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Typology of Deforestation in Riau Province

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Abstract. Deforestation assessments based on the rate number and extent of the deforestation area. This assessment of deforestation has the potential to provide wrong information about the condition of a region's forests. High deforestation rates are known as the area with high forest destruction. Otherwise, the area with low rates of deforestation are known as the areas with better forest conditions. The rate of zero deforestation was known as a non-deforestation area. In fact, a low rate deforestation in a region are not necessarily mean having a better forest. This study was aimed to determine the typology of deforestation in Riau Province. The research method was done by analyzing land cover data with Geographic Information System. Deforestation typology assessments were conducted by using the variables of the proportion of the initial forest area of a regency, the incidence of deforestation and the rate of deforestation. The deforestation typology of the regency level in Riau Province has shown in 5 deforestation profiles. The highest typology is Large-Lately-Low Deforestation (5 regencies), which is indicating that the incidence of deforestation in Riau Province occurred in large forest areas, mostly occurred in the second period of observation with high rate. Riau Province is the province with the highest number of forest area in Sumatra (1990) and the highest rate of deforestation (68.18%). Deforestation in Riau Province from 1990 to 2013 is the deforestation typology of Early deforestation.

1. Introduction

Deforestation is the permanent loss of forest stands for other uses. FAO [1] states that deforestation is the conversion of forests to other land uses or reducing tree canopy cover to less than the minimum threshold of 10% for the long term with a minimum tree height of 5 m in a minimum area of 0.5 ha. The term deforestation is still debatable [2], but in this study deforestation which is defined as forest cover that has undergone a change in the form of permanent loss of cover both intact forest cover, fragmented and scattered and transitional period.

The deforestation rate that occurred in Indonesia between 2003-2006 reached 1.174 million hectares per year. [3] states that forest resources experienced deforestation of 1.7% in the period 1990 to 2000 and tended to decline to 0.5% in the period 2000 to 2010. Deforestation in Indonesia is still higher compared to the average deforestation occurred in Southeast Asian countries (1% period 1990 to 2000 and 0.4% in the period 2000 to 2010).

Sumatra is the highest deforestation island in Indonesia. Deforestation in Sumatra is estimated at 6.5 million ha (28%) in the 1985-1997 period (GFW 2002). [4] said that Sumatra had lost around 7.5 million hectares of forest in the period 1990 to 2010. Of this total forest loss, 2.6 million hectares were primary forest. The average rate of forest loss occurred in Riau Province, which was 42% in 1990 to 2010. Deforestation has removed more than 50% of forest cover in Riau [5].



Deforestation that occurs has an impact on global climate change. The result is a decline in biodiversity, rising sea levels to forest fires, such as 9,765,000 ha of forest fires [6]. Deforestation also triggered the degradation of Sumatra's land such as in North Sumatra (2.4 million hectares) [7].

To overcome the problem of deforestation, various studies are needed related to the causes or drivers of the causes of deforestation, the characteristics of their location and their spatial, area, rate, trends and impacts.

Deforestation in each region is believed to be different because it has its own characteristics (typical) called typologies. Typology is a study of type or type. Typologies of deforestation are defined as studies or classifications of types or types of deforestation based on typical characteristics. Typology is also defined as grouping of regions based on certain characteristics that are built based on the biophysical and socio-economic characteristics of the community. Typology is a classification or grouping of objects based on similarities of basic characteristics to certain types. This understanding was modified from the Oxford English Dictionary and the large Indonesian dictionary [8].

Deforestation also results in higher fragmented forests [9]. This forest forms a certain pattern into scattered and non-compact forest groups as before. Forest cover becomes smaller and scattered parts of the forest. Small forests have high potential for deforestation [9]. The primary forest lost in Riau Province (1990–2000) is fragmented and degraded forest [4].

Deforestation events can be recognized and better understood by knowing their typology. This typology will describe the occurrence of each deforestation spatially dispersed with different temporal variations. In addition, research on spatial patterns that focus on deforested areas is still rare. Therefore, this typology of deforestation research in Riau is very important.

2. Literature Review

2.1. Research Location

This research was carried out on forest areas in Riau Province. Data analysis was carried out at the Remote Sensing and GIS Laboratory of the Faculty of Forestry of IPB and the Planning and Forestry Information System Laboratory of the Forestry Faculty of Hasanuddin University. This research is divided into three stages, namely the preparation stage, data collection and field survey and the analysis and discussion stages.

