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ARTICLE

Habitat Suitability Index Modelling for Bluebull (*Boselaphus tragocamelus*) in Pench Tiger Reserve, M.P. India

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ABSTRACT

The habitats for the wild animals are shrinking due to the clearance of forests for agriculture and industrialization. The idea of wildlife conservation begins with the identification of their acceptable habitat. Since this crucial information helps in the development and maintenance of the protected areas. The requirement of habitat varies with different landscapes. The bluebull (*Boselaphus tragocamelus*) is Asia's largest antelope, widespread throughout the northern Indian subcontinent. Peter Simon Pallasin (1766) described it as the only member of the genus Boselaphus. The Wildlife (Protection) Act of 1972 lists it as a Schedule III animal, while the IUCN lists it as Least Concern (LC). Our goal was to design a habitat appropriateness model for blue bull so that it could reduce the conflict with farming community due to crop damage. Model will be develop using RS & GIS technique to protect the species inside the Pench Tiger Reserve (77° 55' W to 79° 35' E and 21° 08' S to 22° 00' N) the central highlands of India. The satellite data from LANDSAT-8 of 4th April 2015, Path- 144, Row- 45, with a ground resolution of 30 meters, were collected from the USGS website. This satellite image was then transferred in image format to ERDAS IMAGINE 2013 for further analysis. The data from satellites were gathered and analysed. The purpose of the field survey was to gather information about the presence of various ungulates. A ground truthing exercise was also carried out. For data processing and GIS analysis, ERDAS IMAGINE 13 and Arc GIS 10 were used. Analytical Hierarchy Process (AHP) was used Factors were identified who were influencing the spatial distribution of the species for conservation planning. The linear additive model was used for HSI. The results show that 242 km^2 (29.48 percent) of Pench Tiger Reserve forest was recognized to be highly suitable for bluebull, while 196 km^2 (23.87 percent) was moderately suitable, 231 km^2 (28.14 percent) was suitable, 109 km^2 (13.28 percent) was least suitable, and about 43 km^2 (5.249 percent) of PTR was completely avoided by bluebull.

1. Introduction

The rate of deforestation has increased the change in forest cover and density to fulfill the demand of human needs, particularly agriculture expansion has shrunken the habitat for the wild species. Some habitat is protected in the protected areas, and it is a need to understand the habitat requirement of the wild species. For the conservation and management of many species, it is essential to understand the relationship between their geographical distribution and their habitats [1].

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The bluebull (*Boselaphus tragocamelus*) is Asia's largest antelope, distributed across the northern Indian subcontinent. Peter Simon Pallasin (1766) described it as the only member of the genus Boselaphus. According to the Wildlife (Protection) Act of 1972, the Bluebull is a Schedule - III animal and is classed as Least Concern (LC) by the IUCN. Conflicts with local farming communities over bluebull crop damage have generated conservation challenges, and we aimed to establish a habitat appropriateness model for bluebull to safeguard within protected areas.

Wildlife management encompasses both the conservation of wildlife species and the management of an entire ecosystem [2]. Remote Sensing (RS) and Geographic Information Systems (GIS), are powerful tools of geospatial technology that can be used to evaluate natural resources. It is possible with remote sensing data to monitor, regular, real-time evaluation and administration of large areas [5]. For a range of species, the US Fish and Wildlife Service has developed habitat suitability index (HSI) models, which are crucial for wildlife and habitat management [3,4]. The outcomes of such models are relatively simple and easy to understand, and they can be used to evaluate environmental impacts or prioritized conservation initiatives in a fast and cost-effective manner [5,6].

We can evaluate the qualities of the habitat using this technique, which evaluates detailed ecological information about the species [4,7]. As discussed in the beginning section, numerous studies have been conducted to assess the habitat of diverse species in various parts of the world, as well as the Indian subcontinent [5,8-11].

The Pench Tiger Reserve (PTR) in Central India represents tropical dry deciduous and tropical moist deciduous ecosystems. The quantitative and qualitative structure of vegetation types in PTR (2012) was initially described by Sankar et al. (2001) [12], Areendran (2007) [13], and Basu (2007) [14]. The impact of changes in the landscape on large mammal habitats in Pench Tiger Reserve in Madhya Pradesh, India was examined by Basu (2012) [14]. In his study, he evaluated the different types of vegetation of the PTR and generated the habitat suitability model for all the large mammals including spotted deer (*Axis axis*), Sambar (*Rusa unicolor*), wild boar (*Sus scrofa*), and carnivores like tiger (*Panthera pardus*), and dhole (*Cuon alpines*).

