IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Spatial Patterns Analysis of Deforestation in Palopo Municipality and East Luwu Regency

To cite this article: S Rijal *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **280** 012028

View the article online for updates and enhancements.

This content was downloaded from IP address 220.130.205.58 on 09/10/2019 at 23:17

Spatial Patterns Analysis of Deforestation in Palopo Municipality and East Luwu Regency

S Rijal[1], D P Vicayana[2], R A Barkey[1], I Alimuddin[3] and A N Mukhlisa[4]

[1]Lecturer of Faculty of Forestry, Hasanuddin University, Makassar
[2]Student of Faculty of Forestry, Hasanuddin University, Makassar
[3]Lecturer of Faculty of Engineering, Hasanuddin University, Makassar
[4]Lecturer of Faculty of Agriculture, Animal Husbandry, and Forestry, University of Muslim Maros

jaysy.rijal@gmail.com

Abstract. Deforestation is an activity or process that converts forest cover into non-forest land cover with a certain pattern. Palopo and East Luwu are two districts in South Sulawesi deforested due to the demand of the human need to convert the land into settlements, infrastructure and timber harvesting. This research was conducted to find out the temporal spatial pattern in dealing with deforestation. Analysis of spatial patterns using fragstat software with input data i.e. land cover shapefile data in 1990, 2000, 2010, and 2016 that produced contour in metrics, and its subdivision in metrics. Temporal spatial patterns of deforestation are built by combining three spatial metric values. Based on the description of deforestation analysis in Palopo Municipality covering 852,96 ha and East Luwu with 86,963,46 ha, Palopo Municipality experienced the highest deforestation from 1990 to 2000 amounted to 451.69 ha and continued to decline in the period of 2000-2010 and 2010-2016. Deforestation in East Luwu Regency is the highest in the 1990-2000 period which is 38.655,05 ha. Deforestation in East Luwu Regency has higher contiguity than deforestation occurring in Palopo Municipality indicating that the occurrence of deforestation occurring in East Luwu Regency occurred directly from previously degraded areas to adjacent forest areas. Palopo and East Luwu Regency show fragmentation rates that tend to decrease due to the decreasing number of fillings that are formed the largest combination of spatial patterns occurring during the observation period was the spatial pattern of deforestation grouped, with high density (not fragmented) in 50 villages (61.72%).

Keyword: Deforestation, Spatial Pattern, Fragstats, Contagion Metrics, Shape Metrics and Subdivision

1. Introduction

Deforestation is the event of loss of forest cover that turns into another cover. Forests in areas of high intensity or directly adjacent to human activities have the potential to be immediately deforested [1]. This deforestation is caused by demands from human needs to converge land into settlements, infrastructure, harvesting timber products for industry, plantations, agriculture, livestock and mining. Forest conversion will produce a new landscape structure which will result in the formation of forest fragmentation. The high population has implications for increasing land requirements which also play a role in increasing forest fragmentation [2-4]. Forest fragmentation can damage biodiversity and ecosystem functions in a landscape.

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

Monitoring deforestation requires calculating the rate of deforestation [5]. The rate of deforestation analysis is carried out to determine the rate and extent of deforestation in a region. Analysis of the rate of deforestation is carried out in each period. Annual deforestation is calculated by the annual forest cover change rate equation derived from multiple interest laws [5-11]. The annual deforestation rate (r) is recommended because it is more intuitive than the formula used by FAO (q) [11]. The value of r is always higher than q. The rate of change in annual forest cover (r,% / year) is calculated based on the initial forest cover area (A1, ha) in the initial period (t1, year) and final forest cover area (A2, ha) (t2, year).

The occurrence of deforestation also results in changes in forest land cover to other closures with certain patterns. This pattern of change forms several patterns of distribution. Distribution patterns are caused by various types of land change activities. The patterns and forms of deforestation that occur indicate driving factors for deforestation.

The temporal spatial pattern of deforestation is built by combining all three values of spatial metrics. The spatial pattern is a function of Cl, Contig MN and PD or expressed as Spatial Index = f (Cl, Ct, Pd). The spatial pattern formed is a function or influence of the third nature of the index. Cl explained the distribution pattern or distribution of deforestation events. Ct shows the level of the contiguity between patches. Pd describes the level of fragmentation [13]. The value of each index describes the state of the class. Fragmentation is defined as the breakdown of the organism's habitat into patches of habitat that make it difficult for organisms to move from one habitat to another. Fragmentation can be caused by the removal of vegetation on a large area or by roads that separate habitats even by electrical wiring [14].

