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Research Article

GEO SPATIAL APPROACH FOR TIGER HABITAT SUITABILITY MAPPING: A CASE STUDY OF ACHANAKMAR-AMARKANTAK BIOSPHERE RESERVE

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ABSTRACT

In the present study, evaluation of Tiger (*Panthera tigris tigris*) as well as their Prey species (Chital & Sambar) habitat was carried out in AABR by using remote sensing, ground and other ancillary data, and these data sources was integrated with GIS using multi-criteria analysis (MCA) model. For the modeling, several variables in the dataset viz., forest cover type, forest cover density, slope, aspect, 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 results 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 dense forest. The habitat parameters have tremendous impact over the habitat utilization and suitability pattern of Tiger, Chital & Sambar in AABR. From this study most suitable habitat for Tiger in AABR is 1290 km² which is 34 % of the total geographical area of the biosphere while 1077 sq. km. area comes under moderately suitable for tiger which is 28 % of the total geographical area of the biosphere. The results pointed out that 62 % of AABR has been found to be high to moderately suitable for Tiger habitat, 77% for Chital habitat and 67 % area for Sambar habitat. The results have been found to be an important input as baseline information for population modeling and natural resource management in the biosphere reserves.

INTRODUCTION

India holds over half the world's tiger population. According to the tiger census report released on March 28, 2011 by the National Tiger Conservation Authority, the current tiger population estimated is 1,706 while in 2008, it was 1,411. Tiger population has seen a 20% increase over three years between 2008 and 2011. But, even if the increase in tiger population is not contested, what is worrying is the shrinking of the tiger habitat. In 2006, India's tigers occupied 93,600 km2; it is down to 72,800 km^2 in 2010.

According to ecological niche theory [1] each species depends on the existence of a specific set of environmental conditions for its long-term survival. This concept refers to not only the abiotic environment but also to biotic factors of the respective ecosystem determining the abundance of resources as well as trophic chain interactions.

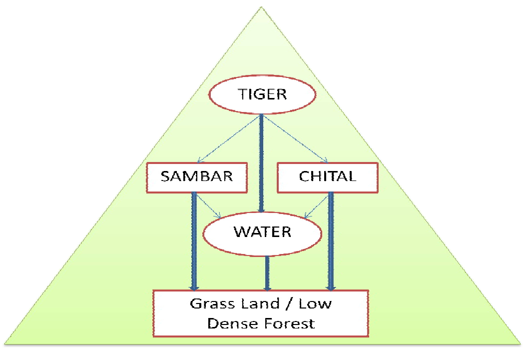

Figure 1 Relational diagram of ecological cycle for Tiger, Chital and Sambar habitat

The large carnivores have been more vulnerable to decline due to their large home range and dietary requirements. For tiger (*Panthera tigris*) a large area (3,000-15,000 km²) of habitat is necessary for long term survival [2]. They prefer broad areas

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having enough cover for stalking sufficient amount of prey populations and water [3].

In this study we investigated the habitat suitability of tigers and their prey (Sambar & Chital) within the Achanakmar Amarkantak Biosphere Reserve. The distribution of preferred tiger prey, sambar and chital is confined to a small area. Gour (Bison), which is distributed throughout the study area, is found in habitats not favorable for tigers. Such a distribution pattern is likely to only support dispersing and transient animals.

Effective conservation of wild species populations requires an understanding of the relationship between populations and their habitats. Scientists have developed multivariate explicit models for conservation ecology, covering many aspects of population viability analysis, biogeography, conservation biology, climate change research, biodiversity loss risk assessment, landscape management for endangered species, ecosystem restoration and habitat or species management. Habitat Suitability Models (HSM) of plants and animals has also come into vague consideration for biodiversity conservation.

In the last two decades, Habitat Suitability Models have been extensively used as a tool to predict the range of habitat variability that will sustain a particular species, and through that prediction the potential impact of habitat alteration [6, 5, 7]. It is one of the most frequently used methods based on the concept of habitat and carrying capacity [8]. In the meantime, Habitat Suitability Models are gaining interest as tools to predict the geographic distribution of species [9,10,11,12].

To build Habitat Suitability Models (HSM), the comprehensive knowledge of potential factors affecting habitat choice of species coupled with their geographical distribution is critical to produce meaningful mapping outputs. As a tool for wildlife managers, the application of HSM becomes more essential day by day not only for effective recovery of wildlife but for predicting potential areas of high habitat quality for a given species to be conserved.

