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Stand-alone GIS Application for Habitat Suitability (Case Study: Javan Gibbon, Gunung Salak, West Java)

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Abstract

Information which constitutes of wildlife distribution and habitat suitability map is important for conservation area management. A standalone Geographic Information System (GIS) application is proposed to fill the gap of urgency need of such information. The paper explains the application which is used to map species distribution based on field survey data and construct habitat suitability map based on presence data (species distribution) and spatial properties (ecogeographical variables) which extracted from certain habitat factors that determined by user. The application is equipped by basic geoprocessing function including point buffering and polygon dissolve. The application was tested to produce habitat suitability of javan gibbon in Mt. Salak and it showed a good performance.

The habitat suitability was constructed based ten ecogeographical variables namely the area of primary forest, secondary forest, low-land forest submontane forest. It contains slope 0-15%, slope 15-45% and slope more than 45%; distance to non-forested land; distance to river / water body and distance to road/tracks. The result shows that Mt. Salak consists 13.20% (17.53 km²), 26.25% (34.86 km²), 19.40% (25.77 km²), 4.16% (5.53 km²), and 20.17% (26.78 km²) of high-suitable, suitable, moderate suitable, less and low suitable level subsequently, and 12.69 km² or 9.56% for not suitable of javan gibbon habitat, from the total area 13278.34 ha.

Keywords: GIS, wildlife, habitat suitability, javan gibbon, Mt. Salak

1. Introduction

One well-known approach to conserve the remaining land on the earth, especially of that containing high biodiversity is through the conservation area establishment (Primack *et al.*, 1998). Wildlife information, constitutes of habitat and population aspects, is often used as standard criteria to select the certain land to be assigned as conservation areas. Every park in Indonesia has to complementarily acquire this framework for determining management zonation (Republik Indonesia, 1998).

A synthesis on wildlife-habitat relationship knowledge, multivariate habitat analysis, with wildlife mapping techniques (which primarily done with certain GIS software) is very promising method to produce efficient wildlife information in which providing a consistent basis for impact assessment, mitigation, baseline, conservation and monitoring studies (Morrison *et al.*, 1992). In contrast, case studies concerning to this synthesis still have been rarely done in Indonesia. The need of it is obvious considering that Indonesia has a lot of protected areas, and therefore, developing such GIS application which carrying the wildlife-habitat relationship could be useful to support designing park zones and management plan spatially.

As a case study, the habitat of javan gibbon (*Hylobates moloch*) in Gunung (Mt.) Salak is assessed and used for the test case of developed GIS application. The conservation status of javan gibbon is critically endangered (Eudey and MPSG2000, 2004) that will extinct in the immediate times. An urgent action is required to inhibit extinction process and promote its survivalness. Reintroduction was arising for one option and hence need assessment to the relatively large habitat such as Mt. Salak (Supriatna *et al.*, 1994; LIPI *et al.*, 2003).

The objective of the paper is to explain the development of standalone GIS application namely SUTTSTAT for generating predictive information on wildlife habitat suitability. It begins with the brief spatial perspective and analysis on wildlife habitat followed by the feature of the system and case study.

2. Spatial Perspective and Analysis on Wildlife Habitat Suitability

2.1. Spatial Perspectives and Analysis

Habitat suitability shows the affordability of an area (a unit of land) indicated by the availability of resources and environmental conditions necessary for relatively successful species survival and reproduction. The affordability can be assessed by examined the relationship between the characteristic of a land (spatial properties or ecogeographical variables) with the species response. The characteristic of a land is numerous than the resources inside. Land resources can be represented either by raster or vector data type. Table 1 shows the example of spatial properties in relation with land resources.

