F-4.2 Studies on the Application of GIS for Evaluation of Biodiversity

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Total Budget for FY1996-1998 29,423,000 Yen (FY1998; 9,279,000 Yen)

Abstract

In this study, two study areas, Taman Negara area in Malaysia and Mengyang area in Xishuangbanna, China, were investigated for application of GIS to preserve biodiversity. Ecological data and several environmental factors (topography, landuse, etc.) for wildlife was collected. Potential habitat for wildlife was evaluated and estimated by GIS analysis of collected data.

In Taman Negara area, database of habitats of many kinds of wildlife was constructed by observation data. DEM was made from topographic maps for analysis of topography. The distribution of altitude, slope gradient and relief were obtained by DEM analysis in the area. Data of Asian elephants were used for the analysis of the relation between their habitats and topographic conditions, and distance from river in GIS. According to the results of the analysis, the distribution of the habitats of Asian elephants was estimated in GIS.

In Mengyang area, database of digital geographic information such as administrative district, elephant distribution, topography, river, vegetation and landuse were made by using the data of joint researchers in China. The relations between habitats of Asian elephants and the environmental conditions were analyzed, and their favorite conditions of habitats were clarified by using GIS.

Key Words Wildlife, Habitat, GIS (Geographic Information System), Biodiversity

1. Introduction

Habitats of precious wildlife are under the influence of human disturbance lately. In order to preserve biodiversity and to develop evaluation method of reserve area, the geographic conditions of habitats for wild life [1), 2), 3), 4)] were analyzed by using GIS. In this study, the topographic conditions of habitats were clarified and potential habitat of wildlife were estimated in GIS at two reserve areas in Southeast Asia.

2. Research Objective

In order to establish appropriate reserve area, environmental conditions of habitats for wildlife, influence of human activity and distribution of potential habitat have to be estimated by various kinds of geographic information. In this study, geographic information such as digital map data, natural and social environmental data, and remote sensing data of study areas were collected in GIS. Environmental conditions of habitats for wildlife are analyzed, and potential habitat of wildlife is estimated by using GIS. Furthermore GIS application for evaluation and establishment of reserve area are studied.

3. Research Method

(1) Taman Negara area (Figure 1)

A. Collection of data

a) Digital map data

Contours, rivers and other features on maps were digitized. DEM (Digital Elevation Model) was constructed from contour data.

b) Wildlife data

Database of habitats of many kinds of wildlife were constructed with the results of field survey executed by Japan Wildlife Research Center.

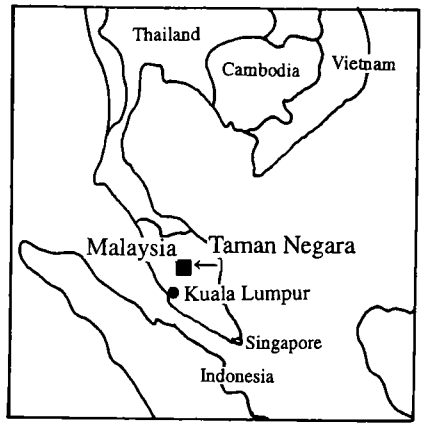

Figure 1 Location of Taman Negara Area

B. Data analysis

a) Study areas

Whole Taman Negara area (4343km^2), Area-1 (3600km^2), and Area-2 (92km^2) were selected. Area-1 extends over in and out of Taman Negara National Park. Area-2 is located near the western border of the Taman Negara National Park.

b) Methods

Topographic conditions were analyzed with DEM of study areas.

Relations between elephant dung distribution and topographic conditions, and relations between its distribution and distance from river were analyzed in GIS on Area-2, to estimate habitats of elephants.

(2) Mengyang area (Figure 2) (This investigation was done in collaboration with the Institute of Ecology and Geobotany, Yunnan University.)

A. Collection of data

a) Digital map data

Digital data of topographic map, vegetation map, land use map, elephant distribution map, village distribution map and other maps were collected.

b) Wildlife data

Data about elephants and vegetation types were collected in four times of field surveys conducted in 1997 and 1998. The locations of the traces of elephants were recorded by GPS.

