Analysis of Forest Patches in Three Regencies in West Java Based on Satellite Data

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ABSTRACT
Forest landscape in Indonesia has undergone changes due to deforestation leading to forest fragmentation and land use transformation. Forests patches within agriculture or settlement matrix can be susceptible to disturbances which could bring about long-term alteration of forest's ecological and economic functions. This study aimed to analyze the distribution and dynamics of forest patches in three regencies by identified it using Post Classification Comparison method (PSC) from multi-temporal Landsat satellite data i.e. 1991, 2001, and 2003. The forest patches were analyzed by the following landscape metrics: patch number, patch size and patch shape. In general, the result shows that the distribution and dynamics among three regencies have similar pattern. The number of small patches was higher than large patches. Smaller patches were more threatened to vanish by disturbances than larger patches. The shapes of all patches were convoluted as indicated by the shape index (SI>1). In terms of patch shape, the shape index has decreased over the study period indicating that the shape of the forest patches has become less convoluted.

Keywords: forest patches, landscape metrics, deforestation.

INTRODUCTION
Forest has ecological function as habitat, carbon sink, carbon source, and also rich of biodiversity. As the human need for natural resources-based product increase, the forest land transformation because of deforestation also increases. According to FAO (1996), about 51.6% of tropical rain forest (1980-1990) has been changed into agricultural lands (20.5%), tree plantations (13.5%), fragmented forests (5,1%), sifting cultivation fields (10.2%), and reforestate lands (2.2%). Deforestation affects biological biological diversity in three ways, i.e. habitat destruction, formation of edge effect between the forest and other land uses, and isolation of habitats as a consequence of forest fragmentation (Skole and Tucker, 1993).

Indonesia has the largest rain forest area in the world after Brazil. In line with the development of the Indonesian for fulfilling basic needs, the rate of deforestation has increased. The rate of deforestation in Indonesia for 1990-2000 was -1.2% (Chaichee et al., 2008). West Java is one of the provinces in Indonesia that has many natural resources including tropical forests. However, the quality and quantity of forest in this province has been threatened due to improper forest management. Data for year 2008 shows that the forest occupies only 18 % of West Java territory. Their percentage is lower than target set by the

provincial government, that is 45 % forest cover aimed at. Around 60% of the forest in West Java Province is located in three regencies (kabupaten), i.e Sukabumi, Cianjur, and Garut.

Deforestation and forest transformation could be studied by using landscape ecology approach. In this approach, the landscape is represented as mosaic consisting of the following elements i.e. patch, corridor, and the matrix. Then, forest can be viewed as a patch in a landscape. In a highly-developed landscape like Java island, forest usually occurs as remnant patch (Forman, 2001) surrounded by agricultural lands or the settlements.

To facilitate spatial analysis, the characteristic of forest can be measured based on landscape metrics e.g. number, size, and shape. Meanwhile, the dynamics of a patch can be seen within a framework of land transformation process. There are five spatial processes in the transformation of land i.e., perforation (making holes), dissection (subdividing of an area using equal-width lines), fragmentation (breaking up of a habitat into smaller parcels), shrinkage (the decreasing in size of object), and attrition (the disappearance of patches) patch (Forman, 2001).

The analysis of landscape metrics and patch dynamics can be facilitated by making use of remote sensing technique and Geographic Information System (GIS). From the satellite image, forest regions can be identified and delineated as pacthes. Furthermore, GIS can facilitate measurement and analysis of the dynamics and the number, size, and shape of forest patches in a certain period.

This research aimed to analyze the distribution and dynamics of forest patch in three regencies of West Java (Sukabumi, Cianjur, and Garut) Indonesia.

MATERIAN AND METHODS

Study Region and Sites The study area covers the regency of Sukabumi, Cianjur, and Garut. The forest in these regions comprises around 60% of the total forest cover in West Java province,-Indonesia.

Material and Methods The analysis was based on multi-temporal Landsat satellite image data i.e., year 1991, 2002, and 2003. The forest cover was identified using Post Classification Comparison method (PSC) for detecting the land cover changes. The 1991 Landsat TM+ data was obtained from www.glcf.umiacs.edu. The 2001 Landsat ETM+ data was obtained from Centre of Remote Sensing, ITB, and 2003 Landsat ETM+ data was obtained from LAPAN. The software used for analysis was ERMapper and ArcGIS. Following the satellite data registration steps, forest cover of each area was identified by their color and texture from satellite images. Identification was also aided by comparing with other land cover information from Google Earth and official land use maps.

