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Full Length Research Paper

Habitat Modeling for Tiger (*Penthra Tigris*) Using Geo-spatial Technology of Panna Tiger Reserve (M.P.) India

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Abstract. The Tiger (*Panthera tigris*) population in India has undergone a sharp decline during the last few years. Habitat zones where prey populations are abundant are likely to be preferred by the tiger in comparison to those where they are scarce or absent. An area having a high density of road would be avoided by wild animals as compared to an area with few or no roads because there is a high traffic and constant noise. Habitat suitability index (HSI) models have been used to evaluate wildlife habitat. These models are based on functional relationships between wildlife and habitat variables. Values of habitat variables (e.g., herbaceous canopy cover, tree canopy cover, tree height) are related to habitat quality on a suitability index (SI) scale from 0 = "not habitat" to 1 = "habitat of maximum suitability." Habitat suitability index scores, also on a 0–1 scale, are usually calculated using a mathematical formula representing hypothesized relationships among the individual SIs. Tiger (*Panthera tigris*) prefer core habitats, generally avoid area with high edge density. In the study area landscape, the Ken River is the perennial water sources; Prey species of tiger and the Tiger also preferred areas proximate to perennial water sources is favored. Tigers, under normal circumstances of human settlement, avoid traversing through such areas. Tiger's preferred prey includes in the study area, this group is commonly represented by Chital (*Axis axis*), Sambar (*Cervus unicolor*), Wild-boar (*Sus scrofa*), Barking deer (*Muntiacus muntjak*), and Nilgai (*Boselaphus tragocamelus*) were also encountered in the study area.

Keywords: Habitat Modeling, Habitat Suitability Index, GIS, Ecogeographical

1. INTRODUCTION

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. Tropical dry-deciduous forests comprise more than 45% of the tiger (*Panthera tigris*) habitat in India. Tiger (*Panthera tigris*) requires large areas of contiguous habitat for long-term survival. In this study tiger densities were estimated using photographic capture-recapture sampling in the dry forests of Panna Tiger Reserve in Central India. The Tiger (*Panthera tigris*) population in India has undergone a sharp decline during the last few years. Of the number of factors attributed to this decline, habitat fragmentation has been the most worrisome (Rathore et al., 2012). The habitat fragmentation issue is of particular relevance to developing countries where most of the biodiversity rich tropical ecosystems are located. Natural ecosystems in many developing nations are currently facing an unprecedented threat from diverse competing pressures arising from a burgeoning human population and unregulated economic growth. India is one of the twelve mega-biodiversity nations of the world (Alfred, 1998). Of these, around 175 animal species are in the IUCN (IUCN, 2010) red list threat category. Information of habitat features used by an animal, and the ones that a preferred or avoided are needed to understand many ecological aspects of animals and further to plan for conservation. We studied tiger and selection of habitat at Panna national park. Tiger is an umbrella species for the conservation of the biota of majority of the eco-regions in Asia. Its role as a top predator is vital in regulating and perpetuating ecological processes and systems. India is home to over 50% of the world's wild tigers in spite of having a growing human population of over a billion. It is also one of the world's fastest growing economies. It is with full recognition of these challenges that India is committed to conserving its tigers and their habitats. India plays an important role in accomplishing the objectives of the Global Tiger Recovery Plan that was ratified at the meeting of world leaders held at St. Petersburg in 2010, out of concern, for the first time in the history of this planet, for a species other than humans (Jhala et al., 2011). Urbanization, industrialization, infrastructure development projects, agriculture, grazing, deforestation, wildlife trade and poaching continue to create tremendous stress on pristine natural habitat and wildlife. Remote sensing and Geographical Information System (RS and GIS) can be used as tool for getting information about the habitat preference of the wildlife species. RS and GIS also help in monitoring areas of land for their suitability to endangered species, through integration of various habitat variables of both spatial and non-spatial nature (Davis and Goetz, 1990). 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 (Kushwaha et al., 2004 and zarri et al., 2008).

Geospatial technology including: remote sensing, geographic information system (GIS) and global positioning system (GPS) along with a habitat suitability index (H.S.I.) model provide an efficient and low-cost method for determining habitat quality (Schamberger et al.,1982). The use of satellite imagery, geographical information systems (GIS) and statistics may assist in quantifying available habitat for animal species (Johnson, 1990). A suitability index provides the likelihood of how much area is suitable for a particular species. The higher the values the better are the chances that a particular location is suitable for the occurrence of that species. In this model, regression is used on several environmental parameters to calculate an index of species occurrence (Clark and Evans 1954 and Schadt et al., 2002). Forest and habitat modeling can be used to evaluate the potential impacts of alternative biodiversity conservation strategies. The effective planning for preservation of biodiversity in managed forest landscapes requires the application of decision support systems (DSS) to evaluate the potential impact of alternative stand and landscape management activities on indicators of habitat suitability. DSSs are most effective when implemented within an adaptive management cycle including a well defined set of indicators, monitoring systems, and mechanisms for feedback from researchers, industry, and stakeholder groups.

The history of the models is back to 1976 when Habitat Evaluation Procedure (HEP) was developed by U.S. Fish and Wildlife Service. The main objectives of Habitat modeling are predicting distribution of wildlife species in geographical area with high species diversity (Butterfield, 1994), locating of species of concern (Sperduto, 1996) predicting area of suitable habitat that may not be currently used by species (Lawton, 1991) and aid to species re-introduction or prediction of the spread of an introduced species (Nazeri et al., 2010). During recent years there has been growing attention to the need to consider models as an integral part of Geographical Information System (GIS) and to improve understanding and application of models. When models are applied to the environment, it is expected that insights about the physical, biological, or socioeconomic system may be derived. They may also allow prediction and simulation of future conditions. The reasons for building models are to understand, and ultimately manage, a sustainable system.

Habitat suitability index (HSI) models have been used to evaluate wildlife habitat and the effects of management activities and development since the early 1980s (U.S. Fish and Wildlife Service 1980 1981). These models are based on functional relationships between wildlife and habitat variables. Values of habitat variables (e.g., herbaceous canopy cover, tree canopy cover, tree height) are related to habitat quality on a suitability index (SI) scale from 0 = “not habitat” to 1 = “habitat of maximum suitability.” Habitat suitability index scores, also on a 0–1 scale, are usually calculated using a mathematical formula representing hypothesized relationships among the individual SIs. Wildlife–habitat relationships may be supported by empirical data, expert opinion, or both (U.S. Fish and Wildlife Service 1980, 1981). Each species has some requirements based on its behavioral, biological, genetics and evolutionary history to choose a habitat for survival and each habitat must provide these species requirements. By identifying species requirements within habitats we can define suitable areas for species survival. This issue is critical, especially in tropical areas with high species richness that the habitat is losing the suitability due to human pressure. The main purpose of habitat Suitability 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 ecogeographical 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).