Geospatial technology was applied in the study to anticipate the appropriate habitats for bluebull in the Pench tiger reserve due to its scale and utility.

Study area

In the Satpura-Maikal ranges of Central India, the Pench Tiger Reserve in Madhya Pradesh is one of the most prominent conservation areas. The Sanctuary was established in 1977, covering around 449.392 square kilometers. In 1983, an area of 292.857 sq km was declared as Pench National Park, while the remaining 118.473 sq km was recognized as Pench Sanctuary. In 1992, India's government designated 757.85 square kilometers, encompassing the National Park and Sanctuary, as the country's 19th Tiger Reserve (77° 55' W to 79° 35' E and 21° 08' S to 22° 00' N) (Figure 1).

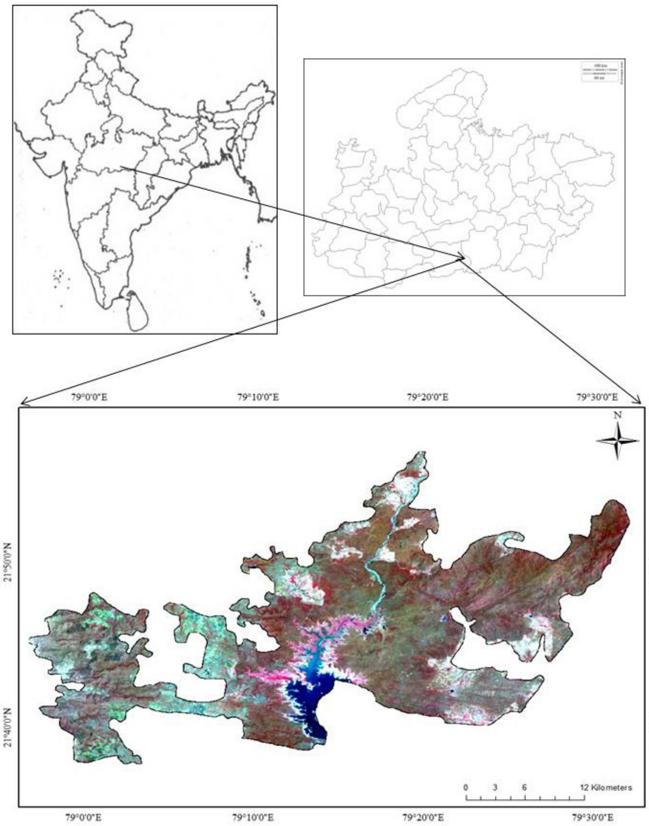

Figure 1. Map of the Pench Tiger Reserve.

The extreme weather conditions prevail in the sanctuary. Temperature varies from 0°C in winters to 45°C in summer. The average annual rainfall is 1400 mm and seasons are categorized as summer, monsoon, post-monsoon, and winter. The PTR is a dry deciduous woodland, dominated by *Tectona grandis*, which includes *Tectona grandis, Anogeissus latifolia, Boswellia serrata, Sterculia urens*, and *Gardenia latifolia* with good predator and prey populations. The major carnivore species of the Reserveares leopard (*Panthera pardus*), Tiger (*Panthera tigris*), dhole (*Cuon alpinus*), small Indian civet (*Viverricula indica*), jungle cat (*Felis chaus*), striped hyena (*Hyaena hyaena*), sloth bear (*Melursus ursinus*), common palm civet (*Paradoxurus hermaphroditus*) and golden jackal (*Canis aureus*). Among herbivores, apart from sambar, the major species are chital (*Axis axis*) gaur (*Bos frontalis*),