Analytical and empirical studies have shown that an important determinant of deforestation is the improved access to previously inaccessible forested areas alongside low governance gradients with high socio-economic value [15] Drivers of deforestation have also been studied and spatial regression models have shown a strong relation between deforestation and the proximity to roads or rivers that facilitate transport of timber and agricultural products to markets [16-18].

Forest fragmentation occurs because large and connected forests are divided into smaller blocks due to road construction, agriculture, urbanization or other development. As a result, the function of the forest as a habitat for various species of plants and wildlife is reduced. Fragmentation also affects the structure, temperature, humidity and lighting that will disturb forest animals whose adaptations have been formed for thousands of years.

The definition of fragmentation is as a result and process. Outcomes of habitat fragmentation are discontinuities obtained from a series of mechanisms, in the spatial distribution of a resource and conditions that exist in an area at a certain scale that affects the occupancy, reproduction or survival of a species. Habitat fragmentation is defined as a series of mechanisms that result in discontinuity of the spatial distribution of habitat. There are four key components of the two definitions, namely: (1) discontinuity, (2) mechanism, (3) spatial distribution of a resource in an area, and (4) demographic attributes [19].

Similar studies related to the temporal spatial pattern of deforestation have been carried out in Indonesia, precisely on the island of Sumatra in Riau Province by Syamsu Rijal in 2016. This research was conducted by linking spatial patterns with deforestation rates. All three spatial metrics are associated with the rate of deforestation to see the correlation. Furthermore, each metric value (Cl, Ct, Pd) per village was analyzed using Principal Component Analysis to see its effect on deforestation events. Deforestation in this study is defined as the land cover which changes in the form of permanent cover loss which results in fragmentation of the forest. The temporal spatial pattern of deforestation is very important to plan for handling deforestation and fragmentation including deforestation in South Sulawesi. For this reason, research in Palopo Municipality and East Luwu Regency is very useful for dealing with changes in forest cover to other coverings.

2. Materials and Method

2.1. Research Location

The research locations were in South Sulawesi Province, namely Palopo Municipality and East Luwu Regency. These two regions are interesting to study because they have different characteristics of deforestation. The location of the study can be seen in the following the figure 1.

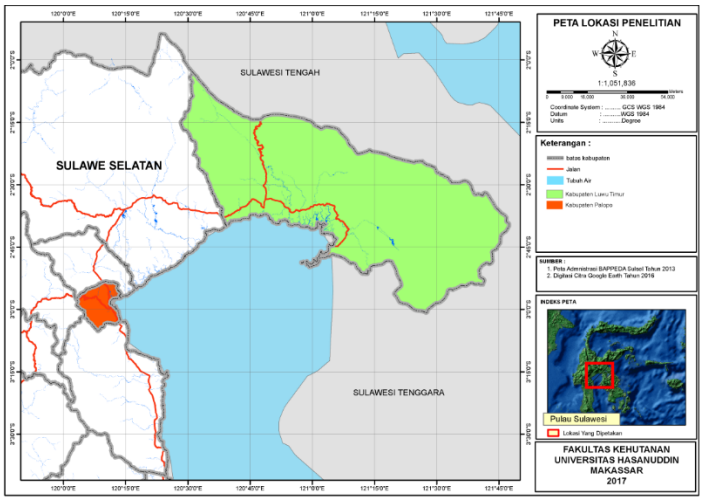


Figure 1. Location Research Map

2.2. Collecting Research Data

The data collected in this study are land cover data in 1990, 2000, 2010, and 2016 from the Makassar VII Region Forest Area Consolidation Center. In addition, the 2014 South Sulawesi administration data was also collected from the Geospatial Information Agency. Land cover data and administrative data of South Sulawesi are secondary data which are then processed using the GIS 10.1 Application. In the GIS application, both shapefile data are overlaid to produce data based on the research location and land cover of Palopo Municipality and East Luwu Regency.

Data on changes in forest cover for non-forest areas were observed in the period 1990–2000, 2000–2010, 2010–2014. Land cover in the form of plantations, settlements, dry land agriculture, rice fields, swamp bushes, bushes, open land, water bodies, and airports are grouped into non-forest. Changes in forest cover in plantations are not categorized as deforested areas because changes in cover do not occur permanently [12]. Accuracy and Kappa accuracy tests are used to assess the reliability of image classification [12,20-22]

2.3. The Processing and Analyzing Data

Deforestation is the change in forest land cover to permanent non-forest cover [12]. Land cover data is analyzed by deforestation. The results of the analysis were then analyzed for spatial patterns. Analysis of spatial patterns of deforestation was carried out to obtain information on the distribution and pattern of deforestation in Palopo Municipality and East Luwu Regency. This spatial pattern of deforestation is then linked to the rate of deforestation. Analysis of spatial patterns of deforestation was carried out in several time periods, namely the period 1990–2000, 2000-2010 and 2010–2016. Analysis of spatial patterns using Fragstat 4.2 software. Fragstat is a spatial pattern analysis program that generates forest landscape metrics. The data format used is data in the ArcGrid format which is a raster format. Each forest land cover vector data deforested per time period is converted into raster data formats and stored in the form of ERDAS Imagine Grid with a grid size of 30 meters x 30 meters [13].