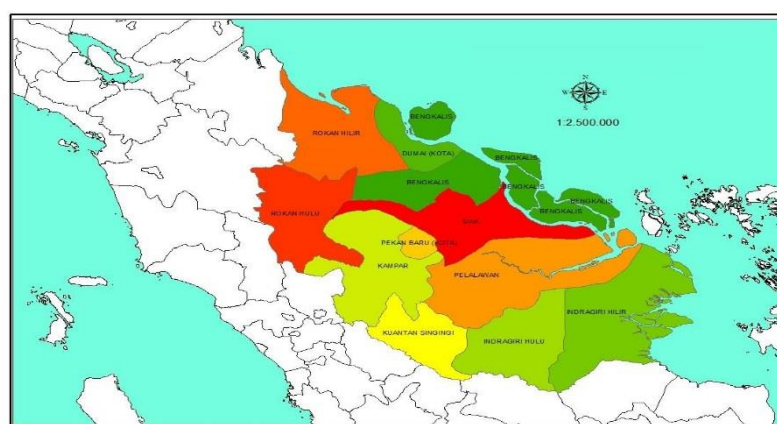


Figure 1. Research Location

2.2. Research Tools and Materials

The tools used in this study are ArcGIS 10.1 and Envi 5 software which are used to interpret satellite imagery and perform spatial analysis. Microsoft Excel is used to analyze data statistically. The tool used in this research survey was field survey equipment consisting of *Global Positioning System* (GPS),

roll meter, Abney Level, guard meter, compass, digital camera, tape recorder and tally sheet as well as several other field survey support tools.

The research data used in this study are primary and secondary data. The data used in this study are the Ministry of Environment and Forestry land cover data and satellite image data downloaded from <http://glovis.usgs.gov>. Landsat imagery was analyzed to obtain a land cover map. The land cover type refers to the classification issued by the Ministry of Forestry 2004. Field surveys are carried out to check the correctness of the interpretation of land cover types and collect vegetation data (ground truth or ground check). Supporting research data is still collected, mainly spatial data such as river network maps, administration maps, road network maps, and other thematic maps. Other secondary data used are population data provided in the form of Village Potential (Podes) data by the Central Statistics Agency.

2.3. Data processing

This research section uses the Ministry of Forestry's land cover data in 1990, 1996, 2000, 2006, 2011 and 2013. The use of land change data can historically improve the accuracy of image classification. Other research data are Landsat imagery. Landsat images downloaded are recording images 1990, 2000, 2010, and 2014 path / row 127 / 59–60 and 126 / 60–61 (4 scenes) per time period so that the total Landsat images collected are 16 scenes. Administrative maps use data released by the Geospatial Information Agency (*Badan Informasi Geospasial (BIG)*) in 2010.

Image pre-processing activities carried out on the digital image with geometric and radiometric correction, layer stacking, mosaicing, and cropping stages using ArcGIS 10.1. Image classification is carried out using the on screen digitation technique following the guidance of PPIK land cover classification, Forestry Planning Agency (2008). Based on the guidelines for 23 land cover classes, the classification is classified into 11 cover classes namely forest, plantation forest, plantation, settlement, dry land agriculture, rice field, swamp shrub, scrub, open land, water body, and airport.

The classification of land cover that has been formed is then overlaid with the Administrative Map of Riau Province in 2010 (BIG 2010). The reliability of the classification results was evaluated using an accuracy test using reference data taken from field observations conducted by purposive sampling in 2014. Evaluation of the results of recording image classification in 1990, 2000 and 2010 was carried out using the "key interpretation" approach in the form of "monogram" Landsat satellite imagery which was built using image recordings in 2014.

The measurement of accuracy test used is using Overall Accuracy and Kappa Accuracy [10, 11]. Analysis of deforestation was carried out on changes in forest cover to non-forest land in the period 1990–2000, 2000–2010, 2010–2014. Forest land cover is grouped into forests while land cover such as plantations, settlements, dryland agriculture, rice fields, swamp shrubs, shrubs, open land, water bodies, and airports are grouped into non-forests [5]. The deforestation table is modified from the land change table in Pando, Bolivia, Bolivia.