2. MATERIAL AND METHODS

2.1. Study Area

Panna National Park is located in North Central Madhya Pradesh. The park lies between north latitudes 24^0 27' & 24^0 46' and east longitudes 79^0 45' & 80^0 9'. Panna Tiger Reserve covers 542.67 km2 of the Vindhyas in north-central Madhya Pradesh. The park is spread across parts of Panna and Gunor tehsil in Panna district and Bijawar and Chhatarpur tehsils in Chhatarpur district, roughly about two thirds of its area is located in the district of Panna and rest within the chhatarpur district. The region has some diamond mines for which it is famous. Like Sariska, Panna lost all of its tigers in 2009 (Gopal 2010) and currently three females and one male have been successfully reintroduced. Two of the reintroduced tigresses have subsequently bred and produced litters. The park occupies an area of 543Km^2 spread over two districts, Panna and Chattarpur. Ken river which is recognised as one of the twelve perennial rivers of the state, enters the park towards the south, flows through its western parts to emerge out at Mandla village in the north. It flows further north to meet Yamuna in Banda district of U.P. Within the park Ken makes boundry between the two districts of Panna and Chhatarpur and traverses a distance of about 55km, which provides water to people and wildlife. Under such circumstances it is no surprise that the park is subject to intense human pressure. There are at present 13 Villages comprising 15 habitations inside the park. These are all revenue villages. The region, famous for its diamond industry, is also home to some of the best wildlife species in India and is one of the most famous Tiger Reserves in the country. The park is known worldwide for its wild cats, including tigers as well as deer and antelope. Due to its closeness to one of the best known Indian tourist attraction in India, Khajuraho, the park is recognized as an exciting stop-over destination. The climate of the region is tropical. The terrain of the reserve is characterised by extensive plataeus and gorges. The reserve which has bench topography can broadly be divided into three distinct tablelands on Panna side: the upper Talgaon Plateau, the middle Hinauta plateau and the Ken valley. Climate is hot and dry for about 7 months. Rains from southwest Monsoon, from about June – end till mid – September, bring much pleasure in the sense that weather then becomes milder with average relative humidity rarely crossing 95%. Average annual rainfall for Panna district is 1,200 mm. and about 1,100 mm. in Chhatarpur. Panna National Parks consisting of 6 types of forests as Southern Tropical Dry Deciduous Dry Teak Forest, Northern Tropical Dry Deciduous Mixed Forest, Dry Deciduous Scrub Forest, Boswellia forest, Dry Bamboo Brakes and Anogessius pendula Forest (Champion and Seth, 1968).

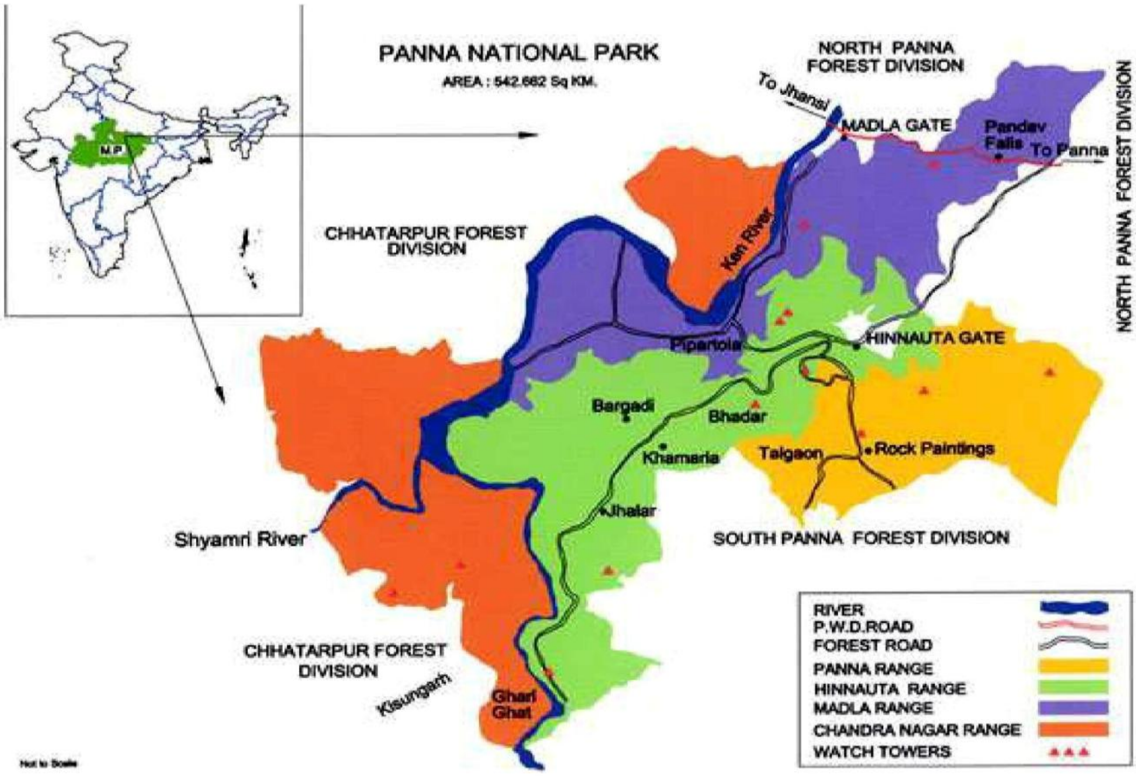

Fig. 1: Location map of Panna Tiger Reserve

2.2. Field Method and Data Collection

Evaluating the habitat suitability for the Tiger (*Panthera tigris*) in the intensive study area of Panna National Parks. The data collection effort was comprised of two components: Prey species population distribution and habitat evaluation. Two methods were used to measured abundance estimates of prey species in the different areas, namely; the line transect Method (Burnham et al. 1980) and pellet group count Technique (Bennett et al.1940, Ebernhardt et al. 1956 and Neff 1968). The ideal habitat evaluation scheme must consider to our understanding of the needs and requirements of the animal

Topographic maps of (1:50 000 scale) were collected from Geographical Survey of India (GSI), Dehradun. All topographic sheets were scanned separately and were georeferenced to Geographic Lat-Long Projection to sub-pixel accuracy. The common uniformly distributed ground control Point‘s (GCP) were marked with root mean square error of one third of a pixel and images were re-sampled by nearest neighbour method with the help of software ERDAS IMAGINE 9.1 in image format (.img) and then mosaicing of them. After Geo-referencing and Mosaicing of all toposheets area of interest (AOI) was extracted. The Landuse land cover map was prepared through digital analysis of satellite data using supervised maximum likelihood classification technique. The layout of data collection and different strategies which were applied for the study described in figure 1 and 2.

