sciendo
DOI: 10.2478/jlecol-2023-0006 Journal of Landscape Ecology (2023), Vol: 16 / No. 1

FINDING THE CORRIDOR POTENTIAL BETWEEN PROTECTED AREAS IN A FRAGMENTED LANDSCAPE, GUNUNGKIDUL REGENCY, INDONESIA

MADINA DWI PANUNTUN[1], EKO HARYONO[2*],
LANGGENG WAHYU SANTOSA[3]

[1] Graduate Program on Environmental Science, Universitas Gadjah Mada, Yogyakarta, Indonesia
[1] Kaleka, Bogor, West Java, Indonesia
[2]Graduate Program on Environmental Science, Universitas Gadjah Mada Yogyakarta, Indonesia*
[3]Graduate Program on Environmental Science, Universitas Gadjah Mada, Yogyakarta, Indonesia
**Corresponding author email: e.haryono@ugm.id*

Received: 12th November 2022, **Accepted:** 17th May 2023

ABSTRACT

Fragmentation impacts disconnecting protected areas in Gunungkidul Regency, namely Bunder Forest Park (BFP) and the Paliyan Wildlife Reserve (PWR). This also decreases the carrying capacity in PWR, degrading the Long-Tailed Macaque (LTM) habitat. Therefore, this research aims to analyze the landscape structure between Protected areas, the habitat suitability of LTM in Gunungkidul Regency, and determine connectivity potential as an environmental management strategy. applied for this research to investigates the structure and fragmentation using Fragstat 4.2 and ArcGIS 10.8 software. Meanwhile, scoring and weighting methods analyze the LTM habitat, while Least Cost Patch Analysis (LCPA) supported by ArcGIS 10.8 determine the corridor. The results showed that the research land cover changed from 1999-2021. Agriculture, scrubs, and settlements are the dominant land cover suspected to cause forest fragmentation. Based on the habitat suitability analysis using parameters such as land cover, vegetation density, slope, altitude, distance from the river, and sources of threats, most of the research area is intermediate habitat suitability class. These findings can be integrated to determine connectivity between protected areas as one of the environment management strategies. Good forest cover can be used to designate a corridor that has the greatest potential to be developed between BFP and PWR and should be maintained as a wildlife crossing.

Keywords: Landscape ecology, Landscape connectivity, Long-Tailed Macaque

INTRODUCTION

Fragmentation breaks large protected areas into smaller units due to human activities, disconnecting vast patches of forests and wildlife corridors. Population growth is aligned with the increase in infrastructure development and the utilization rate of natural resources.

Exploiting natural resources certainly can threaten the sustainability of ecosystems, including animal habitats and the preservation of environmental services to support human life (Utina *et al*., 2015). According to Miller (1982), humans' decline in environmental quality consists of two factors, namely the number of people and the natural resources used. Therefore, it has implications for the decline in the ecological function of the landscape in terms of the distribution of energy, material, and species flows (Prasetyo, 2017) and contributes to declining local biodiversity (Newbold *et al*, 2015).

Gunungkidul Regency in Yogyakarta Province has two protected areas, namely Paliyan Wildlife Reserve (PWR) and Bunder Forest Park (BFP). Furthermore, it has a unique characteristic, namely a karst landscape to protect biodiversity. Before being designated as the Paliyan Wildlife Reserve, Paliyan forest which is one of the karst landscapes in Gunungkidul, was considered to have high productivity, where nearly 90 % of the state forest in Gunungkidul Regency functioned as a production forest (Environment and Forestry Agency's of D.I.Yogyakarta Province, 2016).

In 1998, there was a period of reform that resulted in a lot of encroachment, the conversion of forests to agricultural land, and resulted in forest fragmentation in Gunungkidul Regency. Whereas this Paliyan forest also has a role as the Long-tailed Macaque (LTM) (*Macaca fascicularis)* habitat. LTM are one of the primate species that is affected by human activities in exploiting their habitat (Hambali *et al,* 2012). To restore landscape function, the Government of Gunungkidul Regency rehabilitated the area from 2003 to 2015 (Natural Resources Conservation Agency Yogyakarta Province, 2018). Furthermore, to optimize the Paliyan Forest in terms of preservation and protection of the wild, one of which is LTM habitat, Paliyan Forest was designated a Conservation Area in 2000 through the Decree of the Minister of Forestry Number 171 on 29 June 2000 and designated as Paliyan Wildlife Reserve through of Decree of the Minister of Forestry Number 1870 on 25 March 2014.

Morphologically, PWR is steep slopes with an altitude of 100-300 m asl. The majority of soil types in PWR are latosol or clay soils with minimal soil depth (average <50 cm) (Natural Resources Conservation Agency Yogyakarta Province, 2018). Furthermore, the existence of the forest in Paliyan provides many benefits for the living things in it, especially as a habitat for the LTM.

Over the years, fragmentation in the PWR has increased and resulted in the interruption of gene flow and species, including disturbance of the LTM habitat. Habitat loss due to logging, farming, and human housing has resulted in LTM's living in close proximity to humans in rural and urban environments (Hadi, 2005; Gumert, 2011; Aggimarangsee, 2013). The decreased carrying capacity of PWR also has led to encroachment on communal land. The distribution of LTM was considered a pest disruption, specifically for the people around the PWR with agricultural land. This agrees with Fauzi *et al* (2020), which describe that in its natural habitat, LTM impacts buffer zones in the form of wild activities that damage crops on plantation lands.

According to Lesson *et al*. (2004), the maximum area capacity for Long-tailed Macaque (LTM) is around 3-4 ind/ha. Therefore, the PWR area cannot support the habitat of the LTM with the number of individuals that have exceeded the threshold and making community land a destination to fulfill their needs. The IUCN Red List (2022) categorized LTM as endangered species animals. Therefore, the population should also be maintained. One of the strategies to protect community land from disruption and maintain the habitat is by developing corridors between protected areas. The protected areas in Gunungkidul Regency beside PWR is Bunder Forest Park (BFP). Forest Park is a nature conservation area built for the purpose of collecting plants and animals to be used for the purposes of research, science, education, supporting cultivation, culture, tourism and recreation (Law of Republic

Indonesia Number 5, 1990). Forest cover in BFP, which is abundant, has many benefits, including providing environmental services and as a habitat for wildlife.

Connectivity between protected areas in Gunungkidul Regency can be formed when components that match the characteristics of wild habitats, namely Long-Tailed Macaque as an indicator of target species are fulfilled. As stated by Buček *et al* (2012), an ecological network in the landscape consists of all existing and proposed landscape segments of ecological significance that can contribute to conserving landscape biodiversity. This research is focused on areas between protected areas and their surroundings because they are considered to be part of a landscape that can act as gene flow, species in each conservation area that are interconnected and have the opportunity to become areas of biodiversity protection outside conservation areas.

Maintaining habitat quality and connectivity to avoid anthropogenic disturbance is the main challenge of biodiversity conservation efforts (Wang *et al*, 2014). However, it can be an optional strategy to reduce the impact of habitat fragmentation and support the flow of energy, materials, and species by uniting protected areas to form a network on a larger scale through the establishment of habitat corridors (Bruinderink *et al*., 2003).

Several protected areas, designated as part of a landscape that safeguards biodiversity, natural resources, and life support systems for environmental sustainability, can be linked through this connection. Therefore, this research aims to analyze the landscape structure between Protected areas, the habitat suitability of LTM in Gunungkidul Regency, and obtain connectivity potential as an environmental management strategy.

DATA AND METHODS

Study area and context

Fragmentation landscape refers to a location between protected areas. Based on administrative, this is located in Playen, Wonosari, and Paliyan Districts, Gunungkidul Regency, Yogyakarta Province, Indonesia, at coordinates 110°29’2” - 110°35’3” East Longitude and 7°52’30” - 8°3’0” South Latitude. The research area is 11,984.5 ha (Fig. 1).

The boundaries of two protected areas (Table 1) are determined based on the buffer average home range of LTM, approximately 1 km. This research was conducted using the landscape ecology approach. The critical concept of the landscape ecology approach is structure, function, and change (Hersperger, 1994).

