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# Use of Remote Sensing, GIS and Analytical Hierarchy Process (AHP) in Wildlife Habitat Suitability Analysis

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## Abstract
Habitat evaluation is a foremost task of wildlife manager for wildlife species conservation and management. We did habitat evaluation through Habitat Suitability Index model using Remote Sensing, GIS and Analytical Hierarchy Process. The study was conducted in Motichur range of Rajaji national park for tiger ($29^0$ 59' 30" to $30^0$ 05' N latitudes and $78^0$ 04' 30" to $78^0$ 15' 30" E longitudes). For the modeling, topographic sheets (scale 1:50000), maps of sanctuary , Forest types and Forest density were procured from Forest and Ecology Division, Indian Institute of Remote Sensing (IIRS), Dehradun, India. Digital elevation map was generated from contour maps of topographic sheets. All these variables were considered as input data for developing the model. Experts' views and field experience were considered while allotting values to variables for AHP analysis to generate final weight. The model revealed that out of 115 $Km^2$, 28.03 $Km^2$ (24.37%) of forest area was highly suitable for tiger, whereas, 12.99 $Km^2$ (11.29%) moderately suitable, 46.37 $Km^2$ (40.32%) less suitable and 27.61 $Km^2$ (24.01%) was least suitable. The study advocates the potentiality of remote sensing, GIS and AHP in wildlife habitat evaluation with minimal efforts and financial budget.

*Kew words:* Remote sensing, GIS, AHP, Modelling, Wildlife

## 1. Introduction
Wildlife management is not only preservation of wildlife species, but it also involves management of a complete ecosystem [1]. Until recently many conventional techniques have been applied for collecting data on natural resources for management, consequently large numbers of ground-based studies have been carried out on wildlife species and their habitats [2, 3]. Ground survey methods and mapping of habitats are always useful, however, these are tedious and have limitations as whole area can't be accessed in one go in many of the cases and the information collected may not have high accuracy level [4].
Remote sensing and GIS are relatively new techniques which can be used as tool for getting information about the habitat preference of the wildlife species specially for endangered species [5]. The outputs of such models are usually simple, easily understandable and can be used for the assessment of environmental impacts or prioritization of conservation efforts in a timely and cost-effective manner [6]. Geospatial technology (Remote Sensing, GIS and GPS) provides an efficient and low-cost method for determining habitat quality [7]. A suitability index provides the likelihood of how much area is suitable for a particular animal species.
The concept of wildlife habitat analysis started with the development of 'habitat evaluation procedure (HEP)' [8]. Lyon [9] used the concept of HEP and remote sensing data in modeling the nesting sites of American kestrel, *Falco sparverius* and Bright [10] for habitat assessment of elk, *Cervus canadenis.* In 1994, Andries et al. [11) used SPOT remotely sensed data to extract landscape characteristics for spatial modeling of barn owl habitat. Furthermore, Store and Jokimaki [12] used geographic information system, integrated with habitat suitability index and multi-criteria evaluation approach to produce georeferenced ecological information about the habitat requirements of different species. Similarly, Jordan et al. [13] tested the use of Habitat Suitability Index (HSI) scores as predictors of abundance of blue-winged teal in Ohio, USA and find it reasonably well.

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During late 1980s, Indian researchers also started to use geospatial technology for analyzing the "habitat suitability index". In 1986, Parihar et al. [14] evaluated habitat of Indian one-horned rhinoceros using LANDSAT remotely sensed data, while Roy et al. [15] used this technology for habitat suitability analysis of *Nemorhaedus goral*. Kushwaha1and Hazarika [16] used LANDSAT-TM imagery and IRS 1D LISS-III imagery to assess the habitat loss of elephant in Arunachal Pradesh and Assam, India. Kalra [17] and Unial [18] used remote sensing and GIS for the habitat evaluation of Great Indian Bustard and Lion in desert national park and Palpur Kuno proposed lion sanctuary, respectively.

