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Connectivtiy of Remained Tropical Rain Forest in Langkat District, Indonesia

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Abstract

Remained forest connectivity facilitates organism movement, genetic exchange, and other ecological material flows. Low connectivity may decrease ecosystem production and cut the material flows within the forest ecosystems. The connectivity of ramaining forest is needed to determine the management strategy of forest landscape as a wildlife habitat. This paper describe connectivity of remaining tropical forest in Langkat district and explain correlation between connectivity and biophysical as well as anthropogenic factors. Landsat satellite imageries of year 1990 (Landsat TM), 2010 (SPOT), and 2015 (Landsat 8 OLI) were used to identify land cover in several different years. Fragstat was used to generate landscape metrics of the study area. Landscape metrics were analyzed using a scoring method to determine the connectivity degree of remaining forest. A Pearson correlation analysis was performed to obtain a correlation between connectivity degree and the distance from roads, the distance from rivers, elevation and slope. The study found that the total forest area and the landscape connectivity tend to decrease over the period from 1990 to 2015. The lowest connectivity degree was found in Wampu watershed. . The connectivity degree of remaining forest has a positive correlation with the slope and and the elevation.

Keywords: connectivity; tropical rain forest; Leuser ecosystem; degraded forest; fragstat.

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1. Introduction

Forest connectivity is important in the contex of organism movement in forest ecosystem. Connectivity has become a primary issue in various studies due to its potential in mitigating the impacts of habitat fragmentation [1, 3]. One of the main objectives of forest landscape management is improving ecosystem connectivity [32] besides maintaining the stability and integrity of natural ecosystems [10]. As was shown in the study [37], the establishment of certain bird community was supported by the change in the surrounding landscape, not in the site where the animals live. Connectivity of forest landscape can be evaluated and improved through land rehabilitation and land reforestation around the forest [18, 19]. Forest landscape connectivity were influenced by different aspects of landscape structure [20]. There are two general predictions that are able to explain landscape connectivity measures, i.e. (1) a significant increase in inter-patches distance decreased landscape connectivity, and (2) the effect of constituent elements of landscape connectivity was smaller than the effect of habitat elements. Forest landscape connectivity is as a degree of spatial connectivity among landscape elements such as patches, corridors, and matrix [16, 17]. Forest patch connectivity emphasized on a number as well as a series of habitat patches and the Euclidean distance or effective distance between the patches [4]. Corridor connectivity indicated a linear connection and its distribution can be improved through connectivity restoration [9, 21]. Connectivity matrix can be used to evaluate overall landscape mosaic, including landscape matrix to maintain maximum landscape continuity of non-built areas [27]. Thus, landscape mosaic is important as a whole, not only as landscape counterparts [1].

Forest landscape connectivity is related to the functional connectivity within the landscape. Forest landscape connectivity is actually more than just a physical connection but also include a resistance to movement due to barrier or land use type. Landscape connectivity emphasized not only the spatial characteristics but also the ecological processes and the organism movement (functional connectivity). Some studies and literatures only emphasized natural landscape study at local scale. However if we take a look at its relation as well as its effects on existing lives inside it, there is connection that geographically cover a much larger area, for instance at regional scale or a watershed. The restoration of habitat connectivity is the application of landscape ecology concept and metrics. Connectivity is extremely important and is a tangible characteristic of landscape. This is a parameter of landscape functions and is a major issue in assessing as well as planning biodiversity conservation. A well-understood fact is that connectivity is important for the disturbance on plants and animals in a fragmented landscape [25, 26].

Forest landscape connectivity is fundamental to spatial concept that support some land-use planning and conservation strategy [42]. Some connectivity metrics can be applied to model ecological processes, e.g. to obtain average isolation and predict relative connectivity of habitat [22, 35]. Connectivity metrics are based on network theory [25, 26]. Connectivity can be improved through landscape restoration. Restoration can be considered to speed up the succession. A restoration decision making can be made through landscape modeling [40] as well as landscape connectivity approach. In some cases, most of the analysis methods of connectivity metrics were supported by spatial data [36]. Sites in areas of high landscape connectivity level will be given a priority in conducting restoration activity. These can be identified through the application of landscape ecology principles focusing on population dynamics, to provide information on each stage of restoration decision-

making process [30]. It is practically difficult to assess which landscape ecosystem that deserves to be main priority for restoration. However this can be solved if the potential ecological characteristics in the context of its ecosystem structure and function can be recognized during ecological restoration [7, 21]. Thus the purpose of this study is to obtain landscape connectivity indices and its correlation with biophysical as well as anthropogenics factor.