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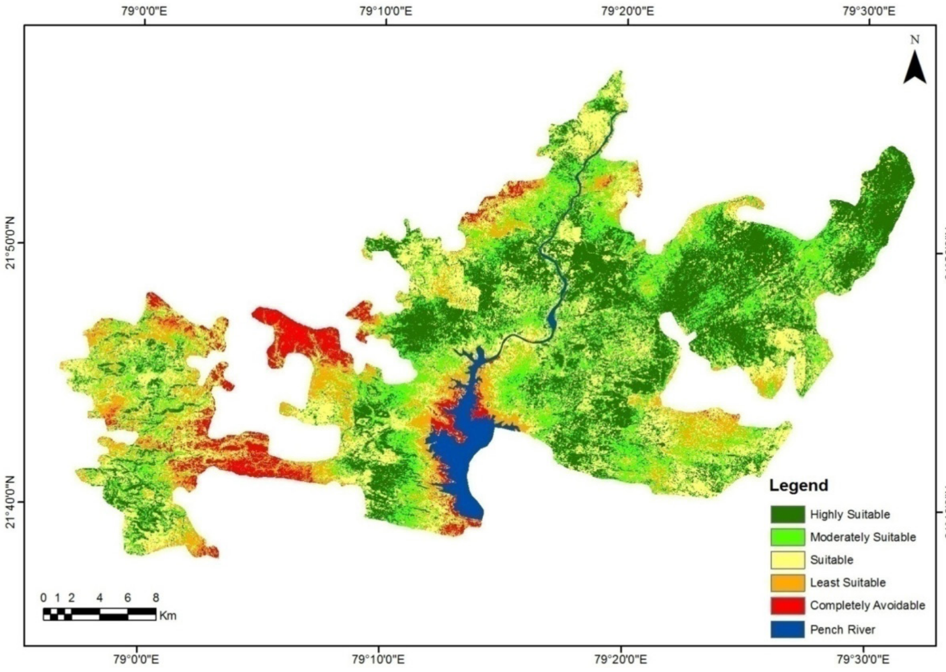

Figure 2. Habitat suitability map for Bluebull

bluebull (*Boselaphus tragocamelus*), chowsingha (*Tetraceros quadricornis*), barking deer (*Muntiacus muntjac*), and sambar (*Rusa unicolor*).

2. Materials

Satellite Data

It was obtained from the Landsat-8 OLI Data of 4th April 2015 and Digital Elevation Model ASTER DEM.

Ancillary Data

Topographic maps and Digital boundary of the Pench Tiger Reserve obtained from the Forest Department.

Software's

ArcGIS 10; ERDAS IMAGINE 2013.

3. Methodology

The aim of the study was to evaluate the appropriateness of the habitat suitability index for Bluebull in the Pench Tiger Reserve. For this, satellite data were analyzed. A field survey was carried out to collect evidence of the occurrence of various ungulates. Ground Truthing exercise was also carried out. The post-field effort included the establishment of a database and the modeling of the habitat appropriateness index. In the present study, ERDAS IMAGINE 13 and ArcGIS 10 software were deployed for processing data and GIS analysis.

Factors influencing the habitat suitability

For establishing an effective conservation strategy and habitat suitability evaluating methods it is essential to identify factors determining species distribution [15]. Therefore, in the present study, parameters related to the distribution of ungulates from the previously published literature, statistical data from the field surveys, and suggestions from the conservation experts were determined and used in developing a model. These variables were operational, representative, and indicative for the analysis. Along with this these variables can provide the large amount of information needed for the assessment. These included slope, vegetation types, distance from water resource, and distance from the road were developed using topographic sheet based on some prior habitat evaluation analyses [16,17]. These variables were selected since they effectively represent the main features of appropriate habitats for ungulate species and can be used as variables in a habitat suitability model. After analyzing remote sensing imagery in the GIS domain, the aforesaid parameters were discovered [11].

Data collection and data processing

The satellite data from LANDSAT-8 of 4th April 2015, Path- 144, Row- 45, with a ground resolution of 30 meters, were collected from the USGS website. This satellite image was then transferred in image format to ERDAS IMAGINE 2013 for further analysis. An area of interest

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(AOI) was identified using satellite data, and an FCC was created. ASTER (Advanced spaceborne thermal emission and reflection) data were downloaded from the USGS website, and a digital elevation model (DEM) was developed in the domain of ERDASusing this data. A slope layer was created using a DEM.