The metric group used is Contagion Metrics, Shape Metrics and Metrics Subdivision [13]. The Contagion Metric group used is the Clumpiness Index (CI) metric. CI was used to describe the temporal spatial pattern of the distribution of village level deforestation in the two regions in several observation periods. CI shows a range of values between -1 and 1. Values close to -1 indicate uniform distributed patches, values close to 0 mean patches are randomly distributed, and the value 1 indicates that patch classes are distributed in groups (clumped distributed) [13].

Clumpiness Index calculated using equations:

$$Given\ Gi = \left[\frac{g_{ii}}{\sum_{k=1}^{m} g_{ik}}\right]$$

$$clumpy = \left[\begin{cases} \dfrac{G_i - P_i}{1 - P_i} & \text{for } G_i \geq P_i \\ \dfrac{G_i - P_i}{1 - P_i} & \text{for } G_i < P_i; P_i \geq 5 \\ \dfrac{P_i - G_i}{-P_i} & \text{for } G_i < P_i; P_i < 5 \end{cases}\right]$$

Explanation:

g_{ii} : the number of class i patch pixels that borders and corresponds based on multiple calculations

g_{ik} : the number of class i patch pixels bordering class i and k is based on multiple calculations

$m_{in\text{-}ei}$: minimum perimeter (on a number of cell surfaces) of patch type (class) i for maximum class groups

P_i : the proportion of landscapes placed by patch class i.

The Shape metrics group used is the Contiguity Mean Index (Contig MN) to describe the form of closeness and the contiguity between patches. Contig MN is a shape metric that is used to assess patch shapes in describing spatial relationships or contact of individual patch cells with other patches (connectedness and contiguity). The MN index value is measured based on the relationship or spatial contact between cells in the patch. The higher the MN Contig value, the greater (near) the connection [13]. Low value metrics describe the connection between patches that are low.

$$CONTIG\ MN = \frac{\sum_{j=1}^{n} Xij}{\text{ni}}$$

Explanation:

Contig MN : the same average patch contiguity value

X_{ij} : the value of the corresponding patch to the value of the patch;

N_i : number of patches of the same type

The landscape metric used to show the level of fragmentation is Patch Density (PD) which is part of the area/density/edge metric [13]. High-value PD shows that land cover classes are increasingly scattered or fragmented. Patch density is the number of patches in each area of 100 ha of landscape units.

$$PD = \frac{\mathrm{N}}{\mathrm{A}} * (10000) X\ (100)$$

Explanation:

PD : Number of forest patches per 100 ha

N : Number of forest patches

A : Area of forest landscape

The temporal spatial pattern of deforestation is built by combining all three values of spatial metrics. The spatial pattern is a function of Cl, Contig MN and PD or expressed as Spatial Index = f (Cl, Ct, Pd). The spatial pattern formed is a function or influence of the third nature of the index. The combination of the three spatial metrics, namely clumpiness index (Uniform, Random, Clumped), Contiguity index (Low contiguity, Medium contiguity, High contiguity) and Patch density (unfragmented and fragmented) form 18 possible combinations of spatial patterns of deforestation.

The combination of spatial patterns formed is:
Spatial Patterns of Deforestation : 3-2-1; 3 = Cl 2 = Ct 1 = Pd

Clumpiness Index (Cl)	: 1 = Spread	2 = Random	3 = Cluster
Contiguity Mean Index (Ct)	: 1 = Low contiguity		
	2 = Medium contiguity		
	3 = High contiguity		
Patch Density (Pd)	: 1 = Not fragmented		3 = fragmented

Cl explained the distribution pattern or distribution of deforestation events. Ct shows the level of the contiguity of between patches. Pd describes the level of fragmentation [13]. The value of each index describes the state of the class.

