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Spatial Metrics of Deforestation in Kampar and Indragiri Hulu, Riau Province

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Abstract

The Riau Province has been suffering from the highest deforestation rate in Sumatra, Indonesia. Many and various factors haved been discussed as causes of different deforestation types. This research is focused on evaluating the spatial pattern of deforestation in a specific location respresenting a typical deforestation in Riau. The main objective of this study was to identify spatial metrics to describe deforestation that occurred in Kampar and Indragiri Hulu regencies.The study divided the deforestation process into 3 periods of observation, e.g., 1990–2000, 2000–2010, and 2010–2014. The study based on Landsat satellite imagery aquired in 1990, 2000, 2010, and 2014 as the main data sources. The deforestation was detected using post-classification comparison (PCC) on the basis of 11 land cover classes developed prior to any further change detection. The deforestation was initially derived from reclassifying the original classes into only forest and non-forest classes, and then followed by spatial pattern analysis using Fragstat software. The study shows that 2 spatial pattern of deforestation in Kampar distinctly differs from those occurred in Indragiri Hulu Regency, particularly for the period of 1990–2014. The spatial pattern of deforestation in Kampar Regency were clumped, low contiguous between patch, and high fragmentated. Meanwhile, the spatial pattern in Indragiri Hulu Regency were clumped, high contiguous between patch, and low fragmentated. Profile of deforestation in Kampar Regency was cathegorized into early deforestation and Indragiri Hulu Regency as lately deforestation.

Keywords: spatial pattern, deforestation, clumpiness, contiguity, patch density

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Introduction

Sumatra is an island with the highest deforestation rate in Indonesia, because it encountered 70% forest conversion in the period 1990–2010 (Margono *et al.* 2012). The Sumatera's deforestation reached 6.5 million ha (28%) in 1985–1997 (GWF/IFW 2002). Sumatra had lost about 7.54 million ha of primary forests (47%) in 1990–2010. The remaining primary forests amounted to 30.4% (Margono *et al.* 2012). Riau and South Sumatera Provinces in Sumatera were experiencing great loss of primary forests of more than 50% in the period 1990–2010. The greatest Sumateran forest loss occurred in Riau Province that reached 42% of the total forest areas in the period 1990–2010 (Margono *et al.* 2012).

The change of Sumatra's forest cover was caused by conversions to other land covers. Changes in forest cover into other land covers in several periods led to changes in a certain pattern. Change pattern was driven by various triggering factors of deforestation, either directly or indirectly and planned or unplanned factors (Sunderlin & Resosudarmo 1997; MoF 2010; Margono 2012;). Examples of the indirect factors are population growth through encroachment and clearing of forest areas into plantations, fields, agricultural areas, and settlements. Direct factors are road constructions that support the development of settlements and farmlands (Geist & Lambin 2002). Planned factors are the forest policy for conversion of areas into other uses, while unplanned factors are forest fires in large areas.

Forest directly adjacent to human activity has high potential for deforestation (Wade *et al.* 2003). Increased population leads to increased forest fragmentation (Batistella *et al.* 2000; Nagendra *et al.* 2003; Gonzalez-Abraham 2007; Shearman *et al.* 2009; Giordano & Boccone 2010; Reddy *et al.* 2013; Newman *et al.* 2014). Deforested forest area increased while the remaining forests suffered damage or called fragmentation, characterized by a reduction of canopy cover. Deforestation and declining forest quality were caused by logging activities, encroachment, fire, grazing, plantation, cultivation, farming, and firewood gathering. Deforestation and the destruction of tropical rain forests had reduced biological resources (CBD 2005; Townsend *et al.* 2009).

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Smaller and scattered forest areas tend to have higher probability to be deforested than the larger and compact ones. Margono *et al.* (2012) found that more than 50% of primary forest loss in Riau Province in the period 1990–2000 was fragmented and degraded forests. Forest fragmentation results in increasing number of patches, consisting of small and scattered forests areas that usually less than 1 ha (Laurance 2005). Forest fragmentation impacted on forests biota destruction and the loss of suitable habitat for sensitive species (Mendoza *et al.* 2005). Incompact and small forest areas also increase competition from common species (Laurance *et al.* 2009) and genetic isolation of sub-populations (Goosem 2007). Fragmentation is also one of the main factors triggering the loss of forest landscape biodiversity (Fahrig 2003) and the threat of biodiversity loss (CBD 2005) in some species.

