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Identifying Eco-corridor Location for Reconnecting Fragmented Forests Using Remote Sensing Techniques*

Ahn, Seung-mahn[1] and Kyoo-seock Lee[2]

[1] Asia Aero Survey Co. Ltd., [2] Dept. of Landscape Architecture, Sungkyunkwan University.

원격탐사기술을 이용한 절편화된 산림 연결 생태통로 위치 파악*

안승만[1] · 이규석[2]

[1] (주)아세아 항측 · [2] 성균관대학교 조경학과

ABSTRACT

산림의 절편화 및 마식은 단순한 녹지면적의 축소만이 아니라 야생동물의 이동통로 단절로 인한 서식지 축소 및 나아가서는 소멸을 초래한다. 이를 해결하고자 최근에는 생태통로를 조성하는 작업이 수행되고 있으며 이는 목표종의 선정 및 적절한 위치 선정을 필요로 한다. 본 연구에서는 대전광역시와 그 주변을 대상으로 지난 50년 동안 인간 활동에 의해 절편화된 녹지를 파악하고자 원격탐사(RS) 자료를 이용하였다. Landsat MSS(30m)나 TM(79m)과 같은 중저해상도 위성영상으로는 절편화를 야기하는 산림 절편화 및 마식 파악이 어려워 본 연구에서는 1954년에 취득된 항공사진들과 2000년에 취득된 KOMPSAT-1 EOC 영상 및 국립지리원에서 발행한 수치지도 및 수치토지이용도를 이용하여 1954년, 2000년 각각의 삼림분포도를 작성하였다. 현지 확인 및 수정과정을 거쳐 최종적으로 생성된 자료를 근거로 산림 절편화 및 마식의 정도를 정량적으로 기술 및 평가하였고 녹지(patch)의 크기와 현장 조사한 야생동물서식도를 바탕으로 생태통로의 위치를 도출하였다.

Key Words : *Forest fragmentation, Eco-corridor, Remote sensing.*

Ⅰ. INTRODUCTION

The land use in the metropolitan area has been changed rapidly due to the urban expansion in South Korea during the last half-century. As urban areas expand, they cause fragmentation of natural environments(Fleury and Brown, 1997). In many land transformation procedures, fragmentation causes shrinkage and the decrease in size of forests. These fragmentation and shrinkage effect all ecological patterns and processes, from genes to ecosystem functions(Forman, 1995). Ultimately it deteriorates

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the biodiversity of the region. So, a regional greenway network is proposed to reconnect fragmented landscape elements in an ecological way(김귀곤과 최준영, 1998, Bueno, 1995, Ministry of Environment in Korea, 1995). In order to complete this reconnection, it is necessary to identify the size and location of fragmentation and shrinkage, then to pinpoint the location of ecobridge(Labaree, 1992).

For identifying the fragmentation and shrinkage of forest, multitemporal remote sensing (RS) data combined with other geographical information system (GIS) data are used to delineate the areal changes, showing the impact and trend of the changes in green space and vegetation cover efficiently.

Therefore, the purpose of this study is as follows, First, to delineate forest fragmentation and shrinkage in the metropolitan area by using multitemporal high resolution remote sensing data, Second, to identify the eco-corridor location reconnecting fragmented forests, Ultimately the purpose of this study is to contribute to the restoration of urban green spaces.

Ⅱ. MATERIALS AND METHOD

1. Study area

The study area was Daejon metropolitan area located at the central part in South Korea. From 1970's the economy and population of the metropolitan area have grown rapidly mainly due to the relocation of government-supporting research institutes and some government agencies. Daejon covered 35.7㎢ area in 1949(Daejon Administration, 1989) and it now covers 540.1㎢. During this urban expansion period, barren land and agricultural field were changed into the urbanized land(Ahn et al., 2002). These urban growth patterns are visible throughout the region in satellite images.

2. Data used in this study

For remote sensing (RS) data, Korea Multi-Purpose Satellite-1 (KOMPSAT-1) Electro Optical Camera (EOC) images with 6.6m resolution and air photo images at 1 : 20,000 or 1 : 10,000 scale were used to enhance the accuracy of image interpretation

Table 1. RS data used in this study.