The forest patch analysis was conducted for three aspect i.e., number, total area, and shape of patch. The forests in each region were classified into six classes, according to its area i.e. <10 ha, 10-50 ha, 50-1.000 ha, 1.000-5.000 ha, 5.000-50.000 ha, and >50.000 ha. Information on the patch number, size, and shape was then calculated for each class. The number and size of patch were calculated by ArcGIS. The shape of patch was represented by shape index (SI)

following Patton's formula (1975) that is $SI = \frac{P}{200[\pi A]^{0.5}}$. A and P indicate the area and perimeter of forest patch respectively. The patch's SI values of around one indicate that the patch was approximately circular. Increasing values of SI indicate less circular and high values of SI generally indicate elongated or convoluted patch and a long perimeter relative to the area. In this paper, the distribution and dynamics of forest patch were firstly analyzed separately for each regency and subsequently they were compared to each others. Field survey was only conducted in small number of sites to observe the real forest condition to observe the real forest condition.

RESULT AND DISCUSSION

1. Forest patch dynamics in Sukabumi region (1991-2003)

Patch number. The number of small forest patches in this regency was higher than large patches (Table 1). No patch with an area of >50.000 ha was found in this region. Examination on some sites indicates that the small patches could be mixed gardens or woodlands. Meanwhile, the very large patch (5,000-50,000 ha) were conservation areas.

The dynamics of patch number in this region shows that the quantity of patches sized <10 ha, 10-50 ha, and 50-1.000 ha has drastically decreased during 1991-2003 period. In contrast, the number of patches of 1,000-5,000 ha has declined during 1991-2001, but it has remained stable during 2001-2003 (Table 1). Whereas, the number of patches sized 5.000-50.000 ha has been constant over the whole periods (1991-2001, 2001-1003).

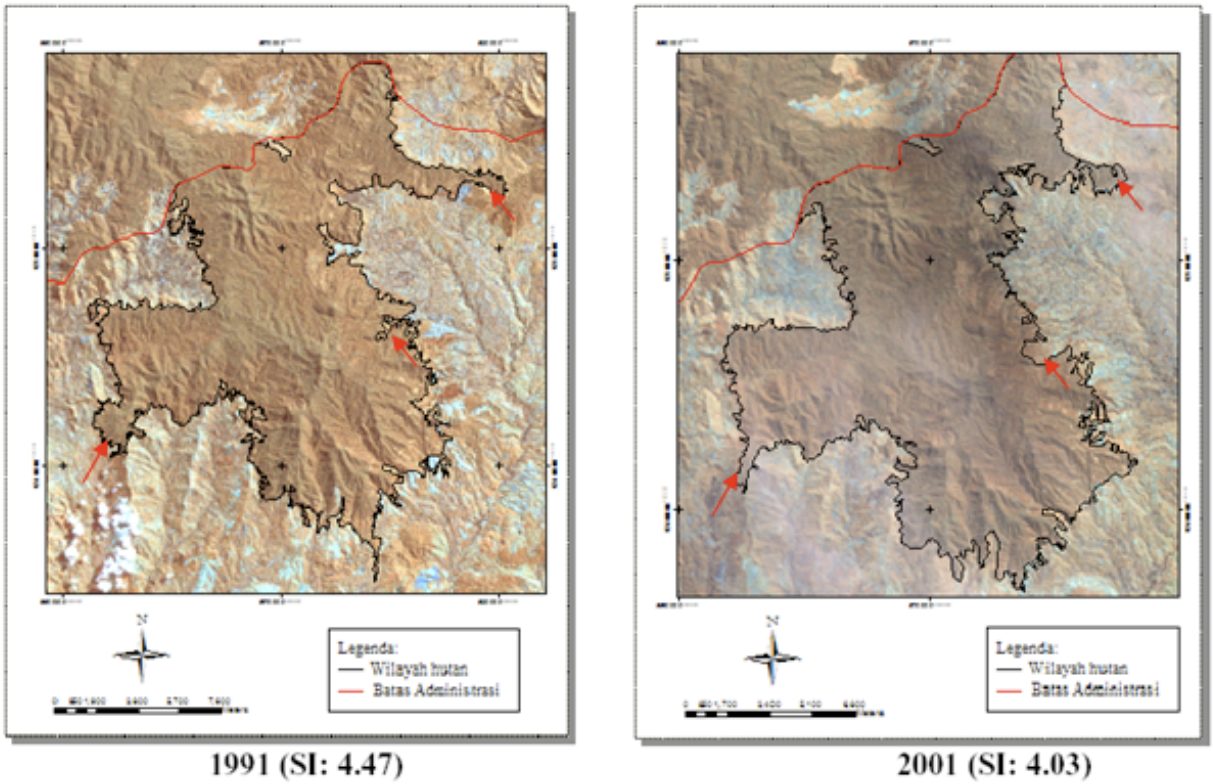
Table 1 The number and total area of forest patches in Sukabumi region

