Forest	32,051.20
3	Road	15,326.40
4	Mixed garden	2,406.71
5	Oil palm plantation	236,191.00
6	Bare lands	21,424.90
7	Settlement	2,934.10
Total		314,004.92

There is six identified land cover of the Labuhanbatu Selatan area, namely: water bodies with an area of 3,670.61 ha, forests with an area of 32,051.20 ha, mixed gardens with an area of 2,406.71 ha, oil palm plantations with an area of 236,191.00 ha, bare land with an area of 21,424.90 ha and a settlement of 2,934.10 ha. The forest cover of the Labuhanbatu Selatan district has changed Kaswanto et al. (2021) and reach 3,450 ha within 2002-2020. It shows that the reduction in forest area is due to the conversion of forests into oil palm plantations. This is in line with Prasetyo (2017) which states that deforestation and forest degradation are influenced by two (2) factors driving the acceleration of change, namely direct and indirect factors. Direct factors (pressure) include population density or demography, population density with the eyes of farmers seeking, and expansion of agricultural land. Meanwhile, indirect driving factors are high timber prices, palm oil, economic crises, macro-economic destabi-

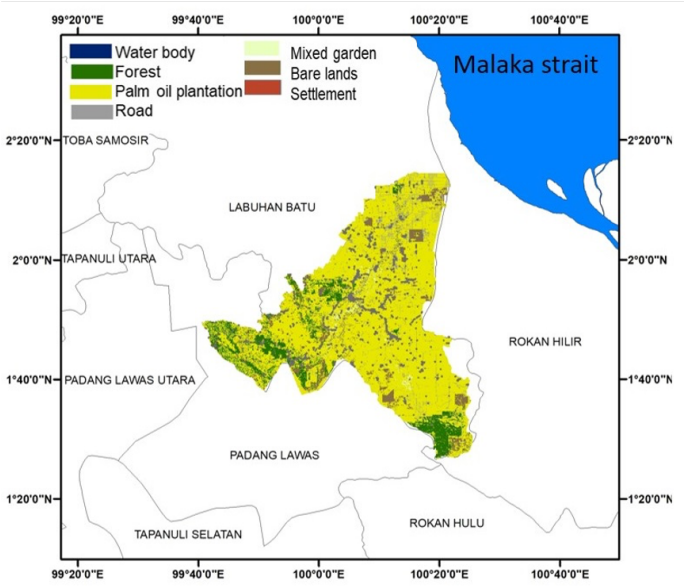

Figure 2. Landcover Map of Labuhanbatu Selatan District

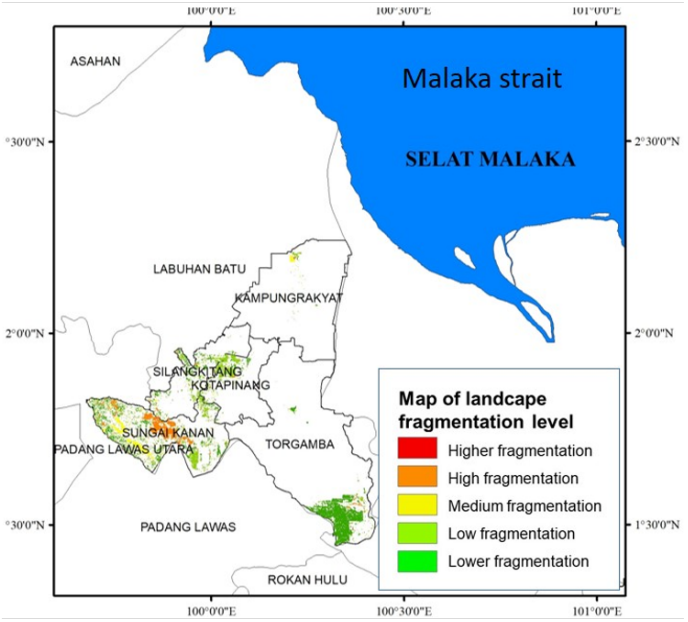

Figure 3. The Degrees of Landscape Forest Fragmentation Map, Labuhanbatu Selatan District

