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# TYPOLOGY AND DEFORESTATION OF LOWLAND TROPICAL RAIN FORESTS

**Dahlan Dahlan[1,2,4]*, I Nengah Surati Jaya[3], Muhammad Buce Saleh[3], Nining Puspaningsih[3] and Dalil Sutekad[1,4]**

[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala
Jl. Tgk. Syech Abul Rauf No. 3, Darussalam, Banda Aceh, Indonesia
[2]Department of Forestry, Faculty of Agriculture, Universitas Syiah Kuala
Jl. Tgk. Hasan Krueng Kalee No. 3, Darussalam, Banda Aceh, Indonesia
[3]Department of Forest Management, Faculty of Forestry and Environment, IPB University
Kampus IPB Dramaga, Bogor, Indonesia
[4]Forestry Research Center, Universitas Syiah Kuala
Jl. Teuku Nyak Arief, Darussalam, Banda Aceh, Indonesia

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## ABSTRACT

Deforestation is a global issue that attracts international community attention. This paper describes the behavior of deforestation of lowland tropical rain forests within the period of 2009-2015. The main objective of this research is to develop a typology of deforestation rates and identify trends in deforestation according to land conversion groups. To develop a behavioural typology of the deforestation rates, this study investigates whether the unit analysis of the sub-districts can be classified or grouped into some typology classes. From the analysis by considering the sub-district level as the smallest unit analysis, the study found that the rate of deforestation of lowland tropical rain forests in West Kalimantan Province is similar over the province, where the sub-districts could not be grouped according to the biophysical and socio-economic aspects. This research also finds that the trend of deforestation in the lowland tropical rain forests of West Kalimantan by land conversion group is: (1) unauthorized land conversion of 1,256,862.80 ha (65.28%); (2) semi-authorized land conversion of 308,247.14 ha (16.01%); and (3) authorized land conversion of 360,231.36 ha (18.71%). Unauthorized deforestation reached 65.28%. Therefore, it is necessary to increase the capacity of the community towards the authorized use of forests and increase supervision from the government.

**KEYWORDS:** Typology, deforestation, lowland, tropical rain forests

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## 1. INTRODUCTION

Natural resources, especially forests in the world, are constantly changing or losing (Lombardi et al., 2020; Mikusiński et al., 2018; Namkhan et al., 2021), including Indonesia. Forest cover loss continues to occur from year to year in Indonesia (FWI, 2014; KK RI, 2012; KLHK RI, 2014; KLHK RI, 2015; KLHK RI, 2017; Margono et al., 2014). Deforestation has become an international, national, regional issue and even at the site level. This problem cannot seem to be eliminated, but efforts to minimize can be done by studying the causal factors and the driving force factors of deforestation that are influenced by various biophysical, socio-economic, cultural, and political factors. Several studies have studied the causes and the driving force of deforestation (Agaja et al., 2020; Fagariba et al., 2018; Prasetyo et al., 2009; Purwanto et al., 2015; Reddy et al., 2020; Sulistiyono et al., 2015; Wijaya et al., 2015).

Forest cover change to non-forest (deforestation) including plantation forests in Indonesia during the period 2009-2011 amounted to 0.45 million ha/year (KK RI, 2012). Then in the 2012-2013 period, it increased by 0.73 million ha/year (KLHK RI, 2014), in the 2013-2014 period it declined again by 0.4 million ha/year (KLHK RI, 2015), and increased again in the 2014-2015 period by 1.09 million ha/year (KLHK RI, 2017). The rate of deforestation in Indonesia reached 1.13 million ha/year in the period 2009-2013 (FWI, 2014). Indonesia lost primary forest in the period 2000-2012 by 0.84 million ha or an average of 700 000 ha/year (Margono et al., 2014).