2.4. Data Analysis

Data analysis was carried out by utilizing the results of an overlay between changes in land cover with district and village administrations in Riau Province in several periods. The first data analysis conducted is an analysis of deforestation. Deforestation occurred was divided into several periods, namely the period 1990–1996, 1996–2000, 2000–2006, 2006–2011, 2011–2013 and 1990–2013. Monitoring deforestation requires calculation of deforestation rates. Annual deforestation is calculated by the annual forest cover change rate derived from multiple interest law [12,13,14] which is formulated as follows [15].

$$r = \left(\frac{1}{(t_2 - t_1)} \right) \times \ln \left(\frac{A_2}{A_1} \right) \dots\dots\dots (1)$$

The extent and rate of deforestation during the observation period in each district are explained descriptively. Changes and trends in spatial deforestation events during the observation period can provide information on trends in deforestation events in Riau Province.

The next analysis is a typology analysis of deforestation to identify other variables that provide a specific type of deforestation event. This typology of deforestation analysis is carried out by paying attention to the importance of the existence of the initial forest area owned by each region, the period of deforestation events and the deforestation rate or what is called the deforestation profile [5].

The typology of deforestation is defined as a combination of three components. The first component is the proportion of the initial forest area to the area of the district which is categorized as small, medium and large (small, medium, large). The second component is the proportion that indicates the highest deforestation events from two periods, namely the pre-reform period (1990 to 2000) and the post-reform period (2000 to 2013). This proportion measures deforestation events based on deforestation rates per period. This proportion is categorized as beginning, middle and end (early, middle, lately deforestation). The third typology component is the deforestation rate for the period 1990 to 2013. This category is classified as low, medium and high (low, moderate, high deforestation) [5]. The formula of each proportion is written as follows:

$$PLH = \frac{LHA}{LWK} \times 100\% \quad \dots\dots\dots (2)$$

$$PKD = \begin{cases} \text{If } LD1 - LD2 > 20\% & ; \text{ then } PKD = I \\ \text{Else : If } LD1 - LD2 < -20\% & ; \text{ then } PKD = III \\ \text{Else : } PKD = II & \dots\dots\dots (3) \end{cases}$$

$$LD = \text{average } (LD1; LD2) \quad \dots\dots\dots (4)$$

Description:

PLH	: The proportion of the initial forest area per district; <i>small (<30%), medium (30% – 50%), large (>50%)</i>
LHA	: Area of forest early in the year of observation (Ha)
LWK	: District administration area (Ha)
PKD	: Proportion of deforestation events; <i>early, middle, lately</i>
LD1	: Deforestation rate for the first period 1990 – 2000 (%)
LD2	: Second period deforestation rate 2000 – 2013 (%)
LD	: Average rates of deforestation for periods 1 and 2; <i>low (<1%), moderate (1% – 2%), high (>2%)</i>

The value of the proportion of the initial forest area (PLH) smaller than 30% is categorized as an area with a small forest area (small), PLH value with a value of 30 to 50% included in the medium category (medium), and PLH value 50% greater (large). The value of the proportion of deforestation events (PKD) greater in the first period is categorized as high deforestation events in the initial period / reform (early deforestation). The high PKD value at the end of the period is categorized as a deforestation event in the final period / post-reform (lately deforestation). High PKD values in both periods are categorized as middle deforestation. The average deforestation rate (LD) of 1% is categorized as low deforestation, LD values of 1% to 2% are categorized as moderate deforestation, while LD which is more than 2% is classified as high deforestation. The categorization of PLH is based on the RTRW rules regarding the constancy of forest area in an area, which is at least 30%. Categorizing LD (low and high deforestation) based on the deforestation rate of 2% is based on the consideration that the rate of deforestation that occurred in Southeast Asia averaged 1% for the period 1990 to 2000 and 0.4% for the period 2000 to 2010 [3]. The deforestation rate of 2% is driven by several considerations such as the condition of the larger forest area, the larger population and the high deforestation incidence so far in Indonesia compared to countries, especially Southeast Asia.

The combination of the proportion of the initial forest area, deforestation events and the average rate of deforestation forms 27 deforestation profiles. In addition to these 27 profiles, districts that do not

have forests (no forest area / NFA) and regencies that have forests have no deforestation (no deforestation / ND) [5].

