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Assessing habitat suitability for tiger (*Panthera tigris*) in Panna Tiger Reserve, Madhya Pradesh, India: a geospatial approach

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Abstract

Habitat loss is the major factor affecting the tiger population, so it is vital to identify and map the most suitable habitats to ensure more protection and for the conservation plans. A study was conducted to generate habitat suitability map for Panna Tiger Reserve, Madhya Pradesh, India, using spatial data and secondary field data, employing GIS Multi Criteria Analysis (MCA). The analysis revealed that large proportion of the area (71.7%) was found to be highly suitable followed by low suitable area (13.9%). The output map may be used to understand how the reintroduced tigers interacts with the landscape features and for developing future strategies for tiger conservation efforts in Panna Tiger Reserve.

Keywords : Tiger, Habitat Suitability, MCA, GIS, Wildlife.

INTRODUCTION

The tiger was ranked as one of the top ten endangered species by the Wildlife Conservation Society in 1994 and was listed as the first-rank protected animal in the world. In the recent years, habitat degradation and fragmentation, damage to ecosystems, food scarcity, geographical isolation and large scale human hunting have drastically reduced the habitat and number of tigers in the wild, leaving them now on the verge of extinction (Singh et al., 2009). Reintroductions has proved to be a valuable tool for the recovery of the species that has become either globally or locally extinct in the wild (Woodroffe and Ginsberg, 2002). Since the success rate of reintroduction is very less, it becomes highly imperative that reintroductions should be based on sound scientific principles and methodology. Habitat may be characterized by a description of the environmental features that are important for a species. Such descriptions are often based on field experience and non-quantifiable human perceptions (Burgman and Lindenmayer, 1998). Such information is also used to develop wildlife habitat models (Store and Kangas, 2001; Malczewski, 1999; **Hirzel** et al, 2006). Application of remote sensing and Geographic Information System (GIS) as tools has assumed an immense significance in habitat suitability assessment and are widely used in conservation biology and wildlife management. The use of satellite remote sensing and GIS is a cost effective and quicker way to generate habitat suitability maps (Kushwaha and Roy, 2002; Karanth et al, 2004). During the habitat suitability analysis, the need to use data from different sources and scales usually makes the task more complicated and leads to increased data volumes. Hence, the present paper deals with GIS based Multi Criteria Analysis (MCA) strategy to accomplish the task.

STUDY AREA

The Panna Tiger Reserve lies between 790 45′ E to 800 09′ E Longitude and 24^0 27′ N to 24^0 46′ N Latitude and is situated in the Vindhyan Range within the Biogeographic Province 6A Deccan Peninsula - Central Highlands (Rodgers *et al.*, 2002) and spreads over Panna and Chhatarpur districts in the northern part of the Madhya Pradesh, covering an area of 543 sq. km. The altitude of the reserve is 212 m to 538 m above M.S.L. There are six forest types here; (1) Southern Tropical Dry Deciduous Teak Mixed Forest, (2) Northern Tropical Dry Deciduous Mixed Forest, (3) Dry Deciduous Scrub Forest, (4) *Annogeissus pendula* Forest, (5) *Boswellia* Forest, and (6) Dry Bamboo Brakes. The Panna Tiger Reserve is classified as 'high-rainfall dry deciduous forest' and is largely dependent on monsoon rainfall during July - September, which usually fluctuates within the range of 1000mm. Following the monsoon, there is a cool season until February, followed by dry summer when the temperature often exceeds 45°C (Karanth et al., 2004). In total, there were 13 revenue village enclaves inside the park boundary, most of the village enclaves have been transformed into successional grasslands with scattered trees after translocation of these villages.

The Panna Tiger Reserve supports good population of Sloth Bear (*Melursus ursinus*). Other prominent carnivores are Leopard (*Panthera pardus*), Striped Hyena (*Hyaena hyaena*), Wild Dog (*Cuon alpinus*), Jungle Cat (*Felis chaus*) and Jackal (*Canis aureus*). The major ungulates that form prey for these carnivores are Sambar (*Cervus unicolor*), Chital (*Axis axis*), Nilgai (*Boselaphus tragocamelus*), Chinkara (*Gazella bennetti*),