The tiger (*Panthera tigris*) is highly endangered throughout its range and the primary causes of disappearance of tigers are poaching, habitat loss and degradation, prey depletion, and conflict with humans [19]. Recently these factors have drastically reduced the number and distribution areas of tigers in the wild, leaving them now on the verge of extinction with a population of only 1411 tigers in the wild [20], therefore, they need immediate protection. Furthermore, being at the top level of the food chain, tigers directly or indirectly control the herbivorous primary consumers and play an extremely important role in the balance of ecosystem [21]. This threatened species effectively function as umbrella species for the remaining mammals [22].

The traditional methods of tigers conservation have always been useful [23], however, these methods cost too much and the data required are hard to get. With the development of spatial and cyber technologies, Remote Sensing and GIS provide a powerful tool for habitat assessment on a macroscopical scale [12]. It is considered that use of these technologies provide a stronger basis for protection of tigers [24, 25].

Considering the magnitude and effectiveness of geospatial technology, it is used in present study to model the suitable habitats available for tiger in Motichur Range, Rajaji National Park.

## 2. Materials and Methods

### *2.1. Study Area*

Motichur range (study area), is a part of Rajaji national park, Dehradun, Uttrakhand, India. It is covering an area of approx. 115 sq km and situated between $29^0$ 59' 30" to $30^0$ 05' N latitudes and $78^0$ 04' 30" to $78^0$ 15' 30" E longitudes respectively (Fig. 1).