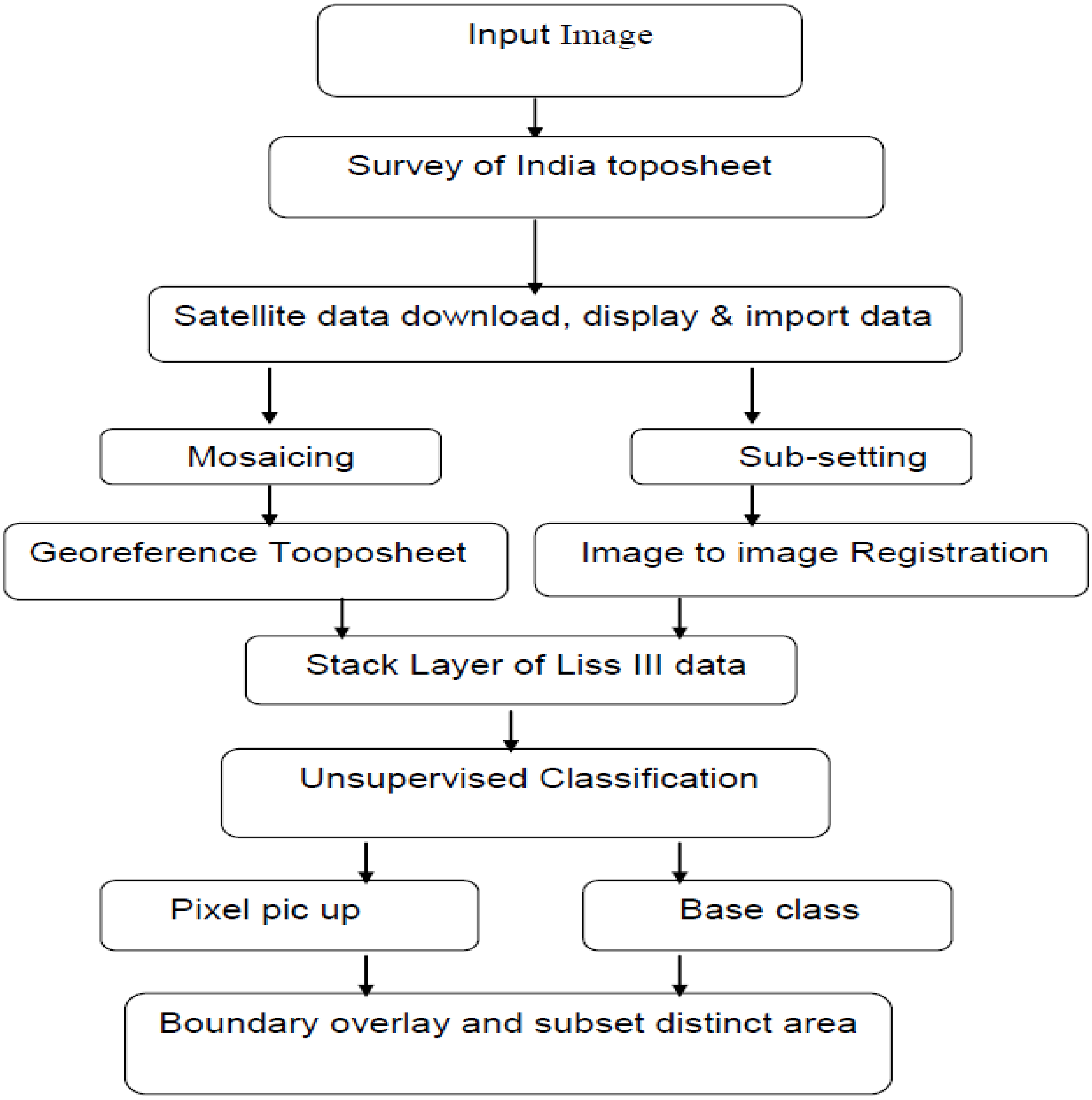

Fig. 2: Flow Chart of data collection

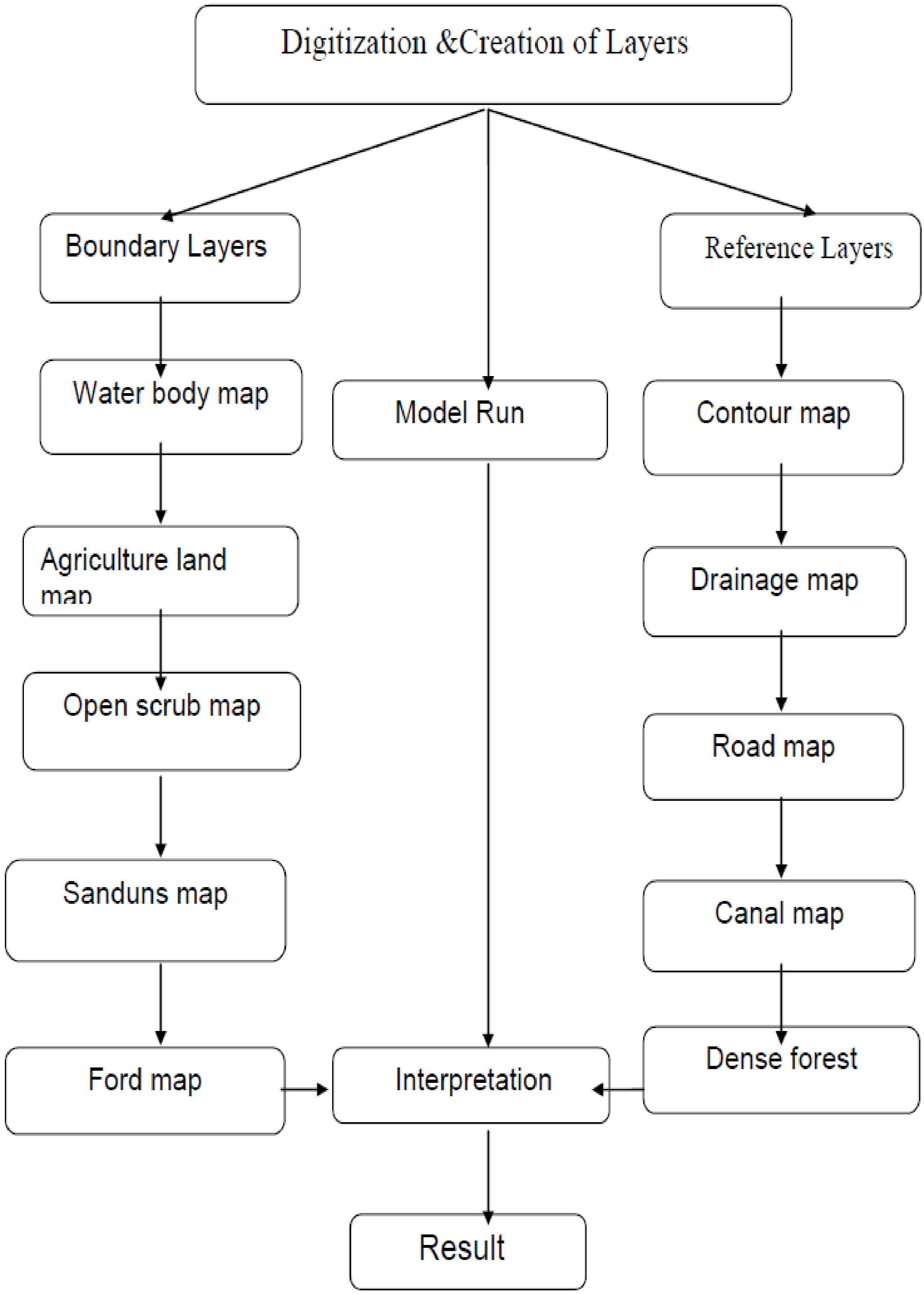

Fig. 3: Flow Chart of digitization & layer creation