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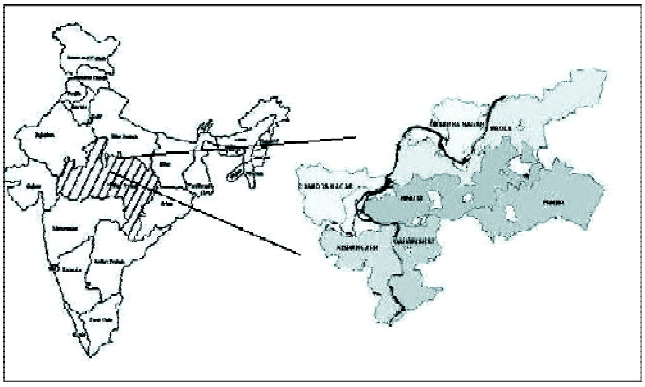
Four-Horned Antelope (*Tetraceros quadricornis*) and Wild Pig (*Sus scrofa*). The Common Langur (*Presbytis entellus*) is widespread, while Rhesus Macaque (*Macaca mullata*) is found only along the forest peripheries closer to human habitations. There are over 150 bird species in and over 105 species of Reptiles including Long Snouted Crocodile and Marsh Crocodile, and over 50 species of fishes including two globally threatened Masheer species.



METHODOLOGY

Habitat is a sum total of environmental condition of a specific place occupied by wildlife species or a population of such species (Singh *et al.,* 2009). The variables 'Habitat Factor' that affect the habitat suitability for individual species of animals vary from species to species. Some of these variables include (i) distance from human settlements, (ii) distance from waterbody, (iii) slope and elevation, (iv) prey availability, (v) vegetation type, (vi) forest density, (vii) regional ecosystem, and (viii) soil, etc. The evaluation procedure consists of the following steps (Store and Kangas, 2001): (i) the assessment of a suitability structure: choosing the habitat factors and determining their importance and effect on the habitat priority. Here, judgments made by experts on ecology should be applied, (ii) producing map layers: a GIS application is used for managing, producing, analyzing and combining spatial data. The data describing the habitat factors are rasterized and every factor is stored in its own map layer, and (iii) cartographic modeling: defining the feasible area and combining the habitat factors. The broad methodology includes deriving various input parameters from remote sensing and ancillary sources along with field verification and evaluates them for tiger habitat suitability using multi-criteria approach.

Data Collection

Data collection involved collection of spatial as well as non-spatial data, such as Landsat ETM +, October 2006, Survey of India Topo sheet and location data. ArcGIS 9.2 and Erdas imagine 9.2 were used to process and analysis the input parameters.

Forest Density

Normalized Difference Vegetation Index (NDVI) was used for density classification of forest cover:

$$NDVI = (IR-R) / (IR + R)$$

Where IR stands for the infrared portion of the electromagnetic spectrum, and R stands for the red portion of the electromagnetic spectrum. The forest density classes used here are dense forest, moderately dense forest and open forest.

Slope

Slope map was derived from digital elevation model (DEM) prepared from the interpretation of Survey of India topo sheet (1:50,000) with the contour interval of 20 meters.

Human Settlements and Road

The villages and the roads are considered to be the disturbances and their locations are extracted from topo-sheet and satellite image. A variable buffering with respect to the radial distance from the point of disturbance was performed and weightage is set proportional to the distance. The areas beyond 1 km from the disturbances are considered to be highly suitable.

Water Availability

The water body map was prepared from the satellite image and topo-sheet. In contrast to the settlements and roads, the areas closer to the waterbody are highly suitable and the weightage is set inversely proportional to the distance.

Prey Availability

Tigers prefer to hunt bigger prey like Sambar, Chital and Nilgai over smaller prey like Wild pig, Langur, etc. The prey availability map was prepared from the field survey data, through visual sighting of the animals or by indirect evidences that the animals left behind such as hoof mark and pellets, using GIS.

Data Analysis

The habitat suitability for the tiger was developed using Multi Criteria Analysis (MCA) by integrating various factors determining the habitat suitability for tigers. An output map was generated for each variable with three orders i.e., highly suitable, moderately suitable and low suitable. Each variable was given a weightage based on its significance. All the output layers were overlaid to generate the habitat suitability map.