Class of Area	Patch Number			Total Area(ha)			Mean Shape Index		
	1991	2001	2003	1991	2001	2003	1991	2001	2003
<10 ha	171	30	14	509,93	106.14	53.48	1.46	1.47	1.37
10-50 ha	71	32	19	1,311.64	712.03	546.65	1.86	1.71	2.46
50-1,000 ha	40	30	18	6,557.10	6,496.36	3.288.48	2.58	2.49	2.41
1,000-5,000 ha	4	1	1	9,285.32	1,240.56	1,030.21	4.88	4.42	4.08
5,000-50,000 ha	2	2	2	21,210.89	20,915.37	20,115.16	3.91	3.40	3.31
>50,000 ha	-	-	-	-	-	-	-	-	-

Patch Total Area. From total area aspect, the data (Table 1) indicates that the total area in each class has declined over 1991-2003. An interesting trend can be seen by comparing the changes in total area and patch number. For small patch (<10 ha, 10-50 ha, and 50-1,000 ha), the decrease in total area was followed by the decrease in the number of patches. This finding indicates that deforestation affects not only total forest area but also the distribution of forest patches. In contrast, for large patch especially sized (5,000-50,000 ha), the decrease in the total area was not followed by the decrease in the number of patches.

Patch Shape. Generally, the shape index increases as the patch area increases (Table 1). This indicates that larger patches, tended to be more convoluted. When the dynamics was analyzed, it shows that, for each class, the patch shape tended to become less convoluted

overtime. The change of patch shape overtime found in this study indicates instability of patch caused by interaction of patch and other land uses (Lele et al., 2007). An example of the change of patch shape in this region can be seen in Figure 1. Red arrows denotes example of spots where the forest edge has been converted into different land uses.



1991 (SI: 4.47) 2001 (SI: 4.03)

Figure 1 An example of change in patch shape found in Sukabumi region (satellite data)

2. Forest patch dynamics in Cianjur region (1991-2003)

Patch number. The distribution of forest patches in Cianjur region was similar with the distribution of forest patches in Sukabumi (Table 2). The number of small patches in this region was also higher than the number of large patches and no patch more than 50,000 ha found in this region. As in the Sukabumi region, the large patches (5,000-50,000 ha) were mainly conservation areas.

The data presented in Table 2 shows different patterns for forest patch sized <10 ha and 10-50 ha in compared to that of in the Sukabumi region The dynamics of patch number for both classes have decreased slowly during 1991-2001 period, but have drastically declined during 2001-2003. On the contrary, the number of large patches (5,000-50,000 ha) had been relative stable during 1991-2003 periods.

Table 2 The number and total area of forest patches in Cianjur region

Class of Area	Patch Number			Total Area(ha)			Mean Shape Index		
	1991	2001	2003	1991	2001	2003	1991	2001	2003
<10 ha	137	130	25	440.20	410.61	114.76	1.54	1.47	1.45
10-50 ha	118	110	38	4,169.71	3,426.74	1,123.55	2.08	1.85	1.77

50-1,000 ha	64	21	16	13,539.47	4,555.91	4,853.57	2.66	2.44	2.28
1,000-5,000 ha	4	2	2	87,920.92	5,464.69	4,906.78	3.41	3.38	3.04
5,000-50,000 ha	2	2	2	16,543.3	16,145.57	15,726.77	4.17	3.68	3.08
>50,000 ha	-	-	-	-	-	-	-	-	-

Patch Total Area. An interesting trend can be seen by comparing change in patch total area and patch number (Table 2). The Ttotal area of patches in Cianjur region has been decreased overtime, except for the size of 50-1, .000 ha. For the small patches (<10 ha and 10-50 ha), the decrease in the total area was followed by the the decrease in the number of patches. Meanwhile, the decrease in total area of 1,000 – 5,000 ha patches was followed by the increase in the number of patches of 50-1,000 ha during 2001-2003 periods. This trend indicates that the deforestation happening in the medium sized patches (1,000-5,000 ha) has triggered forest fragmentation into smaller size (50-1, 000 ha). For the patches sized 5,000-50,000 ha, the decrease in total area was not followed by the decrease in the number of patches. As in the Sukabumi region, those large patches were also conservation forest.