2. Material and Methods

2.1. Study Area

The study was conducted Langkat District which consists of 5 watershed that are Besitang, Lepan, Batang Serangan, Babalan and Wampu. The study area was located between 3^o 5' 43.84" - 4^o 16' 50.57" N and 97^o 48' 10.22" - 98^o 42' 2.6"E (Fig. 1). The study was conducted from April 2015 to August 2015. The study area covered an area of ha at elevation of around 0 to 2,600 m above the sea. Based on its topography, the study area consists of flat area (0% - 20 %) of around 84.25% of the total area and a quite steep to steep area (> 15%) of around 13.62 % of the total area. Base on Oldeman climate classification, research area have A1, B1, C1, D1, D2, E2 and E3 types. Based on the Decree of the Indonesia Minister of Forestry No. 579 Year 2015, the study area consists of Nature Reserve Forest (33.077%), Production Forest (4.05%), Protection Forest (3.35%), Limited Production Forest (6.9%) and Other Landuse (53.35%). Nature reserve forest, protection forest and conservation forest were managed by the Ministry of Forestry and were important sites for the diversity in the Sumatra Island. The most of remained forest in research area is part of Leuser National Park Ecosystem Forest. It is also a habitat of Sumatera orang utan (Pongo). The remained forest in Langkat district has biodiversity richness as a home of thousand species of flora and fauna such as a hundred of mammals species, a hundred of birds species, some types of herpetofauna and a hundred of plant species..

2.2. Materials

This research used satellite imagery, i.e. Landsat TM 1990, SPOT 2010 and Landsat 8 OLI 2015; contour map, road network map, and river map. Material used comprised of field survey equipment and data analysis tools. Field survey activity used GPS, haga, phi band, compass, and talley sheet. While data analysis tools consisted of Erdas Imagine 9.1 that was used to interpret satellite imagery, Arc Gis 9.3 to perform spatial data analysis, Fragstat 3.3 to create landscape metrics, Excel and SPSS ver 16 to perform statistical data analysis.

2.3. Data Analysis

To obtain landscover map, interpretation of satellite imagery was conducted using a supervised classification method. The result of satellite imagery interpretation was examined for its accuracy using Overall accuracy and Kappa accuracy [23]. Accuracy test was performed using 70 field check-points to test the accuracy of 2015 landsat image classification. Land cover map data of 1990 and 2010 published by the Ministry of Forestry of Republic of Indonesia were used to validate accuracy of image classification of 1990 and 2010. Landcover map obtained from SPOT interpretation was used to validated of landcover map developed from Landsat image.