The Remote Sensing and Geographic Information System (GIS) combined with habitat modeling 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 [4]. This is a necessary prelude to estimate the potential population size [13].

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.

Study Area

Achanakmar Amarkantak Biosphere reserve located at the junction of hill ranges of Madhya Pradesh and Chhattisgarh state, India, occupying total area of 3835.5 km^2 with topography ranging from high mountains, shallow valleys and plains. This is the meeting point of the Vindhyan and the Satpuras, with the Maikal hills being the fulcrum. Narmada, Sone and Johila River originate from this place.

The core region of Achanakmar Amarkantak Biosphere Reserve falls in Chhattisgarh state lies in between 22^{0}15’ to 22^{0}58’N and 81^{0}25’ to 82^{0}50’E, falls under the Survey of India Toposheet No. 64 F/5 to F/15, 64J/1, and J/3.The Biosphere is bounded by Anuppur, Dindori and Bilaspur district. The entire area of 551.15 sq. km of Achanakmar sanctuary has been designated as core zone and remaining area of 3284.36 km^2 serves as buffer zone. Out of this an area of 1224.98 km^2 falls in Madhya Pradesh and the rest of the area of 2059.38 km^2 fall in Chhattisgarh state.

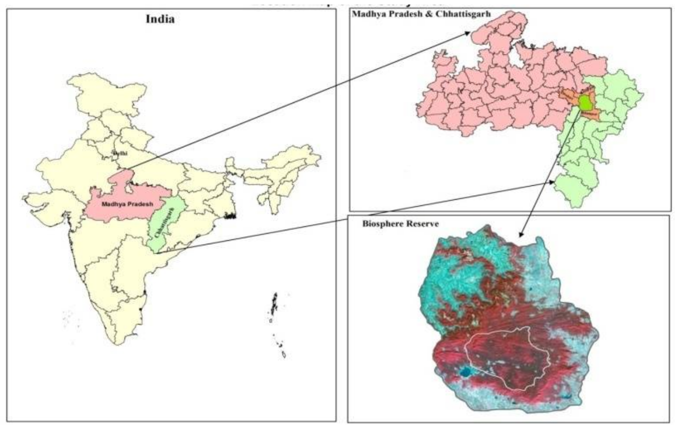

Figure 2 Location Map of the Study Area

Data Sets

To develop Habitat Suitability model, various metrological variables, satellite data, ground truth data and some other information were required. This information was required to plan the work component such as planning of field data collection, GPS data collection and identification of optimum period for remote sensing data acquisition and development of habitat suitability models for mapping suitability Index. The information and data used was as follows:

Satellite data

Landsat TM satellite data has been downloaded from the website www.glovis.usgs.gov,which has swath width 185*185 sq. km. with a ground resolution of 30 m. The digital elevation model (DEM) data of ASTER has been downloaded from the website (http://Gdem and imported to ERDAS IMAGINE 9.1 for producing the layer maps of aspect, slope, elevation, and altitude.

Field Data

The field survey has been carried out for the period of 22 days from 20th April to 27th April 2012, 1st Nov to 8th Nov 2012 and 6th Feb to 13th Feb 2013. Ground truthing has been done by matching the tone, pattern, texture, association, shape and size of the features from the FCC for a particular habitat with the help of GPS location and check the road and rail network of the biosphere. Interview surveys have been conducted with local hunters, local field experts, regarding their hunting experiences, common hunting places, animal killing information, habitat use of the tiger and its prey species, land use situations and land use changes in the core zone. Subdivisions of existing vegetation classes and ground truth collection in the core zone have been also conducted with the help of Global Positioning Systems (GPS) and field experts.

METHODOLOGY

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 [14] 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 [15]:

1. ***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 had been applied.
2. ***Producing map layers:*** GIS application was used for managing, producing, analyzing 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. ***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.

