

Dynamics Change of Vegetated Lands in A Highway Corridor during 37 Years (Case study of Jagorawi Toll Road, Jakarta-Bogor)

B P Perdana¹, Y Setiawan^{1,2}, L B Prasetyo¹

¹Department of Forest Conservation and Ecotourism, Faculty of Forestry,
Bogor Agricultural University, Kampus IPB Darmaga, Bogor 16680, Indonesia

²Center for Environmental Research, Bogor Agricultural University, Kampus IPB Darmaga, Bogor 16680, Indonesia

Email: bayuputraperdana07@gmail.com

Abstract. Recently, a highway development is required as a liaison between regions to support the economic development of the regions. Even the availability of highways give positive impacts, it also has negative impacts, especially related to the changes of vegetated lands. This study aims to determine the change of vegetation coverage in Jagorawi corridor Jakarta-Bogor during 37 years, and to analyze landscape patterns in the corridor based on distance factor from Jakarta to Bogor. In this study, we used a long-series of Landsat images taken by Landsat 2 MSS (1978), Landsat 5 TM (1988, 1995, and 2005) and Landsat 8 OLI/TIRS (2015). Analysis of landscape metrics was conducted through patch analysis approach to determine the change of landscape patterns in the Jagorawi corridor Jakarta-Bogor. Several parameters of landscape metrics used are Number of Patches (NumP), Mean Patch Size (MPS), Mean Shape Index (MSI), and Edge Density (ED). These parameters can be used to provide information of structural elements of landscape, composition and spatial distribution in the corridor. The results indicated that vegetation coverage in the Jagorawi corridor Jakarta-Bogor decreased about 48% for 35 years. Moreover, NumP value increased and decreasing of MPS value as a means of higher fragmentation level occurs with patch size become smaller. Meanwhile, The increase in ED parameters indicates that vegetated land is damaged annually. MSI parameter shows a decrease in every year which means land degradation on vegetated land. This indicates that the declining value of MSI will have an impact on land degradation.

Keyword: Highway Corridor, Vegetated Land, Patch Analysis, Landscape Metric

1. Introduction

Large scale road construction project executed by the government recently has affected the existing landscape condition. The planned toll road construction will connect the west end to the east end of Java Island. The construction requires large area hence the changes will greatly affect the exiting landscape condition. Development of transportation infrastructure is one of the factors that affect the level of landscape changes [1] in an area as the development of toll road and main road (motorway). Jagorawi toll road is one of the alternative toll roads that connect Bogor to Jakarta. The toll road becomes one of the factors that affect the development of developed land in the area.



Toll road is one of the required transportation infrastructures in an area to assist the accessibility of economy development and to connect regions. Development of toll road does not only provide positive impacts but also negative impacts to an area. The development positively induces the economy, trading, and governmental development, and improves the welfare of the community [2]. The negative impacts of the development are the increasing of land cover utilisations and changes, the decreasing of Green space, the increasing level of pollution, as well as conversion and change of undeveloped lands to developed lands.

The development of landscape changes that occurs can be ascertained through the use of technology of remote sensing and geographic information system (GIS) [3,4]. Remote sensing is a science or an art to obtain information about objects, areas or phenomena by analysing the data obtained through the use of devices, with indirect contact with the objects, areas or phenomena of the study. GIS technology uses optical images from satellite to measure and interpret the data on the field. Commonly used optical image is Land Satellite Image (Landsat). The image has sufficient frequency of shooting to monitor the land changes throughout the year. The objectives of this study are: 1) to examine land cover changes at Jagorawi Toll Road in 1978-2015, 2) to analyse landscape patterns around Jagorawi Toll Road and 3) to evaluate the changes on landscape pattern based on factor of distance from Jakarta to Bogor.

2. Methodology

2.1 Study Site

This study encompasses the Jagorawi highway (toll road) from Jakarta to Bogor. The distance is equal 2 to 42 km. In order to calculate a landscape pattern of that highway corridor, 2 km buffer right-left prepared (Figure 1).