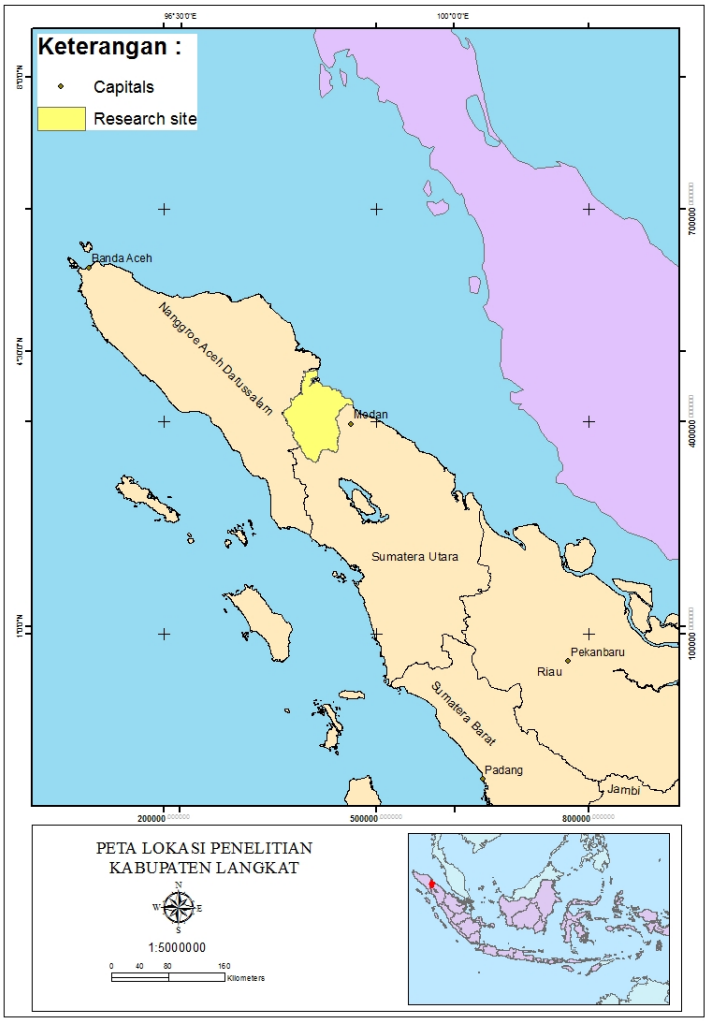


Figure 1: The research site

Forest landcover type was analyzed using Fragstat 3.3, to obtain forest landscape metrics [27, 28]. Then each forest landscape metrics was classified into 5 (five) classes and was scored using Likert scale basis. Landscape metrics for determining the connectivity of forest landscape was the interconnectedness between forest patches (connectance) as well as the extent and compactness of forest patches (*radius of gyration*) (Table 1). The scores were summed algebraically. Equation 1 is used to convert the total score into 0 – 1 value [24].

$$Ind\_FLF = \frac{(Score_{total} - score_{min})}{Score_{tot\text{-}max} - score_{tot\text{-}min}} * (Ind\_FLF_{max} - Ind\_FLF)$$

Notes :

Ind_FLC = index value of forest landscape connectivity

$Score_{total}$ = total score as input

$Score_{tot-min}$ = minimum value of total score

$Score_{tot-max}$ = maximum value of total score

Ind_FLC_{max} = maximum index of forest landscape connectivity (converted value)

Ind_FLC_{min} = minimum index of forest landscape connectivity (converted value)

Connectivity index was further classified into 5 (five) forest landscape connectivity degree. Each class used the same value range of 0.2 so that the five classes are as follows: very low FLC (0 – 0.2), low FLC (0.21 – 0.40), moderate FLC (0.41 – 0.60), high FLC (0.61 – 0.80) and very high FLC (0.81 – 1.00).

Table 1 : Landscape indices used in the connectivity analysis of forest landscape.

Metric	Code	Description	Value	Skor
Connectance	CONN	*Connectance* is defined on the number of functional joining between patches of the same type, where each pair of patches is either connected or not based on a user-specified distance criterion. Connectance is reported as a percentage of the maximum possible connectance given the number of patches.	<20	1
			20 – 40	2
			40 – 60	3
			60 – 80	4
			>80	5
Radius of gyration	GYRATE	*Radius of gyration* is a measure of patch extent; thus it is effected by both patch size and patch compaction. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.	<200	1
			200-400	2
			400-600	3
			600 – 800	4
			>800	5

3. Results and discussion

3.1. Landcover of Langkat district

Classification of Landsat TM imagery year of 1990 and Landsat 8 OLI year of 2015 produced land cover maps Langkat district. The results of image classification in 1990 and 2015 verified using land cover map of 2010 obtained from SPOT 2010 interpretation. Based on separability analysis and verification of classification results produced land cover maps of 1990 and 2015, can only distinguish 5 land cover types with high separability for

the water body, bareland, forest, shrubs, paddy field and mangrove. Sparability value generated, respectively, 1928, for the classification of Landsat 1990 and 1940 for the classification of Landsat in 2015

Combination of band 7, band 5 and band 4 of Landsat imagery 8 OLI using supervised classification method, could classify the image into 7 land cover types (Fig. 1). Accuracy test using overall accuracy and Kappa accuracy provided sufficient results of 82.3% and 79.1% respectively. Using the land cover map from SPOT 2010, land cover types of clouds and cloud shadows were corrected and resulted eight types of land cover : forest, bare land, water bodies, dryland agriculture mixed shrubs, schrub, plantation crops, and paddy field (Table 2).