The topographic maps of the study area (55 O/2, 55 O/5, 55 O/6, 55 O/9, 55 K /13, and 55 K /14) were collected and collated from the Survey of India (SOI), Jabalpur, while the forest border map was obtained from the Pench Tiger Reserve, Seoni, Madhya Pradesh. These topographic maps were scanned and exported to ERDAS IMAGINE and were geo-referenced with a one-third pixel root mean square error and re-sampled using the nearest neighborhood methodology. For further analysis, the data was re-projected into the UTM-WGS 84(Universe transverse Mercator geodetic system-84 projection).

Field Survey

From 2013 to 2015, a field study was conducted throughout the year (except during the monsoon). The Pench Tiger Reserve is comprising of major three ranges namely Kurai, Karmajhiri, and Gumtara. Pench Mowgli Sanctuary is formed by the Kurai range, whereas Pench National Park is formed by the Karmajhiri and Gumtara ranges. Because it was difficult to cover all three ranges, therefore, the Karmajhiri range was selected as an intensive study region for data gathering. And for the long-term study distinct habitats within the Karmajhiri range were chosen. In the selected habitats, 15 line transects were laid down with 10 circular plots at every 200m distance on each transect. Thus, in total 150 sampling plots were determined and species occurrence data were collected from these plots in different seasons for 2 years from 2013 to 2015 along with the GPS coordinates. Other data such as vegetation cover (tree cover, shrub cover), distance from the nearest human settlement, distance from waterhole were also collected during field surveys. Slopes and road distances data were obtained using remote sensing as they could be more accurately calculated and analyzed in a GIS framework [11].

Post-field analysis *Land use/Landcover*

The LULC map of the study area was generated using unsupervised classification via geo-coded FCC of LANDSAT 8 of April 4, 2015. For differentiating spectral reflectance of various objects, the ISODATA algorithm has been used. The spectral signatures of the spectral classes present in the image were identified using multi-spectral imaging. Land use/cover types were classified using unsupervised clustering. Maximum probability classification was used since it has been shown to be particularly effective for land use/cover mapping. The accuracy assessment was followed by the unsupervised classification. The most crucial part of assessing the accuracy of maps is to analyse their reliability. The accuracy assessment approach was utilized in this study, and the software generated random points. Cohen's Kappa Statistics were used to assess accuracy [18].

The accuracy of the map was tested by 100 randomly picked points. These places' land cover information was compared to classified maps. Cohen's Kappa Statistics (Khat coefficient) were used to assess accuracy [18].

Database preparation for Habitat Suitability Analysis

In the research region, vector layers of roads and water bodies were generated, as well as a distance map. LULC maps were created through unsupervised classification and categorized them into twelve classes. Slope and elevation maps were generated using 30 m resolution ASTER DEM data. The ecological importance of the habitats for the studied species were evaluated using these different layers. In order to determine the appropriateness of habitats for different ungulates in the PTR, a linear additive approach was used after the classification of all layers. An Analytical Hierarchy Process (AHP) devised by SAATY (1980, 1991) [19,20] was implemented to assess the weight allocated to distinct base layers.

AHP is an advanced approach in providing a methodology and reducing uncertainty in the evaluation of environment and regional sustainable management processes [20]. In this method, a numerical value is designated to each factor to determine its relative importance [21]. Each factor is then, evaluated against the other through assigning a relative dominating value between 1 and 9 to the intersecting cell in the construction of a pair-wise comparison matrix (Table 2). With the help of the relative scale measure mentioned in, a pair-wise comparison matrix was created for ungulates.

In the AHP process, the eigenvector plays a crucial role in the calculation. Each element of the eigenvector denotes the relative importance of the corresponding factor [21,22] i.e., When one factor is favoured over another, the eigenvector component of the favoured factor is larger. The eigenvalue and subsequent eigenvector are calculated using the sum/product method. The final weights calculated by AHP are utilised to create the HSI model.

In order to analyse the rationality of AHP, it is necessary to determine the degree of consistency that has been applied in producing the judgments. The consistency ra-

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tio (CR) is an AHP consistency metric that evaluates the probability that matrix judgments were produced randomly [22,23].

CI/RI = CR,

Where RI is an average consistency index based on the order of the matrix given by Saaty (1977), and Consistency Index (CI) is defined as:

CI = (_max(-n)/ (n-1)

Major Eigen value of the matrix is _max(-n), and the order of the matrix is n.