The metric group is then linked to the rate of deforestation that occurs in Palopo Municipality and East Luwu Regency. To calculate the deforestation, rate the following equation is used:

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

Explanation:
R : Deforestation Rate (% / year)
A1 : Area of Initial Cover
A2 : Final Cover Area
t1 : Early Period
t2 : Final Period

3. Results and Discussion

3.1. Deforestation Area

The results of the land cover classification analysis based on data from BPKH 1990, 2000, 2010 and 2016 resulted in 10 land cover which were then grouped into 8 land cover. The 8 land cover are forests, settlements, bushes, agricultural land, open land, water bodies, mines, and ponds. This land cover data is then classified into forest and non-forest. The forest group consists of secondary forest and mangrove forest.

Non-forest groups (other than forests) consist of dryland agriculture, paddy fields, swamp shrubs, settlements, airports, open/empty land and water bodies. After that, an analysis of deforestation was carried out on the results of the classification of land cover (forest and non-forest). Analysis of deforestation was carried out on forest cover to determine the extent and distribution of deforestation that occurred during several periods, namely the period 1990–2000, 2000-2010, 2010-2016 and the overall period of observation for 26 years (1990–2016). The extent of deforestation that occurs can be seen in Table 1.

Table 1. Deforestation for some periods in Palopo Municipality and East Luwu Regency.

Municipality / Regency	**Deforestation Area per Period (ha)**			
	1990-2000	**2000-2010**	**2010-2016**	**1990-2016**
Palopo	451,69	390,71	10,56	852,96
East Luwu	38.655,05	10.743,40	37.715,32	86.963,46

Based on the description of the results of the analysis of deforestation in several periods, deforestation has occurred in both regions over a period of 26 years covering an area of 87,816.42 ha. Deforestation in Palopo Municipality is 852.96 ha and in the East Luwu Regency is 86,963.46 ha. The highest deforestation of each region occurred in the same period. Palopo Municipality experienced the highest deforestation in the period 1990–2000 amounting to 451.69 ha and continued to decline in the period 2000-2010 and 2010-2016. Deforestation in East Luwu Regency was the highest in the 1990–2000 period of 38,655.05 ha.

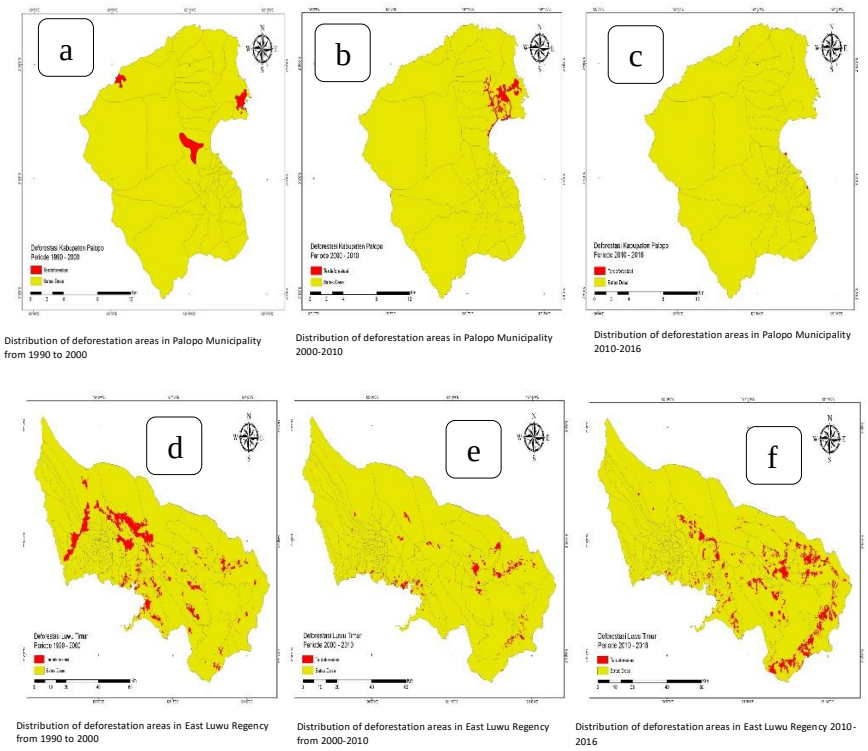


Figure 2 Distribution of deforestation areas in Palopo Municipality (a) 1990-2000, (b) 2000-2010, (c) 2010-2016, East Luwu Regency (d) 1990-2000, (e) 2000-2010, (d) 2010-2016.