Table 1 Spatio-temporal deforestation matrix in Riau Province [16]

No	Tipology of Deforestation	Code	NPT
1	<i>Small-early-low</i>	1-1-1	1
2	<i>Small-early-moderate</i>	1-1-2	2
3	<i>Small-early-high</i>	1-1-3	3
4	<i>Small-middle-low</i>	1-2-1	4
5	<i>Small-middle-moderate</i>	1-2-2	5
6	<i>Small-middle-high</i>	1-2-3	6
7	<i>Small-lately-low</i>	1-3-1	7
8	<i>Small-lately-moderate</i>	1-3-2	8
9	<i>Small-lately-high</i>	1-3-3	9
10	<i>Medium-early-low</i>	2-1-1	10
11	<i>Medium-early-moderate</i>	2-1-2	11
12	<i>Medium-early-high</i>	2-1-3	12
13	<i>Medium-middle-low</i>	2-2-1	13
14	<i>Medium-middle-moderate</i>	2-2-2	14
15	<i>Medium-middle-high</i>	2-2-3	15
16	<i>Medium-lately-low</i>	2-3-1	16
17	<i>Medium-lately-moderate</i>	2-3-2	17
18	<i>Medium-lately-high</i>	2-3-3	18
19	<i>Large-early-low</i>	3-1-1	19
20	<i>Large-early-moderate</i>	3-1-2	20
21	<i>Large-early-high</i>	3-1-3	21
22	<i>Large-middle-low</i>	3-2-1	22
23	<i>Large-middle-moderate</i>	3-2-2	23
24	<i>Large-middle-high</i>	3-2-3	24
25	<i>Large-lately-low</i>	3-3-1	25
26	<i>Large-lately-moderate</i>	3-3-2	26
27	<i>Large-lately-high</i>	3-3-3	27

(a) Description :

Deforestation Tipology	: 1-2-3; 1 = LH 2 = KD 3 = LD
Forest Area (LH)	: 1 = Small 2 = Medium 3 = Large
Deforestation events (KD)	: 1 = First Period (Pra Reformaion) 2 = Second half of the period 3 = Third Period (Post-Reformation)
Average Deforestation Rate (LD)	: 1 = Low 2 = Middle 3 = High
NPT	: Tipology Number

3. Result

3.1. Forest Area, Area and Deforestation Rate

Riau Province has the largest forest area in Sumatra amounting to 5,657,461.03 ha in 1990. Forest area in Riau Province in 2013 was left 1,799,956.22 ha. The total area of Riau Province is 8,617,213.5 ha. Several studies in Sumatra that are in line with the results of this study have shown the extent of forest loss over more than 20 years, such as the study of [5]. Extent of deforestation in Riau Province during the period 1990 to 2013 covering an area of 3,785,795 ha. This means that during this period, almost 70% of Riau's forest area was lost or deforested.

Land cover analysis that has been carried out using the Ministry of Forestry's Planology Agency land cover data in 2013, obtained the highest forest area of the district at the beginning of observation (in 1990) in Pelalawan District covering an area of 982,011.20 ha. The forest area of Pelalawan Regency is the highest forest area in all of Sumatra. The remaining forest area at the end of the observation (in 2013) is 337,737.56 ha. The area of forest in the early years of observation (1990) and the year of end of observation (2013) at the district level can be seen in 2.

Table 2. District size and forest area at district / city level in 1990, 2000 and 2013 in Riau Province

District	District Area. (ha)	Forest Area (ha)		
		1990	2000	2013
Bengkalis	857.000,8	622.967,1	426.447,1	190.933,0
Indragiri Hilir	1.349.067,9	729.665,5	466.128,0	249.943,8
Indragiri Hulu	770.810,2	546.894,6	416.081,9	220.480,4
Kampar	1.068.133,1	616.073,2	306.553,9	200.155,4
Dumai City	232.505,2	182.415,7	141.759,9	56.794,7
Pekanbaru City	61.165,5	8.779,1	2.170,7	0,0
Kuantan Singingi	524.787,2	271.289,8	143.734,0	86.853,3
Pelalawan	1.265.061,2	982.011,2	741.346,2	337.737,6
Rokan Hilir	902.866,1	571.406,3	369.714,5	84.820,3
Rokan Hulu	805.144,9	376.378,4	223.831,9	81.351,2
Siak	780.671,5	547.865,4	323.891,8	160.881,7

Based on an analysis of the forest area in each district / city in Riau Province it was also found that the city of Pekanbaru had lost all forest areas in 2013.