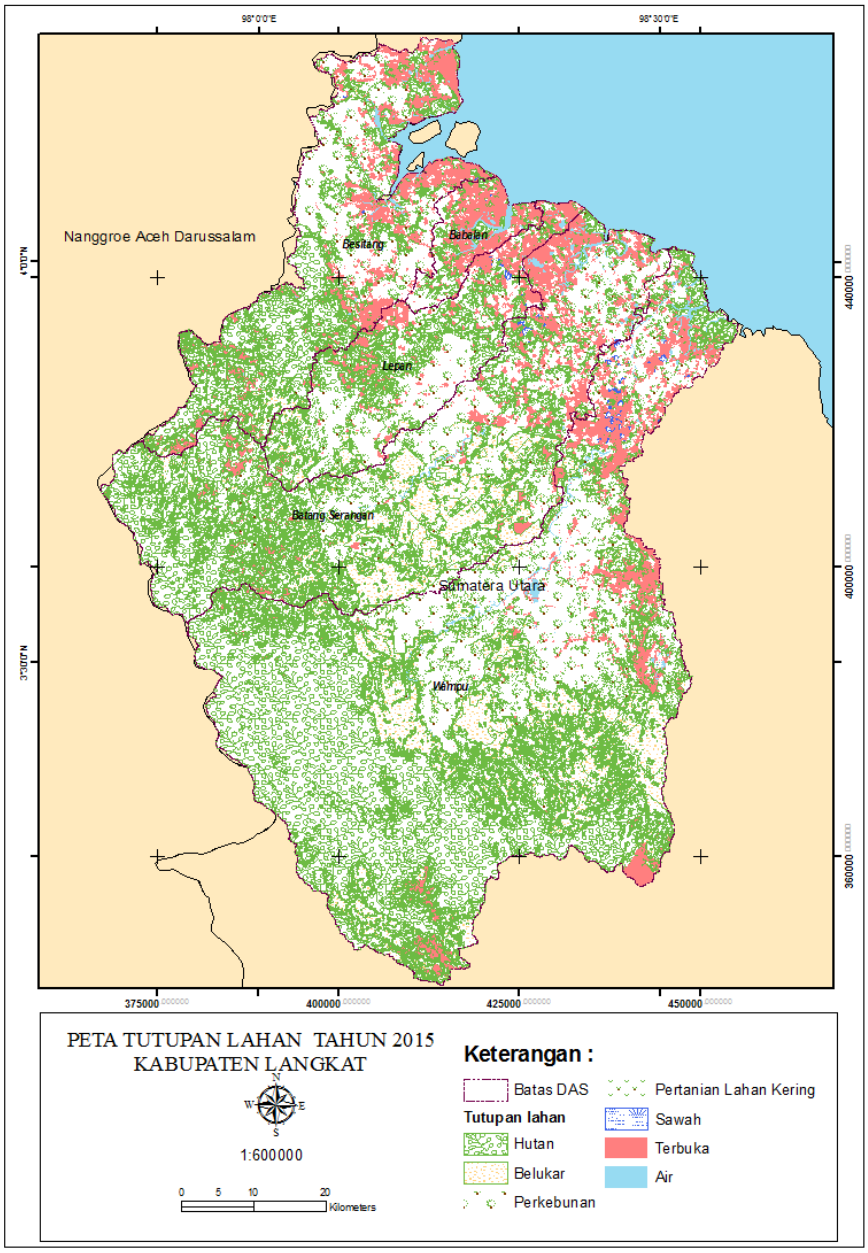


Figure 2: Landcover map of Langkat District year 2015

Table 2: Landcover type distribution based on data aquisition of landsat image (1990, 2015)

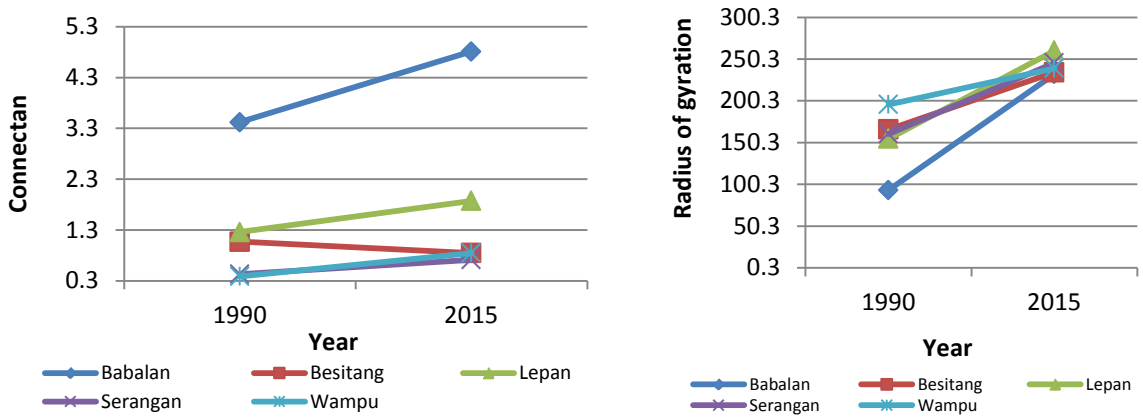
No	Landcover type	1990		2015	
		Area (Ha)	Proportion (%)	Area (Ha)	Proportion (%)
1	Bareland	18,991	2.81	81,525	12.54
2	Dry land agriculture	-	-	6,901	1.06
3	Estate plant	-	-	174,978	26.90
4	Forest	312,238	46.17	231,047	35.53
5	Paddy field	51,531	7.62	1,010	0.16
6	Schrub	268,769	39.74	147,915	22.74
7	Water body	4,434	0.66	6,983	1.07
8	Mangrove	20,272	3.00	-	-
	Total	650,359	100	650,359	100.00