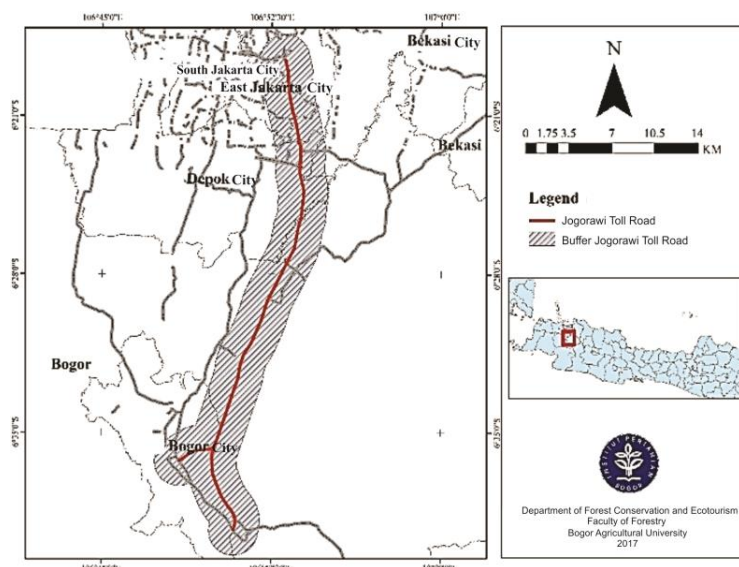


Figure 1. Study site

Jagorawi toll road is the oldest toll road in Indonesia that was built in 1972 and was first operated in 1978 as the main road that connects Jakarta to Bogor and Ciawi, West Java. Jagorawi toll road crosses over 28 villages, 9 villages are located in the administrative area of Jakarta and 19 other villages in the area of Bogor district. There are 11 gates along Jagorawi toll road such as Toll Gate (GT) TMII, Pasar Rebo, Cibubur, Cisalak Cimanggis, Gunung Putri, Citeureup, Sentul, South Sentul, Bogor and Ciawi.

Jagorawi Toll road has a flat topography (slope 0-2%), wavy (3-8%) and corrugated (9-15%). Jagorawi altitude area varies, approximately 20-300 meters above the sea level. Based on Schmidh-Ferguson climate classification, Jagorawi toll road area is classified with climate type A, which has an average rainfall greater than 2000 mm / year.

2.2 Materials and Tools

Tools used in this study are stationery and personal computer equipped with some software, such as: ArcGIS 10.3, Patch Analysis, ERDAS Imagine 9.1, Google Earth, and Ms. Office 2013. Materials used in this study are images from Landsat MSS 2 1978, landsat 5 TM 1988, 1995, and 2005, as well as landsat 8 OLI/TIRS 2015.

2.3 Data Collection

Data used in this study is the images of Landsat 2 MSS, Landsat 5 TM and Landsat 8 OLI / TIRS obtained by downloading from the internet while the field point obtained through ground check by recording the coordinates with a GPS.

2.4 Data Analysis

Data analysis was performed with classification of land cover and analysis of landscape pattern and gradient analysis through the use of patch analysis to describe the pattern of trend (trend) of degree of fragmentation in the region.

2.5 Land Cover Classification

Classification of land cover obtained from image processing through the use of Google Earth in 1978, 1988, 1995, 2005 and 2015 with supervised and non-supervised image classification. Land cover classified into developed land, water bodies, agricultural land, and vegetated land.

2.6 Landscape Pattern Analysis

This study used landscape metrics parameters such as Mean Shape Index (MSI), Mean Patch Size (MPS), Edge Density (ED), and Number of Patch (NumP). According to McGarigal et al. [5] these metrics landscape parameters are able to interpret the structure of spatial element, composition, and distribution in landscape. Landscape metrics include number of patches, edge density and average efficient shape in analysis of changes in land cover [6].

2.7 Gradient Analysis

Analysis of gradient is a method to compare patterns of trend (trend) from multiple locations by observing the slope of the line connecting between the two variables. The spatial patterns of land use reflect the human process that underlie and affect the ecology of urban environment [7]. The analysis performed by creating a 4x4 km swath along the observation area from Jakarta to Bogor. After that, each plot was analysed using the patch chart analysis to determine land cover changes throughout the observation area. Patch analysis parameters used are Mean Shape Index, Mean Patch Size, Edge Density, and Number of Patch.

Table 1. Landscape Metric Equation

Parameter	Formula
Edge Density (m/ha)	$\frac{\sum_{k=1}^M e_{ik}}{A} (1000)$
Mean Shape Index	$\frac{\sum_{j=1}^n \left(\frac{p_{ij}}{\sqrt{\pi \times a_{ij}}} \right)}{n_{ij}}$
Mean Patch Size (ha)	$\frac{\sum_{j=1}^n a_{ij}}{n_i} \left(\frac{1}{10000} \right)$
Number of Patch (Unit)	N

Description: e_{ik} : Total length of the patches in the landscape in m, n : total number of patches in the landscape, n_i : number of patches in the landscape, m : the number of patches in the landscape beyond the limit unless the landscape, m' : the number of patches in the landscape and the landscape, j : number of patches, k : the same patch, A : total area.

3. Discussion and Result

3.1 Land use land cover changes

The term of land cover and land use is often used in the study of land cover changes. According to Lillesand and Kiefer [8], land cover related to the appearance of the Earth's surface, while the land use related to the human activity on the object. There are several classes of land cover around Jagorawi Toll Road such as water bodies including rivers, marshes, and reservoirs; developed land cover class, such as residential areas, economic sectors, and industrial area. Farm land class involves annual plants, and vegetated land class including grass, shrub, and tree areas.