The first period (1990-2000) in the Municipality of Palopo, deforestation occurred and spread to the area around the eastern coast of Palopo. The second period, deforestation still occurs in the area around the coast in a smaller area than the previous period. The third area of deforestation in Palopo Municipality is quite small because the small amount of forest remaining in the area around the coast is the remaining forest area deforested in the previous period [12]. The remaining forest area in the area around the coast is secondary mangrove forest which is under the supervision of the local government. The relatively deforested forest area is the western secondary forest area which borders North Toraja Regency. Deforestation that occurred in the East Luwu Regency in the first period occurred and spread throughout the region. The highest deforestation area in the first period was in the western forest area of the East Luwu Regency. During the second period, the area of deforestation was quite small due to the less remaining area of forest which was the remaining forest area that had been deforested in the previous period. The third period, the extent of deforestation increased again with the presence of newly cleared forest areas or land clearing spread in the eastern part of East Luwu Regency. The forest area that experienced land clearing was carried out by farmers of pepper and companies engaged in mining both nickel and sand. Deforestation occurs mostly in areas with flat to gentle topography. Forests that are not deforestation are forests that are located on hills to high mountains that have high steepness [12].

3.2. Spatial Deforestation Metrics

Assessment of spatial metrics using three indices, namely Clumpiness Index (CI), Contiguity Mean Index (Contig MN), and Patch Density (PD). Spatial deforestation metrics were identified through deforestation maps that occurred in Palopo and East Luwu Regencies in the period 1990-2000, 2000-2010 and 2010-2016. Deforestated forests are analyzed to generate spatial deforestation metrics. Based on fragstat analysis, the spatial pattern of the three observation periods was obtained as shown in Figure 10. The three spatial metrics in the two regions showed a similar trend in the distribution and spatial patterns of deforestation in East Luwu and Palopo Municipality each period.

The Cl value in both regions has a spatial distribution pattern that tends to be the same, namely the

spatial pattern is distributed in groups. East Luwu Regency and Palopo Municipality experienced a decrease in CI values in each period. Based on the results of spatial analysis of deforestation in the two regions in the period 1990 to 2016 caused by changes in the spatial pattern of forests into large-scale plantation patterns and agricultural activities and several incidents of forest fires. This happened because of the increasing population and the development of accessibility such as the construction of road networks.

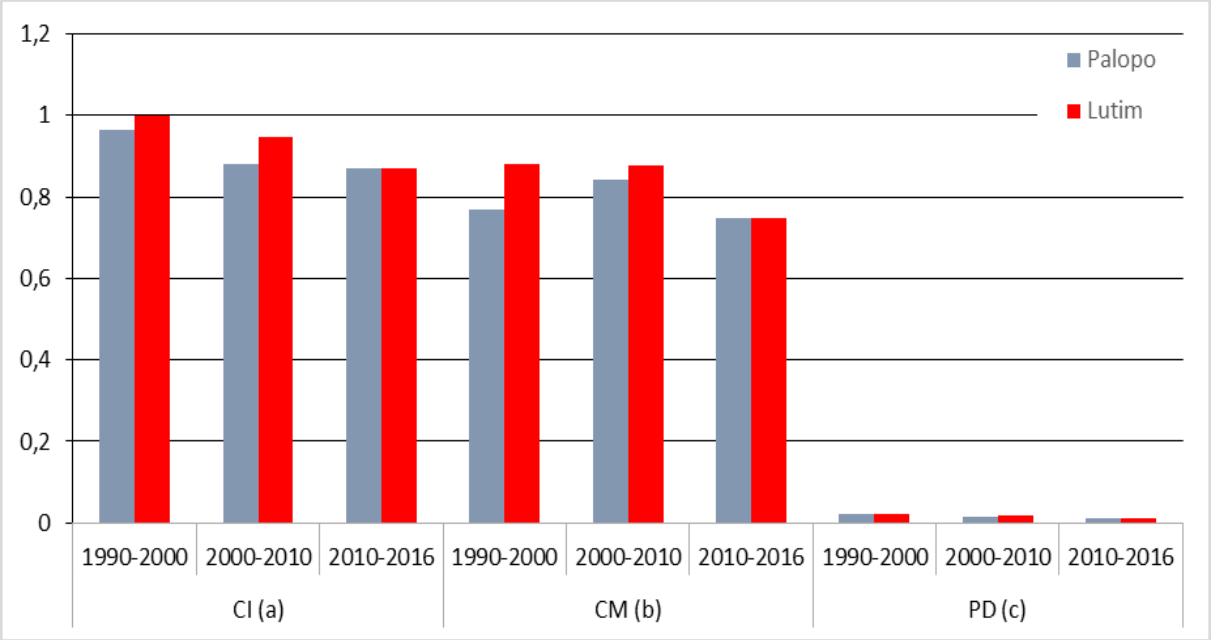


Figure 3. Spatial Metric Deforestation in Palopo Municipality and East Luwu Regency in several periods: Clumpiness Index (a), Contiguity Mean Index (b), Patch Density (c)

In the East Luwu Regency, the contiguity has tended to decline in the period 1990 to 2016. While the Municipality of Palopo has increased the contiguity for the period 1990 to 2010 and subsequently decreased in the period 2010-2016. Deforestation in East Luwu Regency has a higher of contiguity than deforestation in Palopo Municipality.