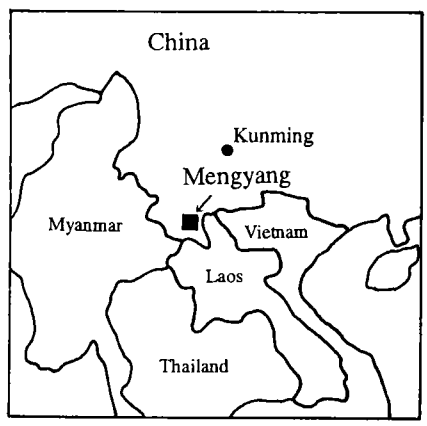

Figure 2 Location of Mengyang Area

B. Data analysis

a) Study area

The study area (approximately 5600km^2) is the area with latitude 22°00' to 22°30' and longitude 100°30' to 101°30' including the reserve area.

b) Methods

The relations between the locations of the traces of elephants and geographic conditions of vegetation types, altitude, distances from villages, and distances from rivers were analyzed by chi-square test.

1) In the computer, the region of Mengyang area was divided into many squares of one square kilometer.

2) The squares in which the survey courses passed were counted as the whole sample area analyzed.

3) The number of squares where elephant traces found was counted in GIS.

4) Major type of vegetation was treated as representing each square.

5) The percentage of various kinds of vegetation in the sample area was calculated.

6) By the percentages and the whole value of the squares in which elephants traces were found, the expected values in various kinds of vegetation were got, supposing there was no choice for elephants to vegetation (null hypothesis H_0).

7) Chi-square was used to evaluate the differences between actual and expected values.

8) If the χ^2-value is larger than the value corresponding to a significance level (α=0.05), we will refuse the H_0, and think that elephants do choose some kinds of habitat, and if it is less than the value, then we cannot think so.

4. Results and Discussion (Taman Negara area)

(1) Topographic analysis

Topographic features of the study areas were analyzed to understand habitats of wildlife.

High altitude areas of more than or equal to 1000m account for 5%, low altitude areas less than 400m account for 70% in Taman Negara area.

Topographic analyses were executed with DEM (100m-mesh) on Area-1. There is a high mountain area of more than or equal to 2000m in the east, and a low mountain area less than 1000m in the west. Low altitude areas between 100m and 300m are widely distributed between the two mountains. The eastern mountain has approximately 30 degrees, the western mountain has approximately 20 degrees, and other low areas have less than 8 degrees of slope gradient (Figure 3). Low slope gradient areas less than 4 degrees account for 40% outside the reserve area and 17% in the reserve area.

Topographic analysis was executed on Area-2. A northeast mountain area in Area-2 is more than or equal to 900m, and a southwest low altitude area is less than 250m of altitude. The low area accounts for 70%. The mountain area is 20 degrees and over, and the low area is less than 8 degrees of slope gradient. Steep slope areas with 8 degrees to 20 degrees of slope gradient exist in the low area where areas less than 8 degrees are widely distributed. It seems that these steep slope areas are boundaries between two

different landforms.

Topographic analyses, concerning slope direction and relief were also executed on Area-1 and Area-2.