3.2. Landscape metrics of remained forest

Fragstat analysis generated landscape metrics i.e. connectan index of landscape, and radius of gyration. It can explain connectivity of forests landscape [11]. Remaining forest connectivity decrease during period of 1990 - 2015. The increased was depicted by the landscape metric value of connectan. It increase from the range 0.2 - 3.3 in 1990 to around 0.7-4.3 % in 2015 (Fig. 3-a). The radius of gyration value increase from around 90-200 in 1990 to around 250 - 300 in 2015 (Fig. 3-b).

3.3. Connectivity index of remaining forest landscape

The connectivity index was developed using landscape metrics of connectan index dan radius of gyration index. Forest landscape connectivity map illustrate that most of remaining forests in watershed of Serangan have lower connectivity degree (index value of around <0.2) and low connectivity degree(connectivity index 0.2-0.4). There is no hight forest landscape connectivity found in the research area. It show that the remained forest have been fragmented and sparated by other landuse. Reforestation and land rehabilitation will connect between remaining forests each others. Improving connectivity will enhance the functional relationship of forest ecosystem. Moderate forest connectivity degree was usually found in more compact forest, while low connectivity was found in the fragmented forests. Connectivity forest landscape index was mapped as illustrated in Fig. 4. Connectivity index map of 1990 show distribution of connectivity degree of forest patch in Langkat district. Moderate connectivity index was found mostly in watershed of Wampu while lower connectivity index was found in watershed of Serangan and Lepan. Low connectivity index was found in small size forest patches that were found among other land cover types. However, connectivity index map of 2015 show that most of Wampu watershed area have moderate connectivity degree, while lower connectivity was found in forest patches in watershed of Serangan).



(a) (b)

Figure 3: Landscape metric values of radius of gyration (a) and connectan (b) during 1990 – 2015

Table 2 show that sub-watershed of Wampu has a relatively large area of moderate connectivity degree compared to four others watersheds. Serangan watershed have relatively lower connectivity degree about 42,771 ha (Table 3). Due the location of sub-watershed of Wampu which is located in the steepy and high elevation have difficult accessibility to get the forest. It made the forest be less threathen by forest conversion. Further more, the remained forest will be more protected from distubance