Data Source	Resolution	Date	Data Type
KOMPSAT-1 EOC	6.6m×6.6m	2000, 03, 01 2000, 03, 09 2000, 05, 08 2000, 10, 02 2000, 10, 27	Digital (6.6m±10%) 0.51 ~ 0.73㎛ CCD/Push-bloom 17㎞ swath (Processing Level : 1R)
Air photos	(1 : 10,000 or 1 : 20,000)	1954	Analogue/Digital

Table 2. Other thematic data used in this study.

Data Source	Scale	Date	Data type	Publisher
Topographic map	1 : 5,000	1999	Digital	Korea National Geography Institute
Land use map	1 : 25,000	2000	Digital	Korea Institute of Construction Technology
Land use map	1 : 25,000	1972	Analogue	Korea National Geography Institute
City planning map	1 : 25,000	1997	Analogue	Korea National Geography Institute
Wildlife habitat map	1 : 25,000	2002	Digital	Landscape Planning and GIS Lab Sungkyunkwan University

for identifying the forest fragmentation. For thematic data, 1 : 5,000 scale digital topographic maps were used to select ground control points (GCP's). 1 : 25,000 scale city planning map, and 1 : 25,000 scale land use maps were also used. Tables 1 and 2 show the RS data and other thematic data used in this study, respectively.

Wildlife habitat map was produced based on the field survey results. From 1999 December to 2002 January, the footprint and excrement of vertebrates concerned were checked in the field. They are wild-boars, Chinese water-deers, and racoons. Of these three species, wild-boar is a key species. Its habitats also contains Chinese water-deers, and raccoon habitats.

3. Method

Satellite images and air photos were geometrically corrected and then, multitemporal land use mapping were done. In terms of RS and GIS softwares, PCI (RS) and ArcView (GIS) were used in this study.

KOMPSAT-1 EOC panchromatic images taken on 1 March 2000, 3 March 2000, 8 May 2000, 2 October 2000, and 27 October 2000 were geometrically corrected by second order polynomial transformation and cubic convolution, and resampled into 6.0m resolution image. Hundreds of air photos in 1954 were scanned, and geometrically corrected by third order polynomial transformation and cubic convolution, and resampled into 2m resolution image.

Multitemporal data sets were used to detect and delineate forest distribution, fragmentation and shrinkage between date of imaging precisely. First, the forest distribution map in 2000 was extracted from visual interpretation of KOMPSAT-1 EOC image by referring to the land use maps published by Korea Institute of Construction Technology. However, several forests were omitted in the land use map because of different classification schemes. So, these omitted forests were corrected by visual interpretation of KOMPSAT-1 EOC images. Second, the forest distribution map in 1954 was made in the same way using air photos taken in 1954 (1 : 10,000 or 1 : 20,000). Forest distribution maps of each year were overlaid to calculate changed area(Ahn, 2001).

Using the wildlife habitat map and the forest distribution comparison map between 1954 and 2000, the eco-corridor location was identified. If habitat type is constant, area is the most important factor in patches concerned(Dramstad, 1996). It is based on major ecological values of large patches, which are water quality protection for aquifer, and habitat to sustain populations of patch interior species(Forman, 1995). In this study site, a wild boar is the key species in biological diversity.

Ⅲ. RESULTS AND DISCUSSION

Air photo images taken in 1954 provided useful information about the chronological change of forest fragmentation and shrinkage in Daejon metropolitan area during the last half-century (1954～2000). Figures 1 and 2 show the forest distribution map in 1954 and 2000 respectively. Tables 3 and 4 show the area of the corresponding number forest patch in 1954 and 2000 respectively. Table 5 shows the change of number and area of forests from 1954 to 2000. There were several large forests in the Daejon (except downtown) area in early 1950s. In 1954, there were two forests larger than 100㎢ in the study area as we can see in Tables 3 and 5. There were four forests whose area was 50-100㎢ and six forests whose area is 10-50 ㎢. There were 17 forests whose area is 1-10㎢, and 114 forests whose area is smaller than 1㎢. However, there were no forests larger than 100㎢ in 2000. There were three forests whose area is 50-100㎢, and 11 forests whose area is 10-50㎢. There were 62 forests whose area is 1-10㎢, and 637 forests whose area is smaller than 1㎢. It