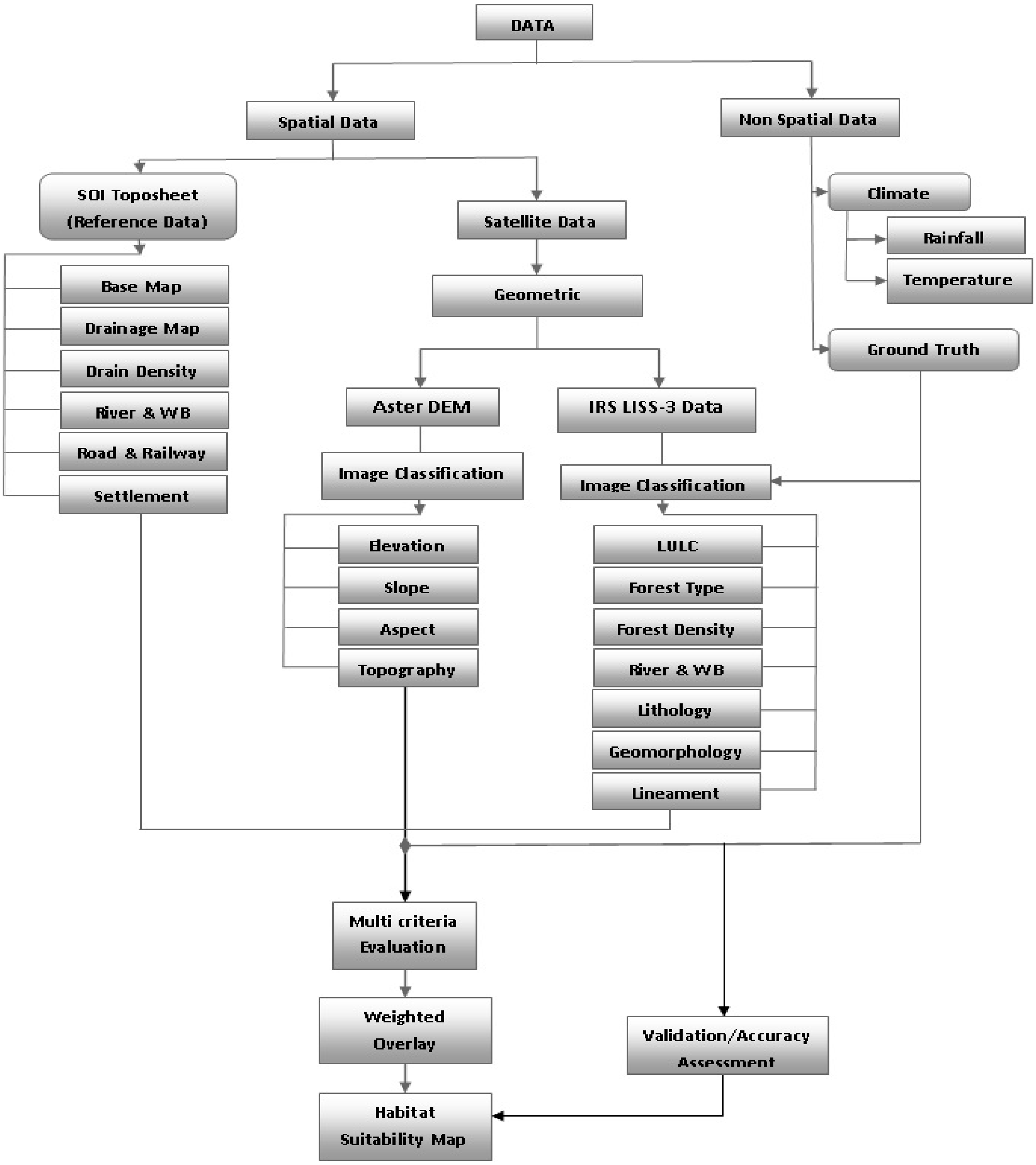

Figure 3 Flow chart showing data and methods employed for the study of Tiger Habitat Suitability Analysis (THSA)

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 [10]. 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 [10].

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. [17] have pursued the idea of multi-criteria techniques with an analytic hierarchy process (AHP). G. Singh et al. (2009) have used multi-criteria analysis technique for Habitat suitability of Tiger in Corbett Tiger reserve, India. [19] Have also used rules/criteria and map overlay method of habitat modelling for Goral habitat evaluation in the Chilla Sanctuary of Rajaji National Park. In this research work primarily i have also apply 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 modeling of Tiger, the most important factor was availability of prey in the area. In Achanakmar Amarkantak Biosphere Reserve Chital and Sambar are the main preys for Tiger. So along with Tiger Habitat Suitability Modeling Chital and Sambar habitat suitability modeling 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 AABR to collect information on habitat use by tiger, Sambar and Chital 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, Chital & Sambar habitat from field experts. The layers of interest have been forest density, vegetation type, land use, lithology, slope, topography and some other human disturbance factors. The evaluations of the respondents have been in agreement.