Table 1. Spatial Properties, Resources and Data Representation

Spatial Properties	Resources / Spatial Features	Type
The area of forest	Forest Type	Polygon
The area of slope in certain	Slope	Polygon
The intensity of rainfall	Rainfall	Line/Polygon
The frequency of soil type	Soil	Polygon
The average of temperatures	Temperatures	Polygon
Distance to settlement	Settlement	Point/ Polygon
Distance to settlement	Open land	Polygon
Distance to non-forested area	Non-forested	Polygon
Distance to river	River	Line/ Polygon
The number of predator	Predator	Point
The number of competitor	Competitor	Point
The number of disturbances	Small disturbance	Point

Table 1 implicitly discriminates between spatial properties and their resources. By looking at those examples, it can be concluded that spatial properties is come after analyzing the land correspond to concerned resources. Several possible analyses are shown in the Table 2.

Table 2. Spatial Properties Analysis

Features Type	Analysis Type	Analysis Outcome
Point	Content Analysis	The existence of point
		The number of point
		The aggregation level of points
	Proximity Analysis	The attribute value of point
		The short distance value to a point
Line	Content Analysis	The attribute value of nearest point
		The length of line feature
		The number of segments
	Proximity Analysis	The attribute value of line feature
		The short distance value to a line
Polygon	Content Analysis	The attribute value of nearest line
		The area of polygon feature
		The number of polygon
	Proximity Analysis	The attribute value of line feature
		The short distance value to a polygon
		The attribute value of nearest polygon

2.2. Habitat Suitability Model

Habitat suitability can be defined as a function of spatial properties of certain area to species survival. There are so many algorithms have been developed to formulate habitat suitability model and to determine the response variable and estimating model coefficient (Guisan and Zimmermann, 2000). One of the simplest habitat suitability models is the model which follows decision-rules method.

Through this perspective, the application namely SUITSTAT was developed. The subsequent sections explain more the specification of SUITSTAT.

3. System Development

The application was developed by using Visual Basic 6.0 under Microsoft Windows XP Professional Edition. ESRI MapObjects 2.1 was installed as the main component to develop application with GIS function capabilities. ESRI ArcView 3.2 was used to prepare the data input. The hardware used to develop the application is desktop PC with specification: Processor Intel Pentium IV, 512MB RAM, and 64MB Graphic Card.

4. Features and Interface

In this section, the features and interface are described including the requirement of the data and some functionality. In general, Figure 1 shows the conceptual features of SUITSTAT.

4.1. Data

SUITSTAT could only process shapefile (.SHP) data format at the moment. The shapefile data are transformed into vector-based grid data format. Vector-based grid format is a spatial representation of a feature composing of regular cells which each cell actually a rectangular polygon. Each cell contains the whole spatial characteristic based on the considered spatial features. Through this format, raster-based model will be much easier to be done. The transformation of vector-based grid facility is provided in the system.

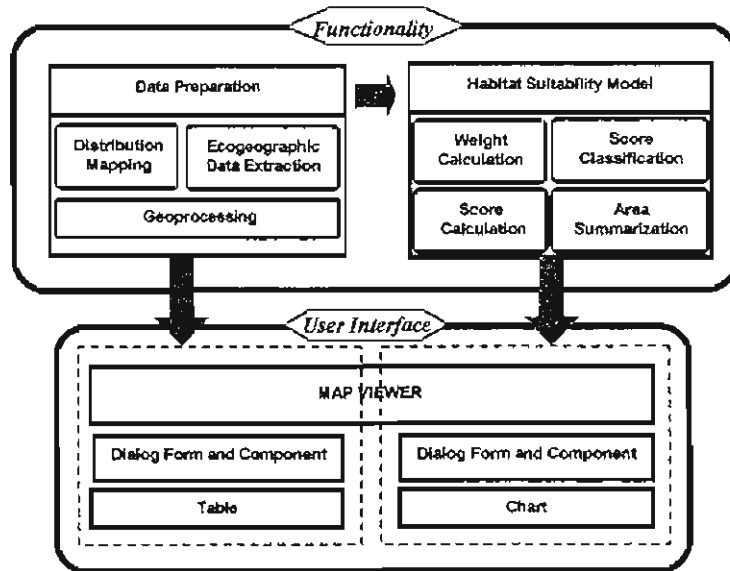


Figure 1. Major Functionalities of the SUITSTAT

4.2. Functionalities

As illustrated in Fig. 1, the system has two group of functionality, i.e.: data preparation utility and habitat suitability modeling. The brief description is given in the following subsections.