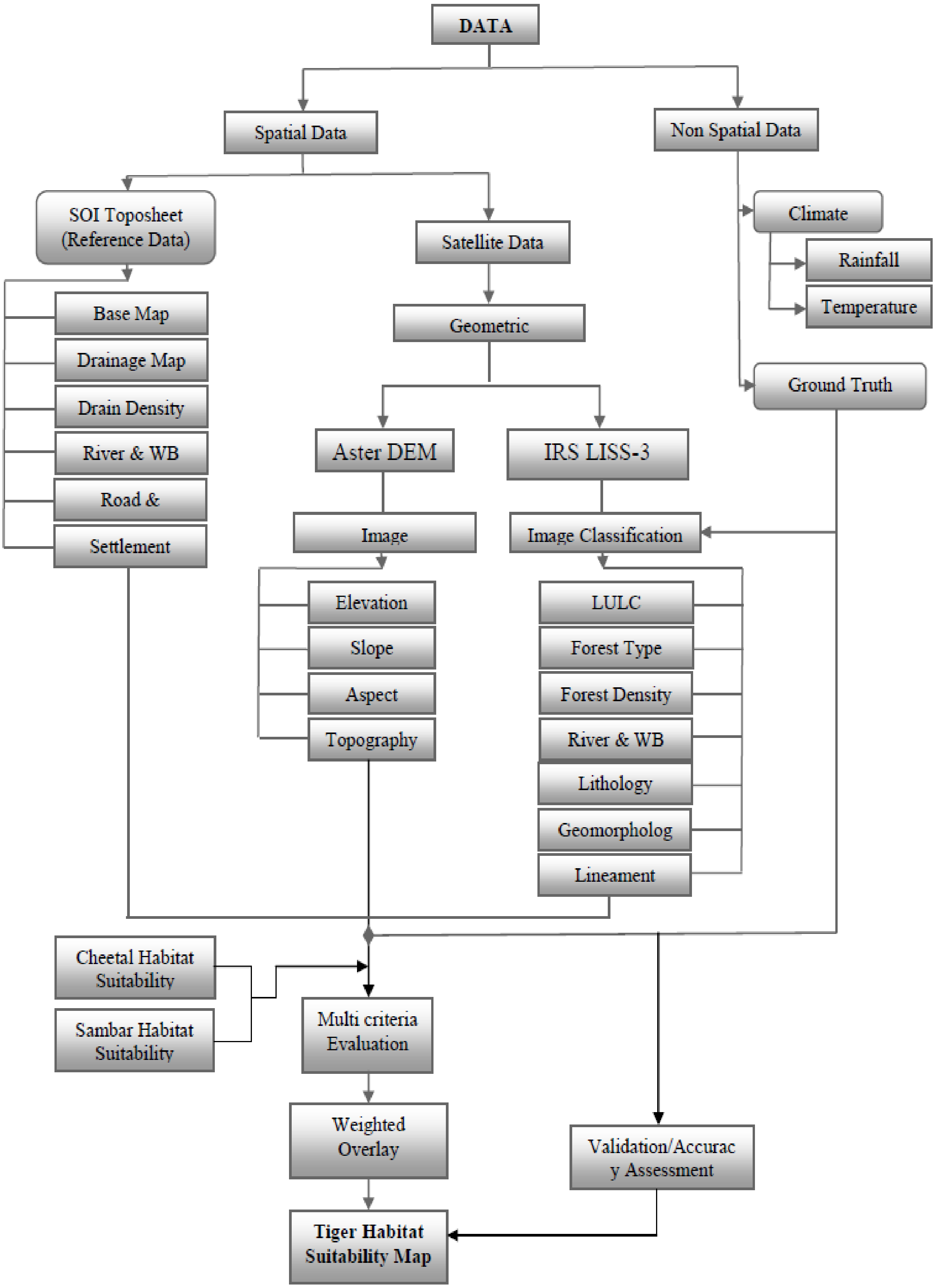

Fig. 4: Flow chart showing data and methods employed for the study of Tiger Habitat Suitability Analysis (THSA)