Habitat Suitability for Tiger

Vegetation Type	*Forest Density*	*Distance to Water*	*Slope*	*Topographic Elevation*	*Drainage Density*	*Distance to Habitation*	*Distance To Road & Railway*	*Prey Availability*
Misc forest with grassland	*Mod. Density*	*0-500m*	*0-2%*	*0-400m*	*Mod.Drainage Density*	*0-100m*	*0-100m*	*High Availability*
Mixed Forest	*Dense Forest*	*500-1000m*	*3-5%*	*400-500*	*High Drainage Dens*	*100-500m*	*100-500m*	*Moderate Availability*
Teak & bamboo plant.	*Non Forest*	*1000-2000m*	*5-10 %*	*500-600*	*Very high drain. Density*	*500-1000m*	*500-1000m*	*Less Available*
Teak Forest	-	*2000-3000m*	*10-15%*	*600-700*	*Low Density*	*1000-2000m*	*1000-2000m*	*Least Available*
Pure Sal	-	*Above 3000m*	*15-20%*	*700-800*	-	*Above 2000m*	*Above 2000m*	
Salai Forest	-		*20-30%*	*800-900*	-	-	-	
Non Forest			*Above 30%*	*Above 900m*				

ASSIGN CLASS WEIGHT

7	*9*	*9*	*2*	*7*	*9*	*2*	*1*	*9*
9	*6*	*8*	*3*	*9*	*4*	*4*	*3*	*6*
4	*1*	*6*	*9*	*6*	*2*	*6*	*5*	*4*
4		*4*	*7*	*5*	*5*	*9*	*7*	*1*
5		*2*	*5*	*4*	-	-	*9*	-
2			*4*	*3*	-	-	-	-
1			*1*	*2*	-	-	-	-

ASSIGN THEAM WEIGHT

Vegetation Type	Forest Type	Distance to Water	Slope Percentag	Topography	Drainage Density	Distance to Road	Distance to Habitation	Prey Availability
15	15	15	10	10	5	2	3	25

Habitat Suitability for Tiger

Table cum flow diagram 4 Flow diagram showing the model structure for Tiger

Suitability scores and preference weights have been determined from questionnaire responses and input into the ARC GIS program. 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, Chital & Sambar.

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 categorized in 0-9 scale which was further grouped into highly suitable, Suitable, moderately suitable, less suitable and unsuitable. Further weighted have been assigned to each parameter so as to accommodate their significance. Weight age 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 vegetation type has assigned the weight age of 20, forest density (15), slope (15), distance to water (15), topography (10), drainage density (10), distance to habitation (10) and distance to road & railway have been assigned the weight age of (5).

For Sambar habitat suitability analysis vegetation type has been assigned the weight age of (20), forest density (15), slope (15), distance to water (25), topography (10), drain density (5), distance to habitation (5) and distance to road & railway have been assigned the weight age of (5).

For Tiger habitat suitability analysis, prey availability has been assign the weight age of (25) vegetation type (15), forest density (15),slope (10),distance to water (15),topography (10), drain density (5), and distance to road-rail & habitation have been assigned the weight age of (5).

Finally, all the parameters (P1…P9) have been integrated to derive the tiger habitat suitability map. Figure 4 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.

RESULT & DISCUSSION

The delineation of habitat suitability zone by reclassifying into different potential zones; Highly, high, moderate, low and unsuitable (Figure 6) was made by utilizing the criteria for GIS analysis have been defined on the basis of field survey, field data and experts knowledge, appropriate weight age 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 2 to 9 (Figure 5). Higher the value indicates more suitability and lower value indicates lesser suitability. CHSI map has been classified using the Arc GIS 9.3 software.
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.

Since the present approach has been built with logical conditions and reasoning, this approach can be successfully used elsewhere with appropriate modifications. Thus, the above study has also clearly demonstrated the capabilities of remote sensing and GIS technique in demarcation of the different habitat suitability zones .The validity of the model developed was tested against the GPS locations of tiger, chital and sambar habitats, the overall accuracy of the model were above > 90 %.