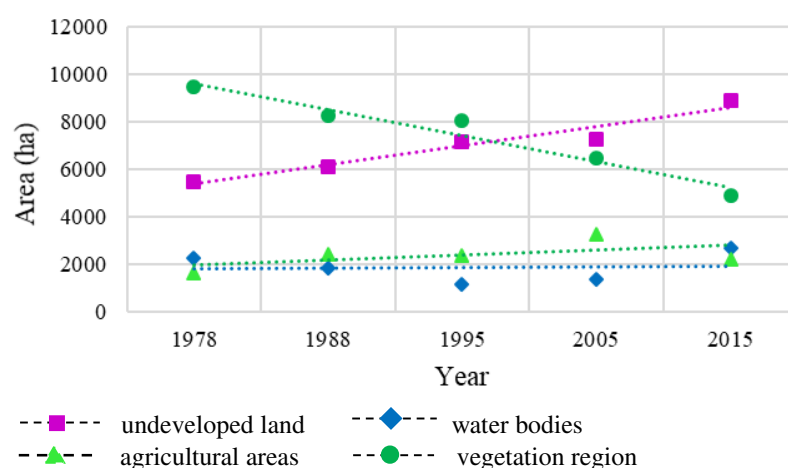


Figure 2. Dynamics of Changes in Land Cover Years 1978-2015

Land cover / land use changes that occurred in 1978-2015 had modified the land area. The undeveloped land in 1978 had an area of 5,465.16 ha or 29% in the year and continued to increase in 1988, 1995, 2005 and 2015 respectively as 6 114.15 ha (33%), 7,169.67 ha (38%), 7,275.96 ha (40%), 8,890.38 ha (48%). The vegetated land area in 1978-2015 decreased about 9 462.24 ha (50%), 8 279.46 ha (44%), 8,036.73 ha (43%), 6,441.56 ha (35%), and 4,901.85 ha (26%). The area of water bodies rose from 2,252.88 ha (12%) in 1978 to 2,654.64 ha (14%) in 2015. The total area of the farm land rose about 1,610.28 ha (9%) in 1978 and 2,207.16 ha (12%) in 2015 (Figure 2).

Figure 3a shows the changes of vegetated land around Jagorawi Toll Road. The vegetated land turned into developed land as much as 4,555.83 ha or 48% over a period of 37 years. The vegetated land turned into agricultural land area of 1,240.256 ha or 13%, the vegetated land turned into water bodies covering an area of 1,051.97 ha or 11%, and existing vegetated land area of 2,569.93 ha or 27%. This suggests that changes in the vegetated land most likely caused by existing development in the area such as the development of residential or industrial area. This is in accordance with statement that the factor of population density and development of motorway that connects the city can accelerate and expand changes of the lands around it.

Figure 3b shows the agricultural land cover changes that occurred around Jagorawi Toll Road. Visible changes could be seen in agricultural land around Jagorawi Toll Road. The agricultural land and undeveloped land transformed into an area of 448.99 ha or 20% over a period of 37 years. The agricultural land changed into land covering area of 142.46 ha of water bodies or 6%, agricultural land into vegetated land area of 1,263.61 ha or 58%, and the rest is agricultural land that does not change as much as 352.08 ha or 16%. According to Trisasonkko et. al [9], the incidence of changes in land use from wetland to dry land was positively correlated with the growth of dry land in the region.

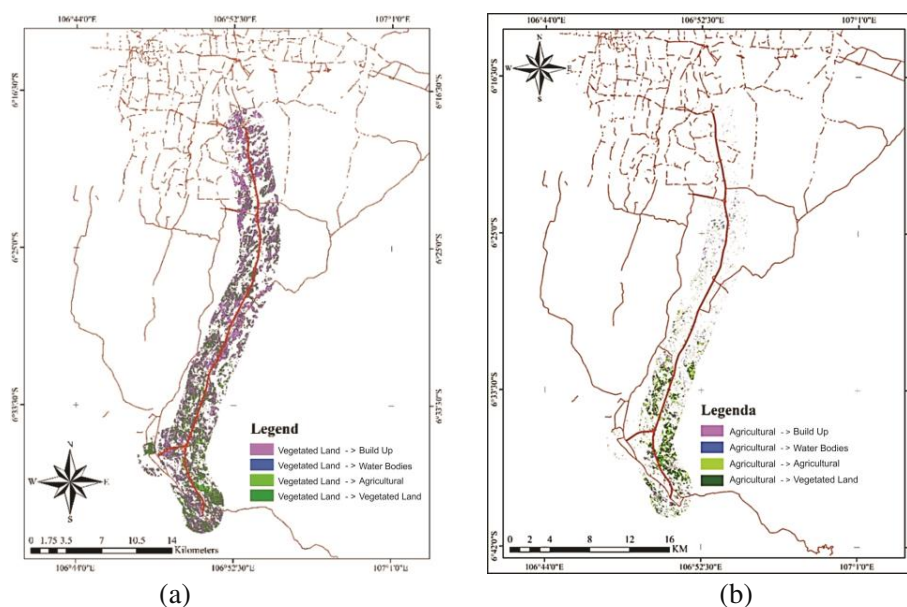


Figure 3. Map of Land Cover Changes in Jagorawi in 1978-2015; a) Vegetated Land, b) Agricultural Land