In the present study, parameters included forest types, distance from the road, distance from water, and elevation were investigated. Expert assessments were used to compare and weigh these factors. Table 1 shows the starting scales for each variable. For calculating the final weight MS Excel was used to create a pair-wise comparison matrix (Table 3). Then, in the GIS domain, the final weight [Consistency Index (CI)] calculated for each variable is employed with the HSI equation.

Table 1. Rank allocated to different layers

S.No.	Layers	Assigned Rank
1	Land use/Land cover	1
2	Distance from water body	2
3	Slope map	3
4	Distance from road	4

Table 2. Pair-wise comparison scale for Analytical Hierarchy Process preferences (Saaty 1980)

Weightage	Preferences
9	Extremely Preferred
8	Very Strongly to Extremely Preferred
7	Very Strongly preferred
6	Strongly to Very Strongly
5	Strongly Preferred
4	Moderately to Strongly Preferred
3	Moderately Preferred
2	Equally to Moderately preferred
1	Equally Preferred

Table 3. Synthesized Matrix of different layers for Bluebull

Class Name		1	2	3	4	Consistency Index (CI)
Vegetation	1	0.66	0.87	0.44	0.36	2.33
Distance from Water Bodies	2	0.07	0.10	0.44	0.36	0.97
Slope	3	0.13	0.02	0.09	0.21	0.45
Distance from Road	4	0.13	0.02	0.03	0.07	0.25

Habitat Suitability Index was calculated by multiplying the total of habitat suitability variables with AHP-determined weights [24,25].

HSI= (i=1) nWi,

Where,

Wi = weight of the factor and
I = I rating factor.

The final weights of the above-mentioned variables were assessed from the aforesaid analysis, and the HSI for various ungulates was calculated as follows:

HSI for Bluebull = (2.33 x LULCI) + (0.97 x DFWI) + (- 0.45 x SI) + (0.25 x DFRI)

Where,

HSI = Habitat Suitability Index,
LULCI= Land use/Land cover Index,
DFWI= Distance from water-body Index;
SI= Slope Index;
DFRI= Distance from road Index

4. Results and Discussion

Habitat Suitability Index for blue bull in Pench Tiger Reserve was generated using the linear additive model. On the basis of assigned suitability weightage, calculated output layers were reclassified. The reclassified raster layer displays areas based on their suitability categories for blue bull, as well as the area of each category, as indicated in Table 4.

Table 4. Area wise Habitat Suitability status for Bluebull in PTR

S. No.	Category	Area (Km^2)	Percentage (% Area)
1	Highly Suitable	242	29.48
2	Moderately Suitable	196	23.87
3	Suitable	231	28.14
4	Least Suitable	109	13.28
5	Completely Avoidable	43	5.24
	Total Area in Km^2	821	100

Habitat Suitability Index

The Habitat Suitability Index for blue bull in Pench Tiger Reserve was created using a linear additive model. Calculated output layers were classified depending on the suitability weightage assigned. The reclassified raster layer displays areas according to their appropriateness categories for blue bull, as well as the area of each category, as given in Table 4.

According to the HSI model developed for bluebull, 81.49 percent of PTR's forest area is appropriate for the species. It has been observed that a large portion of the

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tiger reserve's northeastern region offers very appropriate habitats for the bluebull. In most cases, highly appropriate habitats are surrounded by either a moderately suitable or a suitable environment, creating a buffer zone. PTR's north-eastern part was also connected to other PAs, which may explain why its supports are suitable for bluebull. There are three major and a variety of small portions of appropriate land on the western side of the river. The species, however, avoid or avoids the areas near the reservoir. The HSI map shows that the species avoids the north-central area of the tiger reserve entirely. This could be due to the presence of human habitations and activities. The far western sector of the region, which is connected by a corridor, is significantly less appropriate than the eastern portion of PTR because to its uneven shape and proximity to human settlement and agricultural land. When we look at the narrow corridor, we can observe that bluebull totally avoiding it, which is most likely owing to manmade activity. In the Pench Tiger Reserve, however, the model indicates a clear HSI for bluebull. PTR is one among Madhya Pradesh's best-managed protected areas, with little disturbance. To develop a suitable habitat for the bluebull and other allied species, the less appropriate environment in the north-central area of the tiger reserve must be explored and strengthened.

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