To prevent deforestation, it is not only necessary to identify the driving factors of deforestation but also to investigate the spatial metrics of deforestation. The later is essential to provide quantitative measures in spatial patterns of deforestation in a certain region. To our knowledge, studies on the spatial patterns of deforested areas are still lacking, especially in Indonesia. Some previous studies mainly focused on the spatial pattern of remaining forest covers or forest areas that were fragmented due to deforestation in certain periods. For example, Etter *et al.* (2006) examined patterns of agricultural areas and deforestation in Colombia. Liu *et al.* (2010) analyzed spatial patterns and driving forces of land use changes in China during the early 21st century. Armenteras-Pascual *et al.* (2011) investigated the interaction patterns of spatial characteristics of fire to the climate and vegetation in Colombia. Skole and Tucker (1993) and Marsik *et al.* (2011) investigated deforestation and fragmentation of tropical forests in Amazon. Samsuri (2014) examined the landscape fragmentation of Batangtoru watershed in North Sumatra. Therefore, further studies on the spatial patterns of deforestation are necessary to derive spatial metrics of deforestation that can be used to quantify the extent and development of deforestation over periods in a certain region. Such spatial metrics can be used to identify priority areas for reforestation (Hurd *et al.* 2002) and to formulate habitats and ecosystems management strategies (Priatna *et al.* 2012).

This study was aimed to develop spatial metrics of deforested areas at some periods of time in Kampar and Indragiri Hulu Regency, Riau Provinces. The Kampar and Indragiri Hulu Regency was selected as study areas by considering that events and driving factors of deforestation in these areas represent events across the Province of Riau. In addition, the Kampar Regency represents the regency that has grown rapidly in Riau Province. The Kampar District has high total population, population density, productive age, the density of the road network, river network density, and a high growth area. Kampar Regency also has a forest area bordering the dam used to generate hydroelectric power. Meanwhile, Indragiri Hulu Regency represents a growing new district with a quite low population and the remote location within the center city growth in the Province of Riau. Indragiri Hulu has a lower total population, population density, number of productive age, density of the road network, and river network density than Kampar. These 2 contrasting regencies experienced different deforestation events in the past.

Methods

Study area This study was carried out in Kampar and Indragiri Hulu Regency, Riau Province. Kampar District has an area of approximately 1,128,928 ha lies between N 0°10'40"−S00°27'00" and E100°28'30"−E 101°014'30'. Indragiri Hulu has an area of approximately 819,826 ha, situated between N0°15'00''−S 1°5'00'' and E 101°10'00"−E102°48'00" (BPS 2013).

There are 2 big and several small rivers in Kampar Regency (Kampar river 413.5 km length and Siak river 90 km length). The both rivers above which flows in Kampar Regency used as transportation, infrastructure, clean water resources, and electric power resources. Generally, Kampar Regency has tropical climates. The highest rainfall occurs in Koto Kampar Hulu in November which reaches 969 mm. A number of rain days in the year 2014 most occurred in Kampar Utara (BPS 2015a). In the further while, the amount of rainfall per year in 2014 in Indragiri Hulu amounted to 2,050.1 mm per 178 days. Maximum air temperature at the year of 2014 was around 34.5 ºC while the minimum temperature was around 20 ºC (BPS 2015b).

Supporting data This study used Landsat imagery, land cover data from Ministry of Forestry, and the administrative map of Riau Province in 2010. The Landsat images were aquired from 1990, 2000, 2010, and 2014 path/row 127/59–60 and 126/60–61 (4 scenes) per time period so the total Landsat collected to 16 scenes.

Model classification process Image pre-processing activities was carried out on the digital image to the stages of geometric and radiometric correction, layer stacking, mosaicing, and cropping using ArcGIS Desktop 10.1. Classification of the image was done following the guidelines of land cover classification of Forestry Planning Agency (2008). Under the guidance of the 23 classes of land cover, classification grouped into 11 classes cover the forest, forest plantations, plantations, settlements, dryland agriculture, wetland, swamp thickets, shrubs, open land, water bodies, and airport.

Classification of land cover which had been formed was overlaid with the administration map of Riau Province in 2010. The reliability of the classification result was validated using an accuracy test with reference data taken from field observations conducted by purposive sampling in 2014. Evaluation of the results of image classification recorded in 1990, 2000 and 2010 was done using "interpretation key" in the form of "monogram" Landsat satellite images which were constructed using the results of image recording in 2014.

The size of accuracy test used were Overall accuracy and Kappa acuracy (Jaya & Kobayashi 1995; Jaya 2009; Olofsson 2014). The Overall accuracy and Kappa accuracy are shown in Table 1. Deforestation analysis was performed on land cover change forest to non-forest in the period of 1990–2000, 2000–2010, 2010–2014. Deforestation is

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Table 1 The result of classification accuracy test using the Overall accuracy and Kappa accuracy in Kampar and Indragiri Hulu Regency

Year	Kampar		Indragiri Hulu	
	Overal accuracy	Kappa accuracy	Overal accuracy	Kappa accuracy
1990	95.06	92.58	94.78	92.88
2000	94.44	93.11	95.28	94.02
2010	95.87	94.72	97.00	96.38
2014	95.45	94.41	91.87	89.58

change from forest land cover to permanent non-forest cover. Forests and forest plantations were grouped into the forest, while plantations, settlements, dryland agriculture, wetland, swamp thickets, scrub, open ground, bodies of water, and airport were classified into non-forest. Changes in forest cover on forest plants were not classified as deforested areas because the cover did not change permanently. The remaining forest area in each observation periods were summed with an area of forest plantations.