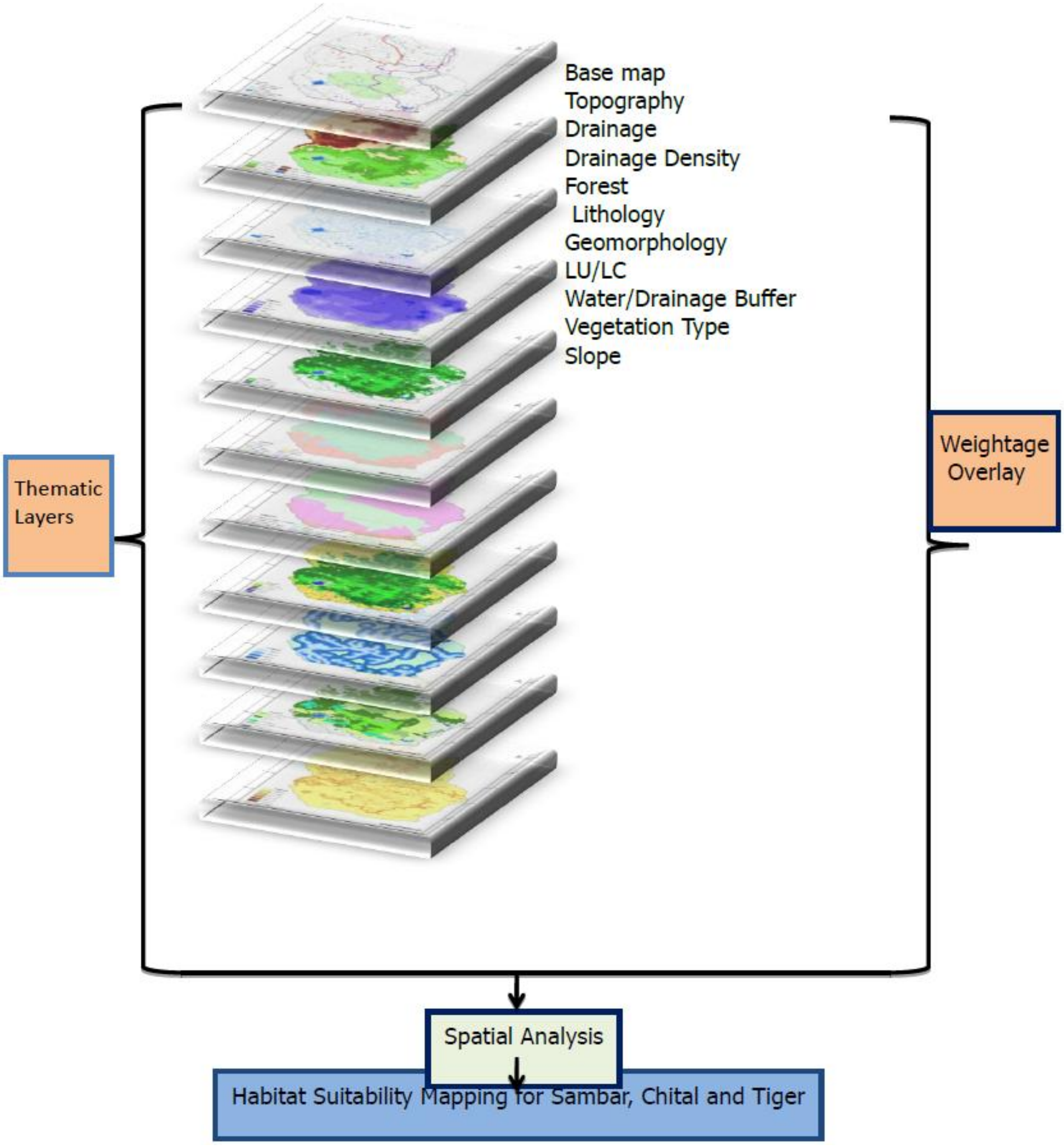

Fig. 5: Geospatial Modeling – Habitat Suitability Mapping

2.3. Satellite data

Indian remote-sensing satellite data of -P6, linear imagine self-scanning LISS-III (IRS-P6, LISS-III) data of dated 25th February 2009, swath width 140 km with a ground resolution of 23.5m has been acquired from National Remote Sensing Centre (NRSC), Hyderabad, India and Landsat TM satellite data has been downloaded from the website www.glovis.usgs.gov,which have swath width 185*185 sq. km. with a ground resolution of 30 m. The satellite data of study area has been imported into *ERDAS IMAGINE 9.1* in img. format for geometric correction. Images have been co-registered with already rectified Landsat TM satellite data of April 2010 to accuracy below root mean square error (RMSE) 0.2 precision. Then rectified scenes (LISS-III) have been mosaiced. From the mosaiced data, a subset of area of interest (AOI) has been made for further analysis. Image has been displayed in false color composite (FCC) using three bands 3, 2, 1 and color print has been taken out for field work (ground truthing).

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 (figure 3).

2.4. Habitat suitability

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 (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 had been applied.

(ii) 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.

(iii) 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. 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). Now a day's tiger is 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.

Suitability maps have been developed by integrating expert opinion with Geographic Information System (GIS) database. The 0-9 points scale multi criteria evaluation methodology has been implemented to solicit the importance of ground characteristics (criteria) for Tiger. 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 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.

2.5. Prey availability

Tigers are carnivores and feed on a wide variety of animals. Although habitat dictates the type of animal that it hunts, the tiger prefers larger prey, such as Sambar (*Cervus unicolor*), Chital (*Axis axis*), Deer, wild-boar (*Sus scrofa*), barking deer (*Muntiacus muntjak*), and nilgai (*Boselaphus tragocamelus*) and buffalo. If the preferred food source was unavailable it also hunts fish, monkeys and various small mammals. In the present study two important species *viz.*, *Sambar* and *Chital* have been identified as major prey as other prey also known to live in the same habitat. The prey availability for tiger has been carried out in two steps. First, habitat suitability evaluation of Sambar and Chital has been done separately using the criteria (Menon, 2003) then prey availability map for tiger was prepared sequentially from high suitability to unsuitable from Sambar and Chital suitability map using overlay operation in GIS.

2.6. Multi-criteria Evaluation

Multi-Criteria Analysis (MCA) is a decision-making tool developed for complex problems. The research studies the conceptual framework of habitat development and introduces the theoretical basis of MCA, and methods such as ranking, rating and pair wise comparisons in the Analytic Hierarchy Process (AHP). This study has used ranking / weighted based analysis.

Table 1: Influences and weightage of different thematic layers for contributing habitat for Chital in Panna Tiger Reserve

Raster Layer	Influence % (Theme Weight)	Feature Classes or Buffer Distance	Feature Class Weight
Vegetation	**20**	**Vegetation Type**	
		Misc forest with grassland	9
		Mixed Forest	7
		Teak & bamboo plantation.	6
		Teak Forest	5
		Pure Sal	6
		Salai Forest	2
		Non Forest	1
Forest Cover	**15**	**Forest density**	
		Dense	6
		Moderate Dense	9
		No Forest	1
River & WB	**15**	**River & WB Buffer**	
		0-500m	9
		500-1000 m	7
		1000-2000m	5
		2000-3000	3
		Above 3000 m	1
Slope	**15**	**Slope Gradient in Degree**	
		0-2 %	2
		2-5 %	9
		5-10 %	7
		10-15 %	5
		15-20 %	4
		20-30 %	3
		Above 30 %	1
Topography	**10**	**Elevation in M**	
		0-400m	9
		400-500 m	6
		500-600 m	5
		600-700 m	4
		700-800 m	3
		800-900 m	2
		Above 900m	1
Drainage density	**10**	**Drainage Density**	
		Very high	9
		High	7
		Moderate	5

		Low	2
Road & Rail	10	**Distance to Road & Rail**	
		0-100 m	4
		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

