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Abhishek Mishra
Department of Earth Science, Barkatullah University, Bhopal, Madhya Pradesh, India

Jyoti Sarup
Department of Civil Engineering, Maulana Azad National Institute of Technology, Bhopal, Madhya Pradesh, India

DC Gupta
Department of Earth Science, Barkatullah University, Bhopal, Madhya Pradesh, India

Geo spatial approach for tiger habitat suitability mapping: A case study of Bandhavgarh national park, Madhya Pradesh, India

Abhishek Mishra, Jyoti Sarup and DC Gupta

Abstract
In the present study, evaluation of Tiger (*Panthera tigris tigris)* and their prey species (Chital & Sambar) habitat was carried out in Bandhavgarh National park by using remote sensing, ground and other ancillary data and these data sources were integrated with GIS using multi-criteria analysis (MCA) model. For the modeling, several variables in the dataset *viz.*, forest cover density, slope, altitude, road, water body, settlement and drainage were used as independent variables in the analysis. All these data sets were considered as input data for developing the model. Expert views and field experience were considered while allotting values to variables for MCA analysis to generate final weight. The result indicated that Sal, mixed Sal, miscellaneous forest, plantation, grassland, agriculture and scrub land are the major land use/land cover types and majority of the study area is covered under forest. The habitat parameters have tremendous impact over the habitat utilization and suitability pattern of Tiger, Chital & Sambar in Bandhavgarh National Park. From this study most suitable habitat for Tiger in BNP is 1264.01 km² which is 56.48% of the total geographical area of the national park while 531.22 km² area comes under moderately suitable for tiger which is 23.74% of the total geographical area of the national park. The results pointed out that 80% of national park has been found to be high to moderately suitable for Tiger habitat. The result have been found to be an important input as baseline information for population modeling and natural resource management in the national park.

Keywords: Remote sensing, GIS, tiger habitat suitability, prey, MCA

1. Introduction
India is known as the territory of Tigers and it goes without saying that it has world's highest population of Tigers. These big cats live proudly in its wildlife sanctuaries, national parks and Tiger reserves. India has recorded total of 2461 Tigers from 2014 to 2018. On June 29, 2019, Prime Minister Narendra Modi has released the latest Tiger census which shown a great rise of Tiger population with 2,961 Tigers in India on Global Tiger Day.

Madhya Pradesh has had poor record for Tiger conservation over the last four years. But it still has risen in Tiger population with 218. According to the National Tiger Conservation Authority, India has reported to lost up to 657 Tigers from 2012 to 2017 and Madhya Pradesh also tops here as well, i.e. by losing total of 141 Tigers.

Since the 1980 due to establishments of Tiger reserves, the state of Madhya Pradesh has claimed the largest population of big cats. The Tiger population started declining due to gradual rise in cases of poaching over the years in Madhya Pradesh. Thanks to the continuous efforts of initiatives and conservation projects, such as Project Tiger, WWF, and Save the Tiger working 24×7, Madhya Pradesh has now managed to see the rise in Tiger population. Today, we proudly have a great number of Tigers.

The Remote Sensing and Geographic Information System (GIS) combined with habitat modelling have proved to be an important tool to assess large scale habitat requirement for a given species. The habitat model gives information about the spatial extent, arrangement and fragmentation of habitat. This is a necessary prelude to estimate the potential population size. Thus the main objective of this study was to explain the usefulness of remote sensing and GIS technique along with ancillary information, to develop the best habitat suitability model for tiger and its prey species.

Corresponding Author:
Abhishek Mishra
Department of Earth Science, Barkatullah University, Bhopal, Madhya Pradesh, India

2. Study Area

The Bandhavgarh National Park is located in the eastern part of Madhya Pradesh at the central part of India. It dwells around the Umaria-Shahdol district surrounded by the Satpura mountain range. The latitude and longitude are lies between 23^0 27' 00" to 23^0 59' 50" North latitude and 80^0 43' 15" to 81^0 15' 45" East longitude, falls under the survey of India topo sheet 64E/1, 64E/2, 64E/3, 64A/13 and 64A/14. The park is elevated at an altitude between 410 m and 810 m. The buffer zone has three administrative zones - Manpur, Dhamokhar, and Panpatha.