Kalimantan Island is the second rank of forest loss after Sumatra Island at 428,900 ha and Sumatra Island at 372,000 ha in the period 2009-2011, the 2014-2015 period on Sumatra Island reaches 519,000 ha and Kalimantan Island 374 800 ha (KK RI, 2012; KLHK RI, 2017). Research on Sumatra Island related to forest loss has been carried out throughout Sumatra (Sulistiyono et al., 2015) and in one province on Sumatra Island, Jambi Province (Wijaya et al., 2015), while research throughout Kalimantan Island has been carried out (Purwanto et al., 2015). Research related to deforestation has never been carried out for the entire province of West Kalimantan which is the main focus of this study, which in the 2009-2012 period experienced deforestation of 41,726.00 ha/year (KK RI, 2012), then decreased in the 2014-2015 period by 40,477.30 ha/year (KLHK RI, 2017). During the period 2009-2013, West Kalimantan lost an natural forest cover of 426,000 ha or an average of 106,500 ha/year (FWI, 2014).

The problem faced today is how to identify the behavior of deforestation that varies according to landscape units which are interactions of various environmental factors both biological, physical, social, economic, cultural, and local geopolitical. Techniques for identifying behavior from deforestation can be expressed at rates and/or spatial distribution patterns that are carried out with various approaches. One of them is the stratification or classification approach to homogeneous sub-regions based on the environmental factors that influence them. Another term often referred to in this grouping is typology, which is a study of

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grouping by type. The grouping according to certain types based on variables or characteristics that are dominant (main) through various weighting or group methods as well as the selection of the factors that characterize object the most (Lastini, 2012; Nielsen-Pincus et al., 2015; Valbuena et al., 2008). Building a typology of forest use in West Usambara only based on socio-economic characteristics (Luswaga & Nuppenau, 2020).

The typology behavior becomes important when the behavior of deforestation varies greatly according to local environmental factors. The development of typology in determining the rate of deforestation will greatly assist decision-makers in controlling the rate of deforestation. The causes factor in deforestation are factors that cause differences in the rate of deforestation directly, while the driving force in deforestation is factors that cause indirect differences in the rate of deforestation. Direct causes of deforestation include deforestation, illegal logging, and uncontrollable forest fires, while indirect drivers include market failure, policy failure, and other socio-economic and political problems in general (Nawir et al., 2008).

The occurrence of deforestation in various regions in Indonesia has different factors including lowland tropical rain forests in West Kalimantan. The various factors that cause deforestation due to relatively large and inter-subdistrict administration in West Kalimantan are assumed to have high diversity, so the typology of deforestation is needed based on each sub-district administrative area with various biophysical and social-economic factors. The objective of the study was to develop a typology of the rate of deforestation and to identify the classification of deforestation trends based on the form of land conversion.

## 2. METHODS

### 2.1. Study Area

The research location is geographically located at 02°04'52.685" North Latitude - 03°02'24,368" South Latitude and 108°50'26,115"-114°13'21.995" East Longitude (Figure 1). The development of a deforestation typology was only focused on sub-districts that had forests in 2009, which were 159 sub-districts, while to identify the trend of deforestation focused at the district/city level which had forests in 1990, namely 14 districts/city (Figure 2). Data processing was carried out at the GIS and Remote Sensing Development Center, Universitas Syiah Kuala and Remote Sensing and GIS Laboratory, IPB University.

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**Figure 1: Study area in West Kalimantan**

### 2.2. Data Collection

The data used in this study were land cover data from the Ministry of Environment and Forestry of the Republic of Indonesia (KLHK RI) (the year 1990, and 2015), data on sub-district boundaries throughout West Kalimantan Province from the Geospatial Information Agency (BIG), Socio-economic data in 2010 and 2016 District of Figures from the Central Bureau of Statistics (BPS), Landsat 1990-2016 satellite imagery throughout West Kalimantan (USGS 2017). The tools used were Global Positioning System (GPS), cameras, and questionnaires. Data processing was done using software: ArcGIS 10.8, IBM SPSS Statistics, and Microsoft Excel.