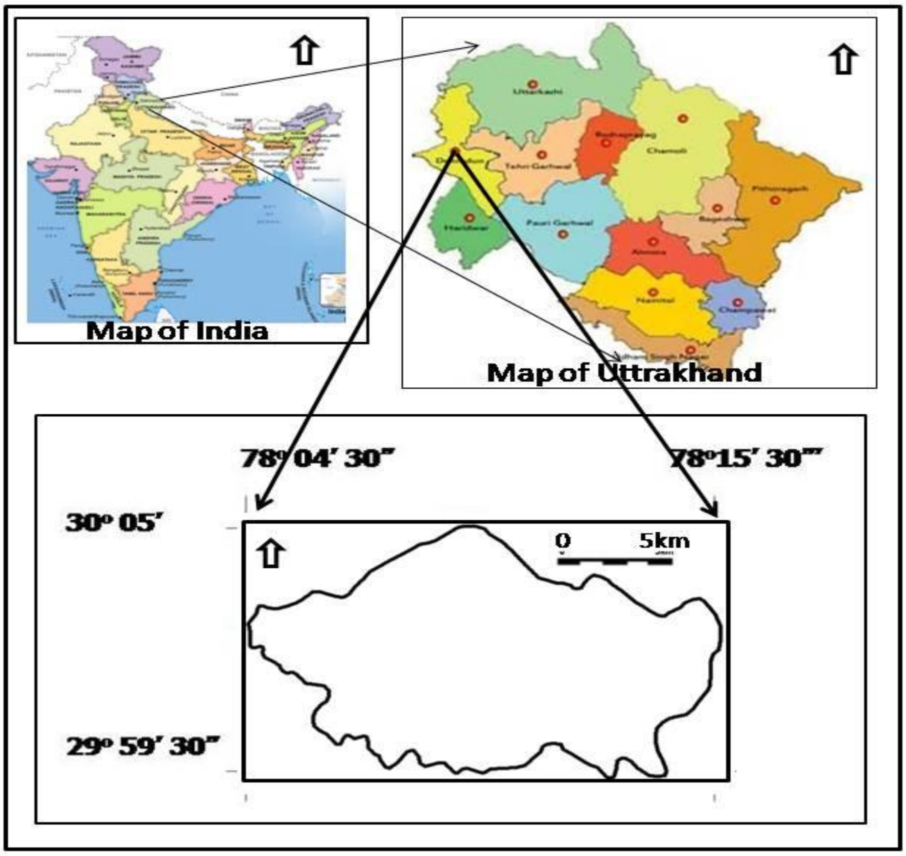


**Fig. 1:** Study area

The climate is subtropical type with three distinct season of winter, summer and rainy. The temperature varies from about 13.1$^0$ C in January to about 38.9$^0$ C in May & June. Monsoon usually starts about in the middle of June and continues till mid of September. The annual rainfall varies between 1200-1500 mm. Topography of the area is extremely rugged and broken with many steep and steep slopes. The area is primarily dominated by North Indian moist deciduous forest dominated by moist Siwalik sal forest and moist mixed deciduous forest, Northern dry mixed deciduous forest and Himalayan sub-tropical chir pine forest. The sanctuary has largest population of elephants in Uttrakhand (India). It also has a healthy population of tigers and leopards. The herbivorous game animals are generally belonging to deer family and cheetals (*Axis axis*) are more common spp. Among omnivora wild bores are abundant in the park [26].

## 3. Methodology

### *3.1. Factors influencing the habitat suitability*

Identification of factors that influence the spatial distribution of animal species is important for developing effective method of conservation planning and habitat suitability evaluation [27]. Therefore, factors related to distribution of tigers related literatures, statistical data from field surveys and suggestions from conservation experts were considered as input data for modelling. These factors are representative, operational and indicative to the analysis and can provide most information required in the evaluation.

Based on some previous analysis of habitat evaluation [12, 19], vegetation types, forest density, slope and aspect were selected as these are basically representing main features of suitable habitats of tigers to provide variables for habitat suitability model. These factors are chosen because tigers have preference for some forest patch, particular slope and forest density [28]. Factors like Forest Types, Forest Density, Aspects and Slope were obtained after analysis of remote sensing imagery in GIS domain [29].

### *3.2. Database creation*

Topographic maps of study area (scale 1:50,000) were scanned and transferred to *ERDAS IMAGINE* 8.7 [30] for rectification. After rectification boundary of Motichur range was marked on it and a subset of AOI (area of interest) was made for further analysis. From topographic sheets, on screen digitisations of contours (of 30 m interval) were done for generating the digital elevation model (DEM). Further, DEM was used to generate Slope and Aspect maps using *ERDAS IMAGINE* software.

Non-rectified vector files of Forest Type and Forest Density maps of study area (extracted from IRS-1D-LISS-III of 2002) were procured from Forest and Ecology Division, Indian Institute of Remote Sensing (IIRS), Dehradun, India.

Non-rectified vector file of Forest Type map was brought to *ERDAS IMAGINE* to rectify and then transferred to ArcView 3.2 [31] for onscreen digitisation. In the present study Forest Type was categories into four classes of Sal forest, Sal mixed forest, Mixed forest and Scrub & grassland and accordingly attributes were allotted. The over all accuracy of 79.8% was recorded for forest type classification.

Similarly non-rectified vector file of Forest Density map was brought to *ERDAS IMAGINE* to rectify and then transferred to ArcView for onscreen digitisation. In the present study Forest Density was categories into four classes of >70%, 40-70%, 10-40% and 0-10% and subsequently attributes were allotted accordingly. After preparation of map layers of Forest Types, Forest Density, Aspect and Slope, weight allotment procedure was carried out with the help of specialist and field visit experience.

### *3.3. Identification of weights of factors*

In the process of habitat evaluation, identification of relative weights among factors is a primary step. The analytic hierarchy process (AHP) is a decision-making method which was first derived by Saaty in 1977 [32]. It is a combination of quantitative and qualitative processes dealing with complex technological, economical, and socio-political problems. For the advance of providing methodology frame and reducing uncertainty, AHP is widely used in environmental evaluation and regional sustainable management [33]. In this numerical values are assigned to judge relative importance of each factor [34]. In the construction of pair-wise comparison matrix, each factor is rated against every other factor by assigning a relative dominant value between 1 and 9 to the intersecting cell (Table 1).