Table 1: Data of Protected Areas in Gunungkidul Regency

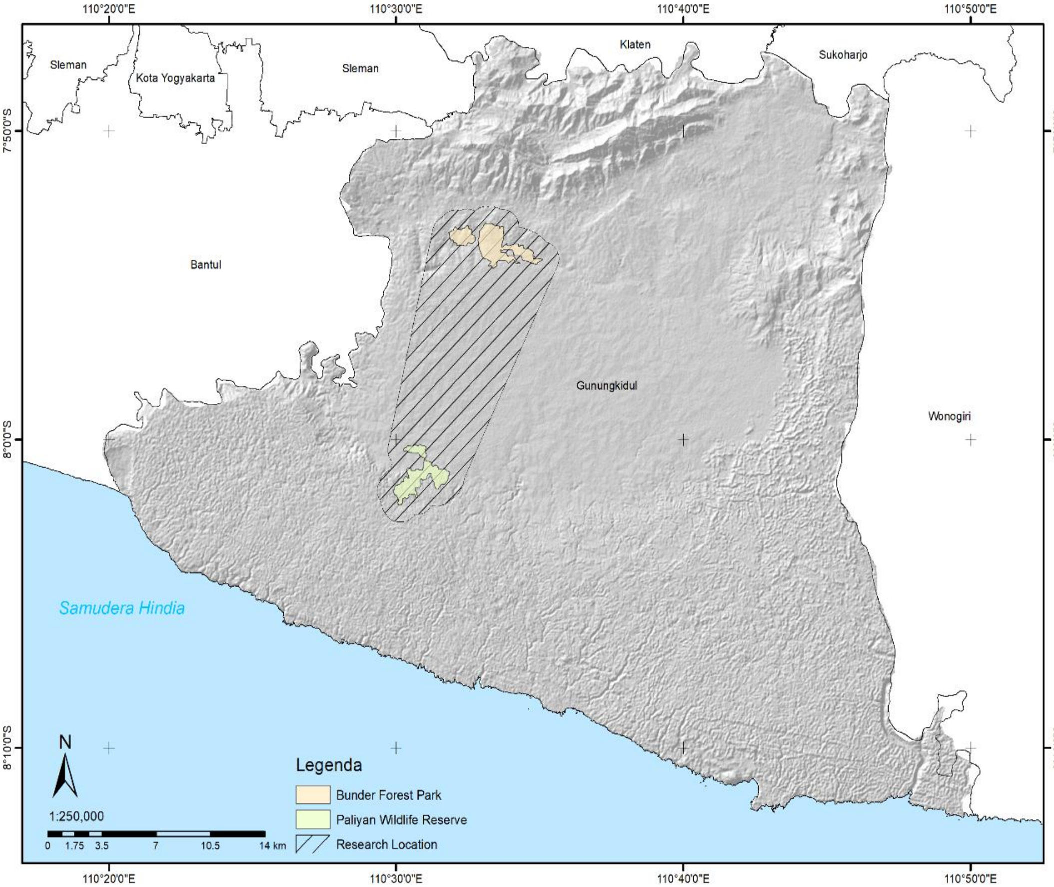
No	Protected Area	Location	Size (hectare)	Decree
				Number
1	Paliyan Wildlife Reserve (PWR)	Paliyan District	434,83	Decree of the Minister of Forestry Number 1870/MoF-VII-KUH/2014
2	Bunder Forest Park (BFP)	Playen & Patuk Districts	634,10	Decree of the Minister of Forestry Number 144/MoF-II/2014

Source: Natural Resources Conservation Agency Yogyakarta Province, Statistics (2022) and Environment- Forestry Yogyakarta Province (2022)

Specifically, to analyze the structure and fragmentation of the landscape, Fragstats 4.2 and ArcGIS 10.8 software were used. The satellite images were used to identify land cover changes sourced from Landsat 5 TM image overview on 30 September 1999 and 15 July

2009 with pixel size is 30 m. Meanwhile, the SPOT 7 image was obtained on 6 August 2021 with pixel size is 6 m. Using satellite imageries of different size due to data limitations.

Fig. 1: Geographic location of the fragmented area between two protected areas



These also ever applied to land use/land over change detection study in Istanbul, which give same result and the efficiency of the two data sets is explained by comparing the thematic map accuracy outputs (Akyürek *et al*, 2018)

The description of the parameters for analyzing the structure and fragmentation of the landscape can be seen in Table 2.

The parameters to determine habitat suitability include landform, land use, vegetation density, and source of threat (Table 3). These four parameters are determined by considering the characteristics of the LTM habitat in Gunungkidul Regency. Source of the threat its means threat of distance from roads and settlements. Then, the landform parameters were processed by area delineation, namely mountain hills, Wonosari Ledok plain, watery valley, and dry valley. Several dominant factors affect LTM's habitat, including altitude, slope, and vegetation density (Hidayat, 2012). Furthermore, LTM is found in forests and community plantation areas (Supriatna & Ramadhan, 2016). According to Lekagul & McNeely (1977), the classic habitat of LTM is a forest with an altitude of up to 2,000 meters above sea level.

Table 2: The landscape matrix used in this research

Matrix	Code	Formules	Description
Class Area	CA	m^2	The total area of each land cover class.
Largest Patch Index	LPI	$\frac{max}{A}$ (100)	LPI calculates the percentage of the landscape that comprises the most significant patch. LPI = 100 when the landscape consists of one appropriate land cover type plot.
Edge Density	ED	$\frac{\sum\ B}{A}$ (10.000)	ED measures the ratio of the edge segment length to the total area. The ED value increases as the patch shape become more irregular due to longer edges between patch types.
Number of Patches	NP	n_i	The NP counts the number of patches of the appropriate land cover type in the landscape. NP=1 when the land cover consists of one patch.
Patch Density	PD	$\frac{ni}{A}$(10.000) (100)	PD calculates the ratio of the number of plots of each land cover type over the landscape area. PD value increases as land cover become more fragmented.
Landscape Shape Index	LSI	$\frac{25E'}{\sqrt{A}}$	LSI quantifies class aggregation in the landscape. LSI=1 when the landscape consists of one square or the densest (nearly square) swath of the appropriate type.

Source: Hakim (2021), with modifications

The parameters were analyzed using the Spatial Multi-Criteria Analysis (SMCA) method to determine the suitability habitat class for the target species of LTM. Scoring and weighting of LTM's habitat suitability is defined based on literature research and expert judgment there are academics and local governments involved in the conservation biodiversity in Yogyakarta Province. Based on the results of the discussion regarding the determination of the scoring, it is known that the higher the score the parameter has meant that it is more in line with the habitat conditions required by LTM. LTM in Gunungkidul Regency has preference habitats such as high vegetation density, dense forest cover, landforms, distance from roads and settlements (Results of expert discussion, 2022). Gunungkidul is known to have varied landforms dominated by karst. The karst landform variations have their own habitat characteristics for LTM. Landform preference in the form of the watery valley or river is the highest compared to other landforms because LTM tends to always need water either for consumption or sometimes just a place to play. Furthermore, the weight value on the landform parameter has the highest weight because LTM has a high dependence on water sources (Hambali *et al*, 2012).

The Least Cost Patch Analysis (LCPA) was used to determine the corridor that used habitat suitability. LCPA is also defined as a landscape ecology method to identify the most effective movement path (Minor *et al*, 2008; Girvetz *et al*, 2007). As seen Larkin *et al*, (2004) LCP is one of the approaches that can be used in identifying corridors. The way LCP works is by determining the area that has the least negative impact (resistance) on the preservation of the habitat of the species (Beier *et al*, 2009; Cushman *et al*, 2009). In this study, we used LTM habitat preference as an indicator for determining connectivity.