lization, and policies and institutions problems. Oil palm is an essential commodity for the global market, and fulfilling this commodity has resulted in many palm oil companies or smallholders expanding oil palm plantations (Amalia et al., 2019; Nawir and Rumboko, 2008). It is also in line with Geist and Lambin (2002) state that deforestation is triggered by agricultural expansion, wood extraction Austin et al. (2019), and infrastructure expansion, with apparent regional variations. This extensive expansion has resulted in changes to the forest landscape. Forests converting to oil palm plantations will result in deformation and fragmentation. The impact of fragmentation will reduce biodiversity and wildlife, loss of natural habitat, and even extinction.

3.2 Forest Fragmentation Analysis

The degrees of forest fragmentation can be determined by knowing the value of each landscape metrics, such as patch area, patch density, contiguity index, and proximity index (Samsuri, 2014). The value of each metric will be grouped into five (5) classes, and the degrees of forest fragmentation is divided into five (5) classes, namely: higher fragmentation, high fragmentation, medium fragmentation, low fragmentation, and lower fragmentation (Samsuri, 2014; Samsuri et al., 2014). Figure 3 depicts the distribution of forest landscape fragmentation in the Labuhanbatu Selatan district.

The degree of forest fragmentation is categorized into five classes based on the value of the forest fragmentation index. The greater the index value, the higher the degree of forest fragmentation. The degree of fragmentation of the Torgamba forest is at a low degree of forest fragmentation. The forest patch area in this district is quite large, and the connectivity between forest patches is of great value. The forest fragmentation degree in Sungai Kanan has three forest fragmentation classes, namely low, medium, and high. It shows that Sungai Kanan forest has various proximity values or isolation degree values. Low fragmentation classes dominate the forest fragmentation in Kota Pinang because the separation distance between forest patches is close.

High forest fragmentation degrees can lead to a reduction in biodiversity. The forest turns into many patches of forest, so the population of living species will be increasingly isolated. The more isolated an individual species, the more difficult it is to breed, which results in a decrease in population. A small patch of the forest will show that the higher the degradation degree, the conservation value has lower (Amalia et al., 2019; Lastini et al., 2011). Furthermore, Lastini et al. (2011) stated that the essential characteristics of forest patches are related to species extinction due to limited resources.

3.3 Typology Forest Fragmentation

Demographic factors form a typology for estimating the degree of forest fragmentation, Labuhanbatu Selatan district has five (5) sub-districts: Torgamba, Sungai Kanan, Pinang city, Silangkitang, and Kampung Rakyat sub-district, Torgamba sub-district has a higher income level than the other four sub-districts (Table 2). The income level is comparable to the fragmentation degree scoring. The transition of forest cover in an area depends on the time and level of economic development (income) (Dwiprabowo et al., 2014). The occurrence of forest transitions is closely related to high economic growth. An increase in per capita income can be interpreted as increasing demand for forest and agricultural products, which directly drives deforestation, resulting

in fragmentation. Population density increases every year (2.57%) BSP (2018) and impacts lands needed. It is one of the factors causing fragmentation in Labuhanbatu Selatan district. Population density affects the rate of forest cover changed. Increasing populations usually need land for settlement and agriculture to ensure their survival. It is in line with Rosalia (2016), who states that the growing population has the consequence that it is increasingly difficult to get land for development and agricultural purposes. The productive age ranges from 15-64 years, which is ideal for workers (Table 3). Generally, getting older, the income will increase, which also depends on the type of work, Kampung Rakyat sub-district is a sub-district with the most minor productive age with a high degree of forest fragmentation.