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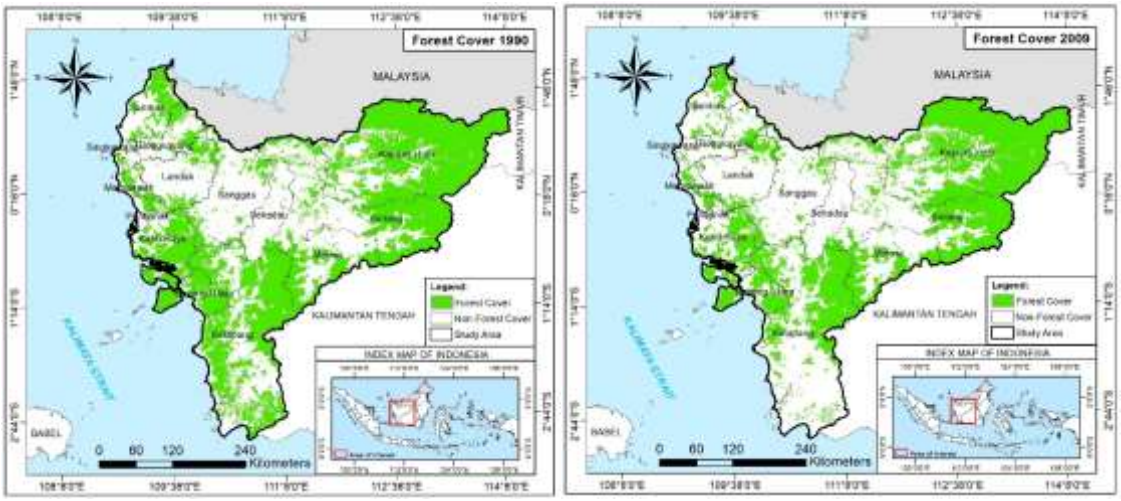
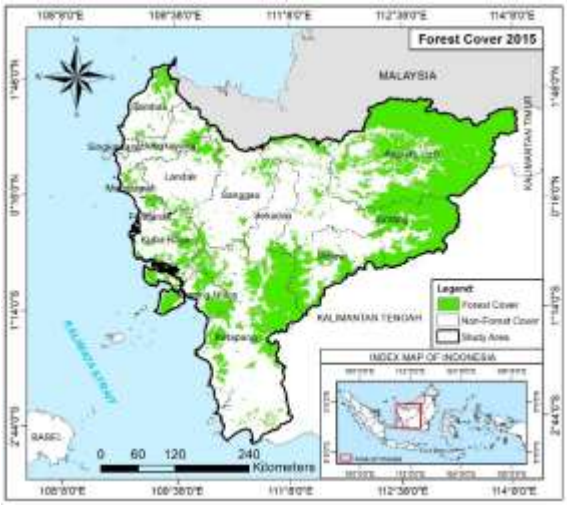
### 2.3. Research Procedures

#### 2.3.1. Validation of Land Cover Data

Validation of land cover data was carried out on the data from the land cover classification of the Indonesian Ministry of Environment and Forestry. Data on deforestation that are illogical was validated. Validation was done with Landsat satellite image data or other images and/or through field checking. Landsat image data is first processed by image pre-processing, including layer band stacking, geometric correction, and image sharpening. Validation was only to match the results of illogical interpretations on KLHK RI land cover data and did not change the polygon. The size of the polygon that is validated was only the size of ≥ 6.25 ha with consideration of the scale of the data.




(a) Forest cover 1990 (b) Forest cover 2009




(c) Forest cover 2015

**Figure 2: Forest cover in West Kalimantan**

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### 2.3.2. Selection of Typology Variables

Typological variables of deforestation are based on the availability of data and are continuous, namely biophysical and socio-economic factors, including 151 variables. Biophysical and socio-economic factors refer to some of the previous ones such as (Dolisca et al., 2007; Entwisle et al., 2008; Fagariba et al., 2018; Romijn et al., 2013). Biophysical variables were obtained from the data of deforestation with modification results by using the sub-district area and population, while the socio-economic variables were obtained from the District Data in Figures (BPS) and with modification results. Biophysical variables consist of 4 variables, while socio-economic variables consist of 147 variables, namely population (13 variables), an education level (38 variables), production and area of food crops (44 variables), and production and area of plantation crops (52 variables).

The selection of variables is based on the relationship between biophysical and socio-economic factors (variable x) with the rate of deforestation (variable y) using the Pearson correlation test. The selected x variable from the correlation test results with the value of $r \geq 0.20$ (Evans, 1996), then Pearson correlation test was conducted between variables x. If between variables x has a correlation $r \geq 0.65$ (de Almeida et al., 2002; Aguayo et al. 2007; Sulistiyono et al. 2015), then one variable will be chosen which has a high correlation with the rate of deforestation.