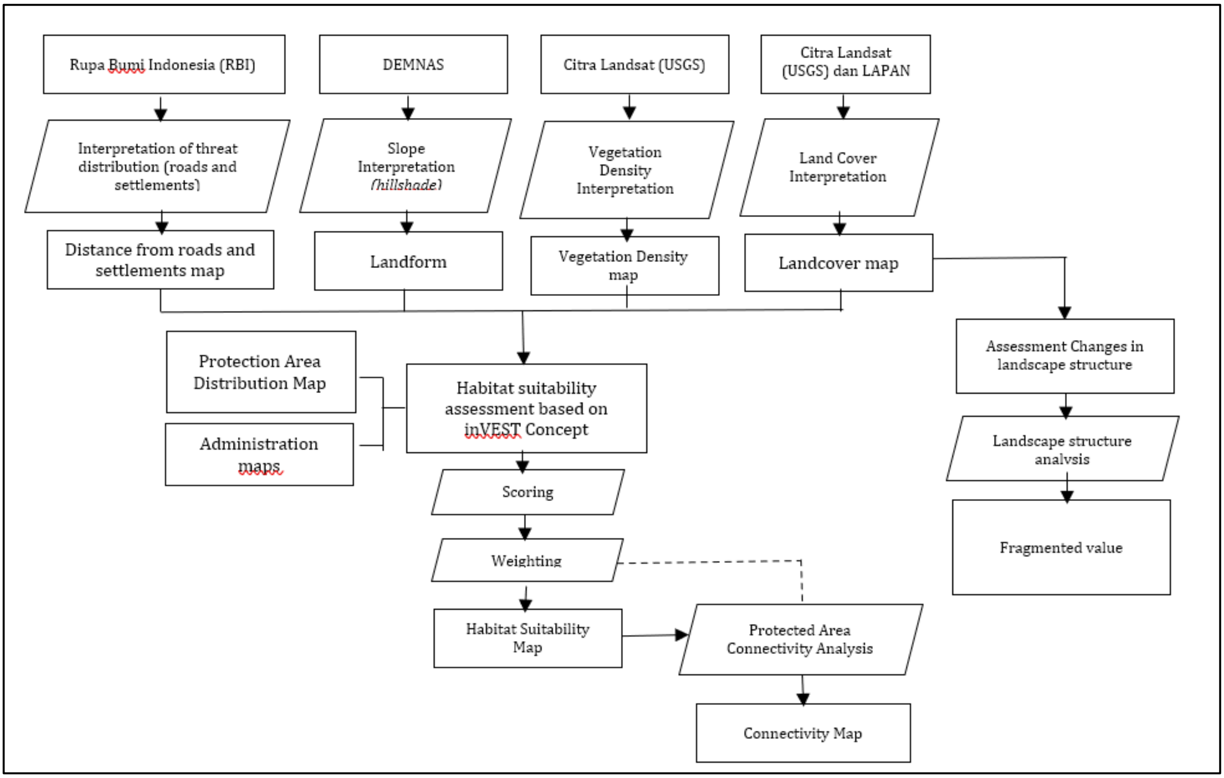
Table 3: Habitat Suitability Parameters

Parameter	Class	Scale	Score	Weight
Vegetation Density	Very low	NDVI ≤ 0.16	1	0.15
	Low	0.16 ≤ NDVI ≤ 0.44	2	
	Moderate	0.44 ≤ NDVI ≤ 0.61	3	
	High	0.61 ≤ NDVI ≤ 0.72	4	
	Very high	NDVI ≥ 0.72	5	
Land cover	Very high	Forest	5	0.25
	High	Waterbody	4	
	Low	Scrubs	3	
	Very low	Rice field	2	
	Non green open space	Settlement	1	
Distance from roads (m)	Very close	<500	1	0.15
	Close	500-1000	2	
	Moderate	1000 - 1500	3	
	Far	1500 -2000	4	
	Very far	>2000	5	
Distance from settlements (m)	Very close	<500	1	0.15
	Close	500-1000	2	
	Moderate	1000 - 1500	3	
	Far	1500 -2000	4	
	Very far	>2000	5	
Landform	Very good	Watery Valley/River	4	0.30
	Good	Wonosari Ledok Plain	3	
	Moderate	Dry Valley	2	
	Not Good	Karst Hills	1	

Source: Abhimanyu (2021); Yumarni (2012) with modifications

In using cost path analysis, it is very important to consider how to weight the raster to create a cost raster. The raster overlay that is done produces a cost surface. This cost surface represents the total area or area that has certain characteristics in relation to the creation of landscape-level connectivity corridors with long-tailed macaque (*Macaca fascicularis*) target indicators. At this stage, two nodes will be determined that represent the starting point (origin) and end (destination) based on Cost distance, namely the shortest path to the destination location by connecting the nodes from one cell to the previous cell, taking into account the calculated value. Each cell is given one value as the smallest accumulated cost function to be returned to the starting point (Ardana, 2013). This cost surface is also used to create backlink costs by ensuring the endpoint (destination) (Wiharja, 2012). The last step is the Cost path analysis which is the calculation of the value of the cost distance and cost backlink/cost direction to form the shortest path from the source to the destination. In this case, potential habitat and connectivity corridors will be generated.

Fig. 2: Data Processing Flowchart



RESULTS

Land cover change in 1999, 2009, and 2021

Gunungkidul Regency was well known as barren area during 1940-1970 (Wardhana *et al*, 2012). Therefore, rehabilitation programs were carried out periodically by academics and the government until 1996. Since around 1998, overexploitation of forest cover has contributed to a decline in forest coverage. Therefore, stakeholders, including the government, NGOs, and academics, have made efforts to rehabilitate several locations in Gunungkidul Regency. One of the programs is called Forest and Land Rehabilitation Movement (GNRHL).

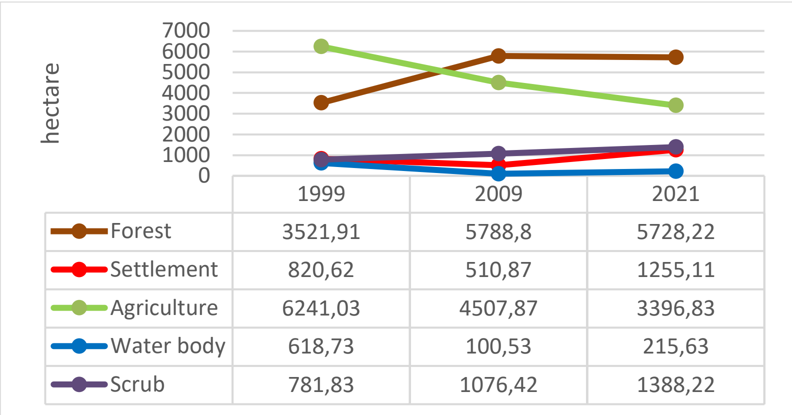
The analysis of land cover changes in Fragmented areas focuses on changes in 1999, 2009, and 2021. The land cover classification was divided into 5 (five) categories, namely forest, agriculture, scrubs, settlement, and waterbody. Several settlements in the Districts of Playen and Paliyan, Gunungkidul Regency, practice agriculture. In addition, rice fields and land with corn or secondary crops constitute agriculture (Central Statistics Agency for Paliyan District, 2021).

The Central Statistics Agency of Playen District (2021) stated six agricultural and farm commodities, namely lowland rice, non-paddy rice, cassava, corn, soybeans, and peanuts. These plant commodities are still a priority in meeting daily needs and trading. Meanwhile, the scrub land cover, specifically in Playen and Paliyan, is a minority compared to other land use types.

Forest cover in the research area seems to fluctuate, and there was an increase and decrease in 2009 and 2021. Meanwhile, there is an increase in settlements along the collector road, which connects Playen and Paliyan. The settlement increased in 2021 following the population of Gunungkidul Regency.

As shown in Fig. 3, the land cover area has fluctuated over the years. Forest cover increased from 1999 to 2009 due to the activities of the GNRHL, which have been carried out since 2004. GNRHL is the government's effort to restore forest cover impacted by massive deforestation in Gunungkidul around 1998. From 2009 to 2021, forest cover decreased due to the large area of settlement areas.

Fig. 3: Graph of Land Cover Change in 1999, 2009, and 2021



Landscape structure in 1999

Based on the analysis of the size of the landscape Class Area (CA) and Large Parch Index (LPI), the largest CA and LPI index values in 1999 were the agricultural land cover class and patch with an area of 6,241.03 ha (52.08 %), and 46,271, respectively. This was followed by the forest patch with an LPI value of 8.26 (Table 4).

Table 4: Size index analysis of the landscape structure

Land cover	Size index analysis								
	Total (Class) Area (CA)						***Large Patch Index (LPI)***		
	1999		**2009**		**2021**		**1999**	**2009**	**2021**
	ha	**%**	**ha**	**%**	**ha**	**%**			
Forest	3,521.9	29.39	5,788.8	48.30	5,728.22	47.80	8.26	39.29	15.18
Settlement	820.62	6.85	510.87	4.26	1,255.11	10.47	0.21	0.06	0.05
Agriculture	6,241	52.08	4,507.87	37.61	3,396.83	28.34	46.27	12.15	4.39
Waterbody	618.73	5.16	100.53	0.84	215.63	1.80	0.89	0.083	0.12
Scrub	781.83	6.52	1,076.42	8.98	1,388.22	11.58	1.64	0.058	0.69
Total	11,984	100	11,984.5	100	11,984	100			

The data showed that in 1999, the research area had agricultural landscapes as a dominant matrix. This is due to massive forest encroachment and replacing the function of land as crops or agriculture to meet community needs. Meanwhile, the highest number of patches (NP) in 1999 was a forest with 884 patches. Similar to the NP index, the highest Patch Density (PD) value in 1999 was forest, with a total of 7.37 patches/100 ha, followed by a total of 4.35 patches/100 ha (Table 5).

Edge sizes and the shape of the landscape's structure can be determined by measuring the components of the matrix class, namely Edge Density (ED) and Landscape Shape Index (LSI). Based on the analysis, the highest ED value was an agricultural land cover, which was 69.4 m/ha. Meanwhile, the two land covers with the highest LSI values were forest patches and agriculture, with values of 31.25 and 26.91, respectively (Table 6). Meanwhile, ED can describe the total area. It is the beginning of rising fragmentation and can be classified in terms of the edge effects. In this case, agriculture is the trigger for forest fragmentation, and the ecological function is lower than forests.