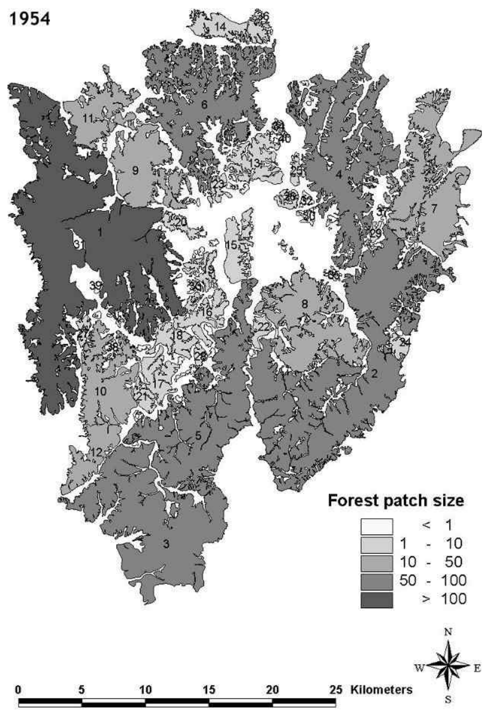

Figure 1. Forest distribution map in 1954.

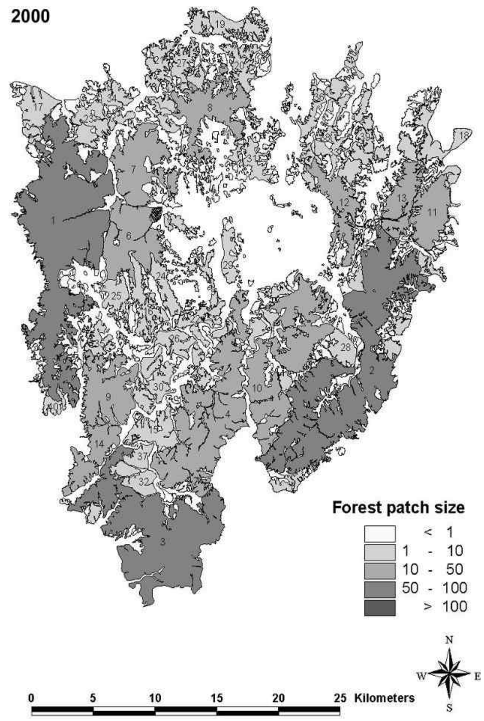

Figure 2. Forest distribution map in 2002.

means the large forests have been fragmented. As a result, the average size of the forest patch decreased and the number of patches increased after the fragmentation.

Table 3. Forest Distribution in 1954.

order	area(㎢)	forest size
1	144.6	> 100 ㎢
2	110.0	> 100 ㎢
3	71.2	50 - 100 ㎢
4	61.2	50 - 100 ㎢
5	60.3	50 - 100 ㎢
6	56.0	50 - 100 ㎢
7	43.9	10 - 50 ㎢
8	35.7	10 - 50 ㎢
9	24.0	10 - 50 ㎢
10	23.7	10 - 50 ㎢
11	16.5	10 - 50 ㎢
12	10.8	10 - 50 ㎢
13	9.7	1 - 10 ㎢
14	8.6	1 - 10 ㎢
15	8.4	1 - 10 ㎢
16	7.8	1 - 10 ㎢
17	6.5	1 - 10 ㎢
18	5.3	1 - 10 ㎢
19	3.5	1 - 10 ㎢
20	2.7	1 - 10 ㎢

Table 4. Forest Distribution in 2000.

order	area(㎢)	forest size
1	82.3	50 - 100 ㎢
2	76.8	50 - 100 ㎢
3	58.9	50 - 100 ㎢
4	46.2	10 - 50 ㎢
5	20.8	10 - 50 ㎢
6	20.6	10 - 50 ㎢
7	19.6	10 - 50 ㎢
8	19.0	10 - 50 ㎢
9	18.8	10 - 50 ㎢
10	16.2	10 - 50 ㎢
11	12.0	10 - 50 ㎢
12	11.5	10 - 50 ㎢
13	10.7	10 - 50 ㎢
14	10.5	10 - 50 ㎢
15	7.3	1 - 10 ㎢
16	7.3	1 - 10 ㎢
17	6.7	1 - 10 ㎢
18	6.3	1 - 10 ㎢
19	6.0	1 - 10 ㎢
20	5.4	1 - 10 ㎢

Table 5. Area and number of forests in 1954 and 2000.