Developing optimization analysis of deforestation spatial pattern Analysis of deforestation spatial pattern was done to obtain information about the distribution and spatial patterns of deforestation in Kampar and Indragiri Hulu Regency. Landsat is sufficient to characterize the spatial patterns of deforestation to analyze spatial pattern (Townsend *et al.* 2009). Analysis of deforestation spatial patterns was carried out using the software Fragstat 4.2. Fragstat is a spatial pattern analysis program used to generate forest landscape metrics (McGarigal & Marks 1995; McGarigal 2001). The data format used is the data in ArcGrid format (raster format). Each deforested forest land cover vector data per time period was converted into raster data formats and stored in the form of ERDAS Imagine grid with a grid size of 30 × 30 m (McGarigal & Marks 1995; McGarigal 2001). The spatial scale of the analysis of the landscape metrics was the regency administrative boundary so that the landscape metrics produced a regency landscape metrics.

Spatial deforestation metrics could be assessed by index value of forest landscape metrics (McGarigal 2001; Garcia 2004; Li *et al.* 2009; Singh *et al.* 2010). The metrics index is selected by consideration of aspects that represent occurrences of deforestation such as area, size, intensity, and time. The group metrics used were contagion metrics, shape metrics, and density metrics (McGarigal 2001). The group contagion metric used was the clumpiness index (CI) which describes the distribution pattern of deforestation in the 2 regencies within the observation period. Shape group metrics used were contiguity mean index (Contig MN) to describe the form of closeness and connectedness between patches. Patch density (PD) is a subdivison group metrics generated to determine the level of fragmentation (McGarigal & Marks 1995; McGarigal 2001; Fahrig 2003; Li *et al.* 2009; Sing *et al.* 2010).

The CI is an index which represents the rate of distribution or spatial pattern of patches in a landscape. This index provides a measure of the effective transmission of specific classes that isolate the configuration component from the area component and thereby providing an effective index of the class that is not confounded by changes in the class. CI is using the nearest neighbor method by measuring the distance using the euclidean distance. CI shows the range of values between -1 and 1. The value close to -1 indicates patches distributed scattered, a value close to 0 means that patches distributed randomly, and a value of 1 indicates that the patch distributed in clustered classes (clumped distributed) (McGarigal 2001). CI is using the method to measure the distance from the center of the patch to the nearest point objects or other patches. CI was calculated using Equation *[1]* and Equation *[2]*.

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

$$\text{Given } G_i = \left[\frac{g_{ii}}{\sum_{k=1}^{m} g_{ik}} \right] \qquad [2]$$

Note:
$\min_{-ei}$ = minimum perimeter (in a number of cell surface) from type of patch (class) *i* to the maximum rating groups
P_i = landscape proportion in place by a patch to the class *i*.
g_{ii} = the number of *i* class pixel patch bordering and corresponding based on double counting
g_{ik} = the number of *i* class pixel patch bordering with *i* and *k* class based on double counting

Contig MN is a metric used to assess the shape of the patch to describe the spatial connectedness or contiguity of cells in individual patches with other patches. Contiguity was measured by the index of connectedness or spatial contiguity between cells in patches (Equation *[3]*). The higher the index values, the greater (close) connectedness. Low value metrics illustrate the connectedness is low.

$$\text{Contig MN} = \frac{\sum_j^n x_{ij}}{n_i} \qquad [3]$$

Note:
Contig MN = the average value of the same patch connectivity
x_{ij} = appropriate metric patch value
n_i = number of patches in the same type

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Scientific Article
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Landscape metrics used to indicate the degree of fragmentation was PD, which is part of the area/density/edge metric (McGarigal & Marks 1995; McGarigal *et al.* 2002; Fahrig 2003). High value patch density indicated that a land cover classes increasingly scattered or fragmented. The density of the patch is the number of patches in each area of 100 ha landscape units (Equation *[4]*).

$$PD = \frac{N}{A}(10{,}000 \times 100) \quad [4]$$

Note :
PD= the amount of forest patch per 100 ha
N = number of forest patches
A = forest landscape area (ha)

A combination of spatial metric could be developed resulting in 12 combinations for every district. Combinations and variations of spatial index values at each occurrence of deforestation per period were analyzed to determine deforestation patterns in Kampar and Indragiri Hulu. Deforestation patterns based on the spatial deforestation index were analyzed descriptively to determine the driving factor or cause of deforestation. In general, the flow diagram of the study shown in Figure 1.

Results and Discussion

Deforestation area The deforestation had occurred in both districts for a period of 24 years covering 888,207.89 ha (Table 2). Deforestation in Kampar Regency was 598,115.96 ha (71.16%) and in Indragiri Hulu Regency area of 290,091.93 ha (60.20%). The highest deforestation in each regency occurred at different periods. Kampar Regency suffered the highest deforestation over the 1990–2000 period (60.18%) and continued to decline. Deforestation in Indragiri Hulu was highest in the period 2000–2010 (38.53%).