Table 3. District / city level of deforestation in Riau Province

District	Deforestation Area (ha)		
	1990-2000	2000-2013	1990-2013
Bengkalis	196.520,1	235.514,0	432.034,1
Indragiri Hilir	263.537,5	216.184,2	479.721,7
Indragiri Hulu	130.812,7	195.601,5	326.414,2
Kampar	309.519,4	106.398,4	415.917,8
Dumai City	40.655,8	84.965,2	125.621,0
Pekanbaru City	6.608,3	2.170,7	8.779,1
Kuantan Singingi	127.555,7	56.880,7	184.436,4
Pelalawan	240.665,0	403.608,6	644.273,6
Rokan Hilir	201.691,8	284.894,3	486.586,1
Rokan Hulu	152.546,5	142.480,8	295.027,3
Siak	223.973,5	163.010,1	386.983,7

The largest area of deforestation in Riau Province during the period 1990 to 2013 occurred in Rokan Hilir District and was the largest area of deforestation in Sumatra. The area of Rokan Hilir forest that is deforested is 464,559.85 ha or an average of 20,198.25 ha per year with a deforestation rate of 31.79%. The extent of deforestation in the five largest regencies / cities in Sumatra all occurred in Riau Province [5]. The five regencies are Rokan Hilir, Pelalawan, Indragiri Hilir, Kampar and Bengkalis Regencies. This shows massive deforestation in Riau Province.

Table 4. District / city deforestation rates in Riau Province

District	Deforestation Area (%)		
	1990-2000	2000-2013	1990-2013
Bengkalis	3,79	6,18	9,97
Indragiri Hilir	4,48	4,79	9,28
Indragiri Hulu	2,73	4,89	7,62
Kampar	6,98	3,28	10,26
Kota Dumai	2,52	7,04	9,56
Kota Pekanbaru	13,97	10,00	23,97
Kuantan Singingi	6,35	3,87	10,23
Pelalawan	2,81	6,05	8,86
Rokan Hilir	4,35	11,32	15,68
Rokan Hulu	5,20	7,79	12,98
Siak	5,26	5,38	10,64

The highest provincial deforestation rate occurs in Riau Province. The conversion of forest areas to non-forest areas in Indonesia is mainly caused by conversion to oil palm plantations. The conversion of forests to plantation areas is carried out by large companies and conversion due to encroachment of the community.

Forest area and extent of deforestation are generally interconnected. High forest area has the opportunity to encourage high deforestation. High deforestation in Riau and Sumatra Provinces generally occurs mainly in areas that have large forest areas. This condition occurred among others in Pelalawan District, Indragiri Hilir, Kampar, Kuantin Singingi, Rokan Hilir and Siak. In addition, districts with large forests and low deforestation also occur. In addition, there were also found several districts with small forest areas with high deforestation events such as in the City of Dumai.

Deforestation calculations based on deforestation rates can lead to misinformation [6, 4]. Small or low deforestation values generally have meant that districts / cities do not experience deforestation. Conversely, high rates of deforestation are interpreted as areas that have large forest damage. This condition also occurs in the assessment of the level of forest damage in Riau Province and Sumatra Island [4].

The results of the spatial analysis of the distribution of deforestation events show a map of the distribution of deforestation that occurred during the period 1990–2011 (Figures 2 to 4). Deforestation has occurred since the first period of observation, namely 1990 to 2000 and experienced various changes in distribution patterns until the last period of observation 2000 to 2011.

Throughout the period of observation, deforestation shows a downward trend in deforestation. Declining deforestation trends are caused by the decreasing availability of forest area [4]. The analysis also shows that the highest deforestation in Sumatra occurred in Riau Province (56%). Deforestation in Riau accounted for almost 50% of the total deforested areas throughout Sumatra during the period 1990 to 2011 [4,16].