Table 1: Spatial, non-spatial data sources used and output maps generated

S.No	Map / Data	Source	Primary Layer	Output Layer
1.	Forest Type	Landsat ETM+	NDVI	Forest Type
2.	Drainage/Water	SOI toposheet, Landsat	Rivers/Drainage ETM+, WII	Distance to water
3.	Settlement/Road	SOI toposheet, Landsat	Settlement/Road ETM+, WII	Distance from Settlement/Road
4.	Panna Tiger	WII Reserve Boundary	Panna Tiger	Boundary Map Reserve Boundary
5.	Slope	SOI toposheet	DEM	Slope
6.	Animal Occurrence	WII	Sign Survey	Prey Availability

Table 2 : The criteria used for habitat suitability analysis

Habitat Suitability Class	Suitability Parameters					
	Forest Type	Slope (Deg)	Prey Availability (% Occurrence)	Distance from Village (m)	Distance from Metal Road (m)	Distance from Waterbody (m)
High	Dense	0 - 20	80 - 100	> 1000	> 1000	0 - 1000
Moderate	Open/Scrub	20 - 40	50 - 70	500-1000	500-1000	1000 - 1500
Low	Non Forest	> 40	0 - 40	250-500	250-500	1500 - 2000

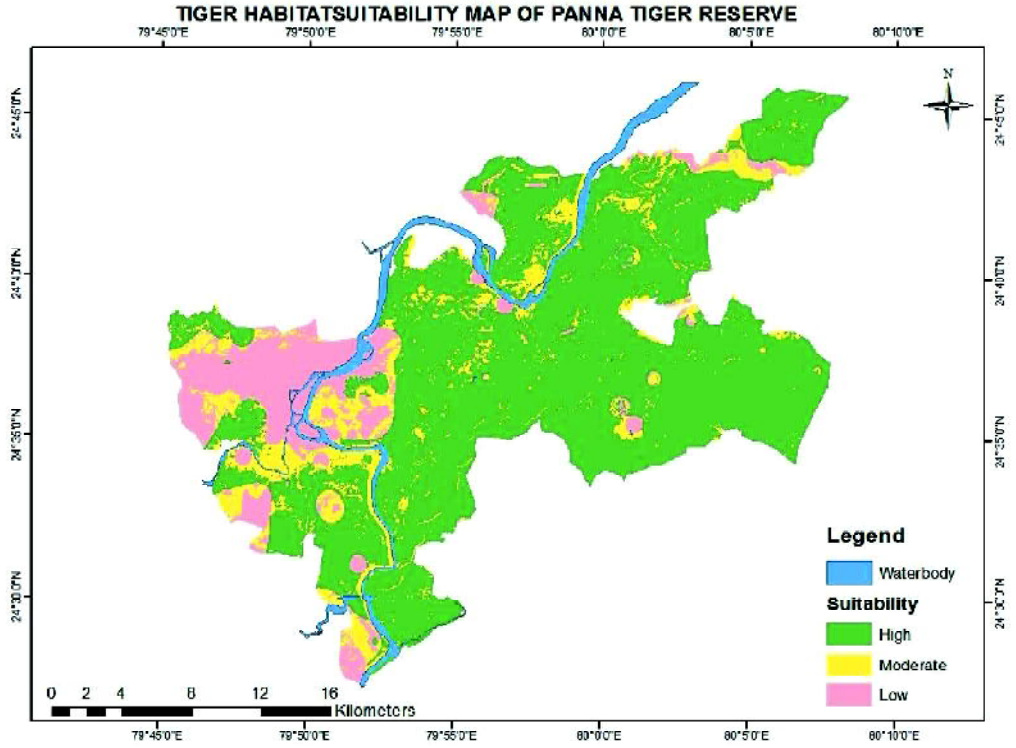


Figure 2: Tiger Habitat Suitability Map

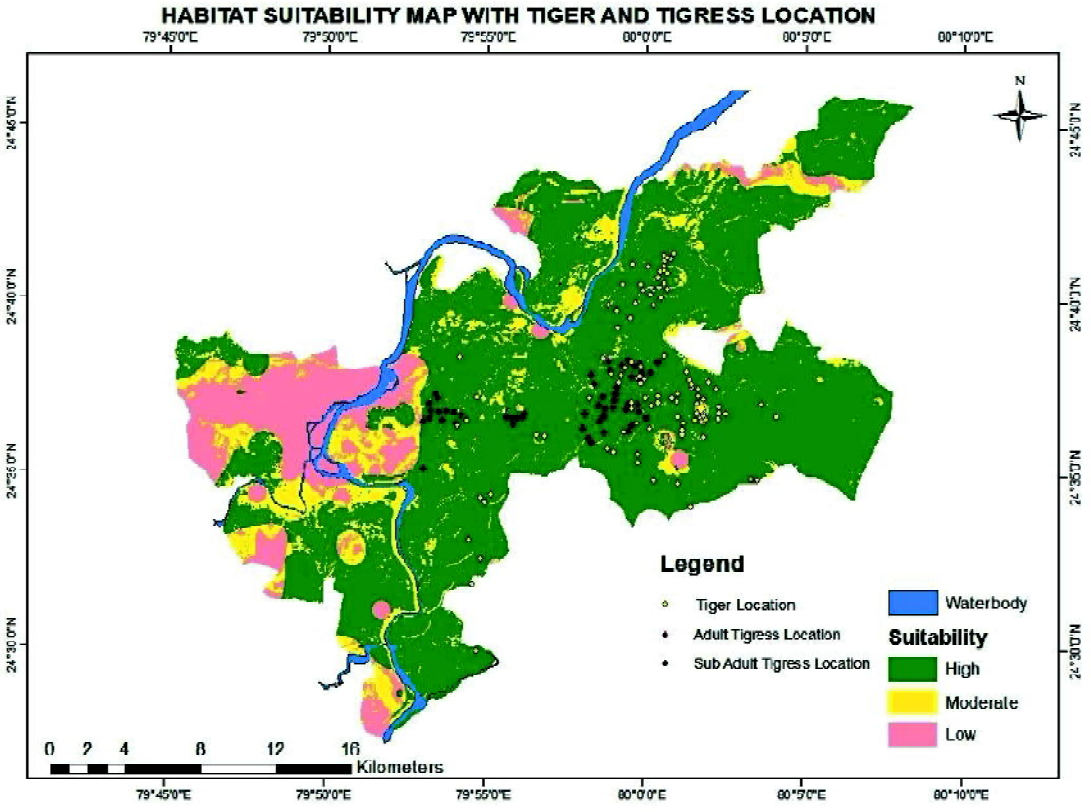


Figure 3: Tiger Habitat Suitability Map with Tiger and Tigress Location

RESULTS AND DISCUSSION

Tiger generally occupy dense forest and is influenced by prey availability, distance to the water body and disturbances. The results indicate that the majority of the area is covered by dense forest (217.60 sq. km) followed by open forest (156.30 sq. km), scrub land (105.37 sq. km) and non-forest and degraded area (52.86 sq. km). The tiger prefer highly dense forest which provides cover from the prey and also the dense forest supports high prey population. The settlements and the roads are the major disturbance to the wildlife and the area farther from these disturbances are highly suitable. The prey availability and the water-body location are the most important variables that determine the habitat suitability for any wild animal. The entire reserve is crisscrossed by streams and the areas where the occurrence of the prey animals (Sambar, Chital, Nilgai and Wild pig) exceeding 80% are considered to be the highly suitable. The slope ranges between 0 to 66 degrees, and the gentler the slope higher the suitability.