Deforestation in Kampar Regency (Figure 2) over the 1990–2000 period spent most of the northern part of the forest that borders the City of Pekanbaru (Figure 2a). The second period, of deforestation occured and spread in all

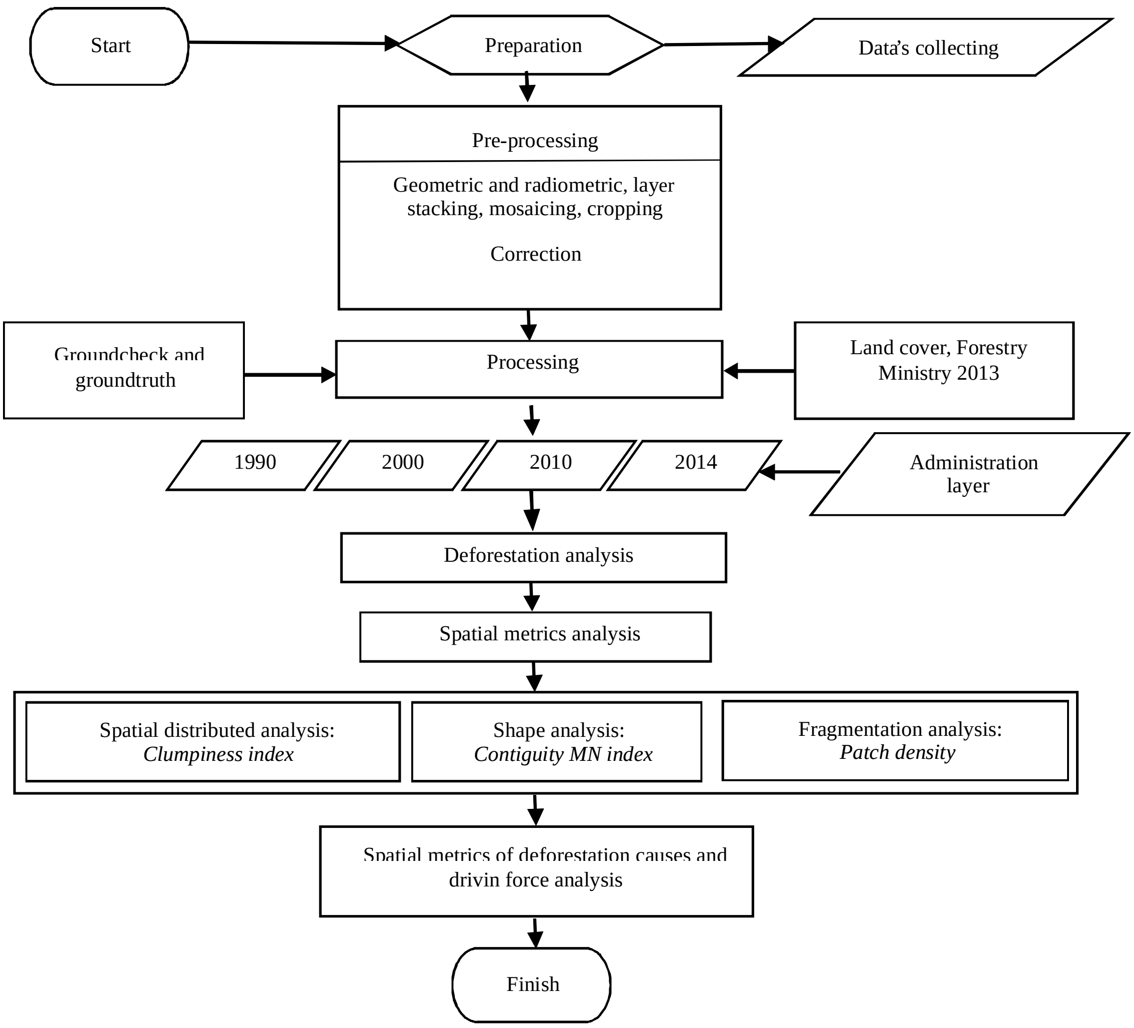

Figure 1 Flow diagram of the study.

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directions of the Kampar Regency, although it was not that extensive as in the first period (Figure 2b). Deforestation area in third period (Figure 2c) was quite small, because many forest areas had been deforested in the previous periods. The remaining forest areas were mostly forest plantation areas. Most of the remnant forests were located in the southern part of Riau Province, in particular in the high slope regions (hill to the mountains). Deforestation tended not to occur in areas with steep topography (Cabral *et al.* 2007; Munroe *et al.* 2007).