**Table 1: Scale of binary comparison (measurement scale according to Saaty 1977)**

| Degree of Importance | Definition |
|---|---|
| 1 | Equal importance |
| 3 | Week importance |
| 5 | Essential or strong importance |
| 7 | Demonstrated importance |
| 9 | Absolute importance |
| 2,4,6,8 | Intermediate values between two adjacent judgements. |
| 1 / 2,1/3,1/4,1/5,1/6,1/7,1/8,1/9 | Reciprocal values of the previous appreciation |

In the process of AHP, the prime task of calculation is the eigenvector corresponding to the largest eigen value of the matrix. Each element in the eigenvector indicates the relative priority of corresponding factor [32, 34], i.e. if a factor is preferred to another, its eigenvector component is larger than that of the other. A sum/product method is used to obtain the eigen value and the subsequent eigenvector. The weights finally derived by AHP are used for developing the HSI model (equation 3).

To examine the rationality of AHP, it is necessary to determine the degree of consistency that has been used in developing the judgments. In AHP, an index of consistency, known as the consistency ratio (CR), is used to indicate the probability that the matrix judgments were randomly generated [32, 35]:

$$CR = \frac{CI}{RI} \qquad \text{Equation1}$$

Where RI is the average of the resulting consistency index depending on the order of the matrix given by Saaty [32], and consistency index (CI) is defined as:

$$CI = \frac{\lambda_{max}^{-n}}{n-1} \qquad \text{Equation 2}$$

Where $\lambda_{max}^{-n}$ is the principal eigen value of the matrix, n is the order of the matrix.

In the present study 4 factors (Forest types, forest density, Aspects and Slope) were considered for assessing the habitat suitability. These factors were compared with each other according to experts' judgments and allotting them priority weight. The criteria used for modelling of habitat evaluation of tiger are shown in Table 2. The initial scale allotted to each variable is given in Table 3. After that Excel software programme was used and pair-wise comparison matrix was developed to calculate final weight (Table 4). Then final weight [Consistency Index (CI)] derived for each variable are used with HSI equation in GIS domain (Equation 3)

**Table 2:**The Criteria used in tiger habitat modelling

| SN | Habitat Suitability class | Slope | Aspect | Forest Type | Forest Density |
|---|---|---|---|---|---|
| 1 | Least suitable | $0^0$ - $18.4^0$ | West & North-west | Sal | >70% |
| 2 | Less suitable | $55.4^0$ - $83.1^0$ | South, South-west & East | Sal mixed | 0-10% |
| 3 | Moderately suitable | $36.9^0$ - $55.4^0$ | East & South-east | Mixed forest | 10-40% |
| 4 | Most suitable | $18.4^0$ -$36.9^0$ | North & North-East | Scrub/other | 40-70% |

**Table 3:** Scale allotted to different variables

| **Variables** | **Scale** | | | |
|---|---|---|---|---|
| Forest Density | >70% =1 | 40-70%= 4 | 10-40%= 3 | 0-10%= 2 |
| Forest Types | Sal=1 | Sal mixed=2 | Mixed forest= 3 | Scrub & grassland= 4 |
| Slope | 0-18.4=1 | 18.4-36.9=9 | 36.9-55.4=5 | 55.4-83.1=4 |
| Aspect | N_NE=1 | E_ES=2 | S_SW_E=6 | W_NW=5 |

N= North, NE=North East, E=East, ES=East South, S=South, SW=South West, W=West, NW=North West

**Table 4:** Pair-wise comparison matrix and calculation of final weight using final priority vectors

| **Class Type** | **Forest Density** | **Forest Type** | **Slope** | **Aspects** | **Consistency Index (CI)** |
|---|---|---|---|---|---|
| **Forest Density** | 0.236 | 0.130 | 0.082 | 0.039 | 0.487 |
| **Forest Types** | 0.100 | 0.080 | 0.035 | 0.022 | 0.237 |
| **Slope** | 0.085 | 0.046 | 0.024 | 0.008 | 0.162 |
| **Aspects** | 0.067 | 0.030 | 0.011 | 0.006 | |
| | | | | **Total** | **1.0** |

## 4. Results and Discussion

*4.1. Habitat Suitability Index (HSI) calculating and priority setting*

HSI was calculated as the sum of habitat suitability factors multiplied by corresponding weights determined by AHP [36, 37]

$$HSI = \sum_{i=1}^{n} W_i \int i \qquad \text{Equation 3}$$

Where HSI is the habitat suitability index, $\mathbf{W_i}$ the weight of factor i and $\int \boldsymbol{i}$ is the rating factor of i.