Table 5: Analysis of the density measure index and landscape structure variability

Land cover	Density measure index and landscape structure variability					
	Number of Patches (NP)			***Patch Density (PD)***		
	1999	**2009**	**2021**	**1999**	**2009**	**2021**
Forest	884	1,220	31,247	7,376	10.18	260.7
Settlement	271	1,897	300,575	2,261	15.83	2,508
Agriculture	522	2,042	92,555	4,355	17.04	772.3
Waterbody	409	276	19,180	3,413	2.30	160
Scrub	404	5,543	57,232	3,371	46.25	477.6

Table 6: Analysis of edge sizes and the shape of the landscape structure

Land cover	Edge sizes and the shape index					
	Edge Density (ED)			***Landscape Shape Index (LSI)***		
	1999	**2009**	**2021**	**1999**	**2009**	**2021**
Forest	56.91	127.10	448.98	31.25	50.87	178.7
Settlement	17.73	26.17	682.41	18.92	46.46	577.6
Agriculture	69.45	135.10	742.25	26.91	63.97	382.3
Waterbody	22.23	6.37	78.26	23.54	19.15	159.9
Scrub	18.78	135.70	461.95	20.41	98.68	371.8

Landscape structure in 2009

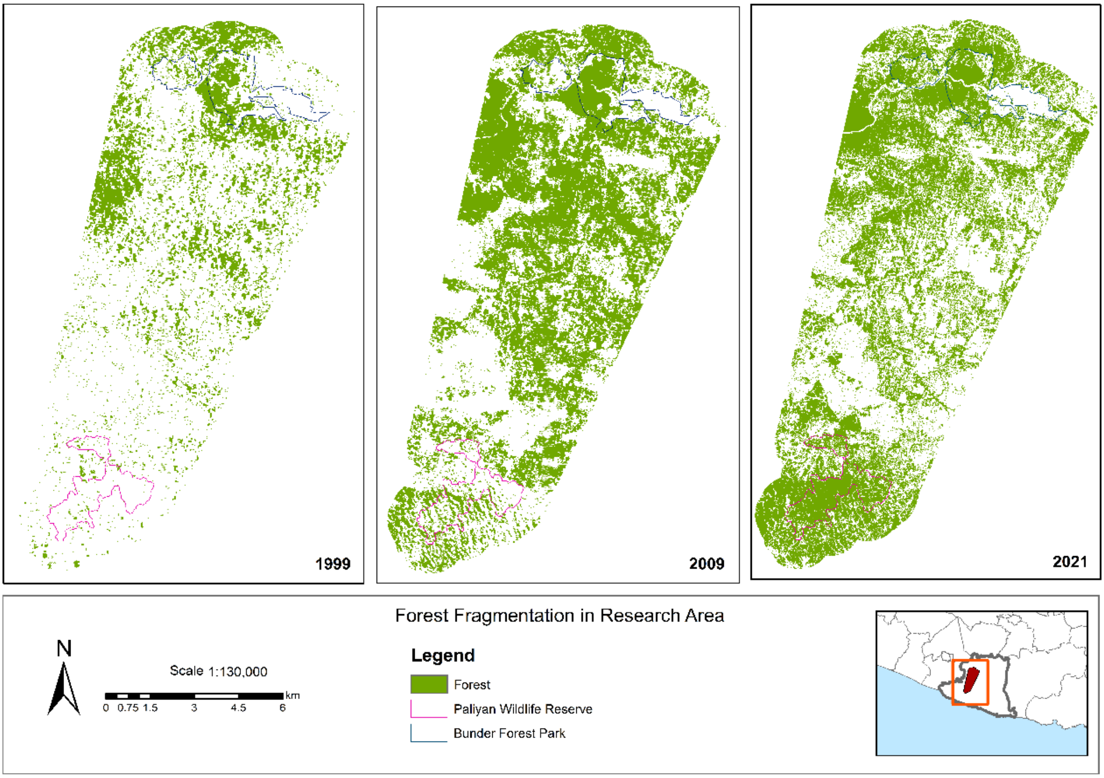
Forest cover in Gunungkidul Regency had grown by 2009, the year following the completion of the GNRHL. Furthermore, when viewed based on the size of the landscape using matrix class components, namely CA and LPI, the largest CA index value was forest with an area of 5,788.8 ha (48.30 %) and followed by agriculture with an area of 4,507 ha (37.6 %), scrubs (1,076 ha or 8.98 %), and settlements (510.87 ha or 4.26 %). The two highest LPI values in 2009 were forest and agriculture at 39.9 and 12.14, respectively (Table 4). The highest NP scrubbed, with a total of 5,543. Similarly, the highest PD in 2009 was scrubbed, with a total of 46.25 patches/100 ha (Table 5).

Based on the analysis of the edge size and the shape of the landscape's structure, the highest ED value in 2009 is scrub patch at 135.7, followed by agricultural and forest patches at 135.1 and 127.1, respectively. Meanwhile, the highest LSI value was the scrub patch at 98.68, followed by the agricultural and forest at 63.96 and 50.86 (Table 6). According to the ecological function, scrub have negatively impact on seedling growth through competition of sharing limited resources or release of chemicals that harm nearby plants (Ktizberger *et al* 2000; Sheffer *et al*, 2014). In addition, scrubs also become one of the obstacles and less supportive of the survival of LTM due to not as feed.

Landscape Structure 2021

The largest CA value in 2021 is a forest with an area of 5,728.8 ha (47.8 %). Furthermore, the two highest LPI values are forest and agriculture, with each value being 15.18 (Table 4). The size of the landscape structure density can be seen based on the NP and PD index values. The highest NP are settlements, with a total of 300,575 patches. Same with the NP index, the highest PD value in 2021 will be settlements with 2,508 patches/100 ha (Table 5). The highest ED value is the agricultural patch at 742.25 followed by the settlement, scrub, and forest at 682.4, 461, and 448.98, respectively (Table 6). Meanwhile, the highest LSI value is the settlement patch at 577.6. The index values of LSI indicate that the patch has the most irregular shape (McGarigal & Marks 1995).

Fig. 4: Forest fragmentation (a) 1999, (b) 2009), (c) 2021. Land cover was extracted from Landsat 5 TM image overview on 30 September 1999 and 15 July 2009, SPOT 7 image overview data on 6 August 2021



As seen in the analysis of the landscape structure, most of the fragmentation in forest cover was caused by the increasing number of agricultural patches in 1999 and 2021 and scrubs in 2009. The forest fragmentation was also evidenced by the decline in the LPI value from 2009 to 2021, where the LPI value was 39.29 and 15.18 in 2009 and 2021.

Table 7: Forest Cover Change in Study Area

Zone	Classification	2021		2009		1999	
		Forest area (ha)	**Percentage (%)**	**Forest area (ha)**	**Percentage (%)**	**Forest area (ha)**	**Percentage (%)**
Upper Zone	Core zone	332.02	5,78	283,66	4,79	200,85	9,16
	Buffer zone	1.061,00	18,47	1.087,14	18,36	624,81	28,51
Middle Zone	Core zone	2.880,03	50,13	3.821,65	64,54	1.284,31	58,60
Bottom Zone	Core zone	363,19	6,32	98,72	1,67	11,03	0,50
	Buffer zone	1.108,86	19,30	630,54	10,65	70,56	3,22
	Total	5.745,10	100,00	5.921,71	100,00	2.191,56	100,00

Note: The upper Zone (core and buffer of Bunder Forest Park), Middle Zone (Area between Bunder Forest Park and Paliyan Wildlife Reserve), Bottom Zone (core and buffer of Paliyan Wildlife Reserve)
Source: Analysis Result (2022)

Forest fragmentation can be caused by removing forest or vegetation in a large area (Fahriq, 2003; Gunawan *et al*, 2013; Samsuri *et al*, 2014). The assessment forest cover change in study area is divided into 3 (three) zones, namely the upper, middle, and lower zones. The zoning division is carried out to determine the specifications for the potential of the LTM corridor line. Each zone is also classified based on the core zone and the buffer zone. The core zone in question is a zone that is located within a conservation area and a wild habitat area connecting conservation areas (PWR and BFR). Meanwhile, the buffer zone is a zone determined based on the extent of the range of LTM activity around the PWR and BFR.

According to Kumar et al. (2018), the decrease in LPI shows that the forest patch with the largest size has shrunk, indicating the occurrence of fragmentation in the forest. In the same period, between 2009 and 2021, the NP and PD are increasing. The NP value from 1999 to 2009 was 884 to 1,220 patches, and from 2009 to 2021, it was 1,220 to 31,247. Meanwhile, the PD value from 1990 to 2009 was 7.37 to 10.17, and from 2009 to 2021, it was 10.18 to 260.7 (Table 5). Increasing NP and PD values indicate that land cover in a landscape has fragmented (Singh *et al*., 2014).

Habitat Suitability

In this research, several components were selected as the basis for assessing the potential analysis of the LTM habitat, including abiotic factors, namely the distribution of threats and landforms. In contrast, biotic factors were vegetation density and social factors, such as land use. Habitat suitability is defined as the ability to provide the necessities of life. It was determined by scoring and weighting each parameter adjusted to the preference of LTM. Scoring and weighting are determined based on a literature research and expert judgment.

According to Widiyatmoko (2013), LTM is one of the primates whose activities are influenced by human activities. Therefore, they can feel disturbed by the existence of settlements undoubtedly different from their natural habitat. Human activities also impact biodiversity, the ecological entity of species in whole communities and ecosystems (Roy *et al*., 2002). This means the closer the settlement, the more incompatible with primate habitats. The entry of primates into settlements will certainly cause conflict between humans and wildlife. Based on the results, several areas are considered not potential because of the discovery of settlements. In this case, it is necessary to analyze a potential corridor by scoring high in areas far from settlements.

Based on the vegetation density analysis, the upper, middle, and bottom zones have moderate to dense, sparse to moderate, and moderate to dense classes. LTM is a primate that requires cover at the tree level in their activities and food sources at the vegetation (Nugroho, 2012). This is in line with Alikodra (2002), which stated that the structure of forest vegetation is a form of protection.