The deforestation in Indragiri Hulu was different from deforestation in Kampar Regency. The highest deforestation

Table 2 Deforestation in some periods at Kampar and Indragiri Hulu Regency

Regency	Period of deforestation							
	1990–2000		2000–2010		2010–2014		1990 –2014	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Kampar	505,828.97	60.18	91,058.88	30.43	1,228.10	0.64	598,115.96	71.16
Indragiri Hulu	65,857.46	13.67	163,897.42	38.53	60,337.05	20.56	290,091.93	60.20

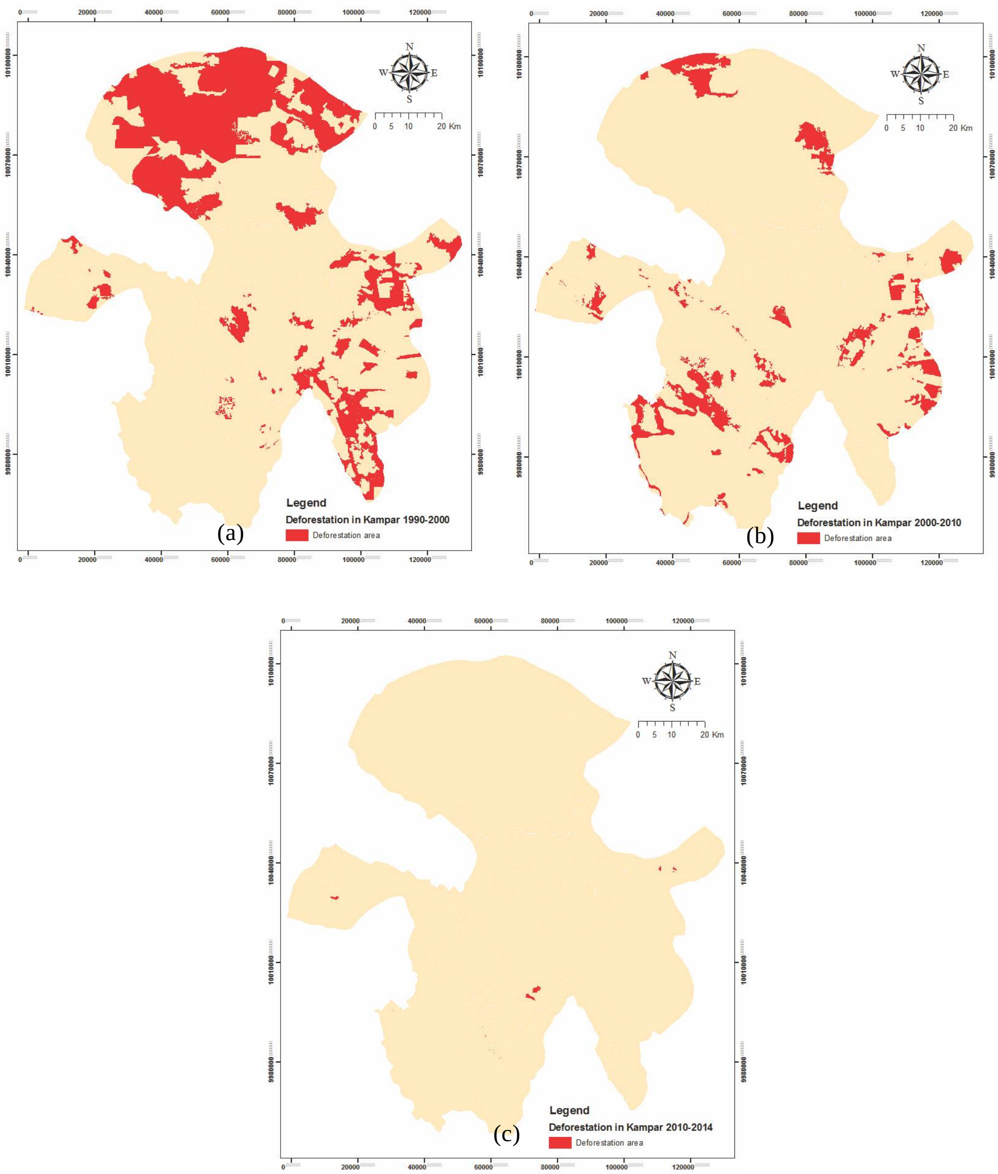

Figure 2 Distribution of deforestation areas in Kampar Regency in the period 1990–2000 (a), 2000–2010 (b), 2010–2014 (c).