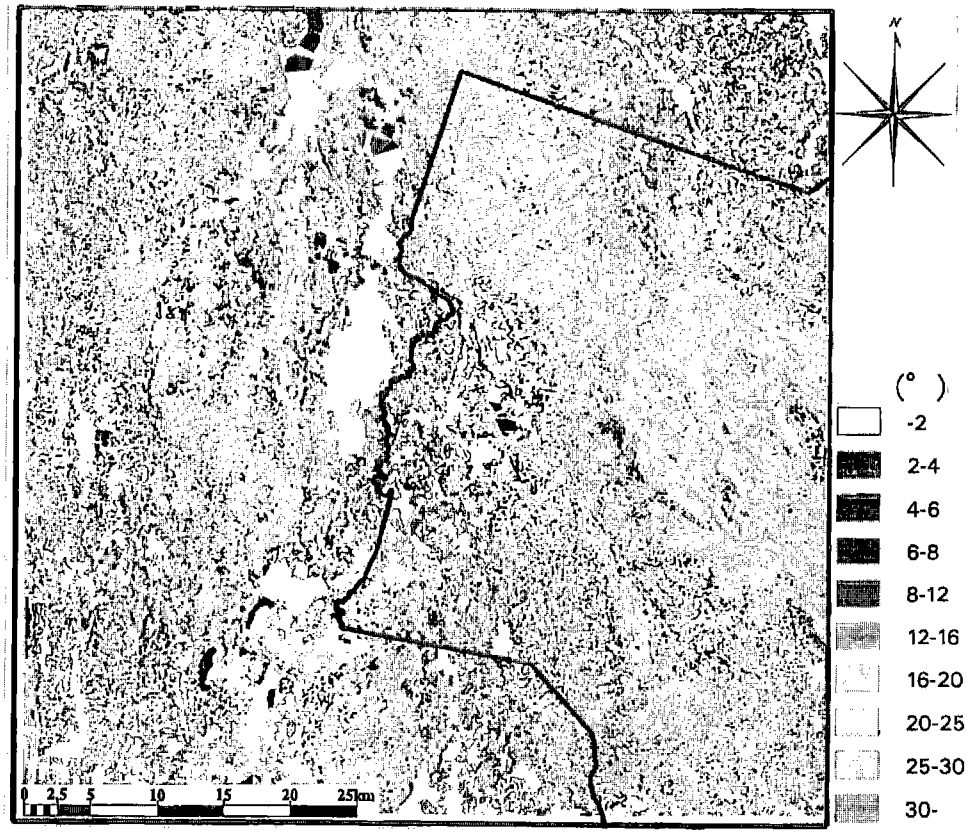

Figure 3 Slope Gradient Map of Area-1

(2) Analysis of wildlife data

Database of twenty-one kinds of wildlife, namely Elephant, Seladang, Tapir, Sambar deer, Gibbon, Wild dog, Wild boar, Fin foot, Small-clawed otter, Tiger, Rhinoceros, Serow, Bear, Siamang, Panther, Barking deer, Mouce deer, Smooth Otter, Argus pheasant, Wild cat, and Slow loris, were constructed in Taman Negara area. Distribution maps of wildlife were made.

(3) Analysis of elephant dung distribution

A. Elephant dung distribution on a jeep track

Habitats of elephants were estimated with the data of elephant dung distribution. Elephant dung was observed on a jeep track (its length is 13 km) in Area-2 in March and July 1998. The track is paved with asphalt and is extended to the southeastward from the western part of Area-2. The twenty-six sections (A-Z) of survey were executed on the track. Each section is 500m long. One block of dung within a radius of one meter of a circle was counted one unit. The quantity of dung is summed up in each section.

Figure 4 shows the quantity of elephant dung of March and July. The amount of the elephant dung of July is smaller than the amount of March, and the distribution of the dung of July is just like March's.

B. Relation between distribution of elephant dung and topographic condition

Topographic conditions of altitude and slope gradient for elephant habitats were analyzed by overlay in GIS. DEM (90m-mesh) was used for the analysis of topographic conditions, and the conditions of the

starting point and the last point in a section were measured in Arc/View software of GIS. Because we considered that the change of topographic condition is smooth through the track, mean value of the starting point and the last point in a section was used as a topographic condition of the section.

Twenty meters interval of altitude class and two degrees interval of slope gradient class were used. Quantity of elephant dung in each class was calculated. In Figure 4 are shown the total quantity of dung in a class (observation value), mean value calculated by the observation value and the number of sections in a class, and expectation value (Figure 5 and 6) that was calculated with all the quantity of dung and all the number of sections, supposing there was no choice for elephants to topographic conditions.