The mountains of Bandhavgarh tala range are being composed of sandstone and the soil is sandy to sandy loam. The whole park is filled with more than 20 luminous streams out of which some of the most important streams are Johilla, janadh, charanganga, Damnar, Banbei, Ambanala and Andhiyari Jhiria. These streams then merge into the son river, an important southern tributary to the river Ganges. Along with that many caves and lakes can also be found at the vicinity of Bandhavgarh National Park specially around the area of the fort which is the most majestic and ancient part of Bandhavgarh.
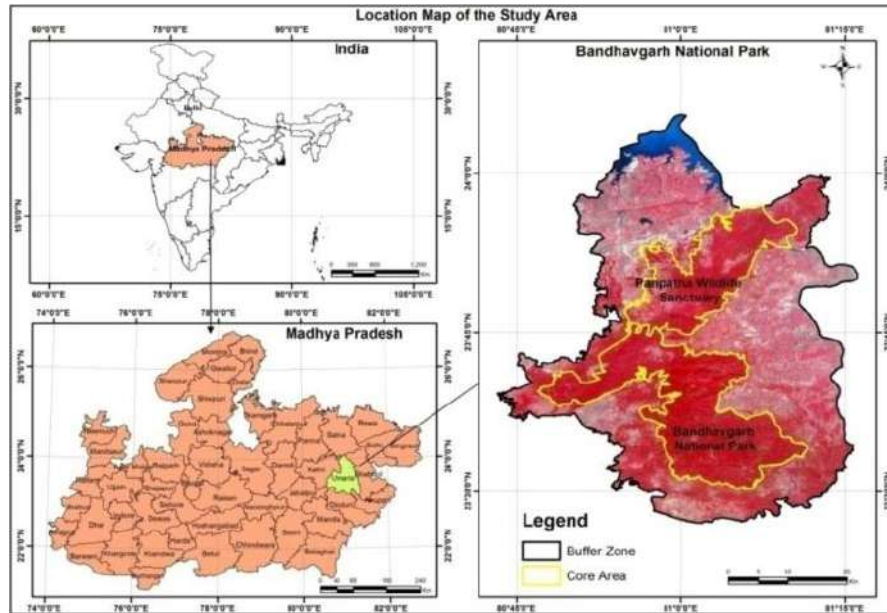

Fig 1: Location Map of Bandhavgarh National Park

3. Methodology

3.1 Habitat suitability

Habitat can be defined as an area which resources/conditions promote the existence of a species and allow the population to survive and reproduce and it may be characterized by a description of environmental features that were important for a species.

Habitat is a sum total of environmental condition of a specific place occupied by wildlife species or a population of such species. All species have specific habitat requirements, which can be described by habitat factors. These factors were connected to the critical characteristics of the habitat, such as vegetation, soil, spatial structure of landscape elements and climatic condition of the area. The evaluation procedure consists of the following steps.

3.2 The assessment of a suitability structure: Choosing the habitat factors and determining their importance and effect on the habitat priority. Here, judgements made by experts on ecology had been applied.

3.3 Producing map layers: GIS application was used for managing, producing, analysing and combining spatial/non spatial data. The data describing the habitat factors were rasterized and every factor have been stored in its own map layer.

3.4 Remote sensing & GIS Integration: After pre-processing, combining data of the different type and from different sources (SOI, GSI and DEM), was the pinnacle of

data integration and analysis. In a digital environment, where all the data sources were geometrically registered to a common geographic base, the potential for information extraction was extremely wide. The integration with GIS allows a synergistic processing of multisource spatial data. The integration of the two technologies creates a synergy in which the GIS improves the ability to extract information from remotely sensed data, and remote sensing in turn keeps the GIS up-to date with actual environment information. As a result, large amount of spatial data can now be integrated and analyses. This was allowing for better understanding of environmental process and better insight into the effect of human activities. Defining the feasible area and combining the habitat factors.

The main purpose of habitat Suitability (HS) models was to define the relationship between biotic and abiotic factors and the species spatial distribution (Guisan *et al.*, 2000). The most important thing to build the habitat suitability model was to identify habitat preferences of the species from an eco-geographical point of view. HS models can then help with describing species-environment relationships and can help to derive a map of habitat quality. The important key for any habitat suitability model was the nature of the species data i.e., presence data, presence and absence data and abundance data (Eastman, 2006).