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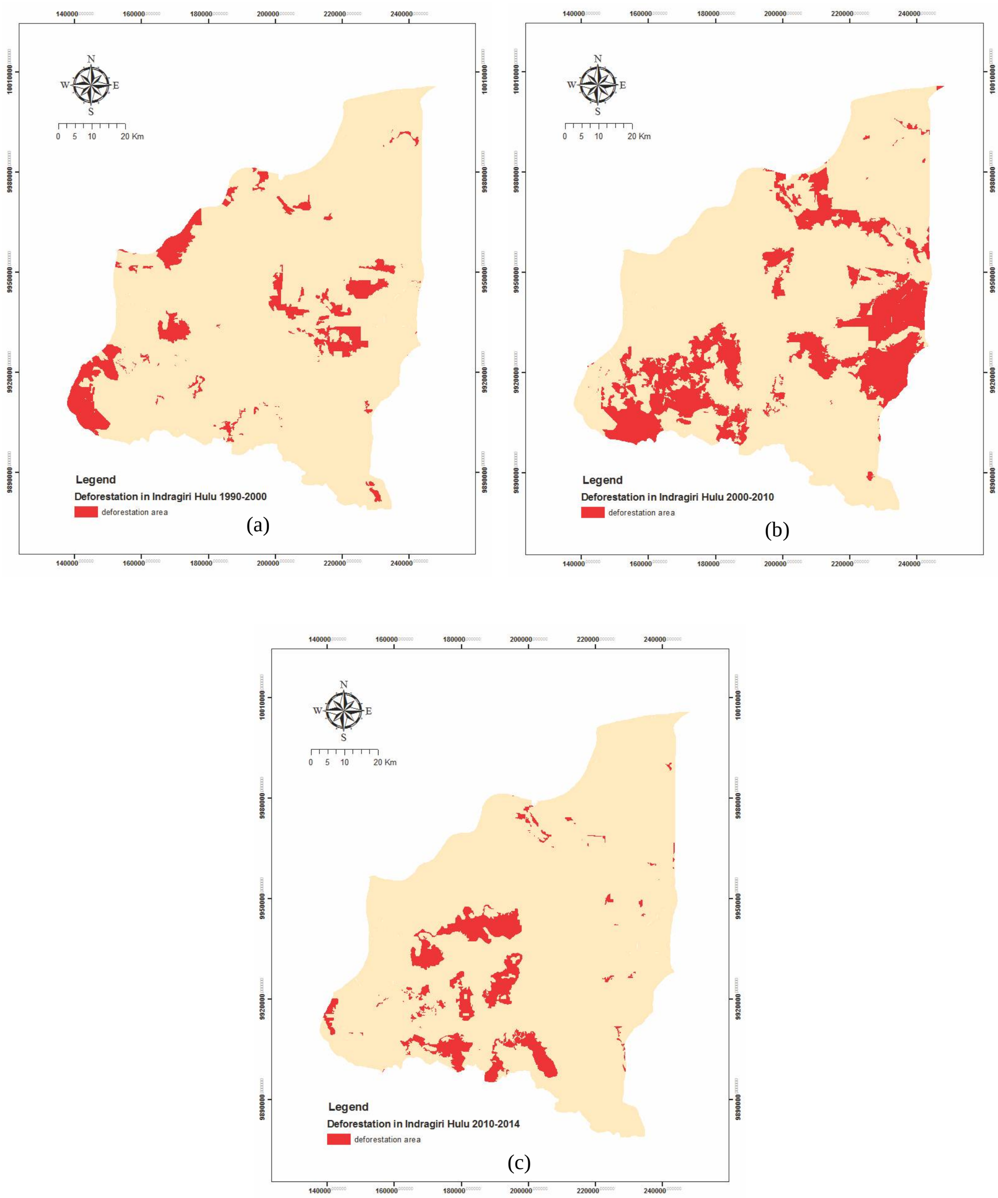

Figure 3 Distribution of deforestation areas in Indragiri Hulu Regency in the period 1990–2000 (a), 2000–2010 (b), 2010–2014 (c).

occurred in the period 2000−2010 (Figure 3b). Deforestation has largely occurred in the flat area to gently sloping topography. Deforestation in Indragiri Hulu continued to occur, with the character converting forest areas nearby (Figure 3a, Figure 3b, Figure 3c). The remnant forests were located in the hilly region and in area of the *Bukit Tiga Puluh* National Park. The existence of the national park could suppress the rate of deforestation.

Spatial deforestation metrics The CI provided describes the distribution and spatial patterns of deforestation in Kampar and Indragiri Hulu each period. CI value in both districts (Figure 4) has a spatial distribution pattern similar in the 1990–2000 period, which distributed clustered. The spatial pattern of deforestation was likely to change in the third period (2010–2014). The spatial pattern of deforestation in Kampar Regency tended to occur randomly while in Indragiri Hulu was remain in clusters.

The deforestation spatial patterns in 2 districts in the first and the second period were caused by changes in the spatial patterns of forest into a pattern of plantation and agriculture. Third period of deforestation in Kampar Regency occurred in a random spatial patterns caused by small-scale plantation development, agricultural activities, settlement development as well as some of the forest fires. This happened due to increasing population growth and increasing accessibility e.g. by construction of the road network. Based on field work observation, this result in line with Liu *et al.* (2014) which suggests that increasing population and accessibility growth will encourage deforestation. In contrast to Kampar, deforestation spatial patterns in Indragiri Hulu remain clustered during the period from 1990−2014. Deforestation was driven by the activity of large-scale plantations and land