Labuhanbatu Selatan district has a flat slope class. More area of Labuhanbatu Selatan is located at an altitude of 100-500 m above sea level. The slope ratio affects the degree of forest fragmentation (Samsuri et al., 2014). The flat slope class triggers deforestation and fragmentation due to the easy access to open land. Moreover, there are rather steep, steep, and very steep slope classes. It is sporadic to find deforestation events, but it does not rule out deforestation and fragmentation if it has mining content on the land. It is supported by the statement of Setiawan et al. (2015) that Land clearing with any topography containing mining content will continue to be exploited.

3.4 Correlation Analysis

Spearman's correlation analysis is used to determine how strong the relationship of a variable is with other variables. The correlation between demographic factors and the degree of fragmentation is significantly correlated with a correlation strength value of 0.01. The correlation between population density and the fragmentation degree is negative (-) or inversely proportional, as shown in the table above (Table 4). The level of correlation between population density and forest fragmentation is very weak. It is indicated by the value of the correlation coefficient of 0.104.

In contrast, the correlation between the ratio of productive age and the degree of forest fragmentation is positive (+) with a very weak correlation. The correlation coefficient value indicates the weak correlation between the ratio of productive age and the degree of fragmentation (0.205). The correlation between the income level and the degree of fragmentation is positive (+), directly proportional to the very weak correlation level. The correlation coefficient value of 0.109 indicates the level of correlation. Meanwhile, the correlation between the slope level ratio and the degree of fragmentation is negative (-) or inversely proportional to a very weak correlation level of 0.63.

The correlation between the degree of fragmentation and each demographic factor in Labuhanbatu Selatan district is very weak. It suggests that there may be other factors causing fragmentation to occur. His research Barlow and Tomich (1991) noted that approximately 20% of all agricultural land in Sumatra and Kalimantan are plantations. It shows the possibility that one of the factors that caused the fragmentation was oil palm land with an area of 23,6191.00 Ha. The oil palm area can be seen on the land cover map of Labuhanbatu Selatan district in Figure 1. In line with Austin et al. (2019), it is also stated that the factors causing deforestation and forest fragmentation in North Sumatra are industrial plantations and expansion of oil palm plantations within forest company concessions.

Furthermore, Samsuri et al. (2014); Nawir and Rumboko (2008) stated two causes of deforestation and fragmentation in Indonesia, namely the direct cause and the indirect cause. The direct causes of fragmentation include: 1) forest fires, 2) flooding, 3) morphological conditions and high rainfall, 4) logging for plantation land clearing, 5) forest encroachment, 6) transmigration programs, 7) land management using techniques unsuitable soil and water conservation, and 8) mining and oil drilling, Meanwhile, the indirect causes include 1) market failure due to the price of forest timber which is too low, resulting in a high desire for logging, 2) Failure of policies granting forest exploitation permits and transmigration programs, policies granting forest exploitation permits are frequently abused, the permit was granted to prosper the community surrounding the forest, resulting in the community overusing the forest, 3) government weaknesses in law enforcement; and 4) broader socio-economic and political causes such as the economic crisis, the reform era, high population density and growth, and unequal distribution of economic and political power.

3.5 Cluster Analysis

Cluster analysis classifies forest fragmentation degrees based on similar characteristics. The analysis results indicate four variables that affect the degree of forest fragmentation. The four variables resulted in three-class typologies, namely: low (typology 1), medium (typology 2), and high (typology 3) (Table 5).

Typology one (1) being in a low fragmentation class is influenced by factors: productive age, population density, population income level, slope level, and population income level. In typology two (2), being in the medium fragmentation class is influenced by the level of population density, the ratio of productive age, the level of population income, and the slope level. At the same time, the third typology (3) is in a high fragmentation class influenced by: the level of population density, the level of income of the population, the ratio of productive age, and the level of slope.