Habitat suitability can be measured by a habitat suitability index, which was a unit less (0 to 9) variable, describing the priority of the habitat with respect to the need of the species (or group of species) under consideration. Anselin *et al.* (1989) have pursued the idea of multi-criteria techniques

with an analytic hierarchy process (AHP). G. Singh *et al.* (2009) [10] have used multi-criteria analysis technique for Habitat suitability of Tiger in Corbett Tiger reserve, India.

Kushwaha *et al.* (2000) have also used rules/criteria and map overlay method of habitat modelling for Goral habitat evaluation in the Chilla Sanctuary of Rajaji National Park.
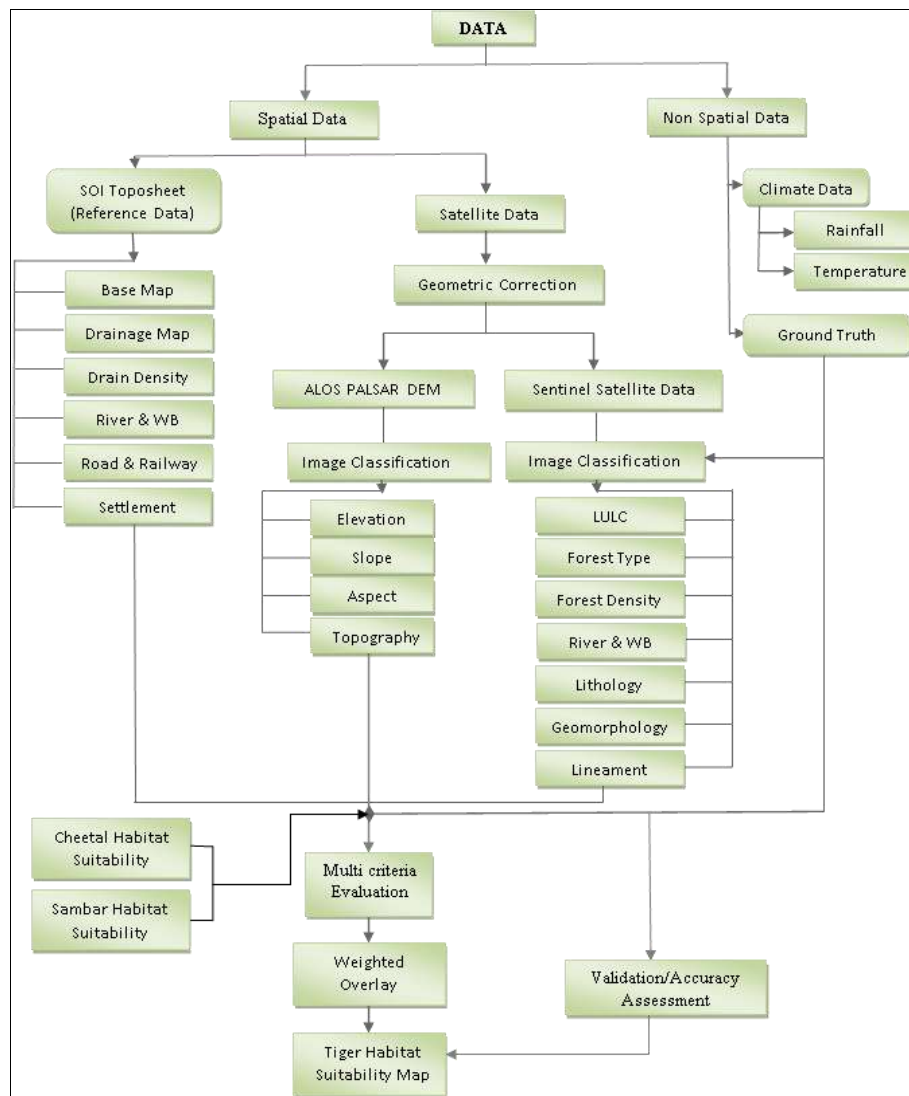

Fig 2: Flow chart showing data and methods employed for the study of Tiger Habitat Suitability Analysis (THSA)

In this research work primarily we have also applied analytic hierarchy process (AHP) & Satty,s analysis for habitat suitability index, but the best result seen in knowledge based multicriteria analysis.