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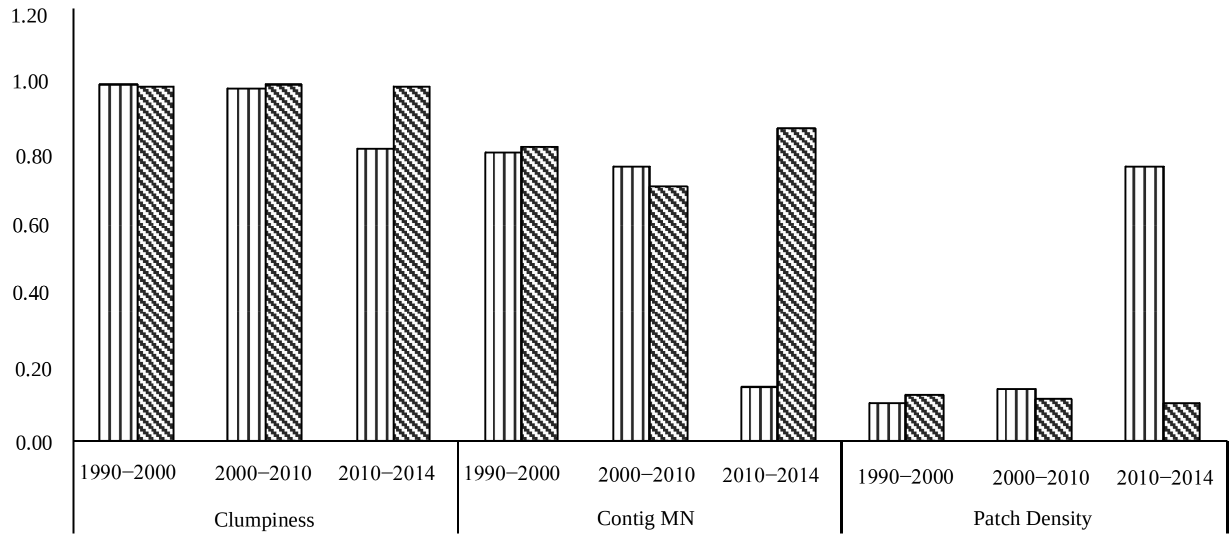

Figure 4 Deforestation spatial metrics patterns of Kampar and Indragiri Hulu in some periods. Kampar (▥), Indragiri Hulu (▧).

tenure for plantation expansion in the area around the plantation. From field work observation, the remaining forest area was mostly found in higher slope conditions. Forest landscapes tend to cluster in the region of hills or mountains (Zhang *et al.* 2010).

Based on the value of the metric of connectedness (Contig MN) (Figure 4) indicates that the connectivity between patches in Kampar Regency and Indragiri Hulu showed the same tendency in the period 1990−2010 and different in the period 2010−2014. Both suffered connectedness decrease in the period 1990 to 2010. The period 2010−2014, connectedness of Indragiri Hulu increased, while Kampar decreased.

Deforestation in Indragiri Hulu Regency had higher connectivity than the deforestation occurred in Kampar Regency. This means that the incidence of deforestation in Indragiri Hulu occur directly on previously deforested areas into the surrounding forest area. These events were generally caused by the activity of conversion of forest land which continually done by encroachment area increasing in surrounding areas to clear land for large-scale plantations, agriculture and settlement. This result was in accordance to Verbug *et al.* (2002). Connectedness index was higher because deforestation events following the distribution of the remaining forests and located around forest areas that were already deforested previously.

Different with Indragiri Hulu Regency, the incidences of deforestation in Kampar Regency tended apart after the second period resulting low connectedness level. This was caused by the location of the remaining forests far apart between each other. Therefore the incidence of deforestation not tended to connect with the previously deforested regions. Deforestation spatial patterns with low level of connectedness driven by deforestation due to small-scale plantations, agricultural expansion for rice cultivation (Sunderlin & Resosudarmo 1997), the construction of settlements, shifting agriculture and forest fires. Rapid deforestation has occurred at the initial period which caused low levels of connectivity. Rapid deforestation in the initial period (early deforestation) due to the remaining forest area spread out, which also caused deforestation happened in next period scattered and far apart.

Next spatial metric is fragmentation metric level, indicated by the Patch Density (McGarigal & Marks 1995; Fahrig 2003). Deforestation landscape structures were characterized by the number and size of the patch (Forman & Godron 1986). The fragmentation degree of deforestation in the regency of Kampar and Indragiri Hulu has shown similiar conditions. Density Patch value in Kampar Regency (Figure 4) shown the fragmentation level is higher than the level of fragmentation in Indragiri Hulu Regency. Fragmentation degree difference was shown in the period 2010–2014. Fragmentation level in Kampar Regency tends to incline while in Indragiri Hulu Regency declined. The high fragmentation in Kampar was caused by the many patches formed, especially in the period 2010–2014. Meanwhile, in Indragiri Hulu Regency was shown the level of fragmentation that tended to decrease because of the declining formed patches. This shows the incidence of deforestation continued to spread in the adjacent area.

The number and density of the patch was formed by the size of deforestation patch. Smaller size patch shows that the deforested landscape areas in the state more isolated and more fragmented. This result in accordance with Forman & Godron (1986) that the size of the area is isolated and fragmented indicated by the small size and many patches. Kampar Regency deforested forest was dominated by the small size patch, therefore the deforested forest was more isolated and more fragmented than in Indragiri Hulu. High fragmentation caused by increased human activities such as shifting cultivation, the high incidence of forest fires and residential development. Increased population also led to increase fragmentation (Gonzalez-Abraham 2007; Giordano & Boccone 2010), the expansion of forest land into plantations, farming and other agricultural activities (Hu *et al.* 2007; Ma & Xu 2010; Tanuwijaya 2012).