### 2.3.3. Typology Determination of Deforestation

The grouping method (typology) used in this study is the analysis of furthest neighbor clustering with the sub-district being the smallest unit. Typological development of deforestation was done using a clustering approach with a standardized Euclidean distance. The use of standardized Euclidean distances is based on the consideration of differences in the range of values and units of variables used in grouping (typology). The distance between two clusters (sub-districts) is calculated by the formula (Jaya 2015):

$$SdED_{jk} = = \left[\sum_{i=1}^{n} \frac{(x_{ij}-x_{ik})^2}{s_i^2}\right]$$

Note:

$SdED_{jk}$ = *Standardized Euclidean Distance*
$S_i^2$ = Variance from variable-i
$x_{ij}$ = Variable value -i from cluster -j
$x_{ik}$ = Variable value -I from cluster -k

### 2.3.4. Typology Accuracy Test

The typology accuracy level of deforestation is determined by calculating Overall Accuracy (OA), Producer's Accuracy (PA), and User's Accuracy (UA) between the administrative areas of the clustering results with the class data on the rate of deforestation in each sub-district administrative area in West

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Kalimantan. Typology accuracy analysis of deforestation was done by creating a contingency matrix based on the calculation of the magnitude of OA, PA, and UA (Alipbeki et al, 2020; Congalton, 2001; Jaya 2015; Jaya & Kobayashi, 1995; Jensen 1996). Determination the best classification of deforestation that must be chosen between clusters (class) using 1 variable or more than 1 variable, then the typology is chosen which uses the least variable while considering the value of Overall Accuracy (OA), Producer's Accuracy (PA), dan User's Accuracy (UA).

### 2.3.5. Analysis of Deforestation

The deforestation in this study was forest cover change both primary forest and secondary forest which became other coverings including changes to plantation cover in the period 1990-2015. The deforestation was analyzed by thematic change method with formulas as examples [Tuplah90]&"-"&[Tuplah15], thus generating data on deforestation to other coverings (including plantation forest cover). Data on deforestation from the results of thematic change were used to calculate the rate of deforestation.

The typology identification uses land cover data from the Indonesian Ministry of Environment and Forestry in 2009 and 2015 from verification results to calculate the rate of deforestation. The use of deforestation rate data in the 2009-2015 period is closely related to the availability of socio-economic data sourced from the 2010 Regency in Figures. The use of socio-economic data of two different years (periods) to obtain data for the year in question and to obtain modified socio-economic dynamics data to classify (typology) the rate of change in deforestation.

### 2.3.6. Grouping Causes of deforestation

Deforestation can be caused by the conversion of land to other covers (not forest) including plantation forest, shrubs, swamp scrub, grass/savanna, dryland agriculture, mixed dryland agriculture, rice fields, ponds, plantations, settlements, airports/ports, transmigration, open land, and mining. Based on the causes of changes in natural forest cover, they are grouped based on the form of change which can be divided into 3 groups, namely:

1) The changes that occur are caused by the unauthorized land conversion. This change is indicated by a change from forest cover to shrubs, swamp shrubs, grass/savanna, water body and open land. Changes from forest cover to shrubs or open land are generally in the form of lands ex-illegal logging or land clearing left by the perpetrators.

2) The changes that occur are caused by the semi-authorized land conversion. This change is indicated by a change from forest cover to dryland agriculture and mixed dryland agriculture. In general, these lands are cultivated by the community, with the permission of the customary head/tribal chief or based on an agreement within the local community. Thus, in this change group, some get official permission from the government and some only get permission from the results of an agreement at the community group level.

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3) The changes that occur are caused by the authorized land conversion. This change is indicated by a change from forest cover to forest plantations, rice fields, ponds, plantations, settlements, airports/ports, transmigration, and mining. In general, plantations, plantations, and mining are managed by companies, with the assumption that these changes have been approved by the authorities. Changes in forest cover into airports/ports and transmigration are land uses for the government's interest, with the assumption that these changes have gone through an official process. Other changes are settlements which are areas designated by the government for community and government activities.