This means that the deforestation event that occurred in East Luwu Regency occurred directly from the previously deforested area in the surrounding forest area. This event is generally caused by forest land encroachment activities carried out to be used as large-scale plantation land, shifting cultivation and agriculture and harvesting of forest products.

Higher contiguity index in East Luwu Regency occurs because deforestation events follow the distribution of the remaining forests (still available). In addition, deforestation events are around forest areas that have been deforested before. Deforestation is greater in the initial period. The remaining forest area from the first period of deforestation events was more clustered. The next period of deforestation (2000-2010) tends to be close together but several deforestation events also occur in forest areas that experience new openings. Newly opened forests are forests that are far apart from other forests so that deforestation events tend not to be related to previously deforested areas.

Deforestation events Palopo Municipality tends to be close together in the second period because deforestation events follow the distribution of the remaining (still available) forests around the forest area that have been deforested in the first period. Whereas in the third period, deforestation events tend to be far apart after the second period so that the connection is low. This is due to the location of the remaining forest which is far from one another so that deforestation events tend not to be connected with the previous deforested area. Another thing that causes the level of connectedness is low because rapid and high deforestation occurs in the early period (early deforestation). As a result, the remaining forest area due to deforestation is more scattered and far apart.

The next spatial metric is the level of fragmentation metric indicated by Patch. The landscape structure of deforestation events is characterized by the number and size of patches. Fragmentation rates of deforestation in Palopo and East Luwu Regencys showed similar conditions in the period 1990

to 2016. The PD scores of East Luwu Regency (Figure 10c) showed a higher level of fragmentation than the level of fragmentation in Palopo Municipality in the period 2000-2010. Palopo Municipality and East Luwu Regency show fragmentation levels, which tend to decrease because of the decreasing number of patches formed. This indicates that deforestation events continue to expand and continue to adjacent or adjacent areas.

3.3. Combination of Spatial Metrics and Rate of Deforestation

Analysis of the spatial deforestation index at the level of Palopo and East Luwu Regencys was carried out to obtain the distribution of the Clumpiness index, Contiguity MN index and Patch Density at the village level. Based on administrative data in 2014, Palopo Municipality consisted of 9 sub-districts with 48 villages. East Luwu Regency consists of 11 sub-districts with 114 villages. The total village of 20 sub-districts in the two regions is 162 villages. Villages that experienced deforestation were 81 villages. Analysis of spatial patterns using Fragstat was carried out based on deforestation events in each village. Spatial deforestation metrics were generated in all deforested villages consisting of 16 villages in Palopo Municipality and 65 villages in the East Luwu Regency.

The combination of the three spatial metrics, namely the Clumpiness index (Uniform, Random, Clumped), Contiguity index (Low contiguity, Medium contiguity, High contiguity) and Patch density (unfragmented and fragmented) forms 18 possible combinations of spatial patterns of deforestation [12]. The results of the analysis of all combinations are shown in Table 2. Based on the combined analysis formed, there were 5 combinations of spatial patterns of deforestation at the village level in Palopo Municipality and East Luwu Regency.

Table 2. A combination of spatial patterns of village-level deforestation in the City of Palopo Municipality and East Luwu Regency

No.	Spatial Pattern Code	Spatial Pattern Group	Number of villages
1.	3-3-1	Clumped-High contiguity-Unfragmented	50
2.	3-2-1	Clumped-Medium contiguity-Unfragmented	4
3.	3-3-3	Clumped-High contiguity-Fragmented	20
4.	3-2-3	Clumped-Medium contiguity-Fragmented	6
5.	2-2-1	Random-Medium contiguity-Unfragmented	1

Based on the combined results in Table 2, the most combinations were Clumped-High contiguity-Unfragmented as many as 50 villages (61.72%). These results generally show that the temporal spatial pattern of village deforestation that occurred in Palopo Municipality and East Luwu Regency in the period 1990 to 2016 was a temporal spatial pattern of clustered deforestation, with a high degree of the contiguity and no fragmentation. The spatial pattern of deforestation almost always occurs in groups and is connected with previous areas of deforestation with large (not fragmented/dispersed) areas. This spatial pattern of deforestation indicates that deforestation in Palopo and East Luwu Regency is generally caused by large-scale plantation expansion.