Gunungkidul has a landform derived from a solutional process with surface characteristics, such as dry valleys, lakes, and flow patterns that enter the soil, and subsurface characteristics. The features of the formation originating from the solutional process can also include karst cones, layers, closed basins (uvula, polje, and Dolin), karst plains, and karst valleys (Mulatisih, 2010). Based on the results, the karst landforms selected in the research area are karst hills, dry valleys, Ledok Wonosari plains, and watery valleys. The four landforms were selected because they dominate the research area and have the potential to determine connectivity between protected areas.

As seen in the analysis of land cover parameters, LTM is considered dependent on land cover and is an essential component in animal survival. According to Supriatna and Ramadhan (2016), LTM can be found in primary, secondary, and plantation land. In addition, the shady tree canopy is a favorite spot for LTM to engage in passive behavior, such as resting. Therefore, tree crowns are a common location for LTM to engage in such behavior (Sinaga, 2010). Widarteti *et al*. (2009) stated that resting activities are essential activities carried out by individuals after eating. In addition to relaxing, forest cover with an agroforestry pattern is also favored by LTM because it provides food for them.

The habitat suitability for LTM is included in the intermediate class, with a value ranging from 3.00 to 3.75 (Table 8). The intermediate suitability class has an area of 4.963,06 or 41.48 % when viewed based on its area Fig. 5.

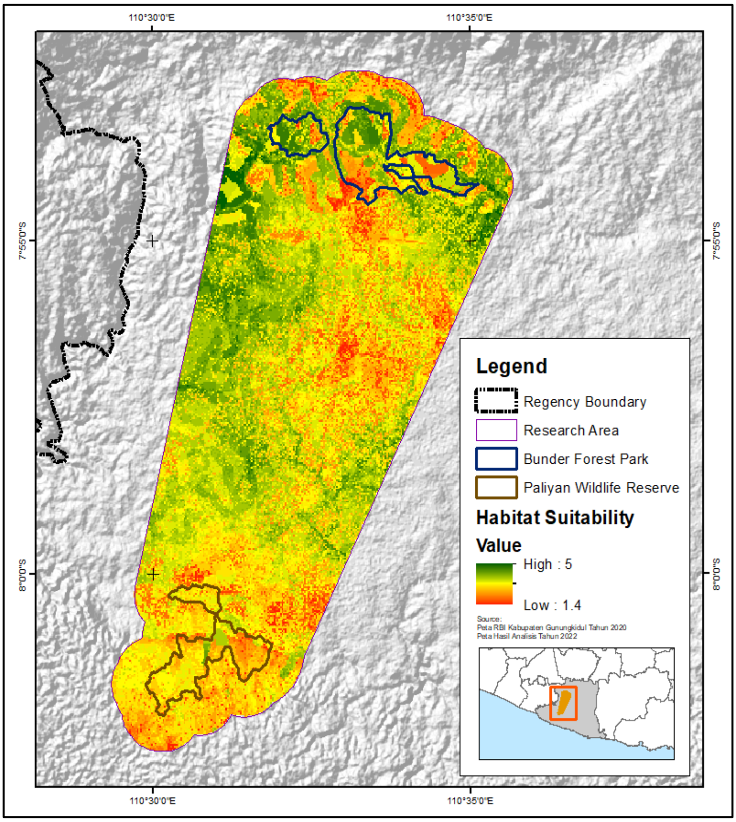
Table 8: Habitat suitability classification

Classification	Scale	Large (ha)	Percentage (%)
Low	1.40 – 3.00	2,084.03	17.42
Intermediate	3.00 – 3.75	4,963.06	41.48
High	3.75 – 5.00	4,916.98	41.10

Based on three parts or zones of the study area, namely the upper part or the area around BFP, the middle part or between conservation areas, and the lower part or the area around the PWR, it is known that there are differences in the level of dominant suitability. At the top shows that the highest level of conformity dominates. This upper part is located in the area around the BFP with dense forest cover and is passed by the Oyo River.

In this case, the upper part of the study area is considered to have high potential as long-tailed macaques habitat due to the availability of sufficient water and the presence of a dense canopy as an activity area for long-tailed macaques under the canopy or in tree branches. Furthermore, in the middle part or the area between conservation areas is dominated by high and medium suitability classes. This high suitability is indicated to have sufficient forest cover while a moderate to high suitability class indicates that the area is a fairly dense residential area with little forest cover.

Fig. 5: Habitat Suitability, the background of the image was from SRTM 2021



Furthermore, at the bottom of the study area, namely around the PWR area, it is dominated by the moderate suitability class. When integrated with the land cover map, it is known that the area around the PWR has sufficient forest cover however the tree species planted may not be able to meet the food and water needs of the long-tailed macaque habitat. In addition, only a small proportion are classified into the high suitability class.

Based on information from representatives of the PWR Resort, the Yogyakarta Province Natural Resources Conservation Center, and the Grogol Forest Management Resort, known that the distribution of LTM has spread to several areas around PWR, namely in Saptosari District and Paliyan District. Meanwhile, based on the results of interviews with several communities around the PWR conservation area, information was also obtained that the distribution of LTM had reached several villages in Saptosari District and Paliyan District.

Table 9: The area of habitat suitability class for each research zone

Zone	Classification zone	Suitability class	Area	Percentage (%)
Upper zone	Main zone (Bunder Forest Park)	Low	134.25	1.52
		Moderate	173.71	1.96
		High	307.12	3.47
	Buffer zone (Buffer BFP 1 km)	Low	430.59	4.86
		Moderate	575.32	6.50
		High	953.46	10.77
Middle Zone	Main zone (Between BFP and PWR)	Low	1,007.22	11.37
		Moderate	2,747.04	31.02
		High	346.88	3.92
Bottom zone	Main zone (PWR)	Low	95.99	1.08
		Moderate	294.44	3.32
		High	44.17	0.50
	Buffer zone (Buffer PWR 1 km)	Low	419.71	4.74
		Moderate	1,178.69	13.31
		High	146.95	1.66

Source: Hasil Analisis, 2022

Corridor Potential

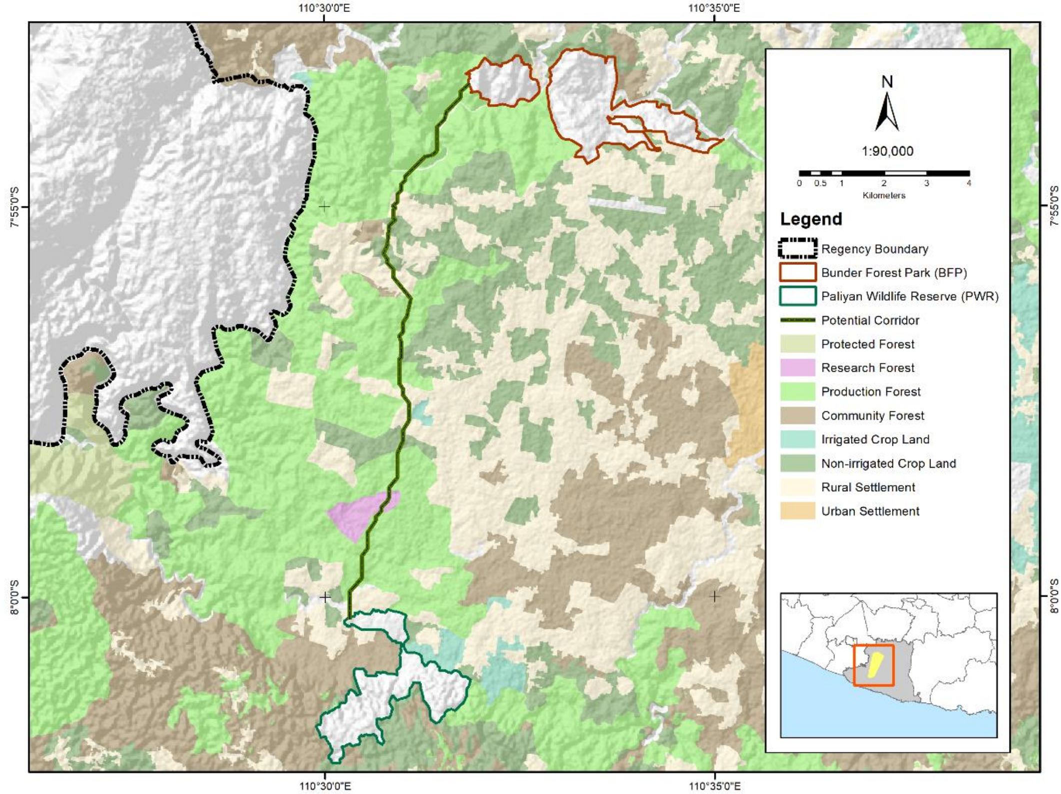
Connectivity or wildlife corridors can be defined as areas or vegetated paths, connecting two or more habitats, which allow the movement or exchange of individuals between animal populations to prevent fragmentation and decline in genetic diversity (Regulation of the Directorate General of Natural Resources and Ecosystem Conservation No. 8 of 2016). This research analyzed the potential for connectivity or wildlife corridors between protected areas in Gunungkidul Regency, namely the Paliyan Wildlife Reserve (PWR) and Bunder Forest Park (BFP). It provided an overview of the potential connectivity of protected areas as a step to reduce community disturbance. Furthermore, the place that will address the least cost path analysis of protected area connectivity is BFP. In definition, forest park is a protected area for collecting natural or artificial plants and animals in genetic resource conservation activities, both in situ and ex situ (Yudohartono, 2006). So, that the BFP have potentially as connectivity protected areas in Gunungkidul Regency.