3.2 Landscape pattern changes of vegetated lands

Landscape quantitative analysis based on fragmentation process is one of the necessary landscape processes that show the effect of human activity and human disturbance on the structure and function of landscape [10]. Landscape metrics provides quantitative method to explain spatial distribution and climate variation on urban temperature patterns in response to land covering pattern in urban landscape [11]. Quantitative metrics as indicators of environmental landscape can be used in a sustainable land use planning [11]. Land cover changes over a period of 37 years from 1978 to 2015 shows that the spatial characteristics of land use classes also changed over time.

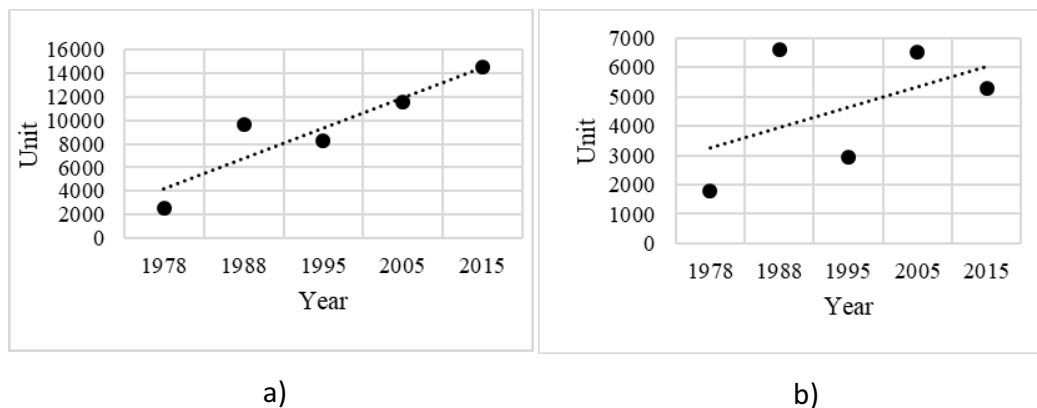


Figure 4. Number of Patch; a) Vegetated land, b) Agriculture land

Indicator of number of patches (NumP) is the total number of patches in the landscape if selected to analyse the 'landscape', or the number of patches for each individual class if selected to analyse the 'class' [5]. The results of NumP obtained in the vegetated land in 1978 was 2534 units, 9671 units in 1988, 8240 units in 1995, 11 576 units in 2005, and 14484 units in 2015. This shows the increasing trend in 1978-2015. Increasing trends of change also occur on the agricultural land for a period of 37 years. NumP obtained from the calculation results show the agricultural land in 1783 units in 1978, 6621 units in 1998, 2932 units in 1995, 6542 units in 2005, and in 5305 units in 2015 (Figure 4). Increased NumP indicates that the higher the value of NumP obtained the higher the level of fragmentation in the region. According Elkie et al. [12] says that the increase in NumP show increased fragmentation with a smaller patch size.

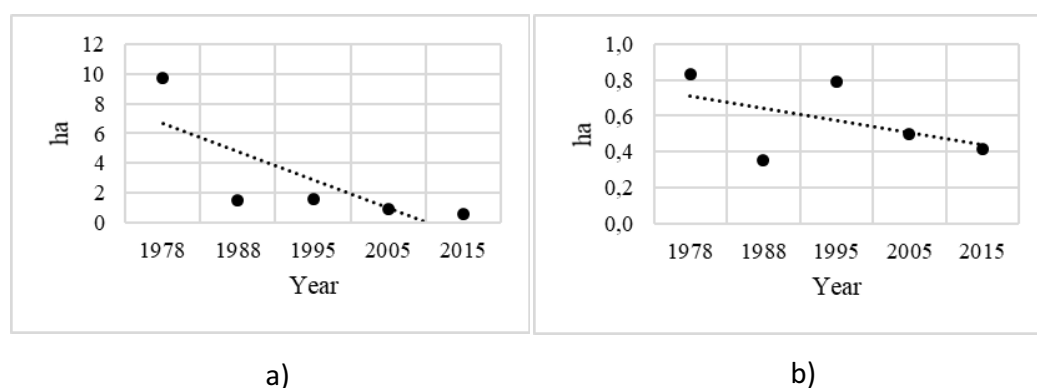


Figure 5. Mean Patch Size; a) Vegetated land, b) Agriculture land

Indicator of mean patch size is a measure of the average patch in particular class, or at the landscape level to the average size of all classes [13]. MPS results obtained in the vegetated land in 1978 was 9732 ha, 1,495 ha in 1988, 1,559 ha in 1995, 0,929 ha in 2005, and 0602 ha in 2015. This indicates a downward trend from the year 1978 to 2015. Impairment MPS in the vegetated land indicates that the vegetated land area within a period of 37 years continues to decline. According to Kamusoko et al. [14], MPS impairment shows the increase in the dynamics of land use patterns, so that the structure of the landscape becomes smaller as the result of land distribution system. MPS calculation results on the agricultural land also showed a decrease in area over a period of 37 years. The agricultural land in 1978 was 0829 ha, 0354 ha in 1988, 0791 ha in 1995, 0497 ha in 2005, and 0414 ha in 2015 (Figure 5).