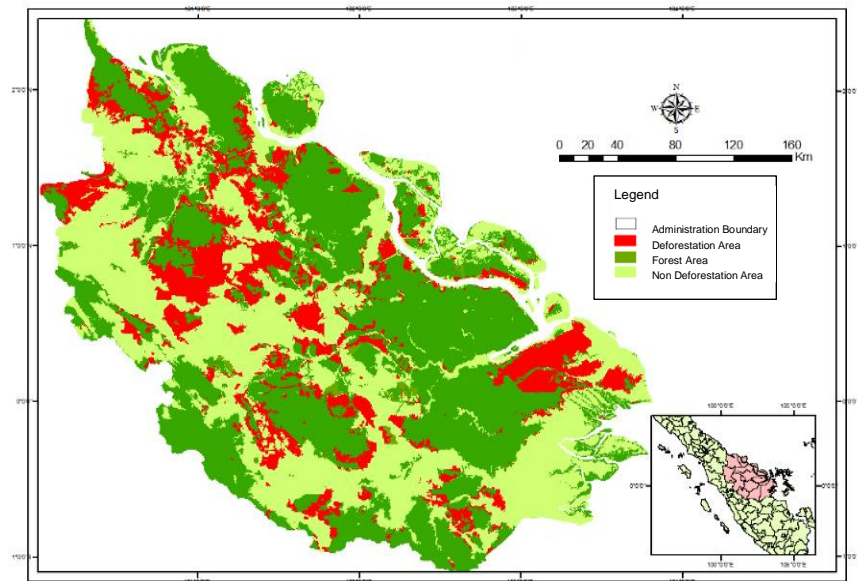


Figure 2. Distribution of deforestation from 1990 to 2000 in Riau Province

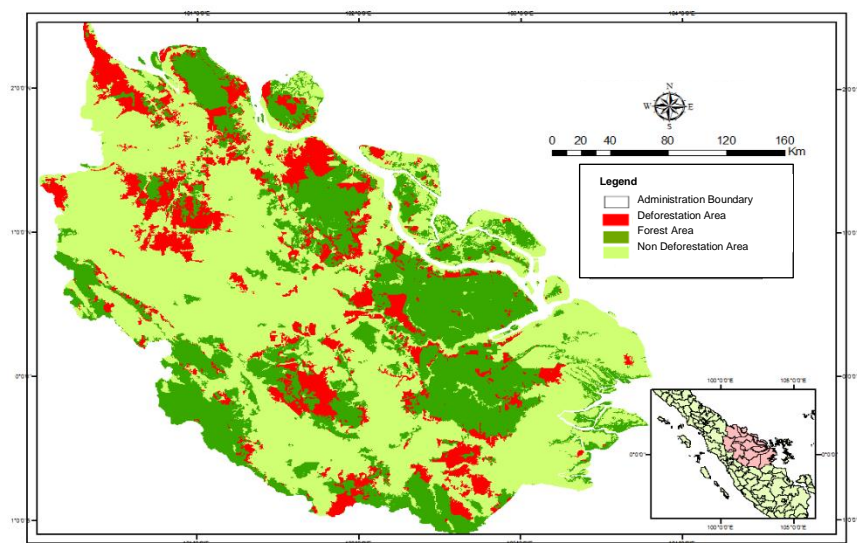


Figure 3. Distribution of deforestation from 2000 to 2013 in Riau Province

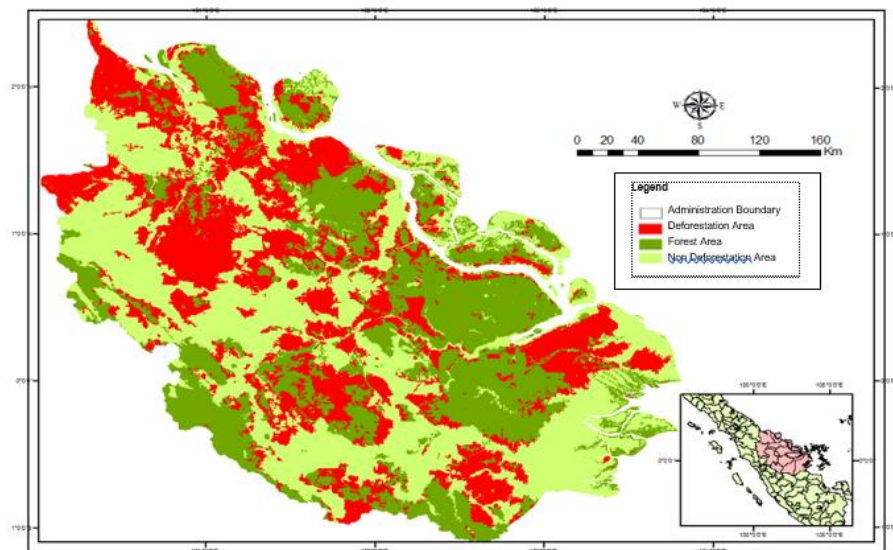


Figure 4. Distribution of deforestation from 1990 to 2011 in Riau Province

Research on factors that influence deforestation is still under-researched. Factors driving deforestation in Riau Province and generally in Sumatra are similar to some previous studies. Three causes of deforestation are agricultural expansion, timber harvesting, infrastructure development and five driving factors. The fifth driving factor is demographic, economic, technological, policy and institutional and cultural factors.