Each reclassified raster layer corresponding to the factors selected, were combined by Raster Calculator function in ArcView to generate the spatial distribution map of HSI (Fig. 2). The HSI values in the grid cells are a series of continuous values. To visualize distribution of different levels of habitat suitability index and to facilitate the process of understanding, these values are classified into different classes of highly suitable, moderately suitable, less suitable and least suitable.

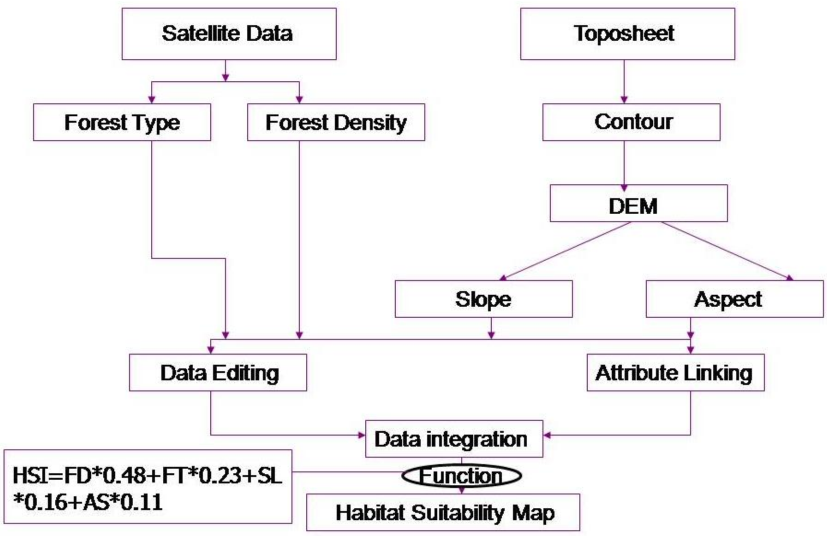


**Fig. 2:** Flow Chat for Habitat Suitability Index Model

The habitat suitability index map (Fig. 3) of Motichur range depicts that out of 115 $Km^2$, 28.03 $Km^2$ (24.37%) of forest area was highly suitable for tiger, whereas, 12.99 $Km^2$ (11.29%) moderately suitable, 46.37 $Km^2$ (40.32%) less suitable and 27.61 $Km^2$ (24.01%) was least suitable (Table 5).
The model revealed that 35.66% of study area is suitable for tiger and these are confined along both sides of river. About 73.98 $Km^2$ (64.33%) of Motichur range, which falls under