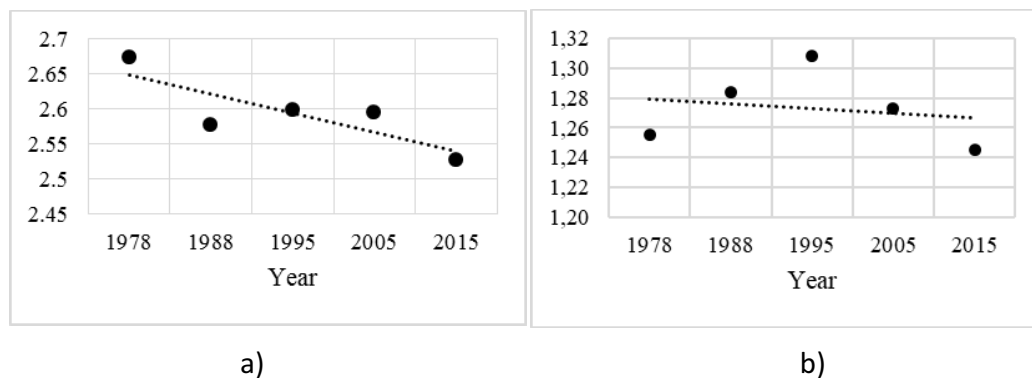


Figure 6. Mean Shape Index; a) Vegetated land, b) Agricultural land

Mean shape index is a parameter of the complexity of form in which the amount of the perimeter of each patch is divided by the square root of the area of the patch (ha) for each class (grade level) or all of the patches (landscape level) [5]. The comparison metric landscape obtained over the past 37 years shows that the average shape index (MSI) in the vegetated land was 2,674 in 1978, 2,577 in 1988, 2,600 in 1995, 2,595 in 2005 and 2,527 in 2015. This indicates a downward trend from 1978 to 2015 year. MSI calculation results in the agricultural land also shows declining trend change. MSI value in 1978 was 1,256, 1,284 in 1988, 1,308 in 1995, 1,273 in 2005, and 1,245 in 2015 (Figure 6). MSI parameters show a decline in each year, which means land degradation occur in the vegetated land and the agricultural land in 1978-2015. This indicates a decrease in the value of MSI have an impact on land degradation. According to Tazeh [11] who states that landform metric indicators can be an indicator that shows the processes of degraded lands.

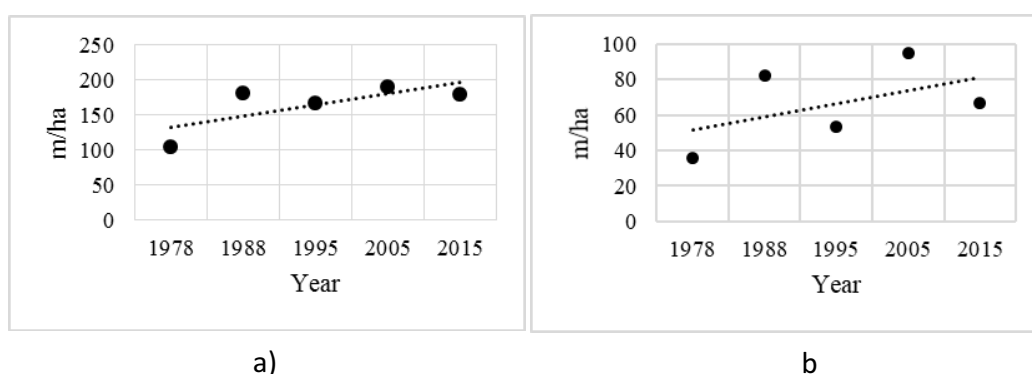


Figure 7. Edge Density a) Land vegetation, b) Agriculture

Indicator of edge density (ED) is the number of relative edges to landscape area [5]. ED is a standardised metric that is useful to compare the landscape with different sizes [12]. Edge density (ED) is the number of relative edges to landscape size. ED result was obtained from the calculation through the use of Patch Analysis on the vegetated in 1978 which was 104 078 m / ha, 181 108 m / ha in 1988, 167 550 m / ha in 1995, 190 518 m / ha in 2005, and 179 734 m / ha in 2015. This shows an increasing trend from 1978 to 2015. Increased ED also occurs on the agricultural land as indicated by the increasing trend in 1978-2015. ED value in 1978 was 35 665 m / ha, 82 260 m / ha in 1988, 53. 189 m / ha in 1995, 94 712 m / ha in 2005, 66 552 m / ha in 2015 (Figure 7). According to Tagil (2007), an increase in the perimeter of the ED will lead to an increase in the length and direction of damages to the land and to show that the landscape can be used in land use changes.