4.2.1. Data Preparation

The data related with wildlife habitat is always representing habitat resources, which already mentioned in the Table 1. However, SUITSTAT used vector-based grid format. It is provided with utility for extracting vector data into spatial properties of a grid. The result is a single dataset consisting of vector-based grids where each grid has its own spatial properties (spatial characteristic). The information written in the grid is spatial properties which determined by the user previously. The other utilities for data preparation are shown in the Figure 1. The interface of extraction utility is given by Fig. 2 and the example of result is given in the Fig. 3.

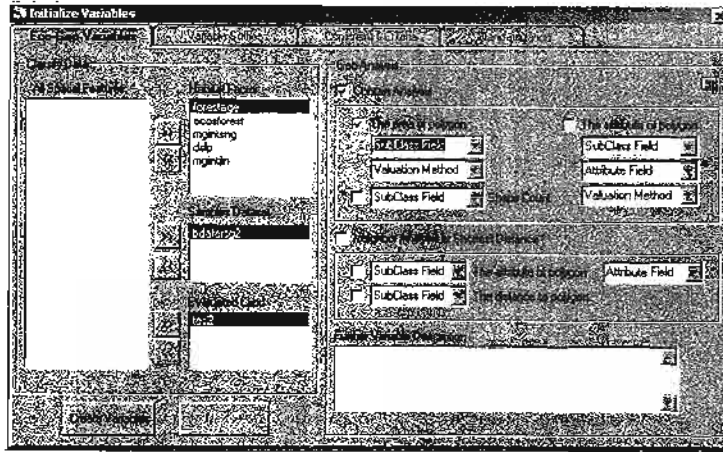


Figure 2. Spatial Properties Selector Interface and Result of Extraction.

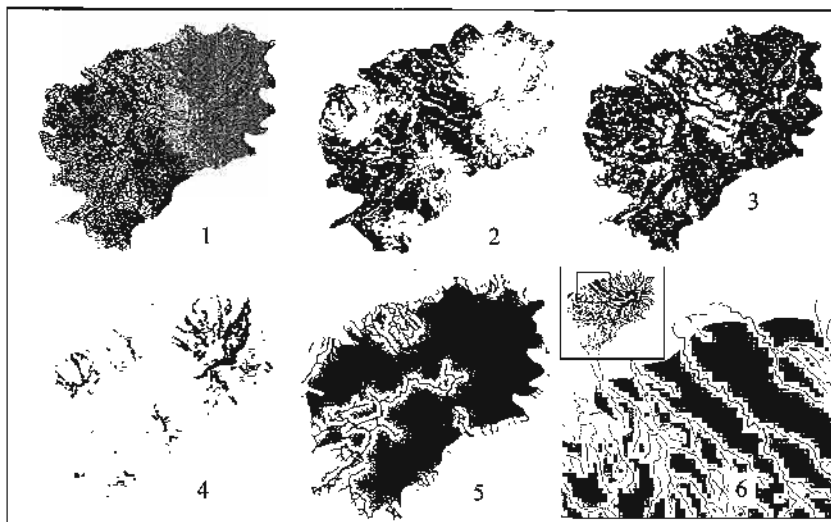


Figure 3. The Result Dataset after Spatial Properties Extraction.

4.2.2. Habitat Suitability Modeling

SUITSTAT provide function to calculate habitat suitability. The function adopts *Simple Additive Weighting (SAW)* method, the most utilized and the simplest one of GIS-based decision rules methods (Malczewski, 1999). The mathematical model used on *SAW* method is given in the equation below:

$$S = \sum_i^N w_i x_i$$

S : suitability score
 w : weight of i-th criterion
 x : the i-th criterion ($i=1, 2, \dots, N$)

The suitability level of each land unit, S , is the sum of its spatial properties or the sum of all standardized of N variable (x) multiplied by its weighted (w). The weight is calculated by using presence data. Presence data (acquired from wildlife distribution data) represents a certain area of which is occupied and exploited by wildlife and indicate their response to the environment (used as a proxy). Presence data is required to identify the level of importance of spatial properties. In order to do so, upon this presence data, spatial properties are examined and analyzed by *Principal Component Analysis (PCA)*. The value of loading factor and magnitude of each component of the

5.3. Result

The weight of each variable was further transformed into the range of value 0 – 1. The final weight calculation result can be seen in the Table 3. The weight of each variable given by the PCA shows the influence level to determine habitat suitability.