## 3. RESULT AND DISCUSSION

### 3.1. Typology of Deforestation

Based on the analysis of the coefficient correlation between the biophysical and socio-economic variables (variable x) and the rate of deforestation (variable y), from 151 variables x, 23 variables have a correlation value (r) ≥ 0.2. To avoid multicollinearity, the coefficient correlation between variables x is high (r ≥ 0.65), only one variable is chosen, especially the variables that are consistent and easily obtained. The biophysical and socio-economic variables that are maintained were variables that have a high correlation with the rate of deforestation (variable y). From the results of the analysis obtained as many as 5 variables x namely the number of students in the period 2009-2015 (x1), the number of students Madrasah Tsanawiyah in 2009 (x2), coffee plantations in 2009 (x3), student ratio in 2009 and 2015 (x4) and the ratio of forest cover in 2009 and sub-district area (x5). The correlation matrix between selected independent variables x and variables y can be seen in Table 1.

**Table 1: Correlation matrix between selected independent variable x and variable y**

| | $Y$ | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ |
|---|---|---|---|---|---|---|
| $y$ | 1.00 | | | | | |
| $x_1$ | 0.41 | 1.00 | | | | |
| $x_2$ | 0.34 | 0.52 | 1.00 | | | |
| $x_3$ | 0.33 | 0.22 | 0.37 | 1.00 | | |
| $x_4$ | -0.25 | -0.64 | -0.04 | 0.01 | 1.00 | |
| $x_5$ | 0.35 | 0.10 | -0.01 | 0.10 | -0.17 | 1.00 |

The accuracy test results for the typology of deforestation based on biophysical and socio-economic factors on the grouping of administrative districts in the lowland tropical forests of West Kalimantan can be seen in Table 2 and Table 3. Socio-economic aspects are more influential than biogeophysical aspects of land cover changes (Widiawaty et al., 2020).

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**Table 2: Recapitulation results of the accuracy test from 5 best combination typology of deforestation into 3 classes**

| No. | Variables | OA (%) | Lowest PA (%) | Lowest UA (%) | Number of Subdistrict | | |
|---|---|---|---|---|---|---|---|
| | | | | | T1 | T2 | T3 |
| 1 | Variable $x_2$, $x_3$, $x_4$ | 78.62 | 33.33 | 7.69 | 151 | 6 | 2 |
| 2 | Variable $x_2$, $x_3$ | 76.73 | 50.00 | 6.90 | 153 | 4 | 2 |
| 3 | Variable $x_1$, $x_2$ | 74.84 | 35.71 | 17.24 | 143 | 14 | 2 |
| 4 | Variable $x_1$, $x_2$, $x_3$ | 73.58 | 31.25 | 17.24 | 141 | 16 | 2 |
| 5 | Variable $x_1$, $x_3$, $x_4$ | 72.33 | 35.71 | 20.00 | 129 | 28 | 2 |

**Table 3: Recapitulation results of the accuracy test from 5 best combination typology of deforestation into 2 classes**

| No. | Variables | OA (%) | Lowest PA (%) | Lowest UA (%) | Number of Subdistrict | |
|---|---|---|---|---|---|---|
| | | | | | T1 | T2 |
| 1 | Variable $x_1$ | 94.97 | 94.90 | 20.00 | 157 | 2 |
| 2 | Variable $x_2$ | 94.97 | 94.90 | 20.00 | 157 | 2 |
| 3 | Variable $x_1$, $x_2$ | 94.97 | 94.90 | 20.00 | 157 | 2 |
| 4 | Variable $x_2$, $x_3$ | 94.97 | 94.90 | 20.00 | 157 | 2 |
| 5 | Variable $x_2$, $x_4$ | 94.97 | 94.90 | 20.00 | 157 | 2 |

Typology of deforestation which is classified into 3 classes with various variable combinations obtained the highest accuracy value is x1x4 with OA value of 78.62%, PA 33.33%, UA 7.69% (Table 2). The typology of deforestation is grouped into 2 classes with various combinations of variables obtained the highest accuracy values are all the best 5 combinations, when viewed from the best number of variables is x1 and x2 with OA 94.97%, PA 94.90%, UA 20.00% (Table 3).