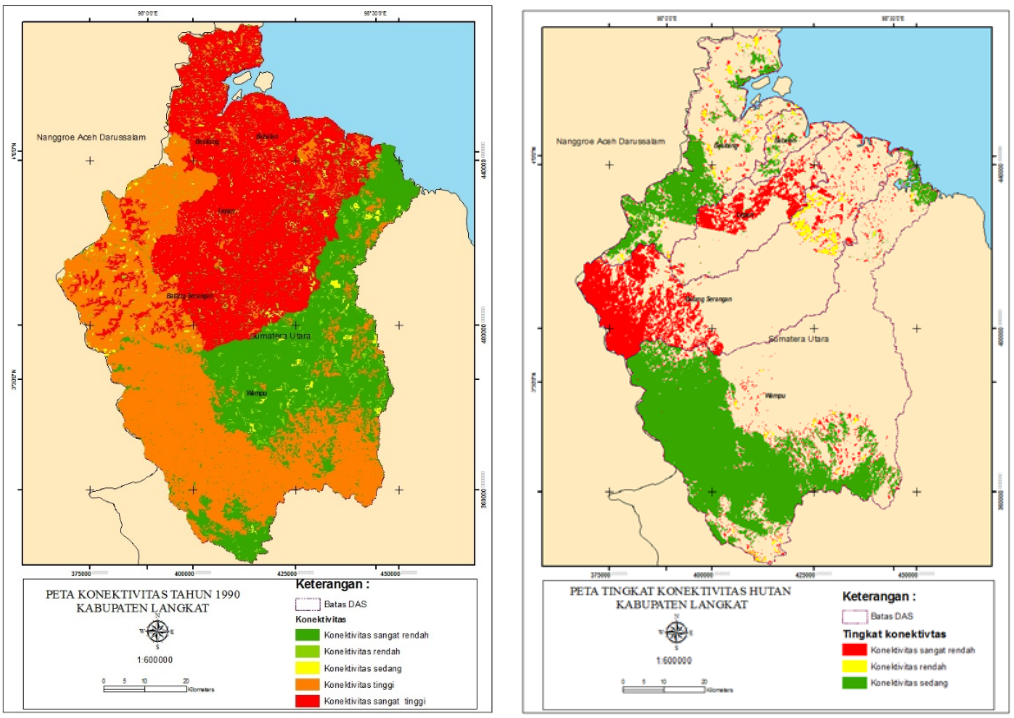


Figure 4: Forest connectivity degree in 1990 (a) and 2015 (b) of remaining forest in Langkat

Table 3: Total area distribution of remained forest connectivity degree in each sub-watershed in 2013

	Area (ha)			
Watershed	Low connectivity	Lower connectivity	Moderate connectivity	Grand Total
Babalan	454	793	1,613	2,860
Batang Serangan	3,745	42,771	34	46,549
Besitang	2,476	3,651	28,748	34,875
Lepan	97	14,141	264	14,502
Wampu	1,340	8,438	122,108	131,886
Grand Total	8,112	69,794	152,767	230,673

Reducing natural connectivity of an ecosystem is the biggest threat in the distribution of wildlife and the living capability, and biodiversity conservation. It need more serious attention especially on improving of connectivity in habitat conservation. The maintenance and restoration of forest landscape connectivity has become a central issue in ecology and biodiversity conservation because landscape connectivity facilitate organism movement, genetic exchange, and the flow of other ecological materials [8]. Organism movement that is considered in determining forest landscape connectivity of remained forest is orangutan as its endemic species especially in Leuser ecosystem. The need for habitat among endemic flora and fauna is a central key in biodiversity conservation as well as the stability and integrity of natural ecosystem [6, 37, 38].

3.4. Forest landscape connectivity index and accessibility

Antropogenic factor and biophysical condition affect the forest landscape connectivity index. Human activities are generally depend on presence of infrastructure to access the forest, i.e. road and river networks, as well as slope and elevation. Pearson correlation can explain the correlation between forest landscape connectivity with the distance from road, distance from river, elevation and slope (Table 4).

The relative highest correlation between connectivity index and the distance from road was found in Besitang watershed while relative the lowest correlation was found in Wampu watershed. Forest near the road will have relatively high distubance to the forest. The farther away from the road, the connectivity tends to be higher in Lepan watershed (Fig. 6.b). This is triggered by road that has become an indirect cause of forest damage in Lepan watershed area [37]. The road will attract human to change land use and land cover. Human will change the forest into cultivation land and gather forest products [40], thus trigger land use change. The high of deforestation degree is trigger by closeness of connection between forest and human settlement [33]. Its distribution and pattern follow the road, since the road trigger settlement establishment. Land forest clearing for agriculture was conducted near road and has left only a small part of forest among cleared land [2, 13, 15]. Further, the road increase connectivity among settlement centre that could threat forests sustainability [14, 33]. A contrast situation was found out in Wampu, Lepan and Serangan watershed that is the higher its distance from main road, the lower its connectivity index.

Connectivity index of forest landscape raise with the increasing of elevation in Wampu, Lepan and Besitang

watershed (Fig. 7). Forest in steep and difficult accessibility area have less human disturbance [5].