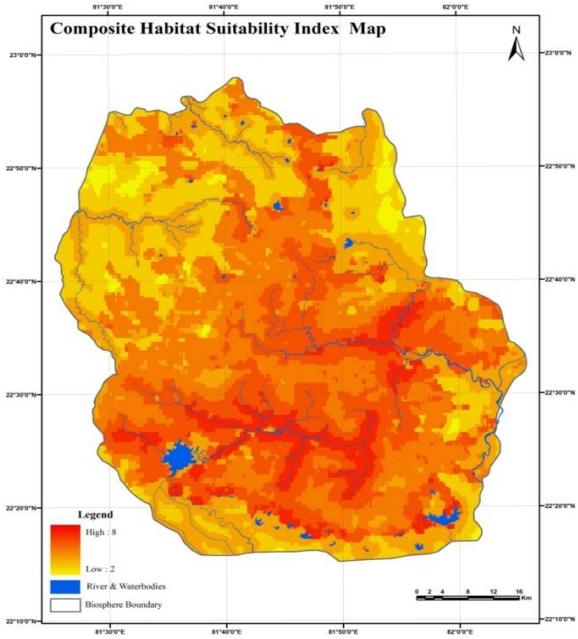

Figure 5 Composite Habitat Suitability Index for Tiger

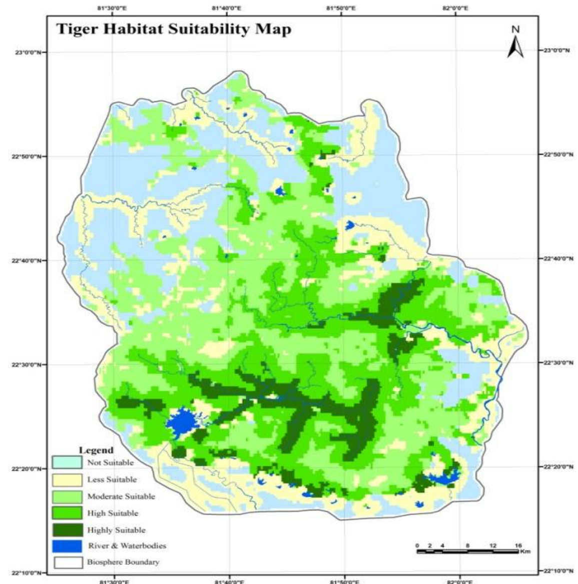

Figure 6 Habitat Suitability Map for Tiger

The model generated will help as a guideline for designing a suitable plan in the future. The spatial distributions of the various habitat suitability zones obtained from the model generally show regional patterns of river, forest density, forest type, drainage, landform and lithology. Spatially the very good and good categories are distributed along areas near to water. The final habitat suitability map generate from weighted overlay analysis show that out of the total geographic area of 3835 sq. km. very highly suitable area is 7.03% (269.54 sq. km.), and highly suitable constitute 23.23 % (890.84 sq. km.) while moderately suitable class cover 28.09 % (1076.92 sq.km.) and less to not suitable class covers about 41.65 % (1597.06 sq.km.) area. The above result clearly indicates that about 58 % area of biosphere are suitable for tiger habitat.

Table 1 Habitat distribution of Tiger

Class	Area in Sq. km.	Area in %
Not Suitable	86.92	2.27
Less Suitable	1510.14	39.38
Moderate Suitable	1076.92	28.09
High Suitable	890.84	23.23
Highly Suitable	269.54	7.03