Table 10: Corridor Potential Analysis of landscape structure and habitat suitability

Landscape Structure Condition	Habitat Suitability	Strategy option
Edges of forest and agricultural land dominate this corridor. Forest fragmentation is low. This corridor has a fairly good ecological function because of the extensive forest cover. LTM likes dense forest cover for activities and rest. They are predominantly located in the Central Zone with a reasonably high forest cover.	Dominated by class according to high to intermediate	Reducing the construction of settlements and roads in this corridor to shift the focus to protecting forest cover planting preferred species as food within the corridor and planting dislike species on the edges of the corridors as fences.

LCPA connectivity (Fig. 6) is the most potential in production forest areas and un-irrigated cropland. This forest area can be enriched with species, primarily to support the habitat of LTM and provide space for other wildlife. In this case, several artificial interventions also need to be carried out to avoid the direction of the indicator animal of the LTM into the community's food area. Production forests passed by corridors should be maintained for the forest cover to exist. On the other hand, species enrichment can also be a focus to support the potential of the protected area landscape corridor in Gunungkidul Regency (Yuwono *et al*., 2007; Atmoko *et al*., 2017).

Fig 6: Potential Corridor. An Environmental Agency supported land Status data. Yogyakarta Province 2021



DISCUSSION

Landscape Structure Change

Landscape structure and composition develops continuously in space and time (Shi *et al*, 2000). These developments are attributable to the complex interaction between natural environment and human activities, resulting in the change of the stability of individual elements in the landscape system and the spatial structure of landscape (Xiao *et al*., 1990). Then, human population grows which has increased built up areas gives impact as landscape fragmentation and decreases larges of habitat (Rahman *et al*, 2020). Human activities by imposing bariers such as roads, pipelines, buildings, dams and cultivation with industrial agriculture, also may disrupt ecosystem in ways that fall outside the range of space-timer scale. This human-induce fragmentation results in a reduction of habitat and connectivity, and species may not ready adapt to these changes (Forman, 2009; Elliot *et al*. 2013).

Fragmentation is considered a primary issue in conservation biology (Meffe & Carroll, 1997). The classic view of habitat fragmentation is the breaking up of a large intact area of a single vegetation type into smaller units (Lord & Norton, 1990). Habitat loss and fragmentation are not the only environmental challenges, but also other such issues loom large, including climate change, invasive species, disease, and overexploitation (Forman, 2009). It can interact synergistically with these other factors to produce harmful effects on two ecology of fragmented landscapes species and ecosystems (Ewers & Didham, 2006).

Fragmentation can also be the impact of political activity, namely to increase the value of the national economy by logging large-scale trees and converting forests into agricultural land and plantations to produce faster production. This incident occurred in Indonesia in the 1997-1998 reform period. Changes in structure of the forest landscape have also occurred in the North and South Korean border region (Sung et al, 2019), due to socio-political activities in the form of civil access restrictions, infrastructure development, and farmland reclamation (Park & Nam, 2013; Sung, 2015). In West African countries, a political-military crisis also caused a degradation of most natural forests, including those of some classified forests and protected area which have impact for degradation of forest resource and crisis on vegetation (Sidibe *et al*., 2020). In Rwadna, War and post-conflict development can interact with land use activities to influence landscape transformation and the severity of forest conversion. (Ordway, 2015)

Landscape fragment have influence of physical process and disturbance regimes on fragments means that following habitat destruction and fragmentation, habitat modification also occurs (Bennett & Saunders, 2010). Then, other effect species in fragmented landscapes are births, deaths, immigration, and emigration (Bennett & Saunders, 2010). Forest structure also has an influences ecosystem services provided by forests, for example, climate change mitigation, flood mitigation, and recreation and education use (Haddad *et al*, 2015). Comparison of landscape are important because landscape have properties that differ from those of fragments; many species move between and use multiple patches in the landscape, and conservation managers must manage entire landscapes (not just individual fragments) and therefore require an understanding of the desirable properties of whole landscapes (Bennett & Saunders, 2010). The development of landscape ecology contributed new ways of thinking about habitat fragments and landscape change. The concept of patches and connection corridors set within a matrix became an influential paradigm (Forman & Godron, 1986).

Habitat Suitability

Habitat suitability means the habitat's ability to support wildlife species and as a tools for biodiversity assessment in forest management (Edenius & Mikusinski, 2006; Muhammed *et al*, 2022). Understanding of the interactions between species and their environment is needed to determine the optimum habitat conditions (Muhammed *et al*, 2022). The habitat suitability concept helps wildlife managers to identifying factors on habitat with spending least cost and time (Bohadori *et al*, 2010). Considering ecological and social aspects is an important part of assessing habitat suitability, for example, Land use land cover, the threat of animals to settlements and other human activities, (Ansari, 2017) and ecological variables will influence the use of species habitat, for example forest cover or land use/land cover (Sani, 2017).

Good forest cover and sufficient water supply throughout the year in the form of parrenial streams and rivers natural habitat for various wildlife (Ahmad *et al*, 2018). Forest is one of the parameters that indicates the sustainability of the habitat for animals such as long-tailed macaques. In this study, the LTM is an animal that is an indicator of species in determining habitat suitability. The Long-tiled Macaca's is one of the most geographically widespread and abundant non-human primate species in the world. This primate is widely distributed in the Southeast Asian region (Thailand, Indonesia, Singapore, Brunei, Malaysia, Philippines, Vietnam and Laos) (Brandon *et al*, 2004). One of distribution LTM Indonesia in Gunungkidul Regency. Aggressively of LTM in Indonesia is the same as behaviour with LTM in Malaysia (Zamzarina, 2003).

Habitat suitability assessment based on habitat preference criteria for LTM animals has the potential to support the sustainability of animal habitats so as to minimize human-animal conflict in settlements. The results show that the medium and high classes are dominated by the study area. This needs to be maintained and can be developed through animal corridor development interventions as a step for merging fragmented forests. Agree with Bennett (2003), the concept of providing linkages for conservation can be applied at several scales: it is relevant both to local conservation efforts and to regional or national strategies. In local environments, habitat links can be protected, managed or restored at the level at which individuals or community groups are able to carry out conservation work.

Corridor Potential

In an effort to combine forest landscapes in Gunungkidul Regency and prevent Long-Tiled Macaca (LTM) from entering community settlements, habitat suitability assessments have a synergistic relationship to assess the most effective corridor path. According to Elliot *et al* (2013), corridors as a solution to connect separated habitats and facilitate wildlife to move and disperse from one habitat patch to another. Habitat suitability will provide an overview of which areas have a function in terms of maintaining habitat for certain animals so that potential corridors can be formed. Restoring and maintaining landscape connectivity is one of the conservation strategies to mitigate the impact of agricultural practices and urbanization (Crooks & Sanjayan, 2006).

Function of the corridor also to facilitate the physical movement of wildlife, for example LTM, which is crucial to the long-term viability of animal population, feeding or foraging, and seasonal migrations (Srivastava & Tyagi, 21016). Landscape corridors can help reduce the negative effects of habitat fragmentation by allowing the dispersal of individuals between large patches of remaining habitat (Bond, 2003; Sutherland *et al*, 2019). In Australia, corridor has successfully supported arboreal mammal's movement (Gracanin, 2023). Same as in Amerika, improving habitat connectivity is the strategy most often recommended and trusted successfully by scientists for allowing species to adapt to changing climate conditions and to migration (Sutherland *et al*, 2019). As seen the resulted, Gunungkidul regency has one of potential corridor with dominated by class according to high to intermediate. River or watery valley form natural corridors has one of highly indicator which is connecting the most protected wildlands, then providing the path required by many aquatic species, and are highly favored by most terrestrial wildlife species (Malo *et al*, 2004).

Meanwhile, to prevent action for LTM so as not enter in community land, need to create a buffer zone that can serve as a permanent habitat, which is have some space that provides food for LTM every day in the morning, afternoon and evening, so as to reduce the pest behavior. In addition. Then, initiate an awareness program also should be conducted for the local people nearby and also for the tourists (Hambali, 2012). The next step that should also be conducted after assessing the potential of the corridor potential are adopt elements of the government's policy plan for support connectivity and continuity of wildlife corridors, including landscape corridors and maintain and/or restore a continuous corridor function between the Landscape of protected areas whenever possible (Scott, 2015).

Potential obstacles that can occur are uncontrolled animal behavior that can damage plants around the corridor, damage to the corridor caused by land clearing can occur if the community needs food and shelter. Solutions that can be offered are routine monitoring of the corridor buffer zone, strengthening regulations regarding the importance of landscape corridors for wildlife, and translocating wildlife.