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Spatial patterns and causes of deforestation In general, deforestation spatial patterns in Kampar Regency showed a clustered distribution patterns and tends to turn into a random pattern, or spread low-level connectivity and high fragmentation pattern as a result. Meanwhile, the spatial patterns of deforestation in Indragiri Hulu showed a clustered distribution pattern, a high level of connectedness, and declining degree of fragmentation (Figure 4).

Based on a combination of spatial metric obtained 12 possibilities combinations, there was only 2 combination of spatial pattern in Kampar and Indragiri Hulu. The spatial pattern found that pattern 10 in Kampar and pattern 11 in Indragiri Hulu. The first metrics combination found in Kampar was clumped, low contiguous, and high fragmented. The combination indicated deforestation caused by large-scale plantations, agricultural activities, and wide settlements. Meanwhile, the second metrics combination found in Indragiri Hulu also clumped but high contiguous, and low fragmented. Based on field work observation, the distribution pattern indicated high deforestation caused by the activity in low to the moderate area which scattered in the observation area, such as, small-scale agricultural activities, plantation, and small area forest fire.

The deforestation spatial pattern for 24 years (1990–2014) was happened due to the conversion of forest land to other uses with characteristics different patterns, especially on the value of the Contig MN and PD index. Forest conversion into plantations (large and small), dryland agriculture, settlements, and forest fires were a major factor to drive deforestation in the 2 regencies. These drivers are based on field work observation in Kampar and Indragiri Hulu.

Spatial deforestation patterns are associated with the incidence of deforestation in 2 different regencies. Deforestation indicated with highest deforestation incidence in each observation periods (beginning of the 1990–2000 period and the end of the 2000−2014 period). Deforestation in Kampar Regency was classified as deforestation occurred at the beginning of the period (1990–2000), while the incidence of deforestation in Indragiri Hulu was classified as deforestation occurred in the final period. Therefore, the incidence of deforestation in Kampar Regency was relatively rapid (early deforestation), while the incidence of deforestation in Indragiri Hulu was relatively slow (late deforestation) (Rijal *et al.* 2016).

Deforestation occurred in both districts over the last 24 years was also triggered by some factors such as increased population growth and accessibility (especially for those bordering the forest), increased the incidence of forest fires and the adjacent location to urban development. Growing population had a high influence to the level forest landscape connectivity, in accordance to Liu *et al.* (2014) and Samsuri *et al.* (2014). Human activities also put oppresion on forests. This indicated that human activity tended to cause fragmentation (Nagendra *et al.* 2003; Shearman *et al.* 2009; Newman *et al.* 2014).

The road became direct cause of deforestation (Geist & Lambin 2002). In general, the closer the distance between forest and road, affected to increased forest fragmentation and deforestation. Kampar had higher road accessibility network than Indragiri Hulu, in accordance with Nagendra *et al.* (2003), Fearnside (2007), and Verbug *et al.* (2002). Distribution and forest fragmentation pattern followed the development of the road network for agriculture and land clearing activities (Arima *et al.* 2005; Feraz *et al.* 2009). The farther the distance of the forest to the road and the river, the connectivity tends to be higher. It was triggered by the presence of access roads into rivers and indirect causes of forest destruction. The existence of roads will attract human to use and change the land cover. In addition, the road and the river were also used as the wooden logs transportation infrastructure.

Deforestation was also caused by an increase in residential area. Increased residential area as a result of increasing population triggered the opening of forest areas. Increased level of public welfare encouraged the increased number of settlements (Ma & Xu 2010). As a result in Kamar and Indragiri Hulu, distribution and land spatial patterns changes tended to follow the development of the settlement.

The result of the 2 regencies also showed that deforestation continued; despite the extensive deforestation tend to decline in the last period. The reduced deforested area occurred because preventive action, rules strengthened and supervision to enforcement action. In addition, a decrease in deforested forest area due to the beginning of the remaining forest was getting fewer. If this situation continued, the remaining forest areas will run out in few years. Precautions and safeguards against the remaining forest areas must be continued and enhanced. The remaining forests of both districs are generally located in areas with steep topography. Forest with steep topography have a low level of accessibility therefore has lower impact and interference from humans (Cabral *et al.* 2007; Munroe *et al.* 2007).

Conclusion

Spatial metrics of deforestation was formed based on spatial metrics index. The metrics combination found 2 forms of spatial pattern. The spatial pattern found that pattern 10 in Kampar and pattern 11 in Indragiri Hulu. Deforestation spatial metric in Kampar regency showed a clustered distribution patterns, low degree of connectivity between patches, and high degree of fragmentation. The combination indicated deforestation caused by large-scale plantations, agricultural activities, and wide settlements. Spatial metric in Indragiri Hulu Regency showed a clustered distribution patterns, high degree of connectivity between patches and low or declining fragmentation degree. The combination indicated deforestation caused by small-scale agricultural activities, plantation, and forest fire. Profile of deforestation in Kampar Regency was classified as early deforestation, while in Indragiri Hulu classified as lately deforestation.

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