Patch Shape. Table 2 shows that, generally, the shape index increased as the patch area increased. This indicates that larger patches tended to be more convoluted. The mean shape index values in decrease each classes during 1991-2003 periods have decreased meaning that, the forest patch shape becomes less convoluted overtime. An example of the change of patch shape in this region can be seen in Figure 2. Red arrows denotes example of spots where the forest edge has been converted into different land uses.

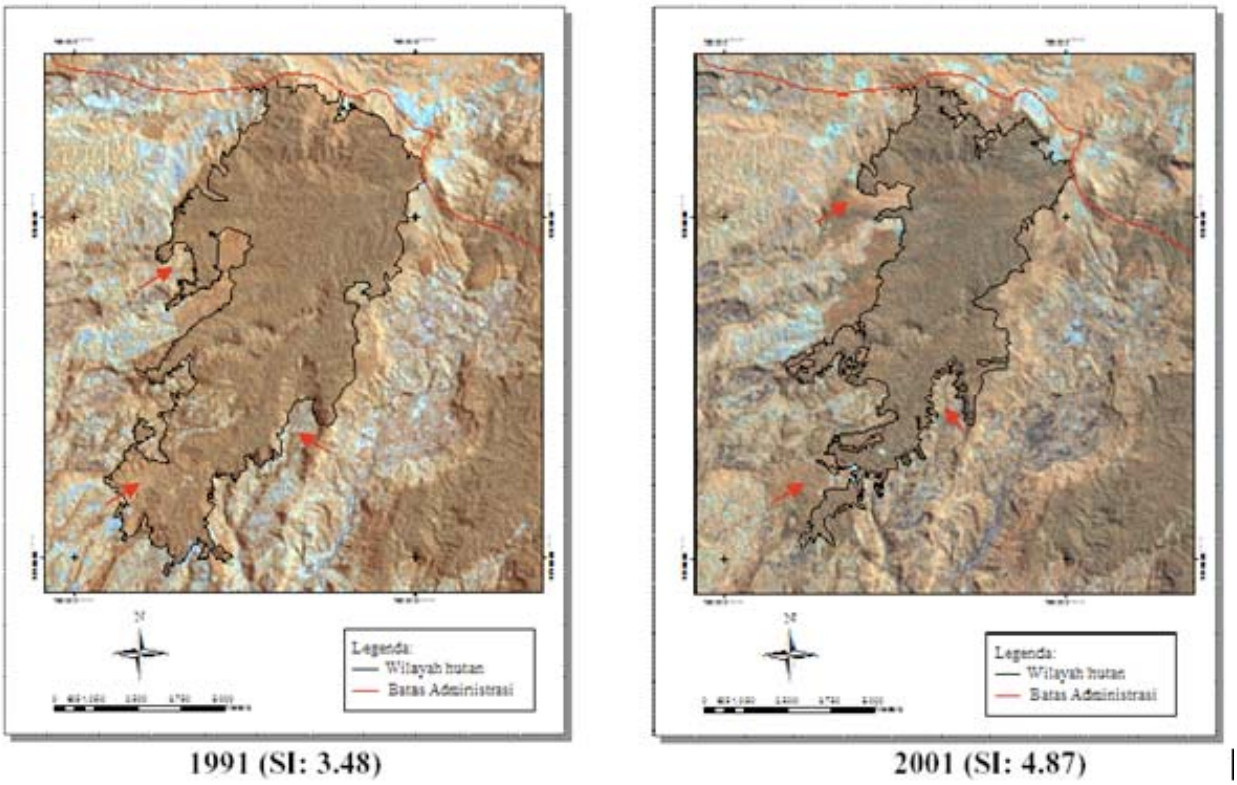


Figure 2 An example of change in patch shape found in Cianjur region

3. Forest patch dynamics in Garut region (1991-2003)

Patch number. As in the other two regions, the number of small patches in Garut region was higher than the number of large patches. Also no forest patch sized >50, 000 ha was found. The dynamic of patch number during 1991-2003 period (Table 3) shows that the numbers of forest patch sized <10 ha and 10-50 ha has decreased drastically. Whereas, the number of patches sized >1,000 ha has been decreased slowly.