Now a day's Tiger was threatened species and holds top position in food chain of forest ecosystem, so the procurement of Tiger was in top priority. For habitat suitability modelling of Tiger, the most important factor was availability of prey in the area. In Bandhavgarh National Park Sambar, Chital and Wild Boar are the main prey for Tiger. So along with Tiger Habitat Suitability Modelling Sambar, Chital and Wild Boar habitat suitability modelling must be done. 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.

Field work has been carried out in Bandhavgarh National Park to collect information on habitat use by Tiger, Sambar, Chital and Wild Boar along with forest type, forest density, slope and topography of the area.

Suitability maps have been developed by integrating expert opinion with Geographic Information System (GIS)

database. The 0-9 points scale multicriteria evaluation methodology has been implemented to solicit the importance of ground characteristics (criteria) for Tiger, Sambar, Chital & Wild Boar habitat from field experts. The layers of interest have been forest density, vegetation type, landuse, lithology, slope, topography and some other human disturbance factors. The evaluations of the respondents have been in agreement. Suitability scores and preference weights have been determined from questionnaire responses and input into the Arc GIS. Habitat suitability have been calculated as weighted averages of suitability scores of individual ground characteristics. The criterion and combined suitability maps produced agreed well with known locations of the Tiger, Sambar, Chital and Wild Boar.

3.5 Multi-criteria Analysis
A model to evaluate Tiger suitability has been developed using multi criteria approach by integrating different inputs parameters. Each parameter has in the form of output map derived from source layers and have been categorised in 0-9 scale which was further grouped into highly suitable,

Suitable, moderately suitable, less suitable and, and unsuitable. Further weighted have been assigned to each parameter so as to accommodate their significance. Weightage for each parameter have been assigned by taking into account the significance of each parameter in deciding Tiger habitat as well as its ecological value derived from literature survey and expert knowledge.

For Chital habitat suitability analysis forest density has assigned the weightage of 30, distance to water (25), slope (15), topography (10), drainage density (10), distance to road & railway(5) and distance to habitation have been assigned the weightage of (5).

For Sambar habitat suitability analysis forest density has been assigned the weightage of (30), distance to water (20), slope (15), topography (15), drainage density (10), distance to road & railway (5) and distance to habitation have been assigned the weightage of (5).

For Tiger habitat suitability analysis prey availability has been assign the weightage of (30) forest density (20), distance to water (20), slope (10), topography (5), drainage density (5) distance to road & railway (5) and distance to habitation have been assigned the weightage of (5).

Table 1: Influences and weightage of different thematic layers for contributing habitat for Tiger in Bandhavgarh National Park

Raster Layer	Influence % (Theme Weight)	Feature Classes or Buffer Distance	Feature Class Weight
Forest Cover	**20**	**Forest density**	
		Dense Forest	5
		Low dense Forest	9
		Open/Scrub Forest	7
		No Forest	3
River and WB	**20**	**River and WB Buffer**	
		0-500 m	9
		500-1000 m	8
		1000-2000 m	6
		2000-3000 m	4
		Above 3000 m	2
Slope	**10**	**Slope Gradient in Degree**	
		0-3%	3
		3-5%	7
		5-10%	9
		10-15%	5
		15-35%	3
		Above 35%	1
Topography	**5**	**Elevation in M**	
		233-300 m	7
		300-400 m	8
		400-500 m	9
		500-600 m	6
		600-700 m	5
		Above 700mm	3
Drainage density	**5**	**Drainage Density**	
		Very high Density	2
		High Density	4
		Moderate Density	9
		Low Density	5
Road and Rail	**5**	**Distance to Road and Rail**	
		0-100 m	1
		100-500 m	3
		500-1000 m	5
		1000-2000 m	7
		Above 2000m	9
Human Settlement	**5**	**Distance to Settlement**	
		0-100 m	2
		100-500 m	4
		500-1000 m	6
		1000-2000 m	9
		Above 2000 m	9
Prey Availability	**30**	**Prey Availability**	
		High	9
		Moderate	6
		Low	4
		Least	1

Finally, all the parameters (P1…P9) have been integrated to derive the Tiger habitat suitability map shows the over view of the model structure. As this approach was common in a

management decision or policy making context, the critical concern was whether the map was so sensitive to variation in inputs that a different decision would be reached with a

different realization of the inputs. A simple correlation between range-wise estimated suitable area and their respective Tiger population distribution has used to qualitatively assess the model prediction.