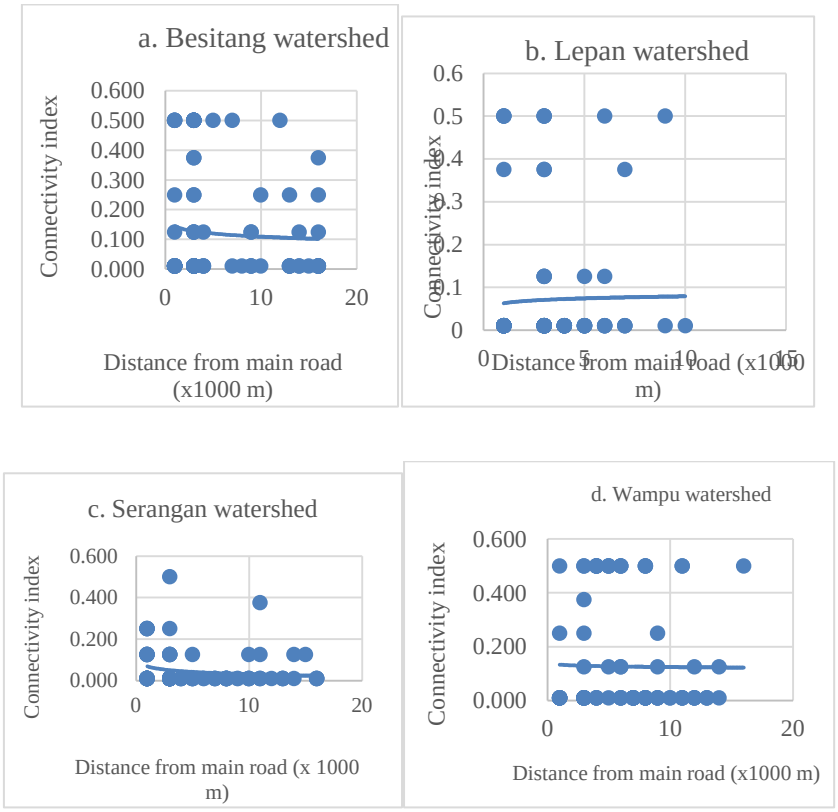


Figure 6: Connectivity index and distance from main road

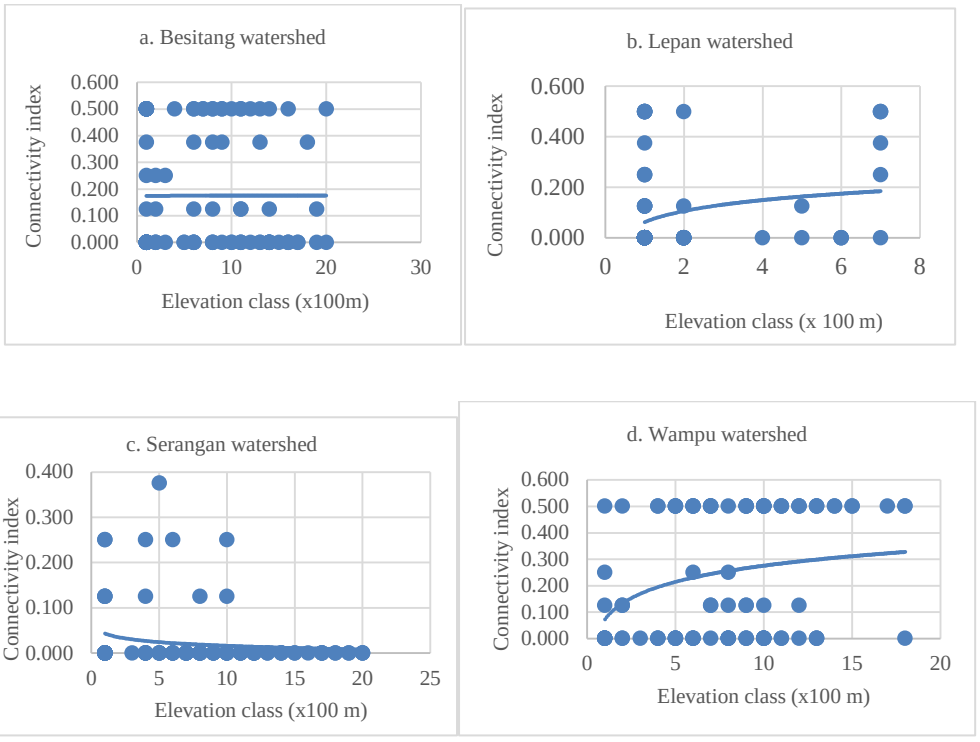


Figure 7: Connectivity index and elevation

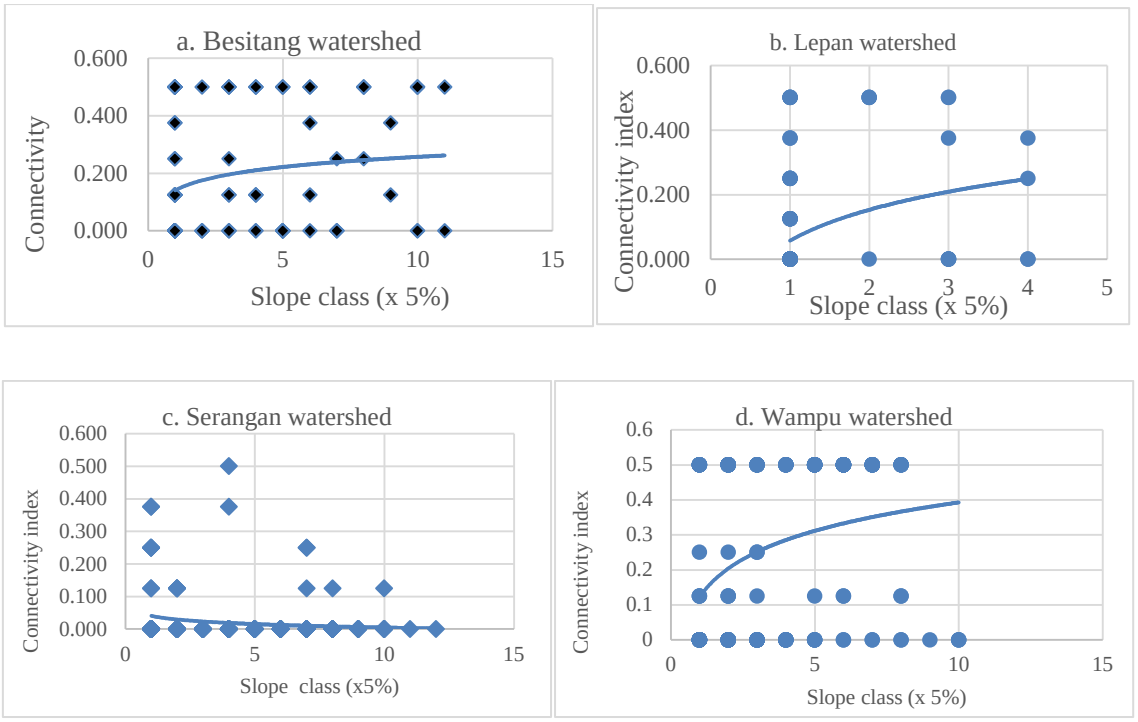


Figure 8: Connectivity index and slope class

Table 4: Pearson correlation between connectivity index and distance from road, elevation, and slope

Variable	Watershed	Pearson correlation	Significant level
Distance from road	Babalan	-	-
	Besitang	0.130	-
	Lepan	0.063	-
	Serangan	-0.128	-
	Wampu	-0.060	-
Elevation	Babalan	-	0.01
	Besitang	0.283**	0.01
	Lepan	0.277**	0.01
	Serangan	0.205*	0.05
	Wampu	0.300**	0.01
Slope	Babalan	-	0.01
	Besitang	0.296**	0.01
	Lepan	0.302**	0.01
	Serangan	-0.136**	0.01
	Wampu	0.306**	0.01

A contrast situation was found out in Serangan watershed that is the higher its elevation the lower its connectivity index. The remaining forests in Serangan have relatively high elevation and were disturbed, while forests in relatively low elevation were more maintenaced and monitored. Slope and elevation have correlation

with the connectivity index of remained forest landscape in four watershed of Langkat district. A significant positive correlation between connectivity index of remained forest landscape and slope was found in Besitang, Lepan and Wampu watershed, that is the higher the slope the higher the connectivity index of remained forest landscape. Meanwhile, a negative correlation was found in Serangan watershed that is the higher the slope the lower the connectivity index of remained forest landscape (Fig. 8). Remainde forest landscape as a wildlife habitat should have high connectivity. Connectivity will be obtained from a relatively large and compact forest ecosystem. Effective conservation and restoration strategy would reinstate the forest ecosystem function [31, 32,37].

4. Conclusions

The degree of forest landscape connectivity in watershed located at Langkat district watershed tend to decrease during 1990-2014. Wampu watershed has large area the lower degree of forest connectivity relatively. The slope and elevation have correlation with connectivity degree of remained forest. The connectivity degree of remaining forest landscape in steepy and high elevation is higher relatively than others . However, as the wildlife habitat, remained forest connectivity in Langkat district could be maintenance and enhanced by restoring or rehabiliting of fragmented forest.

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