The results of the spatial pattern analysis of each metric are then related to the rate of deforestation per village. The spatial pattern of village-level deforestation with deforestation rates shows that each metric forms two patterns. These two patterns are the pattern of low deforestation rates and high rates of deforestation patterns. High or low deforestation rates in Palopo Municipality and East Luwu Regency (appendix 2) are determined by the area of forested areas which has decreased in the area in each period or from 1990 to 2016.

The relationship between the Clumpiness index and the rate of deforestation (Figure 4a) shows that in general there is a spread of two patterns, namely the pattern of low deforestation rate − grouping and distribution of high deforestation rates − grouping. This shows that deforestation in Palopo Municipality and East Luwu occurs with Clumped distribution patterns, both at low and high rates.

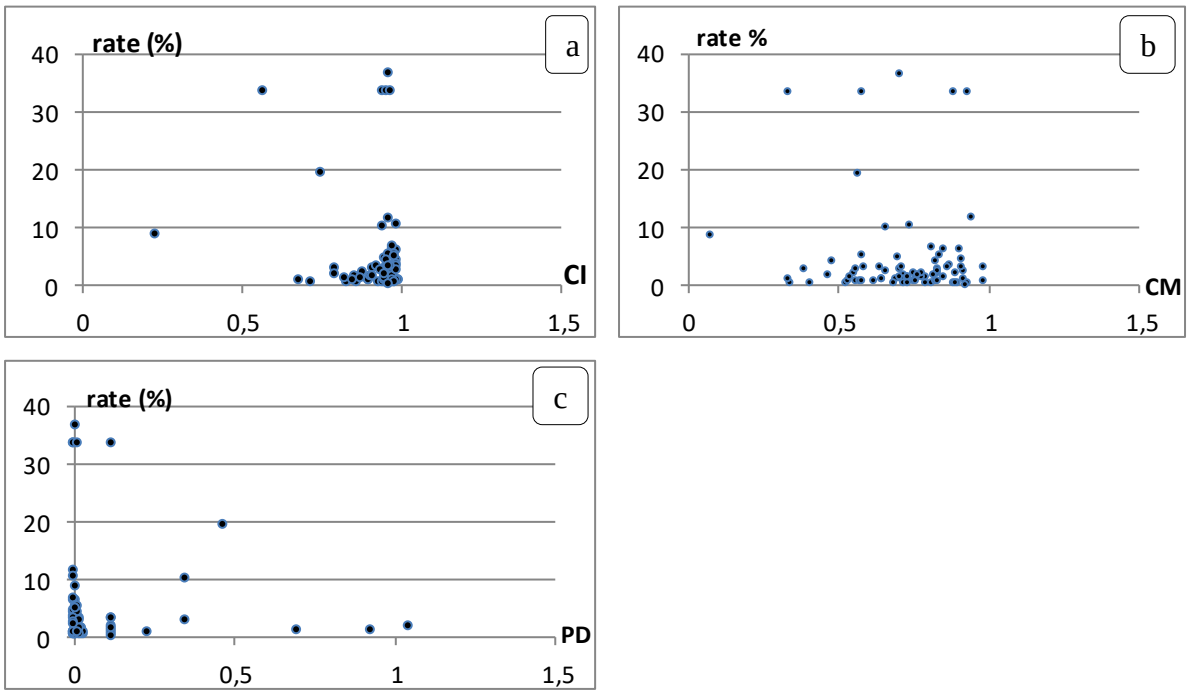


Figure 4. Relationship of spatial metrics (a) Clumpiness Index per village (b) with Contig MN index per village and (c) PD index with deforestation rate per village.

4. Conclusions

Based on the combined analysis formed, there were five combinations of spatial patterns of deforestation at the village level in Palopo Municipality and East Luwu Regency. The combination of the most spatial patterns that occurred during the observation period was Clumped-High contiguity-Unfragmented. These findings indicate that in general, the temporal-spatial pattern of village deforestation that occurred in Palopo and East Luwu Regencies from 1990 to 2016 was a spatial pattern of clustering deforestation, with a high degree of the contiguity and no fragmentation. This pattern shows that the deforestation events from 1990 to 2016 were dominated by large-scale plantation activities. The relationship between the spatial pattern and the rate of deforestation at the village level shows that each metric forms two patterns, namely the pattern of low deforestation rates and high rates of deforestation patterns.