4. Results and Discussion

The delineation of habitat suitability zone by reclassifying into different potential zones highly, high, moderate, low and unsuitable (figure-5) was made by utilizing the criteria for GIS analysis have been defined on the basis of field survey, field data and experts knowledge, appropriate weightage has been assigned to each layer according to relative contribution towards the desired output. The map produced has shown that the habitat suitability zone of the study area was related mainly to forest density, forest type, availability of water, slope and topography of the area.

The integrated resulted have been shown in a Composite Habitat Suitability Unit map (CHSU). The output CHSU map is a surface with all the pixels having unified weight values named as Composite Habitat Suitability Indices (CHSI). These CHSI range from 3 to 9 (figure-4) higher the value indicates more suitability and lower value indicates lesser suitability. The Habitat Suitability potential zones map generated through this model was verified with the field data to ascertain the validity of the model developed. The verification showed that the habitat suitability zones demarcated through the model are truthful.

The habitat evaluation for the wild animals depends on the various environmental and ecological factors like vegetation type, height, slope, drainage patterns, water proximity,

habitation, roads & railways construction, forest type and prey availability. In the Present study we analysis the habitat suitability and preparation of the habitat suitability map for the Tiger on the basis of weighted rank given by opinion of expert, topographic map, remotely sensed data through and field survey method were applied. For the present study area weightage maps figure-3 (a to h) of the parameters forest density, distance to water, slope, drainage density, topography, distance to road & railway, distance to habitation and prey availability have been assigned respective theme weight and their class weights.

The final Habitat Suitability map generate from weighted overlay analysis show that out of the total geographic area of 2238 km². highly suitable area is 4.30% (96.25 km²), and high suitable constitute 52.18% (1167.76 km²) while moderately suitable class cover 23.74% (531.22 km²) and less to not suitable class covers about 19.8% (443.17 km²) area. It is clearly indicates that about 80% area of National Park are suitable for Tiger habitat and only 20% area are not favorable.