Typology 1 includes the landscape forests of Torgamba, Kota Pinang, and Silangkitang sub-district. The ratio of productive age is one of the factors influencing the low fragmentation degree. Torgamba is a sub-district that has the largest population ratio. The level of population density affects typology 1. Kota Pinang sub-district is the largest population sub-district with 129.35 people/km^2. Torgamba is a sub-district with a high-income level compared to other

Table 2. The Income per Household of Sub-districts in Labuhanbatu Selatan District

Sub district	Income (rupiahs (IDR)/month)	Note
Sungai Kanan	1,000,000 - 1,800,000	Lowest income
Torgamba	3,000,000 - 4,500,000	High income
Kotapinang	2,500,000 - 3,500,000	Moderate income
Silangkitang	1,800,000 - 2,500,000	Low income
Kampung Rakyat	1,800,000 - 2,500,000	Low income

Table 3. Productive Age Number of Sub-districts in Labuhanbatu Selatan District

Sub-district	Number of children	Productive age (people)	Oldest age (people)
Sungai Kanan	21,350	32,418	2,831
Torgamba	43,193	74,172	4,119
Kotapinang	21,743	39,729	2,953
Silangkitang	10,459	20,416	2,187
Kampung Rakyat	21,185	19,116	8,833
Total	117,930	185,851	20,923

sub-districts due to the population's income level. Meanwhile, the effect of slope level on the formation of typology one is very low.

Typology 2 includes the Kampung Rakyat forest with a moderate degree of fragmentation. The level of population density is one of the factors that influence typology two. Kampung Rakyat sub-district has a population of 85.9 people/km^2. It also has a productive age ratio that is 19,116 people. The income level of this sub-district is classified as low at 1.8 million–2.5 million IDR. The population with low income usually uses forest products to meet their daily needs. It can affect the rate of deforestation and fragmentation. Typology 2 also has a flat class of level slope.

Typology 3 covered Sungai Kanan forest with a high degree of fragmentation. The level of population density is one of the factors that influence typology three. The population density in this area is 112.19 people/km^2. The dense population needs land to meet their daily needs. The income level of Sungai Kanan community is ranging from 1.0-1.8 million IDR. The productive ratio age population influences the rate of deforestation and forest fragmentation. The level of the slope also has an impact on the formation of typology 3. Sungai Kanan sub-district is in the flat slope class; the flatter the surface, the easier access is made; this follows the statement of Linkie et al. (2004), which states that deforestation and fragmentation are inversely proportional to the distance from the road, the slope, and altitude.

The typology obtained categorizes the spatial heterogeneity of forest fragmentation (Rijal, 2019; Albar et al., 2016). Furthermore, Rijal (2019) states that the typology can describe any deforestation and fragmentation spatially

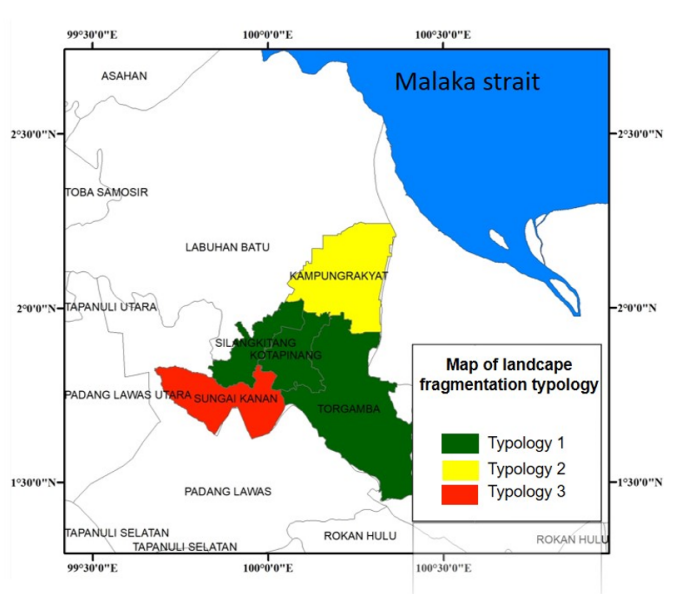

Figure 4. Typology Forest Fragmentation Map of Labuhanbatu Selatan District

dispersed with different temporal variations. The resulting forest fragmentation typology model classifies the forest fragmentation of Labuhanbatu Selatan into three classes: typologies with low, medium, and a high degree of fragmentation. Figure 4 is a map that presents the typology distribution of the Labuhanbatu Selatan district.