The typology of deforestation to subdistrict administrative grouping is based on the consideration of the values of OA, PA, and UA in various classes and various combinations of variables with very low values, especially PA below 50.00%. Therefore, grouping behavior of deforestation with biophysical and socio-economic data approaches at the provincial level with the smallest sub-district observation units in West Kalimantan cannot be grouped. It can be explained that the biophysical and socio-economic conditions of the community are relatively homogeneous in classifying behavior the rate of deforestation.

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The results of the best deforestation typology study as a comparison at the provincial level with the sub-district unit are in Jambi Province, where 2 classes with 1 variable (population density) were obtained in the smallest unit of the sub-district observation resulting in OA 76.00%, PA 89.00%, and UA 83.00% (Wijaya et al. 2015). Other research related to deforestation typology is on the Sumatra Island on the smallest unit of observation at the district/city level which produces 2 classes with 1 variable (rate of increase in the number of agricultural families) with OA 73.10% (Sulistiyono et al. 2015).

### 3.2. Deforestation

Forest cover in 1990 (beginning of the period) in the West Kalimantan study area was 7,550,654.6 ha (51.42%) of the West Kalimantan study area of 14,684,809.4 ha. The deforestation of lowland tropical rain forests for the period 1990-2015 in West Kalimantan reached 1,925,341.30 ha (25.50%), with a rate of 77,013.65 ha/yr (1.02%). For more details, deforestation to various covers other than forest for the period 1990-2015 can be seen in Table 4 and Figure 3.

**Table 4: Deforestation in period 1990-2015**

| No | Change to- | Area (ha) | Percentage (%) |
|---|---|---|---|
| 1 | Swamp shrub | 681,602.58 | 35.40 |
| 2 | Plantation | 305,862.19 | 15.89 |
| 3 | Mixed agriculture land | 300,491.84 | 15.61 |
| 4 | Shrub | 286,302.01 | 14.87 |
| 5 | Bare land | 276,747.04 | 14.37 |
| 6 | Plantation forest | 28,905.93 | 1.50 |
| 7 | Paddy field | 14,915.28 | 0.77 |
| 8 | Water body | 8,470.06 | 0.44 |
| 9 | Mining | 8,451.98 | 0.44 |
| 10 | Dryland agriculture | 7,766.24 | 0.40 |
| 11 | Swamp | 3,772.08 | 0.20 |
| 12 | Transmigration | 819.60 | 0.04 |
| 13 | Pond | 704.12 | 0.04 |
| 14 | Settlement | 530.35 | 0.03 |
| | Total | 1,925,341.30 | 100.00 |

The deforestation in Table 4 show that a relatively large change is the deforestation to swamp shrubs by 681,602.58 ha (35.40%), plantations 305,862.19 ha (15.89%), dry land mixed farming 300,491.84 ha (15.61%), shrubs 286,302.01 ha (14.87%), and open land 276,747.04 ha (14.37%). The relatively small change was only 74,335.64 ha (3.86%) of the total deforestation in the form of plantations, paddy fields, water bodies, mining, dryland agriculture, swamps, transmigration, ponds, and settlements (Table 4). Results suggest that land-use activities for agricultural activities in general (plantation, mixed agriculture land, dryland agriculture, and transmigration) have an important role in deforestation in the lowland

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tropical rain forest of West Kalimantan reaching 31.94% (614,939.87 ha). In addition, a very dominant factor is the activity of using only wood, which is characterized by changes in the land into swamp shrub, shrub, bare land, water body, and swamp reaching 65.22% (1,256,891.77 ha). Although the overall linear trend of deforestation rates in Kalimantan from 1990 to 2015 is decreasing, West and North Kalimantan are likely to increase (Wegscheider et al., 2018).

Factors of changes in forest cover that occur in various areas due to agricultural activities by the community. Agricultural activities have an important role in deforestation in Colombia, although their effects vary widely between regions (González-González et al., 2021). Changes in forest cover in South Texas, the United States for the period 1987-2016 to rangeland-herbaceous cover, agriculture, urban areas, bare land, and water (Lombardi et al., 2020). Deforestation in protected areas on the Amazon, due to urban and agricultural expansion, and infrastructure projects (roads, highways, dams, and land sharing), mining, illegal logging, and livestock farming (Paiva et al., 2019). Furthermore, in Malawi, Africa is losing forest cover due to household needs for agricultural expansion, tobacco curing, and brick burning (Ngwira & Watanabe, 2019).