Table 3 The number and total area of forest patches in in Garut region

Class of Area	Patch Number			Total Area(ha)			Mean Shape Index		
	1991	2001	2003	1991	2001	2003	1991	2001	2003
<10 ha	86	31	10	419.95	124.14	59.76	1.49	1.47	1.42
10-50 ha	85	43	56	2,021.66	1,216.74	2,476.41	1.79	1.69	2.06
50-1,000 ha	58	39	22	11,190.91	8,729.18	7,532.11	2.45	2.51	2.69
1,000-5,000 ha	6	5	5	10,183.54	8,741.95	9,965.53	3.49	3.10	3.02
5,000-50,000 ha	3	3	2	34,177.28	34,669.45	31,696.92	3.29	3.42	4.50
>50,000 ha	-	-	-	-	-	-	-	-	-

Patch Total Area. The result from total area calculation (Table 3) indicates that almost the total area in each patch class has decreased overtime except the patches sized 10-50 ha and 1,000-5,000 ha. The total areas of both classes increased during 2001-2003. This could happen due to fragmentation of patch sized 50-1,000 ha and 5,.00-50,000 ha into smaller size. In the large patches known as conservation area, the decline in the total area was because of patch shrinkage from the forest edge.

Patch Shape. As in the other two regions, the mean shape index values in this regency has increased as the patch area increased. This indicates that larger patches tended to be more convoluted. When the dynamics of patch shape overtime was analyzed, it shows that patches sized <10 ha and 1,000-5,000 ha tended to become less convoluted. Whereas, the mean shape index values of patches sized 10-50 ha, 50-1,000 ha, and 5,000-50,000 ha increased indicating that the shape of patches were more convoluted. An example of the change of patch shape in this regency can be seen in Figure 3. Red arrows denotes example of spots where the forest edge has been converted into different land uses.