For Tiger
HSM = (FDwt * 0.20) + (DWwt * 0.20) + (Slopewt* 0.10) + (Elvwt * 0.05) + (DDwt * 0.05) + (DHwt * 0.05) + (DR & Rwt * 0.05) + (Prey*0.30)
Here,
HSM = Habitat Suitability Map, FD = Forest Density, DW= Distance to Water, ELV= Elevation, DD = Drainage Density, DH = Distance to Habitation, DR & DR = Distance to Road & Railway, wt = Feature class weight.
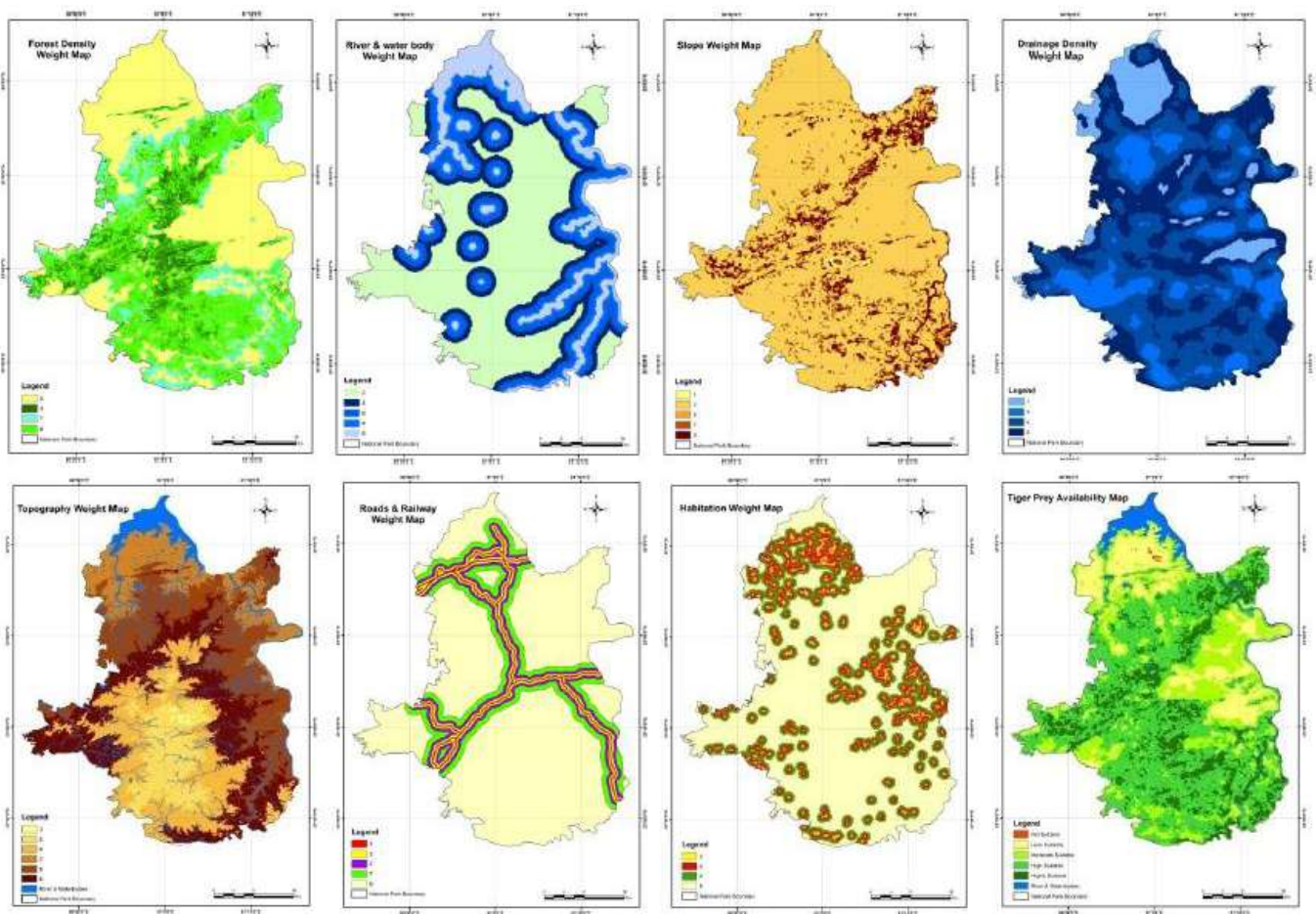

Fig 3: Weight Maps (a) Forest density, (b) River & Water body, (c) Slope, (d) Drainage density, (e) Topography, (f) Roads & Railway, (g) Habitation, (h) Tiger prey availability map
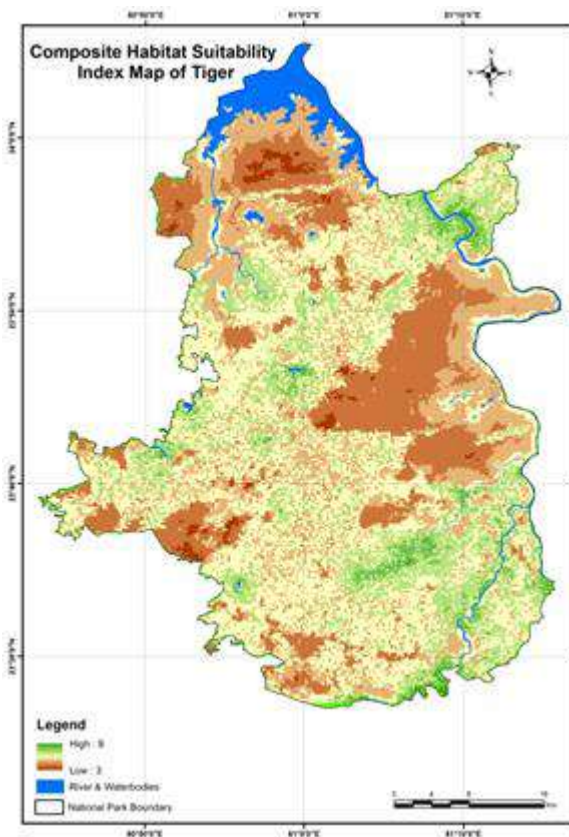
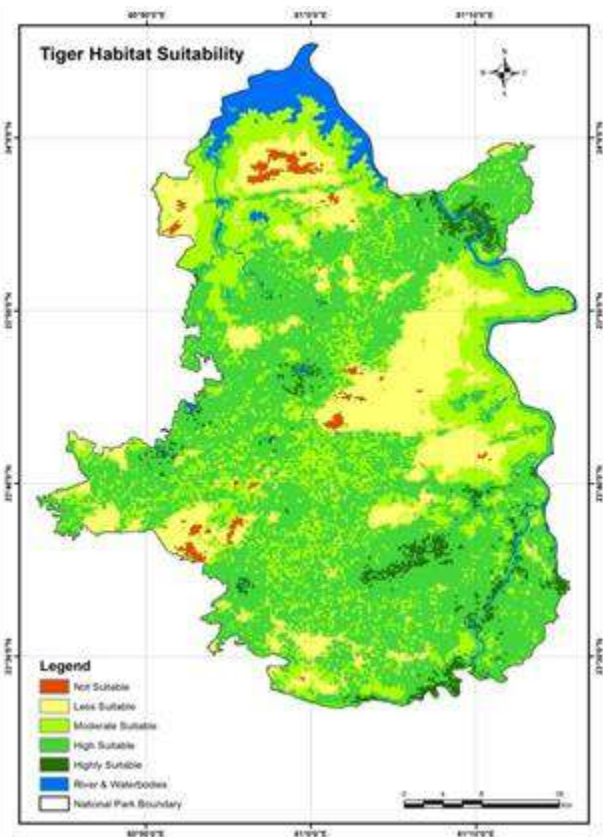**Fig 4:** Composite Habitat Suitability Index Map