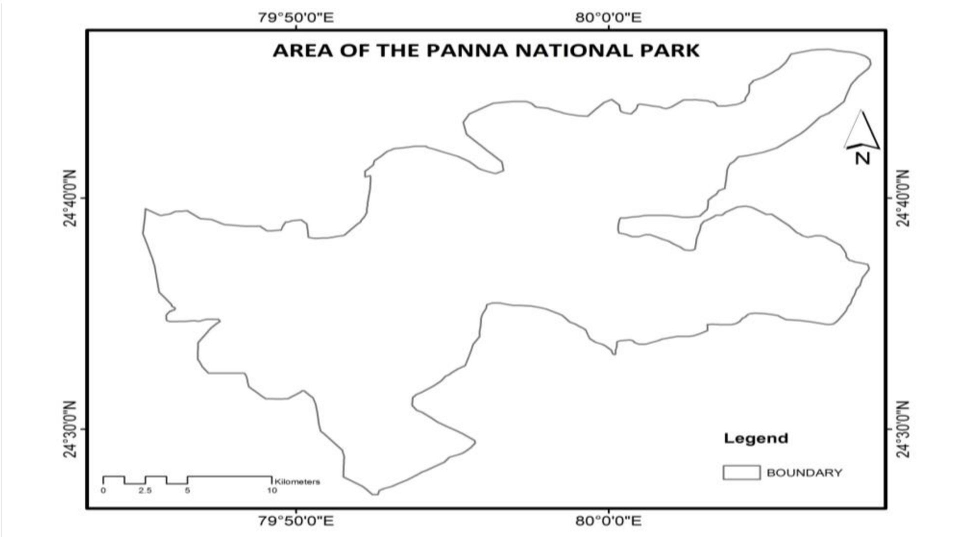

Fig. 6: Area of Interest (AOI) map of the Study area

2.7. Multi-criteria Analysis

A model to evaluate tiger suitability has been developed using multi criteria, suitability index approach by integrating different input 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 8-9, High Suitable 6-8, moderately suitable 4-6, less suitable 2-4 and unsuitable 1. 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 Tiger Habitat Suitability analysis Prey Availability has been assign the weightage of (25) Vegetation Type (15), Forest density (15), Slope (10), Distance to water (15), Topography (10), Drainage Density (5), and Distance to Road-Rail & Habitation have been assigned the Weightage of (5).

Table 2: Influences and weightage of different thematic layers for contributing habitat for Sambar in Panna Tiger Reserve

Raster Layer	Influence % (Theme Weight)	Feature Classes or Buffer Distance	Feature Class Weight
Vegetation	**15**	**Vegetation Type**	
		Misc forest with grassland	7
		Mixed Forest	9
		Teak & bamboo plantation.	4
		Teak Forest	4
		Pure Sal	5
		Salai Forest	2
		Non Forest	1
Forest Cover	**15**	**Forest density**	
		Dense	6
		Moderate Dense	9
		No Forest	1
River & WB	**25**	**River & WB Buffer**	
		0-500m	7
		500-1000 m	9
		1000-2000m	6
		2000-3000	5
		Above 3000 m	4
Slope	**15**	**Slope Gradient in Degree**	
		0-2 %	1
		2-5 %	5
		5-10 %	7
		10-15 %	9
		15-20 %	3
		20-30 %	5
		Above 30 %	2
Topography	**10**	**Elevation in M**	
		0-400m	2
		400-500 m	4
		500-600 m	3
		600-700 m	5
		700-800 m	7
		800-900 m	9
		Above 900m	3
Drainage density	**10**	**Drainage Density**	

		Very high	4
		High	6
		Moderate	9
		Low	1
Road & Rail	5	**Distance to Road & Rail**	
		0-100 m	1
		100-500 m	3
		500-1000 m	4
		1000-2000 m	6
		Above 2000m	9
Human Settlement	**5**	**Distance to Settlement**	
		0-100 m	1
		100-500 m	3
		500-1000 m	5
		1000-2000 m	9
		Above 2000 m	9

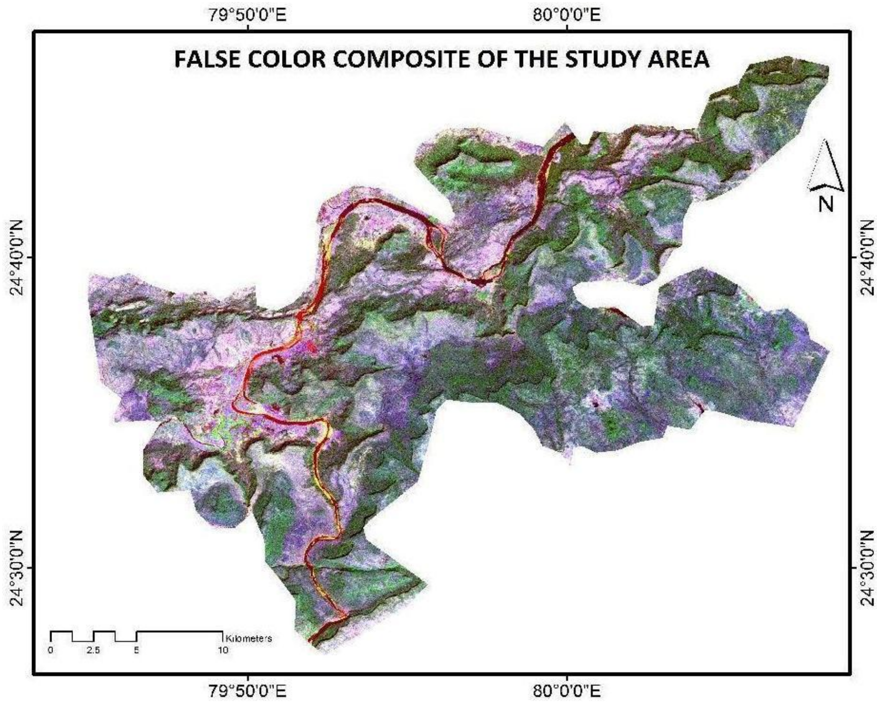

Fig. 7: False Color Composite map of the Study area

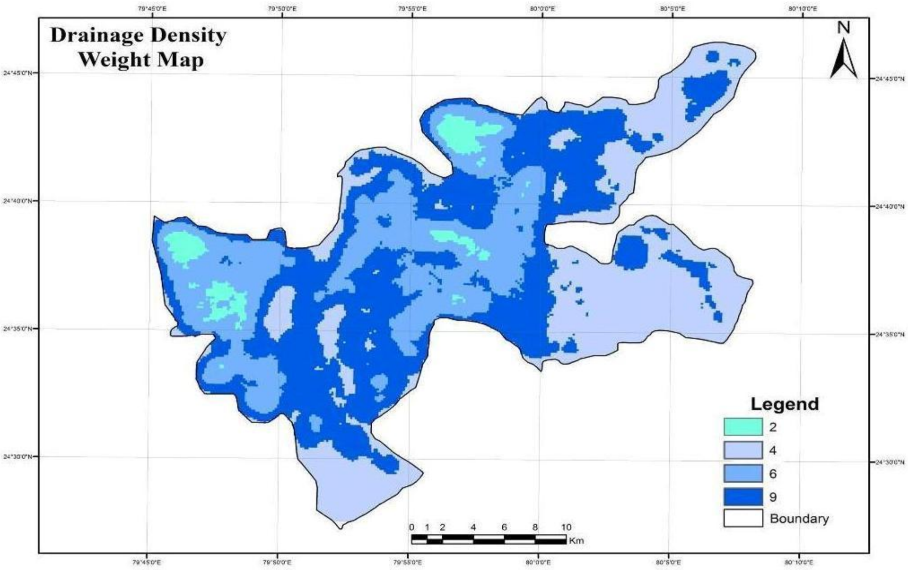

Fig. 8: Drainage Density Weight Map for Tiger

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.