	1954		2000	
	number	area (km^2)	number	area (km^2)
> 100	2	254.6	0	0.0
50 - 100	4	248.7	3	218.1
10 - 50	6	154.6	11	205.9
1 - 10	17	67.9	62	174.3
< 1	114	16.0	637	95.2
Sum	143	741.8	713	693.6*

* : rounding error.

Road construction was the main reason for forest fragmentation among human activities. The increase in road construction and urbanization between 1950s and 2000s explained most of the changes in forest number and size. Due to habitat fragmentation causes habitat shrinkage. As a result, their genetic diversity is decreased by inbreeding. The forest distribution map and the wildlife habitat map were used to pinpoint the location of eco-corridor for increasing the biodiversity for these species. Table 6 shows the fragmentation of the first three largest forests in 1954. The largest forest in 1954 was separated into 80 forests in 2000, the second one into 49 forests, the third one into 23 forests, respectively.

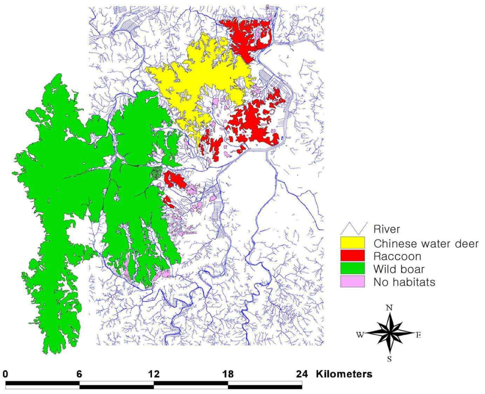

Figure 4. Wildlife habitat map of Yoosung-ku and Gyeryongsan N. P.

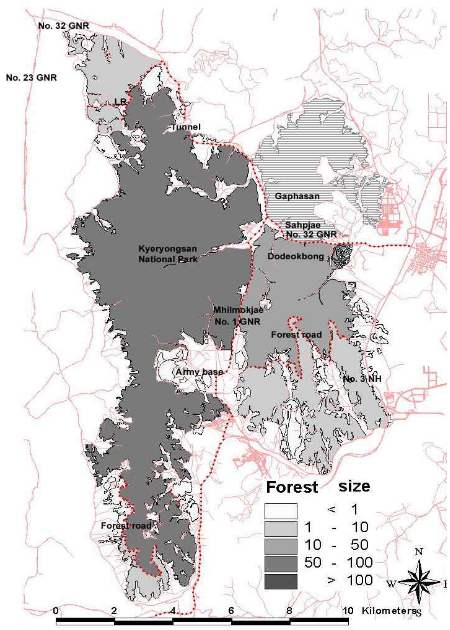

Figure 3. Fragmentation of Gyeryongsan forest in 2000(1st).

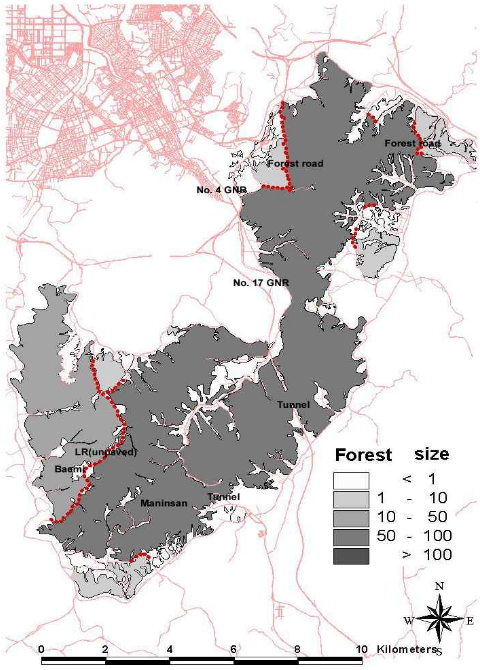

Figure 5. Fragmentation of Maninsan forest in 2000 (2nd).