3.3 Gradient analysis on landscape patterns in the corridor Jakarta-Bogor

The graphic of NumP shows the increasing level of fragmentation in the 37-year period from 1978 to 2015. The vertical side (bottom to top) shows the rise of fragmented land each year. NumP charts in 1978 shows the smallest trend value compared to the other years. This is because in that year the degree of fragmentation around Jagorawi Toll Road was not too severe. Jagorawi Toll Road development impact that year has not been too significant, this can be proved from the presence of good vegetated land. In 1988-2015 on the graphic of NumP can be seen that the degree of fragmentation is increasing every year, which indicates vegetated land in 1988-2015 diminishing in number. In 2005-2015, NumP value shows a high increase, this is caused by the population growth due to urbanisation and continuous development in this year that lead to more fragmented vegetated land.

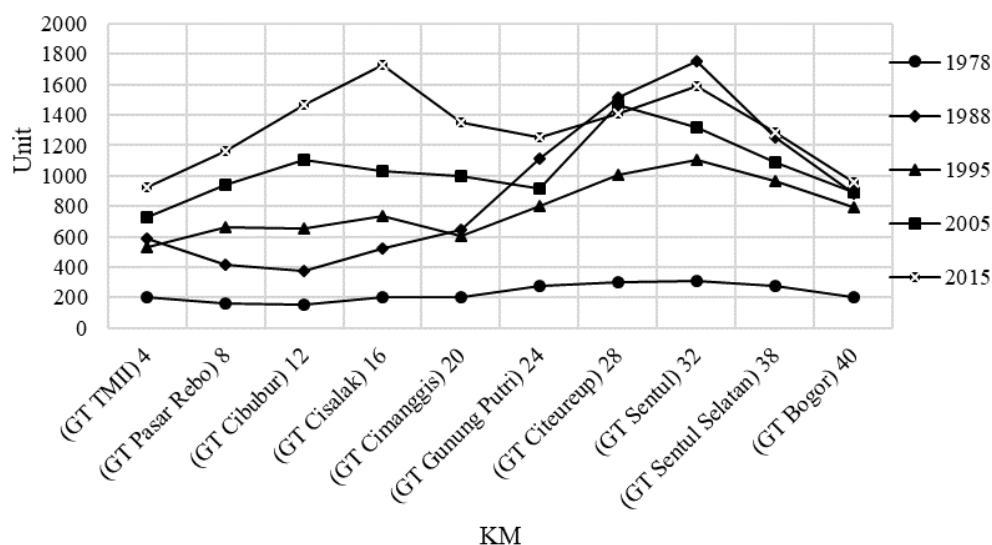


Figure 8. Number of Patch

On horizontal side (left to right) or a change in the landscape around the area of observation, the highest fragmentation of vegetated land at KM 28 and 32 in. Sentul area of Bogor District at km 32 is an area that has a high degree of fragmentation on vegetated land, this was caused by the developments on recreational area, economy area, gymnasium, and resident area. At KM 28, which is the Citeureup GT, the damage occurred on vegetated land in the area caused by the development of industrial area, economy area, and resident area.