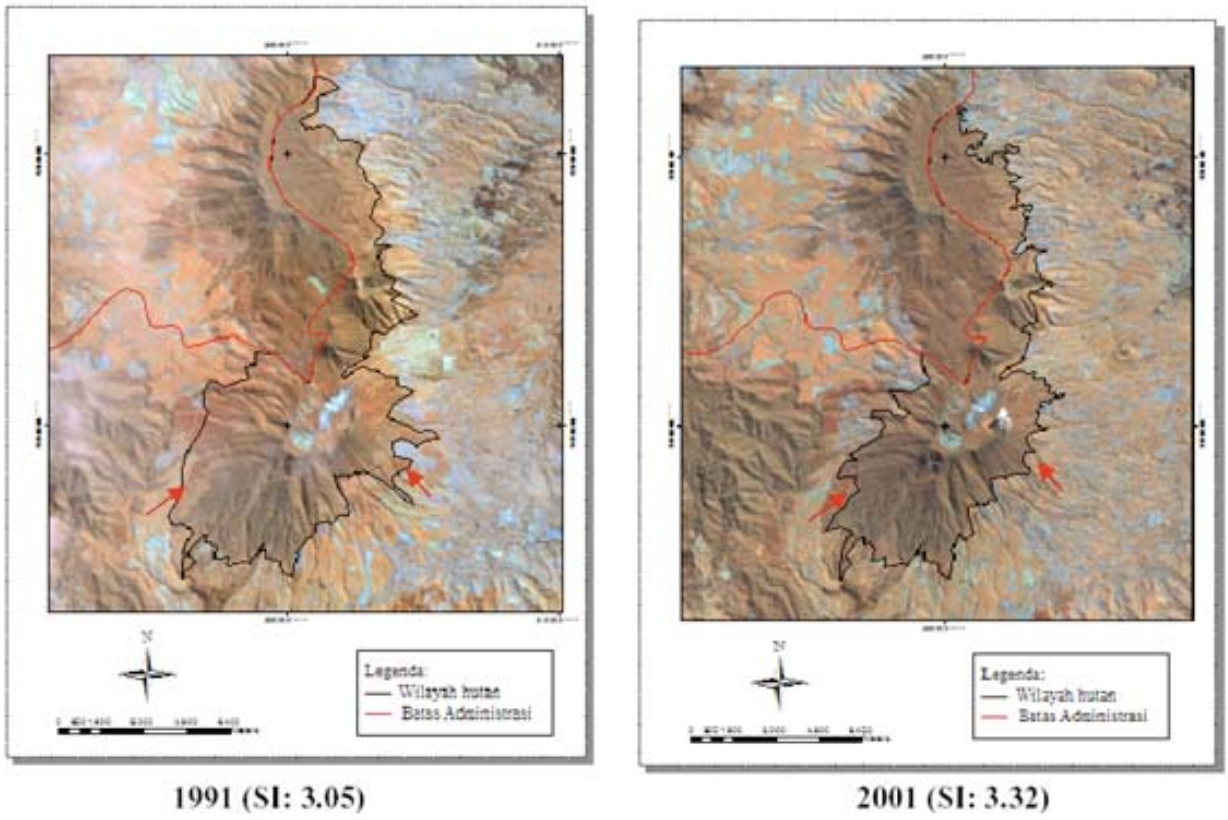


Figure 3 An example of change in patch shape found in Garut Region

4. Comparison of forest patch dynamics in three regencies

The patch distribution in Garut, Cianjur, and Sukabumi regions has the same pattern. Small forest patch could be mixed gardens or woodlands and very large patch was generally conservation area. Forest condition in these three regencies has changed overtime resulted from deforestation and land transformation.

Throughout the time period of the assessment, the small patches have undergone major changes in the patch number, total area and mean of shape index. The changes in small patches could due to natural as well as human disturbances. Conversion into agriculture lands seems to be one reason for the disappearance of the small forest patches in this study. Roy and Joshi (2001), and Lele et al., (2007) found similar trends in India. They suggested that a small patch surrounded by other type of land-use was much more vulnerable to be deforested.

Rusak (2008) stated that 200 ha was the minimum size of forest patch that could survive from disturbance. On the contrary, the finding of this study shows that some patches larger than 200 ha (in the size class of 50-1,000) could not survive due to conversion into other land-uses, which resulting in the disappearance of patch or “patch attrition” (Forman, 2001). There was a trend that the deforestation happening in the medium size patches trigger forest fragmentation. This was indicated by the increase in the number of smaller patches as the number and total area of the medium patches decreased.

Unlike the trends in small and medium patches, for the very large patches in this study, (5,000-50,000 ha), deforestations only caused decrease in forest area ("forest shrinkage") but not "forest fragmentation". Lele et al., (2007) suggested a reason why large patches are relatively less affected by disturbances leading to forest fragmentation. This is due to inaccessibility to interior of those areas. Rusak (2008) also suggested that disturbances were less capable reach large area because of the long edge perimeter. This is because conversion generally started from the edge area. In this study, the large patches exhibiting the phenomenon of patch shrinkage but not fragmentation (5,000-50,000 ha) were conservation area. Therefore, it seems that the status of those forests as conservation areas (national park) has played critical role in preventing the forests from fragmentation due to restriction of access and uses by the park management.

The mean shape index values from this three regions were more than one and this indicates that most patches were convoluted (Molles, 2005 dan Forman, 2001). When the patch shape is compared among the patches of different sizes, it shows that the large patches were more convoluted than small patches. If forest is regarded as a resource that needs to be protected, the convoluted shape as found in this study is not ideal one, because the patch has a long edge perimeter which facilitates higher contacts to disturbance which is usually originated from the edge (Forman, 1986; Forman, 2001; Sulistyawati et al., 2006; Lele et al., 2007). As a consequence, extra management is required to protect more convoluted rather than compact conservation forest patches as the edge area needs to be controlled is extensive.

CONCLUSIONS

The distribution and dynamic formation of forest patch in Sukabumi, Cianjur and Garut regencies exhibits similar patterns, which are:

- The number of small forest patches was higher than the number of large patches and no patch with an area of >50.000 ha was found. The patch shape in all every area classes tended to be convoluted as indicated the values of shape index, which is more than one.
- Deforestation for that most of small patches (<10 ha – 10-50 ha) caused "patch attrition". In the medium size patches (1000-5,000 ha and 50-1,000 ha), deforestation caused "forest fragmentation" into smaller forest patch size. For large forest patches (5,000-50,000 ha), deforestation only caused "patch shrinkage" but inot cause forest fragmentation.
- The mean shape index values of forest patches in all area class decreased 1991-2003 period, indicating that the patches has become less convoluted overtime.

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