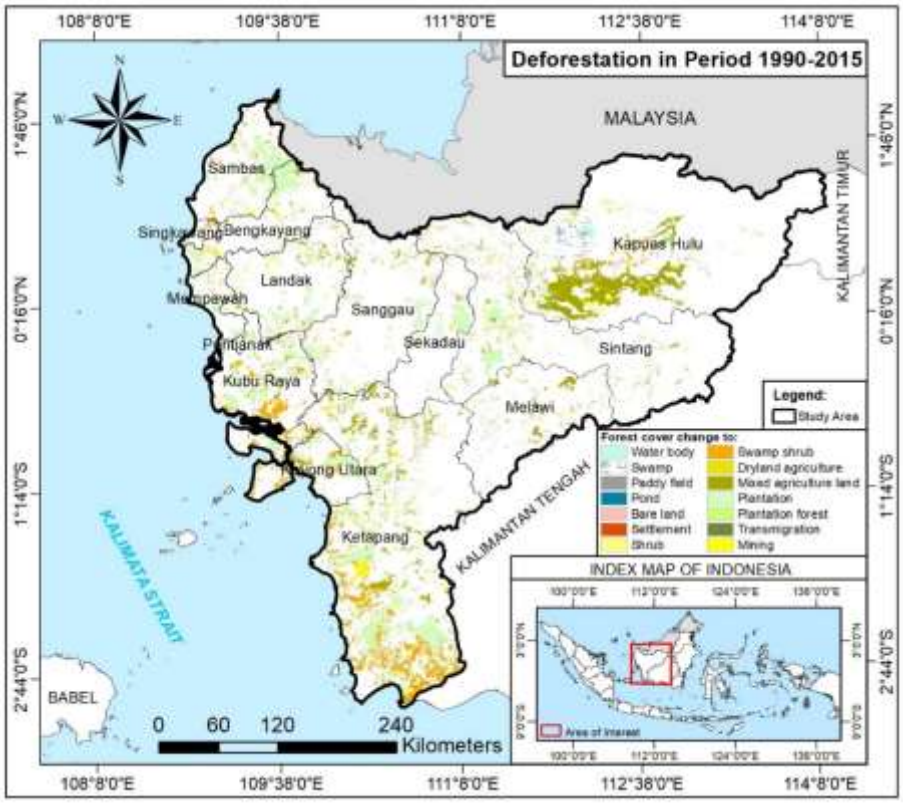


**Figure 3: Deforestation in period 1990-2015**

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Based on the forms of deforestation that occurred during the period 1990-2015, the factors causing land change can be grouped as follows (Figure 4):

a) Changes that occur, caused by unauthorized land conversion, that is, the forest cover to swamp shrub (on wetland) reaches a proportion of 35.40%, being a shrub (on dryland) 14.87% and becomes bare land 14.37%. Of the total forest change caused by the conversion of unofficial forest cover, it reached around 64.64%. The deforestation to a shrub or bare land in general are in the form of illegal logging or land clearing left by the perpetrators. Conditions like this are found in areas with relatively high access, both from the road and from the river. Bare land, in general is a change in recent years where the land is still largely in the form of vacant land.

b) Changes caused by semi-authorized (semi-legal) land conversion, which generally take the form of forest cover to lands cultivated by the community as dryland agriculture or mixed agroforestry. Land use like this is generally carried out with the permission of the customary head/tribal chief or based on an agreement within the local community. Changes because of the semi-legal land conversion there are about 16.01% of the total changes.

c) Changes caused by authorized land conversion, indicated by changes from forest cover to plantations, which are generally in the form of plantations managed by companies, only around 15.89%. Other changes, officially indicated are relatively small, namely changes to plantations, paddy fields, mining, transmigration, ponds, and settlements by only 2.82%. The changes caused by this legal conversion as a whole are only around 18.71%.