The main drivers of deforestation are agriculture, both for food crops or livestock. In addition, the drivers of deforestation and forest degradation in the tropics include shifting cultivation, agricultural land, livestock, logging (for timber and fuelwood industries), drying and burning of peatlands, plantations, and forest fires. In addition, changes in land use can be influenced by topography, accessibility, distribution of urban land and agricultural land. The factor of land distribution is significantly related to GDP per capita. Deforestation also occurs faster in flat and low areas. Low to medium slope levels show high degradation compared to steep slopes. This area is used for agriculture, horticulture, agroforestry and grazing by the community.

3.2. Typology of Deforestation in Riau Province

Based on the typology analysis of deforestation it was found that district-level deforestation in Riau Province in the period of 1990 to 2013 was dominated by the Large-lately-high deforestation typology. This typology occurred in 5 districts / cities (45.45%). The lowest deforestation profile was Small-early-high and Medium-lately-high deforestation that occurred in each district / city (9.09%).

This typology of deforestation shows that deforestation in Riau Province is closely related to the two development eras of Indonesia. Both eras are developments classified into the New Order era to the Reformation (1990–2000) and the post-reform era and regional autonomy (2000–2013).

Table 5. Typology of deforestation in each district / city in Riau Province

District	Typology of Deforestation	Description
Bengkalis	3-3-3	<i>Large-lately-high</i>
Indragiri Hilir	3-2-3	<i>Large-middle-high</i>
Indragiri Hulu	3-3-3	<i>Large-lately-high</i>

Kampar	3-1-3	<i>Large-early-high</i>
Dumai City	3-3-3	<i>Large-lately-high</i>
Kota Pekanbaru	1-1-3	<i>Small-early-high</i>
Kuantan Singingi	3-1-3	<i>Large-early-high</i>
Pelalawan	3-3-3	<i>Large-lately-high</i>
Rokan Hilir	3-3-3	<i>Large-lately-high</i>
Rokan Hulu	2-3-3	<i>Medium-lately-high</i>
Siak	3-2-3	<i>Large-middle-high</i>

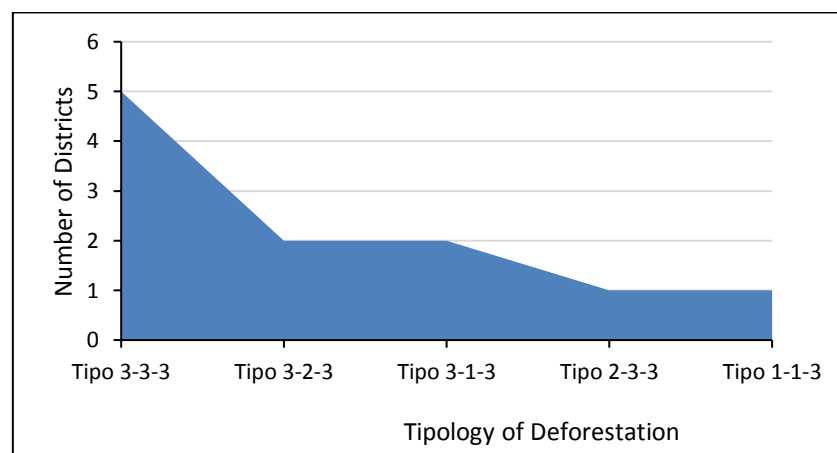


Figure 5. Typology of deforestation from 1990 to 2013 in Riau Province

Figure 5 also shows 5 differences in typology of deforestation that occur in each district / city. So far, the depiction of forest conditions or deforestation is only through the rate and extent of deforestation [4]. As a result, the meaning of the condition of the forest that is lost or deforested is reflected in the high value of the forest. The higher the rate of deforestation, the higher the deforestation that occurs. High deforestation rates are generally associated with areas that have lost more forest area. This study found that the high rate of value in a district / city is not always linear with the area of forest deforested. Other findings are about the rate of the condition of a region's forests. Low rate values do not always reflect better forest conditions than high rates.