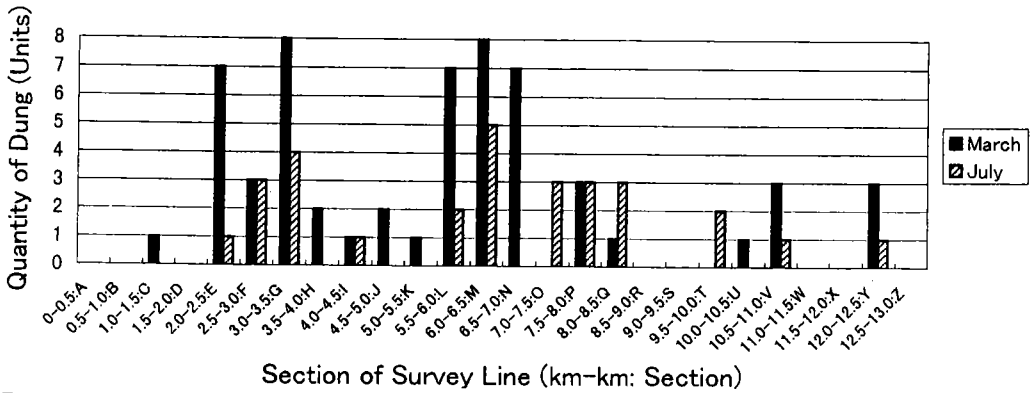

Figure 4 Quantity of Elephant Dung in each Section for Observation

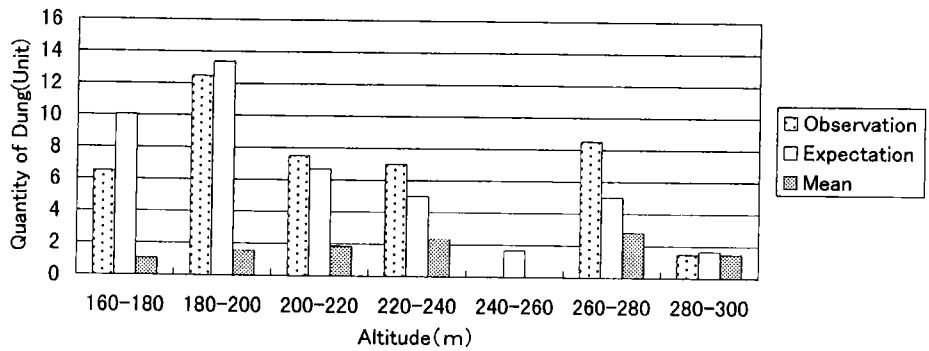

Figure 5 Relation between Distribution of Elephant Dung and Altitude Classes

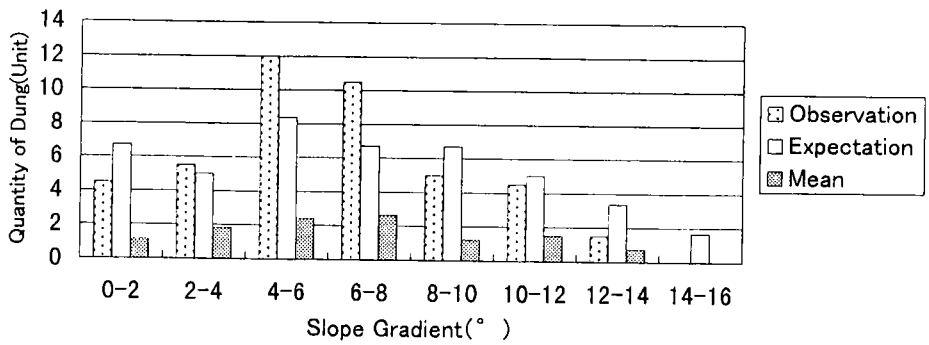

Figure 6 Relation between Distribution of Elephant Dung and Slope Gradient Classes

The value of the 180-200m (more than or equal to 180m and less than 200m; The same meaning applies in the following) class has the maximum in the observation value and in the expectation value. The mean value has the maximum in the 260-280m class. Chi-square test was used to evaluate the differences between observation values and expectation values. As a result, the chi-square value of 6.28

was obtained, which is smaller than the value (α =0.05) of 12.592, and a hypothesis that elephants have no choice of classes of altitude was not refused. But it can be seen that the observation values are larger than the expectation values in the 200-220m, 220-240m and 260-280m classes in Fig.5. Then we tried to analyze the relationship between habitats and topography by assuming that elephants prefer these altitude classes to others.

As for slope gradient, the value of the 4-6 degrees (more than or equal to 4 degrees and less than 6 degrees; The same meaning applies in the following) class has the maximum in the observation value and in the expectation value. The mean value has the maximum in the 6-8 degrees class. Chi-square test was carried out to evaluate the differences between observation values and expectation values. As a result, the chi-square value of 7.68 was obtained, which is smaller than the value (α =0.05) of 14.067, and a hypothesis that elephants have no choice of classes of slope gradient was not refused. But it can be seen that the observation values are larger than the expectation values in the 2-4 degrees, 4-6 degrees and 6-8 degrees classes in Fig.6. Therefore we tried topographic condition analysis of elephant habitat using altitude and slope data.