Fig 5: Habitat Suitability Map

Table 2: Habitat distribution of Tiger

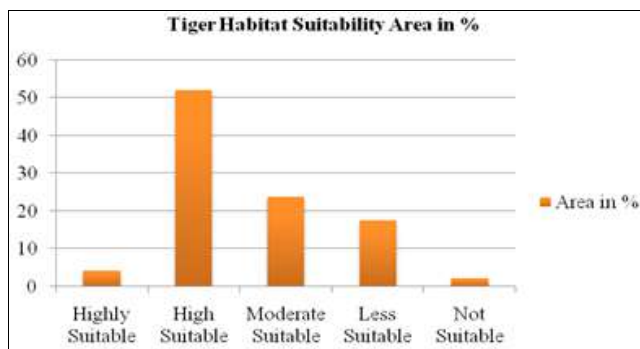| Sr. No.	Class	Area in km²	Area in %
1	Highly Suitable	96.25	4.30
2	High Suitable	1167.76	52.18
3	Moderate Suitable	531.22	23.74
4	Less Suitable	393.40	17.58
5	Not Suitable	49.76	2.22

Fig 6: Distribution of Tiger in different habitat suitability categories

5. Conclusion

Habitat plays a vital role for all wildlife populations; good habitats can support the requirements of Tigers and their prey for long-term survival. Even though international and national organizations support to conduct Tiger conservation efforts, their range and numbers are still declining continuously. This study utilized quantitative ecological analysis by means of a spatially explicit multivariate habitat suitability analysis, in the context of wildlife quantitative research on landscape level. The use of habitat suitability modeling to identify potential Tiger, Chital & Sambar habitats needs time and analysis efforts.

However, it is a really effective and profitable strategy of conservation planning. This study identified potential Tiger, Chital & Sambar habitat areas by producing a habitat suitability map. The sub-objective to support Tiger population conservation has been achieved; because the habitat suitability maps which prognoses the spatial distribution of Tigers can provide valuable information for the development and implementation of protection measures for the Tigers in the national park. The results of this study showed that human settlement along the district road is a major issue of the tiger's specialization within the core area. Although the tiger's presence area is not too different from the rest of the core zone regarding the environmental conditions and it exhibited tolerance towards deviation from optimal habitat, the settlement made the tigers more restricted to the range of conditions they withstand. Tiger distribution points have been always located about 3 km far away from human settlements and road network which also showed their sensitivity to human interferences.

The final result also showed that tigers avoid locations which are closer to human-settlements which restricts the movement of tigers in the core zone. Hence, the detrimental impacts of future development of human settlement should be minimized around the core zone. In addition, all human interferences within the core zone should be prohibited in order to guarantee sustainability of potential tiger habitats.

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