CONCLUSION

This research assessed land cover change in three periods, namely 1999, 2009, and 2021. The results showed that land cover change in the research area is fluctuating, and can impact fragmentation. The highest potential for fragmentation in 1999, 2009, and 2021 was caused by agriculture, scrub cover, and settlements. Most of the areas are classified as moderate suitability for LTM habitat, with a score of 3.00 - 3.75 and a total area of 4,963.06 ha. Based on determining the corridor path between BFP and PWR, a potential corridor was identified. It is vital to preserve the existing vegetation cover in the existing corridor to prevent forest fragmentation caused by land modifications. Other management options to conserve animal habitat while preventing the introduction of LTM onto community land include expanding buffer zones, regulating birth rates, sterilizing, and translocating wildlife.

ACKNOWLEDGEMENT

The authors are grateful to Universitas Gadjah Mada for partially funding this research through the RTA program.

CONFLICT OF INTEREST

The authors declared that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and falsification, double publication and submission, and redundancy, have been completely observed.

REFERENCES

Ahmad, F., Goparaju, L., & Qayum, A. (2018). Wildlife habitat suitability and conservation hotspot mapping: Remote Sensing and GIS based decision support system. *AIMS Geosciences*, *4*(1), 66–87. https://doi.org/10.3934/geosci.2018.1.66

Akyürek, D., Koç, Akbaba, E. M., & Sunar, F. (2018). Land use/land cover change detection using multi-temporal satellite dataset: A case study in Istanbul new airport. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *42*(3W4), 17–22. https://doi.org/10.5194/isprs-archives-XLII-3-W4-17-2018

Alikodra, H.S. (1990). *Pengelolaan Satwa-liar Jilid I.* Departemen Pendidikan dan Kebudayaan Direktorat Jenderal Pendidikan Tinggi. Pusat Antar Universitas Ilmu Hayati. Institut Pertanian Bogor. Bogor.

Aggimarangsee, N. (2013) Status monitoring of isolated populations of macaques and other nonhuman primates in Thailand. In: Marsh LK (ed) Primates in fragments: ecology and conservation. *Springer*, New York, pp 147–158

Atmoko, S.S.U., Diregar, P.G., Susilo, H.D., Rifqi, M.A., Ermayanti. (2017). *Konsep Koridor Orangutan*. Forum Orangutan Indonesia. ISBN : 978-602-17274-4-7

Ardana, D.M.A, dan Purwanto, T.H. (2013). Penentuan Jalur Evakuasi dan Dampak Banjir Lahar Dingin Gunung Merapi Magelang, Jawa Tengah. *Jurnal Bumi Indonesia.* Volume 2, Nomor 2.

Ansari, A. (2017). Habitat Evaluation for Persian Gazele in Southern half of Markazi Province, Iran. Journal of Wildlife and Biodiversity 1(1): 19-23.

Bahadori, F., Alizadeh, A., Kaboli, M., Karami, M., Atarod, P., Mitra, Sh. (2010). Habitat Suitability Modeling of *Sitta europaea* in northern Alborz. Journal of natural environment 63 (3): 225-236.

Beier, P., D. R. Majka, and S. L. Newell. (2009). Uncertainty Analysis of Least-Cost Modeling For Designing Wildlife Linkages. *Ecological Applications* 19:2067–2077.

Bennett, A.F and Saunders. (2010). *Chapter 5: Habitat Fragmentation and Landscape Change*. Conservation Biology for All. Oxford University Press.

Bennett, A.F. (2003). *Linkages in the Landscape: The Role of Corridors and Connectivity in Wildlife Conservation*. IUCN, Gland, Switzerland and Cambridge, UK. 254 pp

Bond, M. (2003). *Principle of Wildlife Corridor Design*. Center for Biological Diversity.

Bruinderink, G.G., Sluis, T.V.D., Lammertsma, D., Opdam, P., Pouwels, R. (2003). Designing a Coherent Ecological Network for Large Mammals in Northwest Europe. *Conservation Biology* 17. Page: 549 – 55.

Brandon-Jones, D., AA. Eudey, T. Geissmann, CP Groves, DJ Melnick et al. (2004). Asian primate classification. *Int. J. Primatol.*, 25: 97-164

Central Statistics Agency for Paliyan District, (2021). *Kecamatan Paliyan dalam Angka* 2021.

Cushman, S. A., K. S. McKelvey, and M. K. Schwartz. (2009). Use of Empirically Derived Source-Destination Models To Map Regional Con-Servation Corridors. *Conservation Biology* 23:368–376

Crooks, K.R., Sanjayan, M., (2006). *Connectivity Conservation*. Cambridge University Press, Cambridge

Edenius, L., & Mikusiński, G. (2006). Utility of habitat suitability models as biodiversity assessment tools in forest management. *Scandinavian Journal of Forest Research*, *21*(SUPPL. 7), 62–72. https://doi.org/10.1080/14004080500486989

Elliot, S.D. (2013). *Restoring Tropical Forests A Practical Guide*, Surrey; Kew Publishing.

Ewers, R.M., and R.K. Didham, (2006). Confounding factors in the detection of species responses to habitat fragmentation. *Biological Reviews* 81:117–142.

Fahrig, L. (2003). Effect of habitat fragmentation on biodiversity An Rev. of Ecology, *Evolution, and Systematics* 34 (1):487-515

Forman, R. (2009). *Ecology of Fragmented Landscapes*. The Johns Hopkins University Press.

Fauzi, R., Wuryanto, T., Endarto, Suarmadi, F., and Tomonob, A. (2020). Distribution of long-tailed macaque (*Macaca fascicularis*) in Kelimutu National Park. *IOP Conf. Series: Earth and Environmental Science* 591. doi:10.1088/1755-1315/591/1/012041.

Gracanin, A., & Mikac, K. M. (2023). Evaluating modelled wildlife corridors for the movement of multiple arboreal species in a fragmented landscape. *Landscape Ecology*. https://doi.org/10.1007/s10980-023-01628-8

Girvetz, E.H.; Greco, S.E. (2007). How to Define a Patch: A Spatial Model for Hierarchically

Delineating Organism-Specific Habitat Patches. *Landscape Ecology 22*, 1131–1142.

Gumert, M.D. (2011). The common monkey of Southeast Asia: longtailed macaque populations, ethnophoresy, and their occurrence in human environments. In: Gumert MD, Fuentes A, Jones-Engel L (eds) *Monkeys on the edge: ecology and management of longtailed macaques and their interface with humans* (pp 3–44). Cambridge University Press, Cambridge.

Gunawan, P. and Prasetyo, L.B. (2013). *Fragmentasi Hutan Teori yang mendasari penataan ruang menuju pembangunan berkelanjutan*. Pusat Penelitian dan Pengembangan dan Rehabilitasi. Bogor.

Hadi, I., Suryobroto, B., Perwitasari-Farajallah, D. (2007). Food preference of semi-provisioned macaques based on feeding duration and foraging party size. Hayati *Journal Bioscince* 14:13–17

Haddad, N.M., Brudvig, L.A., Clobert, J., Davies, K.F., Gonzalez, A., Holt, R.D., Lovejoy, T.E., Sexton, J.O., Austin, M.P., Collins, C.D., Cook, W.M., Damschen, E.I., Ewers, R.M., Foster, B.L., Jenkins, C.N., King, A.J., Laurance, W.F., Levey, D.J., Margules, C.R., Melbourne, B.A., Nicholls, A.O., Orrock, J.L., Song, D-X., Townshend, J.R.. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystem. *Sci Adv* 1: e1500045. https://doi.org/10.1126/sciadv.1500052

Hakim, A.R. (2021). *Dinamika Konfigurasi Lanskap Hutan Kabupaten Kotawaringin Timur, Kalimantan Tengah*. Thesis. Fakultas Kehutanan. Universitas Gadjah Mada. Yogyakarta.

Hambali, K., Ismail, A., & Md-zain, B. M. (2012) Daily Activity Budget of Long-tailed Macaques (*Macaca fascicularis*) in Kuala Selangor Nature Park. *International Journal of Basic & Applied Sciences IJBAS-IJENS*, *12*(04), 47–52.

Hambali, K., Ismail, A., Zulkifli, S. Z., Md-zain, B. M., & Amir, A. (2012). Human-Macaque Conflict and Pest Behaviors of Long-Tailed Macaques (*Macaca fascicularis*) in Kuala Selangor Nature Park. *Natural History Journal of Chulalongkorn University*, *12*, 189–205.

Hersperger, A.M. (1994). Landscape ecology and its potential application to planning. *Journal of Planning Literature* 9(1). Page:15–29

Hidayat, Andoko (2012). Studi Populasi dan Pola Penggunaan Ruang Kera Ekor Panjang (*Macaca fascicularis*) di Hutan Pendidikan Gunung Walat. *Thesis.* Sekolah Pascasarjana. Institut Pertanian Bogor.

IUCN, (2022). *Red List of Threatened Species*: *Macaca fascicularis*.

Khumar, M., Denis, D.M., Singh, S.K., Szabo, S., Suryavanshi, S. (2018). Landscape metrics for Assessment of Land Cover Change and Fragmentation of Heterogenous Watershed. *Remote Sensing Applications: Society and Environment* 10: 224-233. https//doi.org/10.106/j.rsase.2018.04.002.