(4) Estimation of elephant habitats from topographic conditions

The twenty-six sections were classified into three groups, namely rich section, middle section and poor section in the elephant dung, from the mean values of dung of March and July. The rich sections with more than or equal to 3 units are F, P, N, E, L, G and M, the middle sections with 0 to 2.5 units are C, K, U, H, I, J, T, O, Q, V and Y, and the poor sections with 0 unit are A, B, D, R, S, W, X and Z. These three groups are classified considering that each group has nearly the same number of sections. Topographic conditions corresponding to these classified sections were extracted as shown in Table 1. The areas in Area-2 were classified by assigning points to each DEM cells as described below.

Table 1 shows the topographic conditions of the groups. Two points were given to the area of the rich section, one point was given to the area of the middle section and zero point was given to the area of the poor section. Regression analysis was carried out to calculate weights of altitude point and slope gradient point to explain the number of dungs of each section. As the result, weight of altitude is 1.07, weight of slope gradient is 1.28 and constant is –2.47. Topographic conditions expressed in points and multiplied by the weights were overlaid and the constant was added (Figure 7). Fig. 7 is an estimated distribution map of elephant dung or shows indirectly estimated potential habitats distribution. The area under 0 unit is seen in the northeast mountain area, area with more than or equal to 2 units and less than 3 units in the southwest low area. The quantities of elephant dung in border area between the mountain area and the low area vary from 0 unit to 3 units.

Table 1 Relation between the Quantity of Dung and Topographic Condition

Sections	Altitude(m) a : altitude 90m mesh	Slope(°) s : slope 90m mesh
Rich	170≦a＜280	1.3≦s＜11.1
Middle	280≦a＜281	11.1≦s＜13.6
Poor or Unknown	a＜170 281≦a	s＜1.3 13.6≦s

Stereoscopy of aerial photographs lets us clearly interpret vegetation, soil, hydrologic condition, and so on. Aerial photographs of Area-2 could not be obtained. Therefore we employed Landsat TM image

as a substitute for aerial photograph. Landforms of Dissected Valley, Mountain Slope, High Hill, Low Hill, and Lowland were classified with Landsat TM images with parallax generated from DEM in Area-2 (Figure 8). Dissected Valley and Mountain Slope are distributed at the northeast mountain area, and