The typology of forest fragmentation in Labuhanbatu Selatan (Figure 4) classifies three sub-districts as typology 1, namely Torgamba sub-district, Kota Pinang sub-district,

Table 4. Spearman Correlation Analysis between Demographic Variables and the Degree of Fragmentation

Variable	Forest fragmentation	Population density	Productive age ratio	Income	Slope
Forest fragmentation	1	-.104**	.205**	.109**	-.063**
Population density		1	-.024*	-.476**	.171**
Productive age ratio			1	.815**	-.263**
Income				.,000	-.312**
Slope					1

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5. Forest Fragmentation Typology of Labuhanbatu Selatan District

Typology	Variable
Typology 1	Productive age ratio
	Population density
	Community income
	Slope
Typology 2	Community income
	Productive age ratio
	Community income
	Slope
Typology 3	Community income
	Community income
	Productive age ratio
	Slope

Silangkitang sub-district. Typology one is a typology with a low degree of fragmentation. Typology two only covers one sub-district, Kampung Rakyat Sub-district, as a moderate degree of forest fragmentation. Meanwhile, typology 3 includes one sub-district, namely Sungai Kanan District, with a high degree of forest fragmentation.

The development of the existing typology has different effects of specific factors due to differences in location and spatial space (Hosonuma et al., 2012). In the global scope, various phases of forest transition are based on biophysical factors categorized into four phases: pre-transition, early transition, late transition, and post-transition. The pre-transition phase is high forest cover and low deforestation rates; in the initial transition phase, forest cover disappears at an increasingly high rate and high deforestation rates; in the final transition phase. There is little forest area remaining, decreasing deforestation rate and post-transition. It is the phase in which the reforestation process occurs so that forest land cover increases. The island of Sumatra is in the final transitional phase. Aryono et al. (2018) state that demographic factors are one of the strongest factors that cause the high forest transition process; apart from demographic factors, another factor affecting the forest transition process is increased per capita income. According to Rijal (2019); Barri (2018), the driving factors for deforestation and fragmentation on the island of Sumatera are agricultural expansion, timber harvesting, infrastructure development, and five driving factors; the five driving factors are demographic, economic, technological, policy, and institutional and cultural. Meanwhile, Albar et al. (2016) stated that agricultural expansion is the factor that triggers the high deforestation and forest degradation rate in Southeast Asia. This statement is supported by Rijal (2019); Kaswanto et al. (2021), who state that the main driver of deforestation is agriculture, both for food crops and livestock. In addition, changes in land use can be influenced by topography, accessibility, urban land distribution, and agricultural land areas in the flat slope class will experience deforestation rates because the area is used for agriculture, horticulture, and agroforestry.

4. CONCLUSIONS

The forest fragmentation of Labuhanbatu Selatan district has three typologies: low forest fragmentation in three sub-districts, namely Torgamba District, Silangkitang District, Pinang City sub-district, Medium forest fragmentation typology is in the Kampung Rakyat sub-district, and the high forest fragmentation typology is in the Sungai Kanan sub-district. The correlation between population density, population income, the ratio of productive age, and slope level with forest fragmentation degree in Labuhanbatu Selatan district is very weak. The forest fragmentation typology depicts the factors that influence the degree of fragmentation. These findings can be used as a framework in determining how to protect and conserve the remaining forests in the Labuhanbatu Selatan district.

5. ACKNOWLEDGEMENT

The authors would like to thank the Directorate of Research and Community Service (DRPM) for supporting the funding of this basic research for the year 2019. The author thanks Universitas Sumatera Utara for the support as well.

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