Low deforestation rates in several districts / cities in Sumatra are also caused by small initial forest areas. This small initial forest area was caused by deforestation in the previous period. In addition, there are areas that do not have forest areas [4].

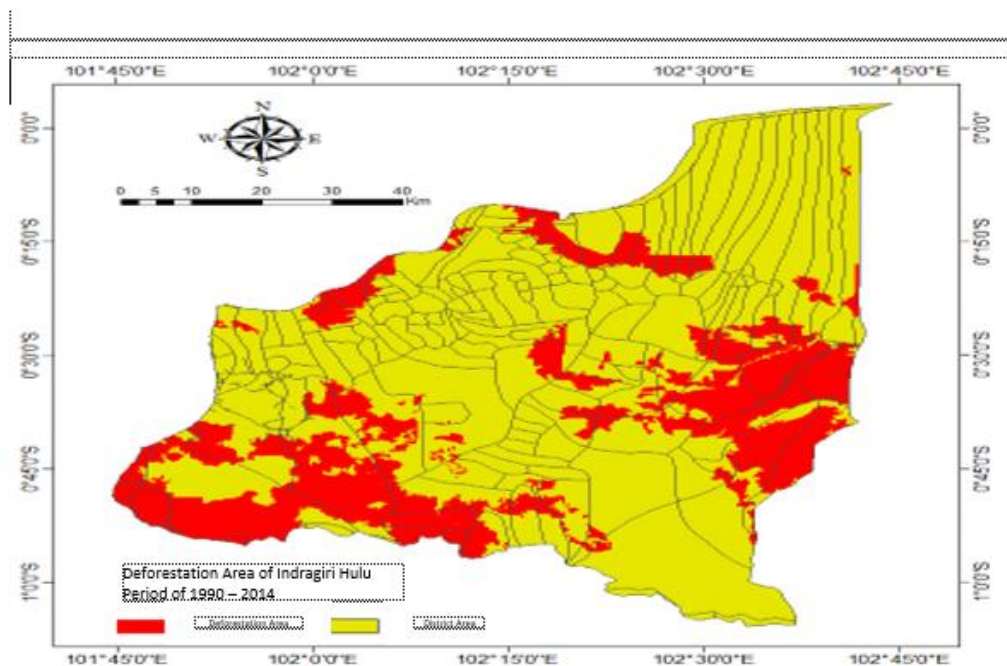


Figure 6. Distribution of deforestation area in Kab. Indragiri Hulu period 1990–2014

Deforestation in Kampar District is different from deforestation in Indragiri Hulu Regency. Deforestation in Kampar District shows that the highest deforestation occurred in the period 1990–2000. Deforestation that occurs mostly is an area with flat to sloping topography. Deforestation occurs in flat areas. Deforestation events in Indragiri Hulu District continue to occur with the characteristic of converting nearby forest areas. The biggest deforestation in Indragiri Hulu occurred in the period 2000–2010. The remaining forests (without deforestation) are forests that are in hilly to mountainous areas and the area of Bukit Tiga Puluh National Park is managed. The existence of the Bukit Tiga Puluh National Park manager is sufficient to reduce deforestation.

4. Conclusion

Deforestation rates do not adequately describe deforestation events. Spatial-temporal patterns provide more information through determining the typology of deforestation. Typology of deforestation is an alternative formula for describing deforestation events. The district-level typology of deforestation in Riau Province produces 5 typologies of deforestation. The most common typology of deforestation is Large-Lately-Low Deforestation which occurs in 5 districts/cities which means that deforestation events in Riau Province occur in large forest areas, predominantly occurring in the second period and at a high rate. Riau Province is the province that has the highest forest area in Sumatra (1990) with also the highest deforestation (68.18%). In general, deforestation in Riau Province in the period 1990 to 2013 is a deforestation typology of Early deforestation.

To improve the assessment of deforestation in an area and even the country, further research is needed on the typology of deforestation and also spatial patterns of deforestation in Indonesia. The research is very helpful in dealing with deforestation problems in Indonesia.

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