5. References

[1] Wade TG, Riitters KH, Wickham JD, Jones KB. 2003. Distribution and Causes of Global Forest Fragmentation. *Conservation Ecology*. 7(2): 7. [internet]. [Download on Sept 7th, 2015] URL: http://www.ecologyandsociety.org/vol7/iss2/art7/

[2] Nagendra et al. 2003Nagendra H, Southworth J, Tucker C. 2003. Accessibility as a determinant of Landscape Transformation in Western Honduras. Landscape Ecology. 18(2): 141–158. http://dx.doi.org/10.1023/A:1024

[3] Shearman PL, Ash J, Mackey B, Bryan JE, Lokes B. 2009. Forest conversion and degradation in Papua New Guinea 1972–2002. *Biotropica*. 41(3): 379–390. http://dx.doi.org/10.1111/j.1744–7429.2009.00495.x

[4] Newman ME, McLaren KP, Wilson BS. 2014. Assessing deforestation and fragmentation in a tropical moist forest over 68 years; the impact of roads and legal protection in the Cockpit Country, Jamaica. Forest Ecology and Management. 315(2014):138–152. http://dx.doi.org/10.1016/j.foreco.2013.12.033.

[5] Ferraz SFdB, Vettorazzi CA, Theobald DM. 2009. Using indocators deforestation and land-use dynamics to support conservation strategies: A case study of central Rondonia, Brazil. *Forest Ecology and Management*. 257(2009): 1586 – 1595.
[6] WRI (World Resource Institute). 1995. World Resources 1994-1995. *WRI, Oxford University Press*, Delhi.
[7] FAO. 2000. Forestry Paper 130. Food and Agriculture Organization of the United Nations, Rome
[8] Menon S, Bawa KS. 1997. Applications of geographic information systems, remote sensing, and a landscape ecology approach to biodiversity conservation in the Western Ghats. *Curr. Sci.* 73: 134-145.
[9] Ramesh BR, Menon S, Bawa KS. 1997. A vegetation based approach to biodiversity gap analysis in the agastyamalai region, Western Ghats, India. *Ambio.* 26: 536-539.
[10] Prasad NS. 1998. Conservation planning for the western Ghats of Kerala: assessment of habitat loss and degradation. *Curr. Sci.* 75: 228-235.
[11] Puyravaud JP. 2003. Standardizing the calculation of the annual rate of deforestation. Forest Ecology and Management. 177(1-3): 593-596
[12] Rijal, Syamsu. 2016. *Pola Spasial Temporal dan Perilaku Deforestasi di Sumatera*. Dissertation of Faculty of Forestry, Bogor Agricultural Institute: Bogor
[13] McGarigal K, Turner. 2001. FRAGSTATS: landscape metric for categorical map patterns.
[14] Rusak, H. and C. Dobson. 2007. Forest Fragmentation. www.ontarionature .org. Accessed date on February 26th ,2007.
[15] Sara Olga Ramirez-Gomez, 2011. Spatial Drivers of Deforestation in Suriname. Center for Agriculture Research in Suriname, Tropenbos Suriname.
[16] Angelsen, A., 2010; Police for reduced deforestation and their impact on agricultural production. Proc. Natl. Acad. Sci. U. S. A. 107. 19639-19644.
[17] Nelson, GC., Hellerstein D., 1997. Do roads cause deforestation? Using Satellite image in econometric analysis of land use. Am. J. Agric. Econ. 79, 80-89.
[18] Brun C., Alex RC., Janice SHL., Serge AW., Lian PK., Luis RC., 2015. Analysis of Deforestation and protected area effectiveness in Indonesia: A comparison of Bayesian Spatial Models. Global environmental change 31: pg. 285-295. Elsevier.
[19] Franklin, A.B., B.R. Noon, And T. L. George. 2002. What Is Habitat Fragmentation? Studies in Avian Biology No. 25:20-29. http://www. Humboldt. edu/-tlg2/publications/whatis habitat20fragmentation.Pdf. Accessed date on May 11th ,2007.
[20] Jaya I, Kobayashi S. 1995. Classification of detailed forest cover types based upon the separability algorithm: a case study in the Yahiko Mountain and Shibata Forest Area. *Journal of the Remote Sensing Society of Japan.* 15(1)**:** 40-53. Jaya INS. 2006. *Teknik-teknik pemodelan spasial dalam pengelolaan sumberdaya alam dan lingkungan*. Bogor: IPB Press.
[21] Jaya INS. 2009. *Analisis citra dijital: perspektif penginderaan jauh untuk* pengelolaan *sumberdaya alam*. Bogor: Bogor Agricultural Institute.
[22] Olson JM, Misana S, Campbell DJ, Mbonile M, Mugisha SA. 2004. Research framework to identify the root causes of land use change leading to Land degradation and changing biodiversity. *International Livestock Research Institute*, Nairobi (Kenya).