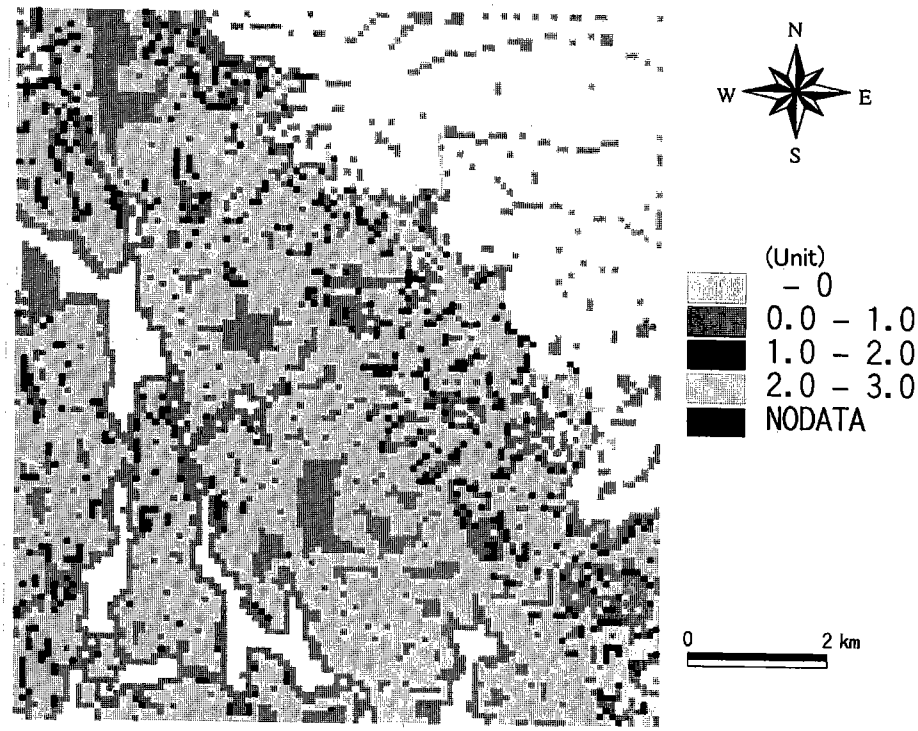

Figure 7 Estimated Distribution of Elephant Dung by Topographic Condition

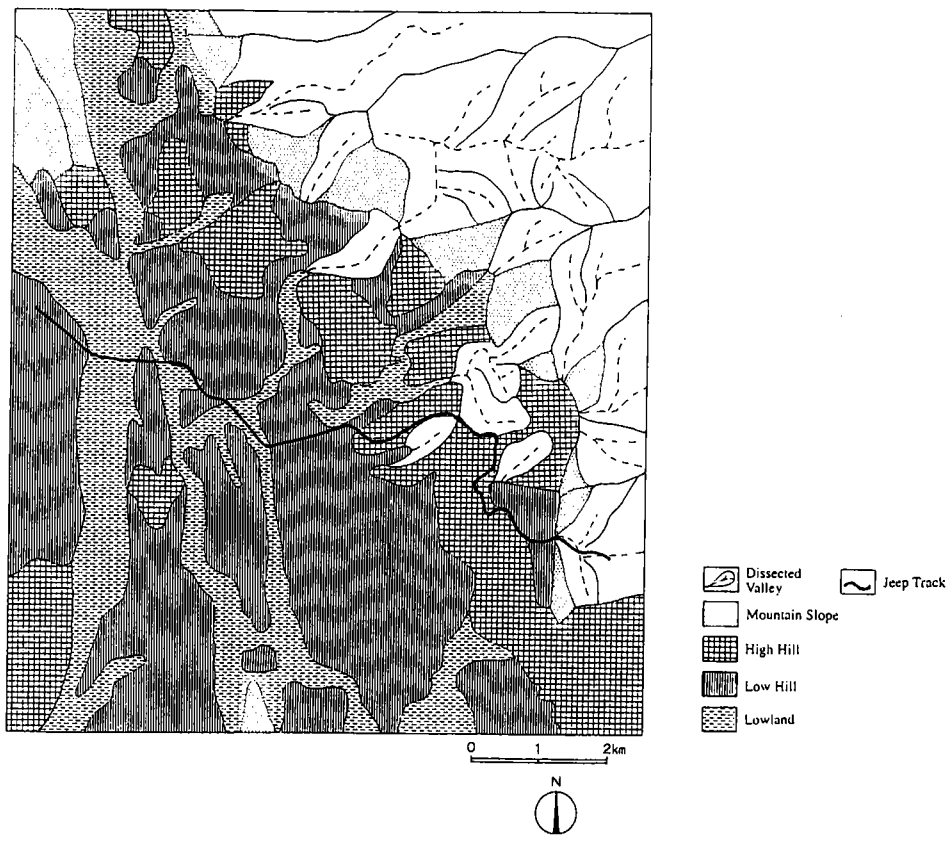

Figure 8 Geomorphologic Map of Area-2

High Hill, Low Hill, and Lowland are distributed at southwest low area. The comparison of distribution of landforms in Fig. 8 with Fig. 7 lets us easy understand that the area with under 0 unit distributes in Dissected Valley, Mountain Slope and Lowland, with more than or equal to 2 units and less than 3 units in Low Hill. The quantities of elephant dung in High Hill vary from 0 unit to 3 units. As the result, the estimated distribution of elephant dung by topographic analysis with DEM has given similar result to the distribution of geomorphologic landforms.

The relation between elephant dung distribution and distance from river was also analyzed with buffering analysis of GIS.

5. Results and Discussion (Mengyang area)

(1) Summary of the investigation

Geographic information (altitude, river, vegetation types, land use, and so on) on maps of Mengyang area were digitized by the Arc/Info and Arc/View software of GIS. According to the previous research, there are about twenty groups, 120-140 elephants in this area. Langcan River (Upper reaches of Mekong River) is the west boundary of the elephant distribution. In north and west the distribution of the elephant is inside the boundary of Mengyang area, and in east the boundary is far beyond the reserve area's boundary.

Elephant Distribution Map (Figure 9), Vegetation Map (Figure 10) are shown, for example.