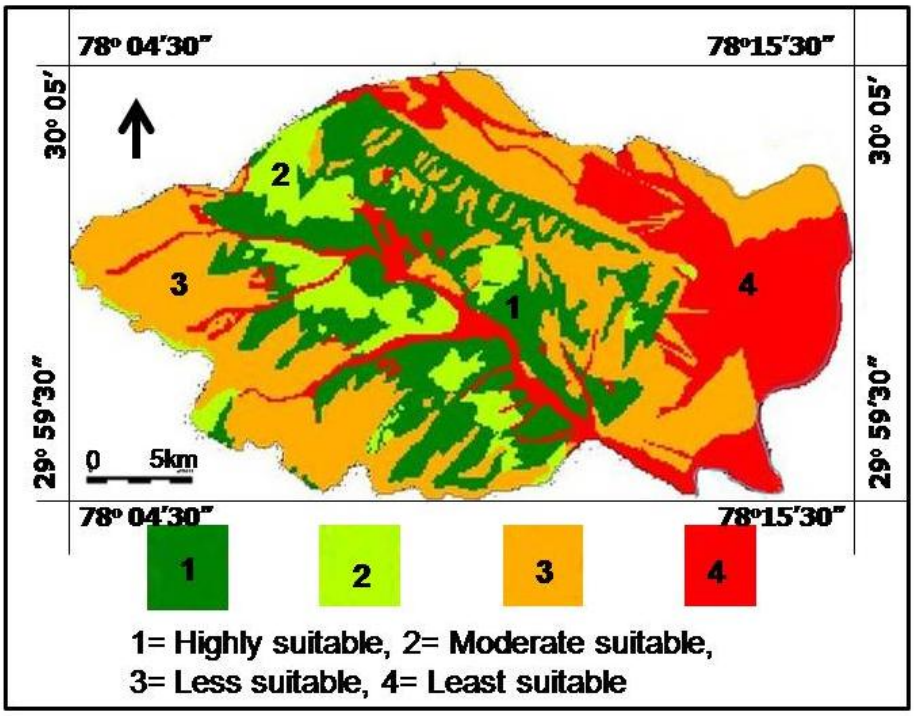


**Fig. 3:** Habitat Suitability map of tiger

the categories of less and least suitable, are located around those habitats which are suitable for tiger, so it can be said that it is working as buffer for habitats suitable for tiger. Habitat suitability index map also shows that except for 4-5 intact patches, most of the suitable habitats are found in fragmented form. Almost major portion of eastern part of study area is either less suitable or least suitable for tiger. Similarly extreme northern part of Motichur range is covered with less or least suitable habitat. Extreme southern portion of study area is also covered with less suitable habitat. However, with compare to other study, Motichur range has fairly good patches of forest which can be consider as suitable for tiger [38].

**Table 5:** Area under different categories of suitability for tiger

| Least suitable (in $Km^2$) | Less suitable (in $Km^2$) | Moderately suitable (in $Km^2$) | Highly suitable (in $Km^2$) | Total (in $Km^2$) |
|---|---|---|---|---|
| 27.61 | 46.37 | 12.99 | 28.03 | 115 |
| 24.01% | 40.32% | 11.29% | 24.37% | 100% |

During the last 50 years, area of forests decreased drastically due to over exploitation of natural resources such as agricultural clearing and logging [39], resulting fragmented habitats and corridors for wildlife to the extent that wild tigers can't live as they were dwelling in the past. Coupled with human population stress, deforestation and poaching, the number of tigers has decreased so rapidly that it is urgent to evaluate some more suitable habitats to add as reserve for the conservation of tiger. Compared to other traditional methods of tiger conservation planning, GIS and Remote Sensing allow us to integrate various spatial information and to conduct spatial analysis [40, 37]. Furthermore, they can generate new information using existing data and get over many limitations in traditional approach of ecology [41]. Analytical Hierarchy Process combined quantitative calculation and experts' judgments to derive the weights assigned to each factor. This method reduced the subjectivity of judgments and promotes the effectiveness of conservation planning to some extent. Through conserving the tiger as an umbrella species, ecosystems and landscapes will be conserved, which intern provides essential ecological services to human ensuring necessities such as food and water, and high-quality environment for the health and economic reasons [42].

In India a great attention has been given to the conservation of tiger and for this number of tiger reserves are in the process of establishment. This process needs sound data which may tell how much suitable habitat is available for tigers in a particular area. Developing habitat suitability index is one of the most potent tools, which is helpful to a great extent in evaluating the suitable habitats available for a particular animal species.

However, there are inevitably errors occurred in the process of weights identification and data processing which cause subjectivity of judgments and precision problems of data [37], hence there is a great challenge to minimise the uncertainties.

In the present study just surface has been scratched. There are still knowledge gaps in the impact of individual parameters, their complex interactions at various locations of the tiger range, and their ability to represent the real situation on the ground [42]. Therefore, it is recommended that for developing the habitat suitability index for tigers in other regions, factors selected and their weights should be adjusted to nature-social conditions existing in that study area.

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