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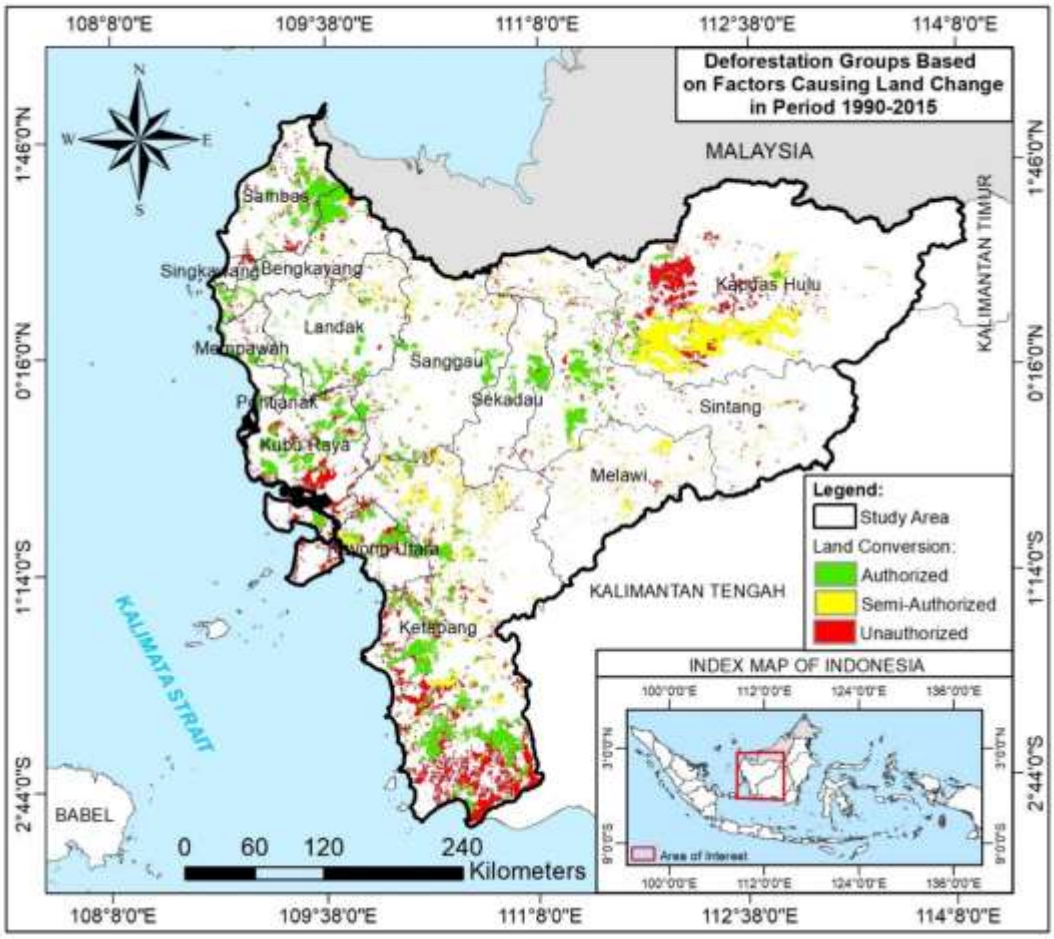


**Figure 4: Deforestation Groups Based on Factors Causing Land Change in Period 1990-2015**

## 4. CONCLUSION

This study concluded that the rate of deforestation of lowland tropical rain forest in the province of West Kalimantan was homogenous at the provincial level, where the sub-district units cannot be grouped based on biophysical and socio-economic aspects. This study also found the factors causing deforestation of lowland tropical rain forests due to land conversion that occurred during the last 25 years (period 1990-2015) in West Kalimantan, can be grouped into 3 (three) as follows: (1) unauthorized land conversion, namely deforestation to swamp shrubs reaching 681,602.58 ha (35.40%), to bushes 286,302.01 ha (14.87%) and become bare lands 276,747.04 ha (14.37%); (2) semi-authorized land conversion, namely deforestation to mixed dryland agriculture 300,491.84 ha (15.61%) and became dryland agriculture 7, authorized land conversion, namely deforestation to plantations amounting to 305,862.19 (15.89%). Other changes that are officially indicated are relatively small, namely changes to plantation forests, paddy

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fields, mining, transmigration, ponds, and settlements by only 2.82%. The changes caused by this legal conversion as a whole are only around 18.71%.

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