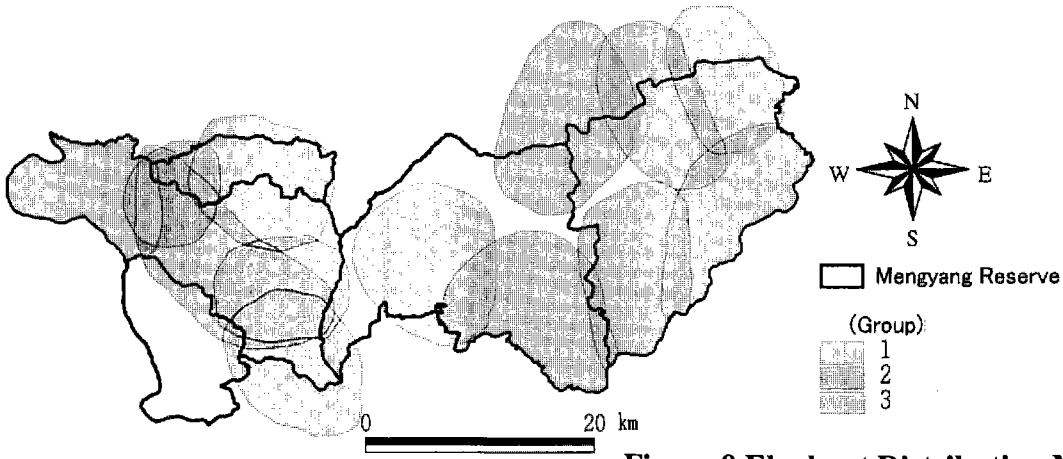

Figure 9 Elephant Distribution Map

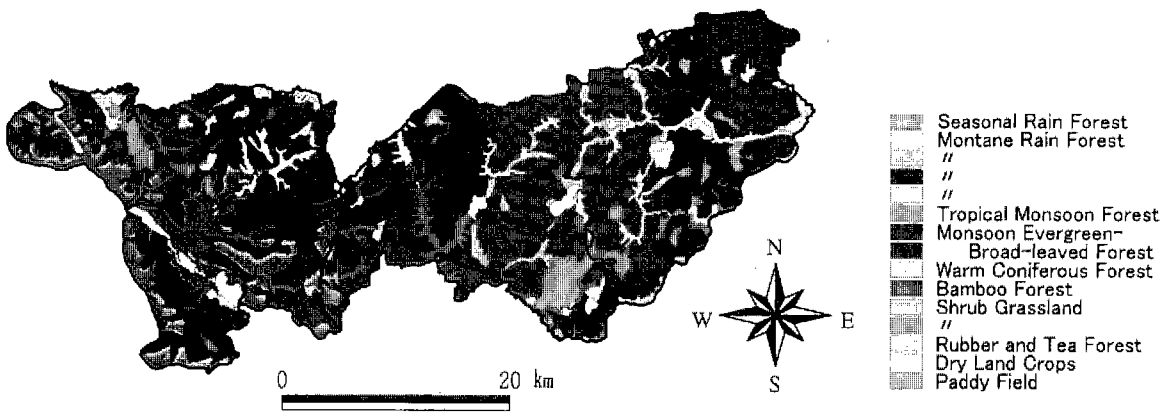

Figure 10 Vegetation Map

(2) Results of the analysis of habitat

A. Relation between elephant and vegetation

The result shows elephants do not show any choice in vegetation of vegetation map. If the vegetation data collected in field survey are used in analysis, elephants seem to choose evergreen broad-leaved forest the most and the farmland the least (Table 2). The result shows a little different from the observation of local people that rain forest is the most favorite vegetation for elephants.

B. Relation between elephant and altitude

In the area, the altitude ranges from 600m to 2300m above the sea level. The result shows elephants favor to visit the habitats of altitude 800-1200m (Table 3). If the classes of altitude are divided into more detailed classes, there is no obvious difference between actual and expected values (Table 4).