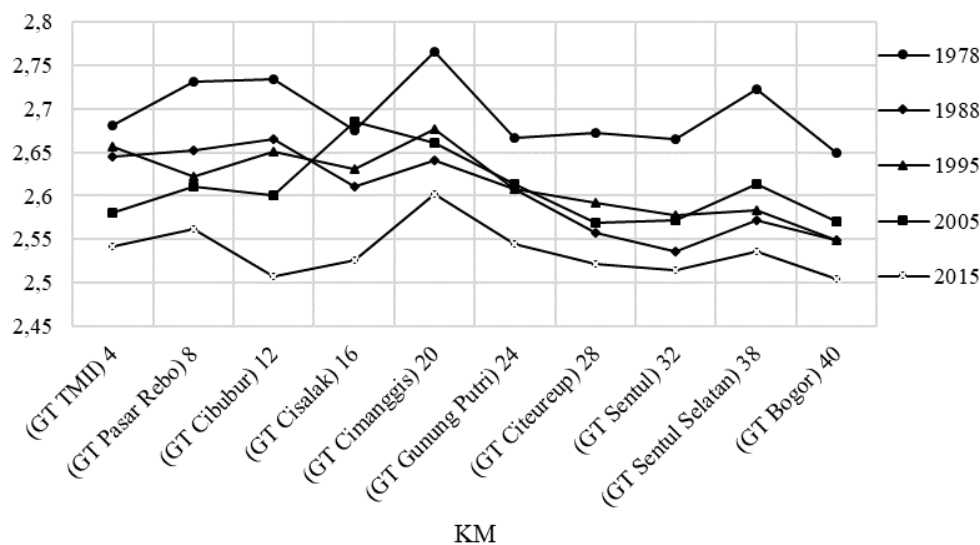


Figure 9. Mean Shape Index

MSI chart shows the pattern of land cover changes along Jagorawi Toll Road. The vertical side (top to bottom) shows a decrease in the value of the MSI over a period of 37 years. MSI chart in 1978 shows the highest value trend, because in that year Jagorawi toll road was still in the initial operation and the existing vegetated land had not yet suffered from severe degradation. The graphic results in 1988-2015 shows the value of MSI decreasing every year. This is shown on the graphic in 2015 where MSI value is the smallest among the other years due to the increasing development caused by the presence of the toll road that diminish the land use trend. Development of an area will generate traffic that affects transportation infrastructure, on the other hand, the presence of good transportation infrastructure will affect land use patterns [15].

The results on horizontal side (left to right) show the spatial patterns of vegetated land in the area of observation. Value trend on MSI parameter fluctuated as seen at KM 20 (Cimanggis Toll Gate) in each year, which means that in these areas, the existing land cover is still in good condition. The changes that occur before and after the KM 20 which shows a decrease on the graphic from MSI parameter indicates that vegetated land is degraded by the construction of this toll road. MSI chart increased at KM 38 (South Sentul) which means the vegetated land in the area is still in good condition. MSI chart in 1978 shows the highest value compared to year thereafter, because in that year Jagorawi toll road was still in the initial operation and the presence of vegetation on the land had not yet suffered severe degradation. Graphic results in 1988-2015 show the value of MSI decreasing every year. This is shown on the graphic in 2015 where MSI value is the smallest among the other years due to the increasing development caused by the presence of the toll road that diminish the land use trend.

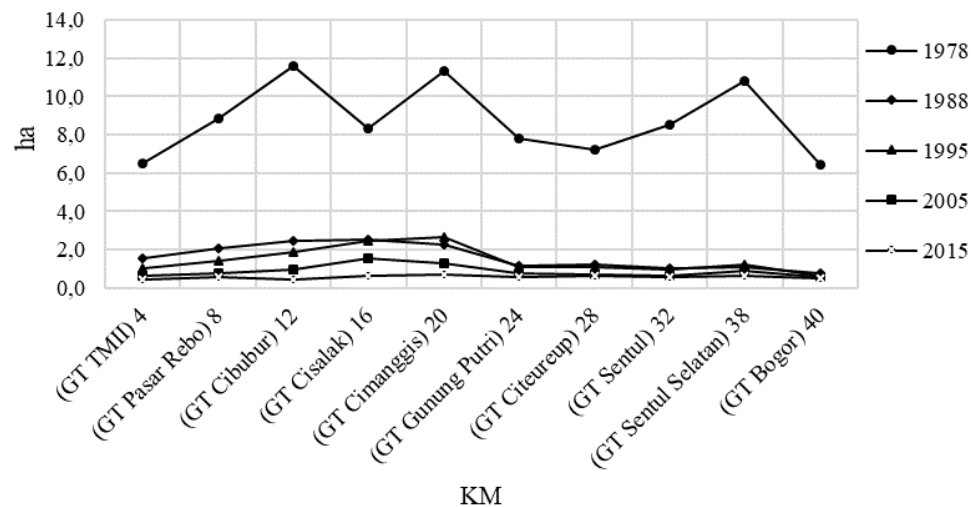


Figure 10. Mean Patch Size

The MPS graphic shows a decrease in the vegetated land area in 1978 to the following years. The vertical side (up and down) shows that the whole vegetated land area in 1978 still had a considerable area along the observation. This was because in that year the construction around the observations line was not too significant and did not affect the existing vegetated land. The 1988-2015 MPS graphic shows a severe deterioration in 1978, this can be seen from the graphic where the value decreases every year. It indicates the development around observation line was very rapid in those ten years. According to Akhirudin and Suharjo [16], the land conversion of land from undeveloped land to developed land is caused by residential, industrial, and other developments to support human life.

MPS graphics on the horizontal side (from right to left) shows the increase and decrease in the total area of vegetated land on observation line. During 1988-2015, visible pattern of land use change on the vegetated land along the observation. The vegetated land area that existed in the 1988-2015 did not experience significant changes each year, in contrast to the year 1978 that there was still a lot of vegetated land observation line. This was caused by during the time Jabodebatek was under rapid development in industrial, trading, and service sector that led to the decrease of vegetated land because it was considered less productive in term of value (land rent).