(i) All the data sets have been then converted into raster grid in the model in order to perform different GIS analysis between data layers such as overlay analysis; (ii) All the data sets have been reclassified based on their importance to Habitat potentiality (availability); (iii). Prior to integration of the data sets, individual class weights and map scores have been assessed based on Multi criteria weighted overlay (figure 6.1, 6.2 and 6.3); (iv) After given the weight of the each class and influence (%) of the each layer depend on the Habitat Suitability prepare the Habitat Suitability Map.

A Number of factors that tells how important a variable are for a particular calculation. The larger the weight assigned, the more that variable will influence the outcome of the operation, called the weighted based function. All following steps have done on Arc GIS.

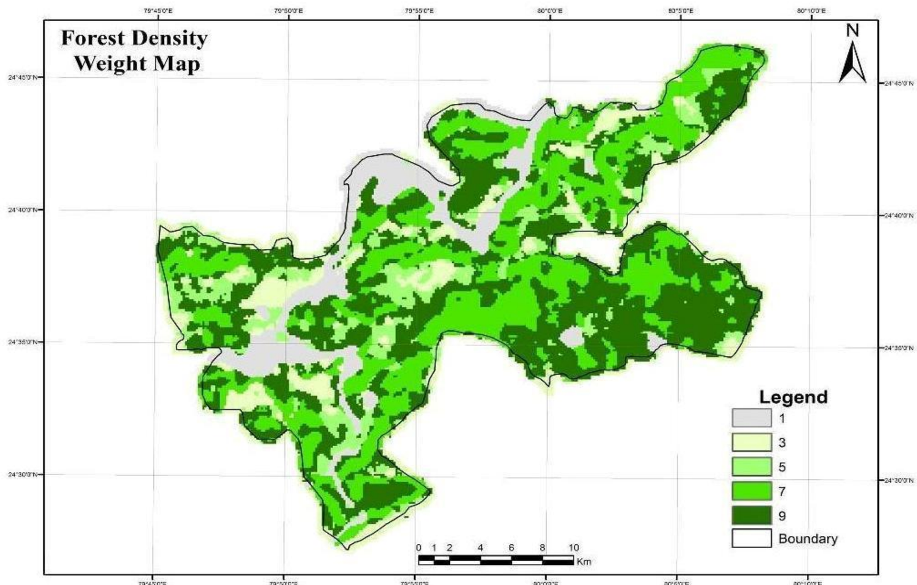

Fig. 9: Forest Density Weight Map for Tiger

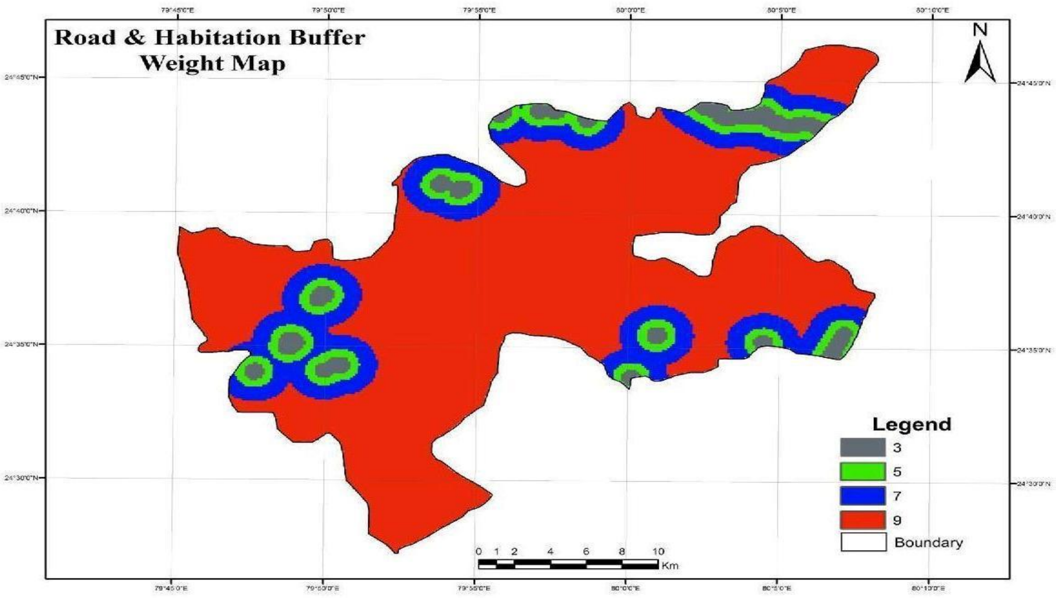

Fig. 10: Road and Habitation Buffer Weight Map for Tiger

3. RESULTS AND DISCUSSIONS

Analysis of wildlife habitat is considered more important for management and planning of protected areas. The effects of fragmentation and habitat loss are modified by landscape configuration, specifically the size, shape and layout of habitat fragments (Saunders, 1991) with decreasing size and increasing fragmentation of habitats; it has become imperative to develop maps of habitat quality for habitat conservation intact. The main objectives of Habitat modeling are predicting distribution of wildlife species in geographical area with high species diversity (Butterfield, 1994), locating of species of concern (Sperduto, 1996), predicting area of suitable habitat that may not be currently used by species (Lawton, 1991) and aid to species re-introduction or prediction of the spread of an introduced species (Table 1). Habitat modeling can create large-scale predictions of habitat suitability for wildlife species, without detailed knowledge of their physiology and behavior. Furthermore, using habitat models can be a cost-effective and productive endeavor. Habitat models simplify the representation of Ecological processes which are very complex and too difficult to show every factor that influences species distribution or abundance (Reichert, 1997).