The habitat suitability map for tigers in Panna Tiger Reserve is shown in the Figure 2. The result indicates that the larger proportion of the Panna Tiger Reserve is highly suitable (71.7%) and 13.9% of the area is less suitable and 14.4% of the area is moderately suitable. The spatial distribution of suitability classes indicated that the dense forests are highly suitable. It also showed a positive relation with parameters like food, cover, disturbance and terrain characteristics.

In the future, more detailed habitat suitability models could be take into account with additional variables such as human population density, prey density and microclimatic conditions. However, although the present models are fairly rough, they are nevertheless useful in guiding future research on tiger habitat in the Panna Tiger Reserve. It appears that there is a good proportion of area suitable for tigers, which indicates that reintroduction of the tiger, remains a possibility worth exploring.

Furthermore, the location of the collared adult tiger between April 1996 and July 1997, adult tigress between January 1997 and July 1997 and sub adult tigress between April 1996 and September 1996 (Chundawat et al., 1999) (Fig. 3) falls in the highly suitable area and qualitatively highlights the accuracy of the model generated.

CONCLUSION

The potential of remote sensing in providing accurate and timely information on essential habitat variables is tremendous (Kushwaha and Roy, 2002). The GIS ability to handle large area, multiple spatial and non-spatial data integration and analysis is a leap forward to understand not only habitats but also the entire ecosystem of the protected areas (Singh *et al.,* 2009). Although the tigers were locally extinct, the Panna Tiger Reserve contains good habitat and can support a viable population of tigers, supported by proper protection and less disturbance. The map generated can be used for conservation measures inside the Panna Tiger Reserve, such as resource allocation, land use planning and sustainable management of natural resources.

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