Kitzberger, T., Steinaker, D.F., Veblen, T.T. (2000). Effects of climatic variability on facilitation of tree establishment in Northern Patagonia. *Ecology* 80:1914–1924

Larkin, J. L., D. S. Maehr, T. S. Hoctor, M. A. Orlando, and K. Whitney (2004). Landscape linkages and conservation planning for the blackbear in west-central Florida. *Animal Conservation* 7:23–34

Lesson, C., Kyes, R.C., Iskandar, E. (2004). Estimating population density of Long-tailed macaques (*Macaca fascicularis*) on Tinjil Island, Indonesia, using the line transect sampling method. *Jurnal Primatologi Indonesia* 4(1):7-14.

Malo, J.E., Suarez, F., Diez (2004). Can we mitigate animal-vehicle accidents using predictive models. *J. Appl. Ecol* 41. Pages: 701-710.

McGarigal, K., Marks, B.J. (1995). *FRAGSTATS.* Spatial Pattern Analysis Program for Quantifying Landscape Structure. Version 2.0. Forest Science Department. Oregon State University

Miller, Jr. G. T., (1982). *Living in The Environment.* Wadsworth Publishing Company. California.

Minor, E.S.; Urban, D.L. (2008). A Graph-Theory Framework for Evaluating Landscape Connectivity and Conservation Planning. *Conserv. Biol 22*, 297–307

Muhammed, K., Anandhi, A., & Chen, G. (2022). Comparing Methods for Estimating Habitat Suitability. *Land*, *11*(10), 1–19. https://doi.org/10.3390/land11101754

Mulatsih, (2010). *Aliran Karbon dalam Tanah di sepanjang Toposekuen Perbukitan Karst Formasi Wonosari Kabupaten Gunungkidul.* Thesis. Sekolah Pascasarjana. Universitas Gadjah Mada.

Newbold, T., et al., (2015). Global effects of land use on local terrestrial biodiversity. *Nature.* Available at: http://www.nature.com/nature/journal/v520/n7545/ full/nature14324.html.

Nugroho, Tri Cahya (2012). *Sebaran Populasi dan Karakteristik Habitat Kera Ekor Panjang di Taman Nasional Gunung Merapi*. Thesis. Sekolah Pascasarjana. Institut Pertanian Bogor.

Ordway, E. M. (2015). Political shifts and changing forests: Effects of armed conflict on forest conservation in Rwanda. *Global Ecology and Conservation*, Vol.3, 448–460.

Park, E.J., Nam, M.A. (2013). Changes in land cover and the cultivation area of ginseng in the Civilian Control Zone - Paju City and Yeoncheon County. *Korean J Environ Ecol* 27:507–515

Prasetyo, L.B. (2017). *Pendekatan Ekologi Lanskap untuk Konservasi Biodiversitas. Bogor.* Fakultas Kehutanan, Institut Pertanian Bogor.

Samsuri, Jaya I N S, Kusmana C, and Murtilaksono K. (2014). Connectivity and ecological indicators analysis of tropical forest landscape in Langkat watershed – Indonesia. *Journal of Agriculture Fisheries and Forestry* 3 (3): 147-154.

Sani, N. A. (2017). A survey on current distribution and habitat suitability of the Great Bustard in West Azerbaijan, Iran. *Journal of Wildlife and Biodiversity*, *1*(2), 88–93. https://doi.org/10.22120/JWB.2017.28295

Scott, J. (2015). *Wildlife Corridor Protection and Enhancement Plan*. https://conservationcorridor.org/

Sheffer, M., Vergnon, R., Cornelissen, H. C., Hantson, S., Holmgren, M., van Nes, E. H., et al. (2014). Why trees and shrubs but rarely trubs? Trends *Ecol. Evol*. 29, 433–434 . doi: 10.1016/j.tree.2014.06.001

Sidibé, O., Kouassi Kouadio, H., Bamba, I., & Kouassi Konan, E. (2020). Political-military crisis and forest fragmentation in the Mont Péko national Park in Côte d'Ivoire. *Cybergeo*, 1–23. https://doi.org/10.4000/cybergeo.34842

Shi, Y., Xiao, J., Shen, Y., Sensing, R., Metrics, L., Basin, H. R., & Effects, E. (2000). Landscape Pattern Change and Associated Environmental Implications in Haihe River Basin, China. *Archives*, 0–5.

Singh, S.K., Pandey, A.C., Singh, D. (2014). Land Use Fragmentation Analysis Using Remote Sensing and Fragstat. *Remote Sensing Applications in Environmental Research*. DOI: 10.1007/978-3-319-05906-8_9.

Srivastava, R., & Tyagi, R. (2016). Wildlife corridors in india. *Environmental Law Review*, 18(3), 205–223. https://doi.org/10.1177/1461452916662114

Sutherland, R., Holmes, S., and Davis, K. (2019). *Wildlife Corridor Protection and implementing the Wildlife Corridors Conservation Act are crucial steps to promoting habitat connectivity and safeguarding America's biodiversity*. Wildlands Network.

Rahman, H., Triyatno, T., Hanif, M., & Indrayani, P. (2020). Spatial Assessment of Landscape Structure Changes and Ecological Connectivity in Pariaman. *Journal of Remote Sensing GIS and Technology*, *6*(2), 10–22. https://doi.org/10.46610/jorsgt.2020.v06i02.002

Roy, P.S., Dutt CBS, Joshi PK. (2002). Tropical forest resource assessment and 120 monitoring. *Tropical Ecology*. 43(1): Pages 21-37.

Sinaga, S.M., Utomo, P., Hadi, S., & Archaitra, N.A.. (2010). *Pemanfaatan Habitat oleh Kera Ekor Panjang (Macaca fascicularis) di Kampus IPB Darmaga*. Fakultas Kehutanan. Institut Pertanian Bogor.

Sung, C. Y., Park, C. B., & Kim, J. S. (2019). Politics of forest fragmentation: a multiscale analysis on the change in the structure of forest landscape in the North and South Korean border region. *Regional Environmental Change*, *19*(1), 137–147. https://doi.org/10.1007/s10113-018-1394-7

Sung, C.Y. (2015). Simulation of crane habitat fragmentation in the North and South Korean border region after Korean reunification. *Landsc Urban Plan* 134:10–18. https://doi.org/10.1016/j.landurbplan.2014.10.008

Supriatna J, Ramadhan R. (2016). *Pariwisata Primata Indonesia.* Yayasan Pustaka Obor Indonesia. Jakarta.

Utina, R., dan Baderan, D.W.K. (2015). *Ekologi dan Lingkungan*. Universitas Negeri Gorontalo (UNG) Press.

Xiao, D., Zhao, Y., Sun, Z., Zhang, H., (1990). Study on the variation of landscape pattern in the west suburbs of Shenyang. *Chinese Journal of Applied Ecology*, 1: 75-84.

Yudohartono, T.P. (2006). Peranan Taman Hutan Raya Dalam Konservasi Sumberdaya Genetik: Peluang dan Tantangannya. *Informasi Teknik.* Volume 6, Nomor 2. Balai Besar Penelitian dan Bioteknologi dan Tanaman Hutan. Bogor.

Yuwono, E.H., Susanto, P., Saleh, C., Andayani, N., Prasetyo, D., Atmoko, S.S.U. (2007). *Guidelines for The Better Management Practices on Avoidance Mitigation and Management of Human-Orangutan Conflict and Around Oil Palm Plantations*. WWF Indonesia. ISBN: 979-99919-6-X.

Wang,F., et al. (2014). Evaluating Landscape Options for Corridor Restoration between Giant Panda Reserves. *PloS one* 9 (8). http://journals.plos.org/plosone/article%3Fid%3D10.1371/journal.pone.0105086_

Wardana, W. Sartohadi, J., Rahayu, L., and Kurniawan, A. (2012). Analisis Transisi Lahan di Kabupaten Gunungkidul dengan Citra Penginderaan Jauh Multi Temporal. *Jurnal Ilmu Kehutanan* (2). Hal: 89-102.

Widarteti, (2009). Perilaku Harian Lutung (*Trachypithecus cristatus*) di Penangkaran Pusat Penyelamatan Satwa Gadog Ciawi-Bogor. *Zoo Indonesia*, 18(1), 33-40.

Widiyatmoko, B. (2013). *Konflik Kera Ekor Panjang (Macaca fascicularis) dan Manusia pada berbagai tipe penggunaan lahan di Suaka Margasatwa Paliyan dan Sekitarnya*. Tesis. Fakultas Kehutanan. Universitas Gadjah Mada. Yogyakarta.

Wiharja, D, dan Purwanto, T.H. (2012). Analisis Perbandingan Jalur Pipa Transmisi Pdam

Eksisting Dengan Metode *Least Cost Path* Di Kabupaten Sleman. *Jurnal Bumi Indonesia*. Vol 1, Nomor 3. Hal:140-146.

Zamzarina, M.A. (2003). *A study on aggressive behavioural in Macaca at taman tasik taiping, perak*, B.Sc. Thesis, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia.