LEAST COST PATH ANALYSIS TO PROMOTE AN ECOLOGICAL CONNECTION FOR GUNUNG MERAPI AND GUNUNG MERBABU NATIONAL PARKS

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ABSTRACT

The prominent protected areas in Central Java, Gunung Merapi and Gunung Merbabu National Parks as the home for high-value biodiversity and as an important catchment area are oppressed by the expanding of agriculture and settlement areas. This situation can be regarded as the fragmentation of habitat for wildlife which leads to their population decline. In order to minimize the adverse consequences, an ecological connection is immensely needed for those two parks.

Reflecting the situation above, this paper has a main objective of promoting an ecological connection by using least cost path analysis tool in ArcGIS software. It emphasizes on the use of valuable geo-information to meet the criteria of suitable corridor based on wildlife predatory mechanism in geophysical condition. The result showed that seven variables were corresponding to the specific criteria for wildlife corridors in an approximately 5.3 km route from the origin to destination location.

Index Terms— Gunung Merapi, Gunung Merbabu, National Park, fragmented habitat, ecological connection, corridor, least cost path

1. INTRODUCTION

Protected areas in Central Java, Gunung Merapi and Gunung Merbabu National Parks (NP) hold an important role in conserving high-value biodiversity as well as water catchment areas. The parks are occupied by more than a thousand fauna species whereas several of them are considered as rare species such as Javan Leopard and Javan Hawk-Eagle. Unfortunately, the landscape connecting the Merapi and Merbabu NPs is severely dissected by densely populated areas and a main road. Fertile soils are surrounding the landscape of Merapi-Merbabu and the existence of this main road, connecting two important municipalities namely Boyolali and Magelang were the main reasons for people to live there.

In terms of ecology, the situation between the Gunung Merapi and Gunung Merbabu NPs can be regarded as a fragmented habitat which leads to species’ decline [1,2]. With an exception for migratory birds which have enough capabilities in adapting to fragmented and patchy habitats [3]. Agricultural expansion adjacent those NPs’ areas obviously caused the shrink of suitable habitat for wildlife. The movement for several species has been restricted not only by their decreased habitat but also the occupancy of human in a particular zone of NPs. Hence, in order to minimize the effect of habitat fragmentation, which often lead to species extinction, an ecological connection is immensely needed for those parks.

An ecological connection or corridor is commonly understood as a natural or even an artificial feature of a landscape which can be used by wildlife for dispersing purposes from a one patched-habitat to another suitable habitat. By definition, it should be specific for certain species. [4,5]. It facilitates populations in extending their habitat, allows them to recolonize and minimize gene pool issues [6]. Once a population is being isolated, it drives the consequences of lacking natural resources in survival process. Limited access to disperse also traps them of having inbreeding practice.

In this paper, a corridor has been analyzed on the perspective of a top predator’s existence, the Javan Leopard (Panthera pardus ssp. melas), and its prey (Muntiacus muntjak) to promote an initiative for ecological connection. Referring to the study about possible corridors for Javan Leopard between Gunung Merapi and Gunung Merbabu NPs [7] which predicted the potential path for the leopard to disperse due to the need of fleeing from a natural hazards and the other reason for survival requirement, this paper discusses the importance of having geo-information knowledge related to the designing process for an ecological connection. This kind of information becomes an important aspect in proposing an ecological link between the Gunung Merapi and Gunung Merbabu NPs. Eventually, it can be used as important information for the conservation stakeholders especially in the Boyolali District as its area might be intersected by a proposed corridor.

This contribution has been peer-reviewed
2. STUDY AREA

Gunung Merapi National Park was appointed as a National Park on 4 May 2004 based on the Decree of Ministry of Forestry (Surat Keputusan Menteri Kehutanan No.134/Menhut-II/2004). The area of this park is approximately 6,410 hectares located in two provinces, namely Central Java and Yogyakarta Special Region. It is occupied by several vegetation types such as *Casuarina sp.*, *Acacia decurrens*, *Schima wallicci*, *Eugenia polyantha*, *Panicum munitum* and fauna like *Macaca fascicularis*, *Trachypithecus auratus*, *Muntiacus muntjak*, *Spizaetus bartelsi*, *Panthera pardus ssp. Melas*. As being the most active volcano in the world, this park is also expected to be the buffer zone for any disaster occurrences on its establishment.

Meanwhile, together with the Gunung Merapi NP designation, the Decree of Ministry of Forestry (Surat Keputusan Menteri Kehutanan No.135/Menhut-II/2004) also appointed Gunung Merbabu National Park as the habitat for flora and fauna to be managed sustainably. Having almost the same characteristic of flora and fauna as the Merapi landscape, this park lies in three districts (Boyolali, Magelang, Semarang) of Central Java. Its size of 5,675 hectares is also considered to be a prominent water catchment area.

3. METHODS

As many previous researches pertaining corridor issues, the model of the ecological link is frequently analyzed by using least cost path (LCP) tool under ArcGIS operation [8,9,10]. It assigns the cheapest cost of a specific route from an origin point to a destination point in raster based operations. The raster of cost distance and backlink raster are utilized as a tool in calculating the least costly route. Different to Euclidean distance which calculate the distance geographically, cost distance defines the shortest distance with respect to weighted variables in cost units. Meanwhile, the backlink raster describes the direction of the route [1,11].

A presence point of Javan Leopard, found by Gunung Merapi NP authority in Gunung Bibi (north-east part of Gunung Merapi), has been set as origin point and presence point of barking deer inside Gunung Merbabu NP’s boundary has been appointed as the end point (destination). In this study, least cost path has been developed by applying seven variables namely landcover, Normalize Difference Vegetation Index (NDVI) value, distance to rivers, distance to settlements, distance to existing paths and slope.

Land cover and NDVI were obtained from Landsat 8 acquired on 14 June 2015 with a 30 meters spatial resolution. The first was processed by supervised classification and the later was derived by applying the formula of near infrared band subtracted by red band divided by near infrared band plus red band. Distance to rivers, distance to paths and distance to settlements were calculated by developing
Table 1. Variable cost value

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description [Cost Value]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landcover</td>
<td>Non-agriculture [1], agriculture [5], Non-vegetation [10]</td>
</tr>
<tr>
<td>NDVI</td>
<td>&lt; 0.2 [10], 0.2 - 0.3 [5], 0.3 - 0.5 [5], 0.5 - 0.6 [3], &gt; 0.6 [1]</td>
</tr>
<tr>
<td>Distance to River</td>
<td>&lt; 100 meter [1], 100 - 250 [2], &gt; 250 [5]</td>
</tr>
<tr>
<td>Distance to</td>
<td>&lt; 500 meter [10], 500 - 1000 [7], 1000 - 1500 [5], 1500 - 2000 [2], &gt; 2000 [1]</td>
</tr>
<tr>
<td>Distance to Path</td>
<td>&lt; 100 meter [10], 100 - 250 [7], 250 - 500 [5], 500 - 1000 [2], &gt; 1000 [1]</td>
</tr>
<tr>
<td>Main road</td>
<td>With bridge-under crossing [1], no bridge [10]</td>
</tr>
<tr>
<td>Slope</td>
<td>&lt; 2% [1], 2 - 7% [2], 7 - 15% [3], 15 - 30% [4], 30 - 70% [5], 70 - 140% [7], &gt; 140%</td>
</tr>
</tbody>
</table>

Euclidean distance of river patterns, road patterns, and settlement areas, respectively, from the Indonesia Base Map (Rupa Bumi Indonesia). Lastly, the contour map with a 12.5 meters interval of Indonesian Base Map was the origin of the digital elevation model, which has been used to produce the slope raster map. The process then continued by reclassifying and scoring the range of each variable under a certain condition (Table 1).

Referring to the previous study pertaining opportunities of habitat connectivity for the tiger in India [8], the range cost values of classes in all variables have been deliberately chosen starting from 1 to 10 which represented the lowest to the highest cost. The highest value of 10 was chosen to reflect the supercritical condition.

As a prerequisite for configuring least cost path, all variables have to be scored in order to determine their weight. Weight raster depicts the most important variable which determines the direction from the origin point to the destination location. Applying Analytical Hierarchy Process (AHP) to determine the percentage of variable priority [1,8], land cover, NDVI and distance to water hold the top tree highest value of 40%, 20%, and 18%, respectively. In the meantime, distance to settlements, distance to paths, main road and slope resulted in the proportion of 4%, 7%, 3% and 8%, respectively. Thus, these values have been used in creating weighted overlay as input cost raster in the process for calculating cost distance. In attempt to define the least accumulative cost path to the nearest start location, cost backlink has been processed by using starting point and weighted overlay. The last step in calculating the corridor using least cost path was deploying destination point alongside cost distance raster and cost backlink raster into cost path tool in ArcGIS.

4. RESULTS

Least cost path tool in ArcGIS has revealed the route which can possibly be used as a consideration in linking Gunung Merapi and Gunung Merbabu NPs. Approximately 5.3 kilometers route as the result of a set of the variable which has been weighted and scored on each class portrays the movement of wildlife from the south toward the north. Starting at the origin point nearby Gunung Merapi NP’s boundary, it clearly indicate that the route begins in left track and continued with slightly leaning to the opposite turn. It then continued with a considerably path in the left direction reaching the destination point (Figure 2).

Considering the spatial plan for the Boyolali District, there are six land use classes which have to be crossed according to the least cost path. Comprising farm, dry-agriculture, national park, settlement, water-based agriculture and ecotourism, the route obviously intersected the first three land use category. Passing through the national park at the very beginning stage, dry-agriculture and farm have to be traversed alternately before reaching the defined end point. Apparently, there are no settlement areas to cross by this path.

In term of topography, the profile of least cost path can be observed in figure 3. The path which started with the downslope track until 300 meters will be continued going up a wavy track until two and a half kilometers away from the starting point. After that, the path will go up steadily reaching the extremely down steep topography after 4.9 kilometers and finally climbing when approaching the end location.

5. DISCUSSION

In this study, least cost path tool in ArcGIS has developed a path from an origin location to a particular destination which also can be considered as a link between the two locations. The need for an ecological connection between Gunung Merapi and Gunung Merbabu NPs has driven the development of a methodology to define a corridor in facilitating the wildlife to disperse for individual survival and population continuation purposes.

The process of developing least cost path as a model for corridor development was started by determining the source and destination location as the initiative concept of linking two protected areas. It proceeded by deploying several variables which have been classified based on their characteristic. The next sequences were weighting variables according to their influences in supporting the potential corridor for wildlife, and scoring classes for each variables as a cost with respect to the impediment factor for movement.

As the important order more in general, defining concept plays a significant role in modeling [12]. Corridors as a mean of wildlife’s dispersal should accommodate species’ needs as their origin habitat [5] and more in general having adequate woody cover and low human interferences [13]. Even though the distance of two NPs is fairly short, roughly 4 to 5 kilometers away from their outer boundaries,
still the model for the potential corridor takes several habitat components in consideration, like food, cover, water and space [3,13,14,15]. Therefore it can be used for both species to live in or just passing through [16,17].

Land cover and NDVI being the most representative variable for cover have been prioritized based on AHP result (consistency 0.07) together with distance to rivers. Species like a primate, ungulate and other herbivores which depend on vegetation as their food source [18] become another consideration in determining land cover as a priority variable. Besides providing food for these species, land cover consists of vegetation, which is also considered as a shelter or protection. Thus, the cost of movement for different land cover types corresponds to above mentioned arguments. The non-vegetated areas which mainly consist of built-areas and bare land, have been given high cost, and agriculture areas and non-agriculture areas (forest) as medium cost and low cost, respectively. As the indication of greenness of a land patch [19], NDVI values were considered as high cost of wildlife movement in low range (<0.2; bare land, sand or rock) to low cost in its high value range (>0.6; tropical forest or uttermost growth phase of crops) [20,21].

Meanwhile, the river as the source of water holds an important role in metabolism for species. Despite the fact that the adaptation level of species to the availability of water might vary, the existence of water source becomes often essential for wildlife [3,18]. As the result, the nearest location to a river, has been assumed to be the lowest cost and vice versa.

The other variables which less were distance to settlements, distance to paths, main road and slope. The fertile soils surrounding Gunung Merapi [22] and Gunung Merbabu NPs have driven people to plant several commodities such as vegetables and live nearby their cultivated areas. Moreover, as the derivative effect, new paths and settlement areas emerged and were expanding over the time. Subsequently, the area of the NPs became oppressed by the existence and expansion of cultivated areas [23]. In some extent, where the main road intersected habitats, roadway underpass will become an alternative channel in a corridor model [13,24]. Furthermore, when looking at slope as a variable, for leopard a steep slope is frequently used as shelter [25], but on the other hand it becomes an obstacle for other mammals like deer and wild boar. Accordingly, seven classes of slope [26] have been scored as high with increasing steepness.

Summarizing, least cost path tool can be regarded as the important model in defining a corridor. The selection of particular variables depends on the concept of the model. Different from the previous research about possible corridors for leopard [7], the predator-prey process within wildlife habitat model underlying the concept of a corridor for wildlife management in general has driven this analysis into a mechanism of predator-prey between a leopard and a barking deer. As an extensive diet for large carnivores like leopard [27,28,29], the barking deer can be found abundantly in the south-east part of Gunung Merbabu (private communication with forest guard and several villagers).

A comprehensive consideration pertaining the process of corridor design, the knowledge of geo-information should be involved inevitably as a fundamental element. Several conditions in developing an ecological connection are necessary to be applied by examining the correlated variables.

Figure 2. Least cost path result to connect the two National Parks over the spatial plan of the Boyolali District

Figure 3. The topography profile of least cost path
in geo-information point of view. The socio-ecological problems which usually emerge in a conservation activity need to be minimized [30]. In order to overcome the social problem such as human interferences upon the desire of a corridor design, which leads to habitat degradation, human-wildlife conflict, chemical contamination due to cultivation activities, and so on, the association among the different land use types can simply be addressed by geo-information.

As the principles of wildlife corridor design which listed that the corridor should have a minimum width of 304.8 meters and maintaining access to the natural open space with the use of roadway underpass [31], the local government of Boyolali District can possibly apply these conditions, when understanding its geophysical status, and considering least cost path analysis results to encourage a corridor design. In addition, as the rule of thumb that an effective corridor should minimize the property rights intersection [32], several endeavors supporting the model of ecological connection can be conducted not only by providing space (spatial area) but also by educating the communities adjacent the proposed corridor. After all, the collaborative conservation program amongst stakeholders which have been supported by a robust on geo-information based model is expected to create some conditions that allow humans and nature living sustainably by sharing a particular land in space and time.

6. REFERENCES


This contribution has been peer-reviewed