Table 3. Principal Component Loadings and Weight for Each Spatial Variable

Variable	PC I	PC II	Weight
HSE	0.244	-0.486	0.130(2)
HPRI	-0.180	0.522	0.140(1)
HDR	0.367	-0.254	0.098(4)
HGB	-0.345	0.297	0.093(6)
SL1	0.361	0.319	0.097(5)
SL2	-0.247	-0.303	0.081(7)
SL3	-0.361	-0.259	0.097(5)
RIV	-0.240	-0.110	0.065(8)
NONFOR	0.345	0.009	0.093(6)
JL	-0.394	-0.257	0.106(3)
Eigen values	3.780	2.40277	
Percent Variance (%)	37.80	24.03	
BrokenStickDistribution (%)	29.29	19.29	

Note:

- HPR=the area of primary forest; HSE=the area of secondary forest; HDR=the area of low-land forest; HGB=the area of submontane forest contained in; SL1=The area of slope 0-15%; SL2=The area of slope 15-45%; SL3=The area of slope > 45%; NFOR=distance to non-forested land; RIV=distance to river / water body; JL=distance to road/tracks;
- Bracket beside the weight value shows the rank

Based on the weight calculation, the suitability score is determined by the following formula:

$$S = 0.13X_1 + 0.14X_2 + 0.098X_3 + 0.093X_4 + 0.097X_5 + 0.081X_6 + 0.097X_7 + 0.065X_8 + 0.093X_9 + 0.106X_{10}$$

Where:

- | | |
|---|---|
| X_1 : the area of secondary forest; | X_6 : the area which has slope 15-45% |
| X_2 : the area of primary forest | X_7 : the area which has slope more than 45%; |
| X_3 : the area of low-land forest; | X_8 : distance to river / waterbody |
| X_4 : the area of submontane forest | X_9 : distance to non-forested land |
| X_5 : the area which has slope 0-15%; | X_{10} : distance to road/tracks |

The result of model shows that habitat with a low suitability shares fairly extent of whole area of Mt Salak. The largest portion of Mt Salak is dominated suitable, low suitable and moderate suitable respectively. Mostly the suitable and highly suitable habitat spread over the primary forest. In contrast, low suitable area is mainly situated over secondary forest. Specifically, from the figure in the Appendix 1 shows that Mt. Salak consists 13.20% (17.53 km²), 26.25% (34.86 km²), 19.40% (25.77 km²), 4.16% (5.53 km²), and 20.17% (26.78 km²) of high-suitable, suitable, moderate suitable, less and low suitable level subsequently, and 12.69 km² or 9.56% for not suitable of javan gibbon habitat, from the total area 13278.34 ha.

The distribution data was superimposed into the habitat suitability class map to know the condition of available gibbon distribution from field survey. Figure in Appendix 1 shows that from 29 gibbon identified groups, 3 and 9 groups are living in high suitable and suitable habitat respectively; 13 groups in moderate suitable, and for each less and low suitable habitat level is lived by 2 javan gibbon groups.

6. Conclusion

- 1). This paper already described GIS application system that used to produce habitat suitability information in vector-based grid format. It is supported by vector-based grid transformation, basic geo-processing tools, ecogeographical data generation, species distribution mapping, weight calculation based on presence species data, and suitability score calculation. Through SUITSTAT, the user is able to select spatial data which represents habitat factors, modify criteria and constraint, and calculate the score.
- 2). Based on habitat suitability model which grouped into 5 classes, Mt. Salak area is dominated by suitable class. The area with score more than the moderate suitable class covers 52.39 km² or 39.5% from total area 132.78 km².

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Appendix 1. Map of Javan Gibbon Habitat Suitability in Mt. Salak