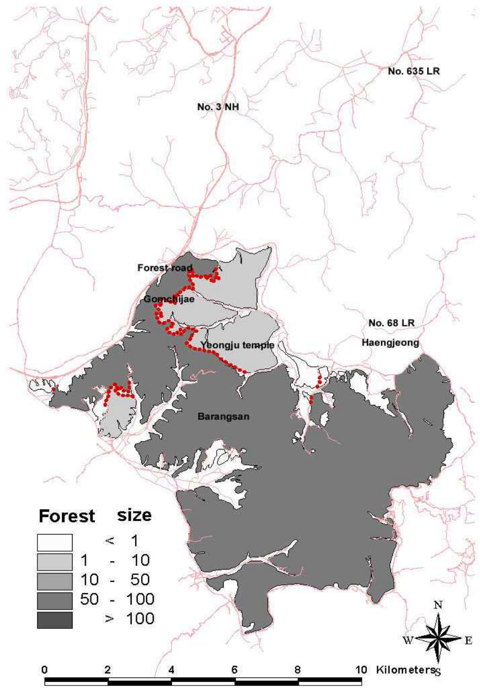

Figure 6. Fragmentation of Barangsan forest in 2000 (3rd).

Table 6. Fragmentation of the first three largest forests in 1954.

Forest size in 2000	Forest order in 1954					
	1st(144.6)		2nd(110.0)		3rd(71.2)	
	count	area (㎢)	count	area (㎢)	count	area (㎢)
50 - 100	1	82.3	1	76.8	1	58.9
10 - 50	1	20.6	1	16.2	0	0.0
1 - 10	6	26.7	5	8.5	4	7.5
< 1	72	11.0	42	5.7	18	2.0
Sum	80	140.5*	49	107.3*	23	70.4

( ) : forest size in 1954, * : rounding error.

Figure 3 shows the fragmentation of the first largest forest (144.6㎢) in 1954. It was divided into three major forest and other 77 forests in 2000. Forests smaller than 1㎢ covered 11.0㎢ (72 forests), forests from 1 to 10㎢ covered 26.7㎢ (six forests), forests from 10 to 50㎢ covered 20.6㎢ (one forest), and forests from 50 to 100㎢ covered 82.3㎢ (one forest). The serious fragmentation occurred at and due to the No. 1 and No. 3

Figure 4 shows the wildlife habitat map in Yoosung-ku and Gyeryongsan National Park. It includes the first largest forest in 1954(Figure 3). As we can see in Figure 4, wild-boar habitats is now fragmented into three habitats due to the general national road (GNR) construction as we can see in Figure 3. The road at Sahpjae fragments Dodeokbong area (20.6㎢) and Gahphasan area(19.6㎢) while the road at Mhilmokjae fragments Gyeryongsan area (82.3㎢) and Dodeokbong area (20.6㎢). Wild-boar is a key species in this study site. In this fragmented status, their genetic diversity would be decreased because of inbreeding. The road at Sahpjae was constructed during Japanese colonial period. The road at that time was unpaved and narrower and much less traffic volume compared with the present. So, there was no serious barrier for wild-boar crossing. In the present it is eight-lane paved road with continuous heavy traffic volume which makes it impossible for wild-boar to cross. So, eco-corridor should be reconstructed at Sahpjae in Gyeryongsan National Park as we can see in Figure 3. It would the first priority one in Daejon metropolitan area. The road at Mhilmokjae is less dangerous for wild-boar movement than that one at Sahpjae. However, due to the continuous increase of traffic volume, the eco-corridor needs to be constructed. These two eco-corridors will reconnect the three fragmented forests (82.3㎢, 20.6㎢, 19.6㎢) into 122.5㎢ of a single larger forest.

Figure 5 shows the fragmentation of the second largest forest (110.0㎢) in 1954. It was divided into 49 forests. The serious fragmentation occurred at Baemi due to the local (rural) road construction. It divided the Maninsan forest into two forests (76.8㎢, 16.2㎢). As a result, forests smaller than 1㎢ covered 5.7㎢ (42 forests), forests from 1 to 10㎢ covered 8.5㎢ (5 forests), forests from 10 to 50㎢ covered 16.2㎢ (one forest), and forests from 50 to

100㎢ covered 76.8㎢ (one forest). The eco-corridor in the second largest forest should be reconnected at Haengjeong. It will reconnect the two fragmented forests (58.9㎢, 46.2㎢) into 105.1㎢ of a single larger forest. Local road at Baemi is now narrow and unpaved. So, it does not affect wildlife fragmentation significantly. However, this road might be paved and widened. After all, it will fragment wildlife movement. Local road at Yeongju Buddhist Temple is narrow and unpaved. However, it is now widened and paved, then it would fragment the forest. So, these two site needs to be considered eco-corridor construction for avoiding fragmentation.