Table 2 Vegetation Types chosen by Elephants (Data of Field Survey)

(Unit: km*)

Vegetation Type	All.	Tra.	Exp.	Sta.
Rain forest	64.4	40	42.25	0.120
Evergreen broad-leaved forest	134.1	125	88.00	15.557
Broad-leaved mixed bamboo forest	33.3	24	21.86	0.209
Shrub grassland	49.8	25	32.68	1.805
Cropland	47.6	2	31.23	27.358
All	329.2	216	216.02	45.064

* All.- Sta. : The same as table 2. Vegetation data gathered in the field survey. * Unit : Length of the sample lines.
χ^2=45.064>9.488(α =0.05)

Table 3 Altitudes of Habitat used by Elephant

(Unit: km^2)

Above the sea level(m)	All.	Tra.	Exp.	Sta.
H≦800	65.97	13.79	23.69	4.137
800<H≦1200	122.45	54.53	43.96	2.542
1200<H	12.06	3.65	4.33	0.107
In all	200.48	71.97	71.98	6.786

* All.- Sta. : The same as table 2.
χ^2=6.786>5.991(α =0.05)

Table 4 Altitudes of Habitat used by Elephant (Detailed Class of Altitude)

(Unit: km^2)

Above the sea level(m)	All.	Tra.	Exp.	Sta.
H≦500	1.65	0.4	0.59	0.061
500<H≦600	9.86	1.2	3.54	1.547
600<H≦700	21.28	3.38	7.64	2.375
700<H≦800	33.18	8.81	11.91	0.807
800<H≦900	36.82	13.69	13.22	0.017
900<H≦1000	32.55	13.29	11.69	0.219
1000<H≦1100	31.65	17.01	11.36	2.810
1100<H≦1200	21.43	10.54	7.69	1.056
1200<H≦1300	9.68	3.33	3.48	0.006
1300<H≦1400	2.12	0.32	0.76	0.255
1400<H≦1500	0.25	0	0.09	0.090
1500<H	0.01	0	0.00	-
In all	200.48	71.97	71.97	9.243

* All.- Sta. : The same as table 2.
χ^2=9.243<19.675(α =0.05)

C. Relation between elephant and village

The distance between elephant traces and villages was measured in GIS to evaluate the disturbance by human to elephant. The result shows only the areas very near to villages (less than 500 meters) are not

frequently visited by elephant. Although it is usually thought elephants avoid visiting the areas that are close to villages except during the period of crop harvest, elephants do visit those areas only a little less than expected. Elephants seem to know that elephant is one of the most important protected animals, and usually do not avoid people when they come across people in recent years. The disturbance is now from elephants to the local farmers by ruining crops.

D. Relation between elephant and river

The distance between elephant traces and its nearest river were measured in GIS as an index to evaluate river availability for elephants. Even in dry season, the water supply for the elephant in the area is not a problem, so it could be understood that there is no clear relationship between rivers and habitats elephants choose. In the area, no point could be found which is apart from a river longer than 10km. And 10 km is not a long distance for the elephant.

6. Conclusion

(1) Taman Negara area

DEM and Database of habitats of many kinds of wildlife were constructed on Taman Negara area. And investigation on GIS application to estimate habitats of wildlife was done.

The overlay analysis of GIS selected the potential habitats for elephants where the both conditions of altitude and slope gradient meet. As the result of the overlay, it seems that the distribution of elephant dung estimated with DEM is similar to the distribution of geomorphologic landforms.

Distribution of elephant dung from river was estimated with buffering analysis of GIS.

(2) Mengyang area

The relationships between the elephant distribution and the habitats, and geographic conditions for elephant are clarified by GIS.

Elephants seem to choose evergreen broad-leaved forest the most and the farmland the least. Elephants favor to visit the habitats of altitude 800-1200m. There is no clear relationship between villages and habitats of elephants, rivers and habitats of elephants.

Reference

1) Herr, A. M. and L. P. Queen (1993): Crane Habitat Evaluation Using GSI and Remote Sensing. *Photogrammetric Engineering & Remote Sensing*, **59**, 1531-1538.

2) Butterfield, B. R., B. Csuti and J. M. Scott (1994): Modeling vertebrate distributions for Gap Analysis. *Mapping the Diversity of Nature,* 53-68. Chapman & Hall, London.

3) Murakami, H. and K. Hirata (1996): Potential nesting site analysis of red-crowned cranes using GIS. *International Archieves of Photogrammetry and Remote Sensing*, **XXXI, B4**, 575-580.

4) Masaharu, H and T. Kuroki (1998) : Geographic Information Analysis for Planning and Evaluation of Wildlife Reserve - Case Study of Taman Negara National Park, Malaysia -. Chiri-joho-shisutemu-gakkai koen-ronbunshu, **7**, 309-312.