ED graphic shows the trend of the value of spatial patterns on the whole area of observation. These results show the pattern of landscape changes that occur over a period of 37 years. The vertical side (top to bottom) shows the increases and decreases in the value of ED in the area of observation. ED graphic in 1978 shows the smallest value compared to the other years. This suggests that in this year vegetated land was still in better condition compared to the years after, because in that year the Jagorawi Toll Road was still in its early stages of operation. After 1978, it is shown in the ED graphic that there is an increase in ED value throughout the years of 1988 to 2015 that indicates the damage to the vegetated land area due to the development undertaken around Jagorawi Toll Road. Figure 11 shows the change from 1978 to 2015 where the vegetated land continues to decline. The increase in ED parameter indicates that vegetated lands are annually damaged. It is in accordance with the statement of Tagil (2007), the increase in the perimeter of the ED will cause an increase in the length and direction of the damage.

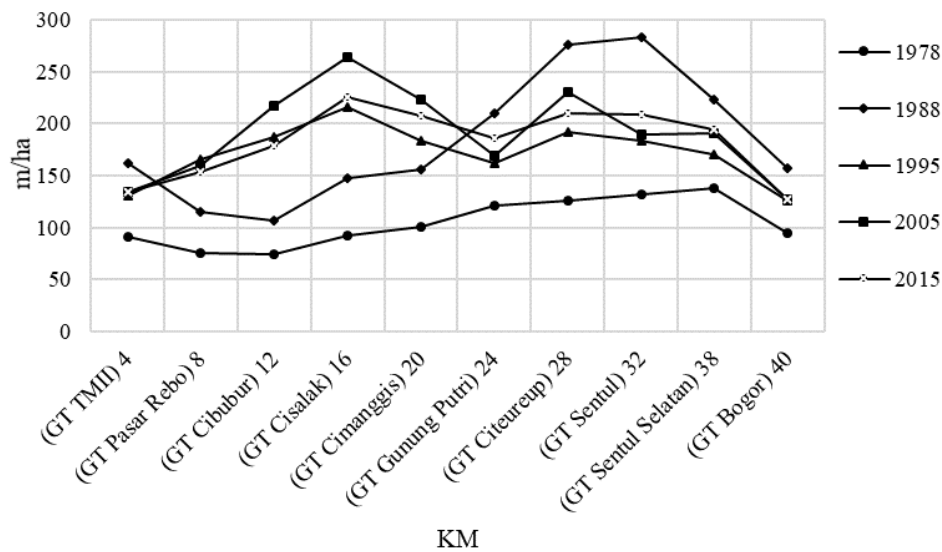


Figure 11. Edge Density

The horizontal side (left to right) shows the increased value of KM 16 and 28 where the vegetated land suffered severe damage compared to the other areas. This damage is caused by the influence of urbanisation such as the development of industrial buildings, the area of the economy, and the residential that leads to reduced vegetated land. KM 16 GT Cisalak, Depok, is an area that has a rapid development growth because it is in suburban area. The closer a developed area to the road then the wider the range will be as the result of the increasing of human activity. This is in accordance with the research of Masykuroh and Rudianto (2016) which states that the existence of toll gate has a significant impact on the land conversion of undeveloped land to developed land (economy and residential areas). The damage on the vegetated land also occurred at KM 28 GT Citereup which caused by the influence of development, industry, economy, and resident area.

4. Conclusion

Vegetation land turned into developed land during the last 37 years was 48% in area. Vegetated land turned into agricultural land was 13% in area, vegetated land turned into water bodies was 11% in area, and the existing vegetated land was 27% in area. Agricultural land turned into developed land was 20%. Agricultural land turned into water bodies was 6% in area, agricultural land turned into vegetated land was 58% in area, and the existing agricultural land was 16% in area.

Increased NumP indicates that the higher the value of the NumP obtained then the higher the level of fragmentation that exists in the area. MSI parameter indicates that the decrease in the value of the MSI will have an impact on land degradation. The decline in the value of the MPS shows increased land use pattern dynamics so that the structure of the landscape becomes smaller. Improvement on ED parameter indicates that the existing vegetated line along observation line is annually damaged.

The result of NumP graphic shows high fragmentation level on vegetated land in KM 28 and 32 in 1988-2015. MSI graphics on KM 20 and KM 36 increased in 1978-2015 which means the vegetated land is still in good condition. MPS graphics during the 1988-2015 did not experience significant changes each year, while in 1978 there was still a lot of vegetated land along the observation line. The ED graphic shows the increase value in KM 16 and KM 28 indicates the vegetated land in this area is more damaged compared to the other area.

Further research needs to be performed by identifying the factors that can affect land cover change around Jagorawi toll road. Based on the results of the calculation of landscape analysis, the upcoming development should take the principles of sustainable development into consideration in order to equalise ecological issue with economy issue. Furthermore, regulations and policies on maintenance of land use development should be released by the government.

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