Figure 6 shows the fragmentation of the third largest forest (71.2㎢) in 1954. It was divided into 23 forests. The serious fragmentation occurred at Gomchijae due to the forest road and local road construction. It divided the Barangsan forest into two forests (58.9㎢, 3.5㎢). As a result, forests smaller than 1㎢ covered 2.0㎢ (18 forests). Forests from 1 to 10㎢ covered 7.5㎢ (4 forests), and forests from 50 to 100㎢ covered 58.9㎢ (one forest). The eco-corridor in the third largest forest should be reconnected at Baemi. It will reconnect the 93.1㎢ of two fragmented forests (76.8㎢, 16.2㎢) into a single larger forest.

In the study site, large forests were located outside urban area. Road construction affected the largest forest (1954) fragmentation. In addition, unpaved low traffic volume, and hilly topography affected the shape and width of roads in 1950s. Therefore, habitat fragmentation was not significantly affected by road construction. Wildlifes might be able to cross the roads. However, as existing roads were paved and widened, and levelled the slope of underlying hilly topography, wildlife movement were blocked. The 2nd (53.0㎢), 4th (38.3㎢), 5th (20.8㎢), 12th (11.5㎢), 13th (10.7㎢), 26th (5.2㎢), 57th (1.8㎢), 122th (0.6㎢) and 152th (0.4㎢) largest forests in 2000 were not fragmented because of tunnel constructions.

Forest (habitat) fragmentation by road construction should be reconnected by eco-corridor construction. The location of eco-corridor is very important for reconnection. In this study, three eco-corridor reconstruction sites were proposed based on fragmented patch size. Table 7 shows the proposed sites for eco-corridor reconstruction.

Table 7. Proposed sites for eco-corridor reconstruction.

Proposed order	Forest in 2000
1st (122.5㎢)	1st (82.3㎢), 6th (20.6㎢), and 7th (19.6㎢)
2nd (105.1㎢)	3rd (58.9㎢), and 4th (46.2㎢)
3rd (93.1㎢)*	2nd (76.8㎢), and 10th (16.2㎢)

* : rounding error.

Several forest fragmentation sites by road construction were not verified because they ware inaccessible in the military base located at Daedeok-ku and restricted forest roads.

The 1954 data in this study provides the landscape in Daejon Metropolitan Area before urbanization and road construction, which is very useful for figuring out the original landscape for the restoration.

Ⅴ. CONCLUSION

After identifying forest fragmentation and shrinkage caused by human activities during the last half-century in Daejon metropolitan area, South Korea. The eco-corridor construction sites were pinpointed by referring to the wildlife habitat map and the forest distribution map which are results of the multitemporal high resolution remote sensing data interpretation. The following conclusions were derived after doing this study.

First, the forests in Daejon metropolitan area decreased from 741.8㎢ in 1954 to 693.6㎢ in 2000, while the number of forest increased from 143 in 1954 to 713 in 2000.

Second, the largest forest area was 144.6㎢ in 1954. However, there were no such large forests in 2000. The largest forest area was 82.3㎢ in 2000. The number of forest larger than 50㎢ decreased from 6 in 1954 to 3 in 2000. The most serious fragmentation occurred due to the road construction.

Third, eco-corridors should be constructed at Mhilmokjae and Sahpjae in Gyeryongsan National Park. It will reconnect the 122.5㎢ of three fragmented forests (81.3㎢, 20.6㎢, 19.6㎢) into a single larger forest. The second eco-corridor should be reconnected at Haengjeong. It will reconnect the two fragmented forests (58.9㎢, 46.2㎢) into 105.1 ㎢ of a single larger forest. Then, the third eco-corridor should be reconnected at Baemi. It will reconnect the two fragmented forests (76.8㎢, 16.2 ㎢) into 93.1㎢ of a single larger forest.

This study is the identification of eco-corridor location mainly based on forest distribution map and key species habitat information. Beyond this information the ecological characteristics of the forest needs to be studied furthermore. Furthermore, the type of the appropriate eco-corridor needs to be studied and designed in the future study.

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