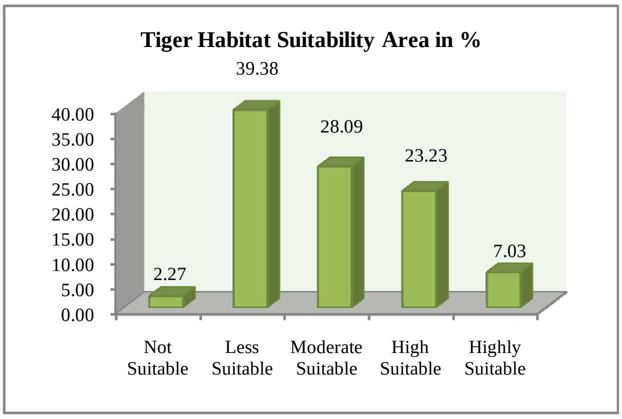

Figure 7 Distribution of Tiger in different habitat suitability categories

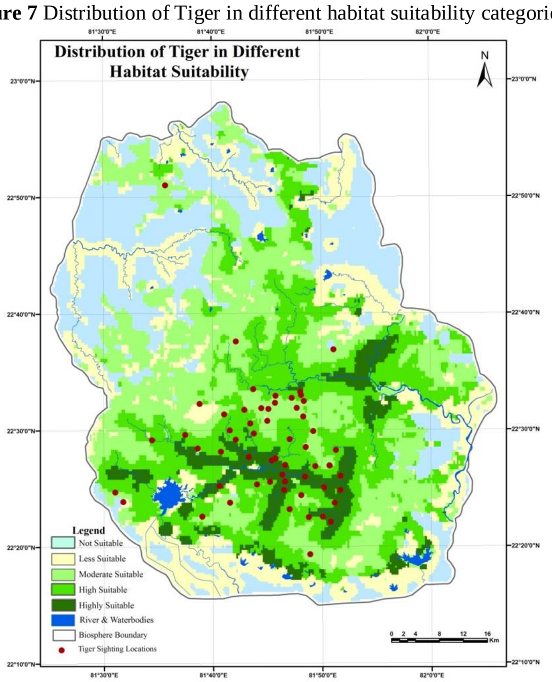

Figure 8 Habitat suitability map of Tiger showing distribution (GPS Locations) of Tiger in different habitat suitability categories

Validation of MAPS

Based on the GPS location data of Tiger in different habitat suitability categories, an accuracy assessment of the habitat suitability map for tiger was done. Overlaying of all the tigers sighting locations (total 57) over the suitability map was done in Arc GIS 9.3 environment. The result shows that out of 57 locations, in 24 locations (about 42 % area) tigers were found in very highly suitable habitat. In 20 location (35%) tigers were found in high suitable area and rests in 13 locations (23%) were found in moderate to less suitable habitat of the Biosphere Reserve. It indicates that the model prepared for the assessment of tiger habitat suitability in AABR has its validation with the reality. It shows that tiger preferred the highly and moderately suitable habitats in comparison to less suitable habitat in the biosphere (Figure 8).

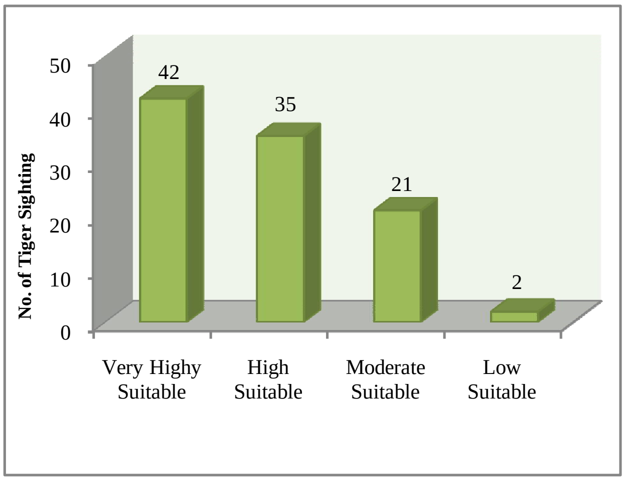

Figure 9 Distribution of Tiger in different habitat suitability categories.

It is evident from the present study that the distribution of Tiger, Chital & Sambar in AABR completely depends upon the habitat parameters like availability of food, plant, distance from water body, distance from road, distance from human settlement, slope, topography, forest cover, landuse etc. The habitat parameters have tremendous impact over the habitat utilization and suitability pattern of Tiger, Chital & Sambar in AABR.The information extracted in this study would be of immense use if linked to other planning and policy making ventures, such as resource allocation, land use planning and sustainable management of natural resources. Data on landuse/landcover classification and landscape patterns can serve as baseline spatial information which could be useful for monitoring changes in land cover and landscape dynamics in future, this spatial data can also be useful for research and management of wildlife species particularly associated with Mixed/degraded and deciduous forests.

Such type of data have also successfully used with multispectral remote-sensing data and elevation- slope complexes to delineate different species assemblages in evergreen forest of Tirunelvi-hills of Western Ghats, Tamil Nadu.

CONCLUSIONS AND RECOMMENDATIONS

Habitat plays a vital role for all wildlife populations; good habitats can support the requirements of tigers and their prey for long-term survival. 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. 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 reserve. 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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