The maps (Figure 8 to 13) of the parameters Vegetation type, Forest density, Slope, Distance to water, Topography, Drainage Density, Distance to Habitation and Distance to Road& Railways have been prepared and assigned respective theme weight and their class weights. The individual theme weight has been multiplied by its respective class weight and then all the raster thematic layers have been aggregated in a linear combination equation in Arc Map GIS Raster Calculator module as given

Here:

For Chital,

HSM = (FDwt * 0.15) + (VTwt * 0.20) + (DWwt * 0.15) + (Slopewt* 0.15) + (Elvwt * 0.10) + (DDwt * 0.05) + (DHwt * 0.05) + (DR&Rwt * 0.10)

For Sambar,

HSM = (FDwt * 0.15) + (VTwt * 0.20) + (DWwt * 0.25) + (Slopewt* 0.15) + (Elvwt * 0.10) + (DDwt * 0.10) + (DHwt * 0.05) + (DR&Rwt * 0.05)

For Tiger,

HSM = (FDwt * 0.15) + (VTwt * 0.15) + (DWwt * 0.15) + (Slopewt* 0.10) + (Elvwt * 0.10) + (DDwt * 0.05) + (DHwt * 0.02) + (DR&Rwt * 0.03) + (Prey*0.25)

Here,

HSM = Habitat Suitability Map, FD = Forest Density, VT= Vegetation Type, DW= Distance to Water, ELV= Elevation, DD = Drainage Density, DH = Distance to Habitation, DR& DR = Distance to Road & Railway, wt = Feature class weight.

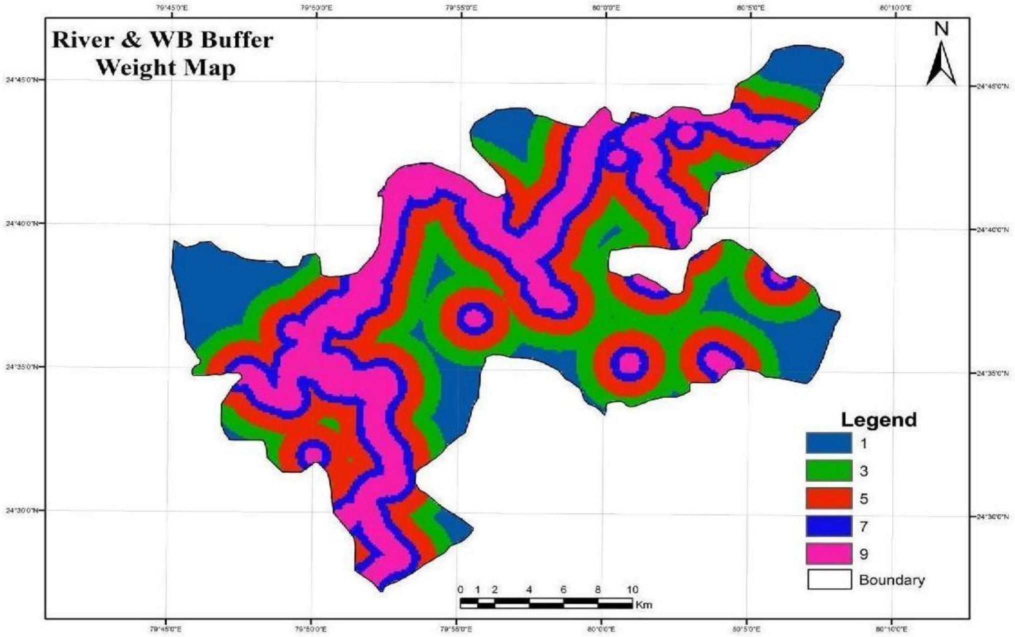

Fig. 11: River and Water Body Buffer Weight Map for Tiger

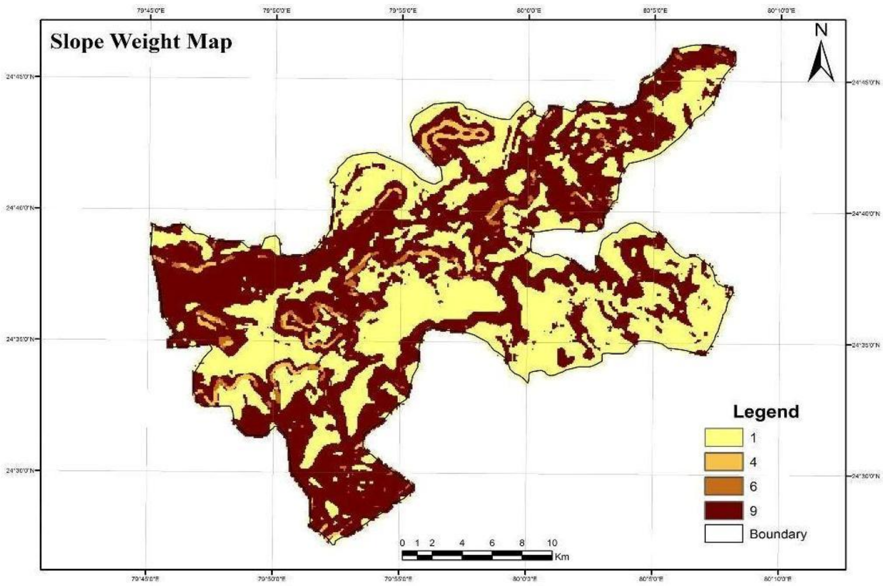

Fig. 12: Slope Weight Map for Tiger

The Arc GIS 9.3 tool has been used for suitability modeling (to locate suitable areas); higher values generally indicate that a location is more suitable. The tool has been used to generate a Habitat Suitable area for Tiger and their Prey species.

The delineation of Habitat Suitability Zone by reclassifying into different potential zones; Very Good, Good, Moderate, Low and Unsuitable (figure 14) 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 project area is related mainly to Forest density, Forest type Availability of water, Slope and Topography of the area. The validity of the model developed was tested against the GPS Locations of tiger habitats, the overall accuracy of the model are above > 90 %.

The integrated resulted 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, Higher the value indicates more suitability and lower value indicates lesser suitability. CGHU map has been classified using the ArcGIS 9.3 software for final 'Habitat Suitability Zone Map' showing spatial distribution of five Habitat Suitability zones (figure 14).

Tigers have very large home ranges which have been reported to be up to 30–40 kilometers or even larger. The habitat layer ranks zones preferred by prey species of tiger in the study area. Assessment of preference is based on field data of pellet counts associated with each cover type. Habitat zones where prey populations are abundant are likely to be preferred by the tiger in comparison to those where they are scarce or absent. Consequently, cost of movement to high prey abundance areas will therefore be less. As can be seen, areas dominated by bamboo are preferred by tiger prey Species as sufficient browse is available at approachable height (Rathore 2012). An area having a high density of road would be avoided by wild animals as compared to an area with few or no roads because there is a high traffic and constant noise. This edge effect includes a distinctive species composition or abundance in the outer part of the landscape patch (Forman 1995). Species like the tiger, which prefer core habitats, generally avoid areas with high edge density.

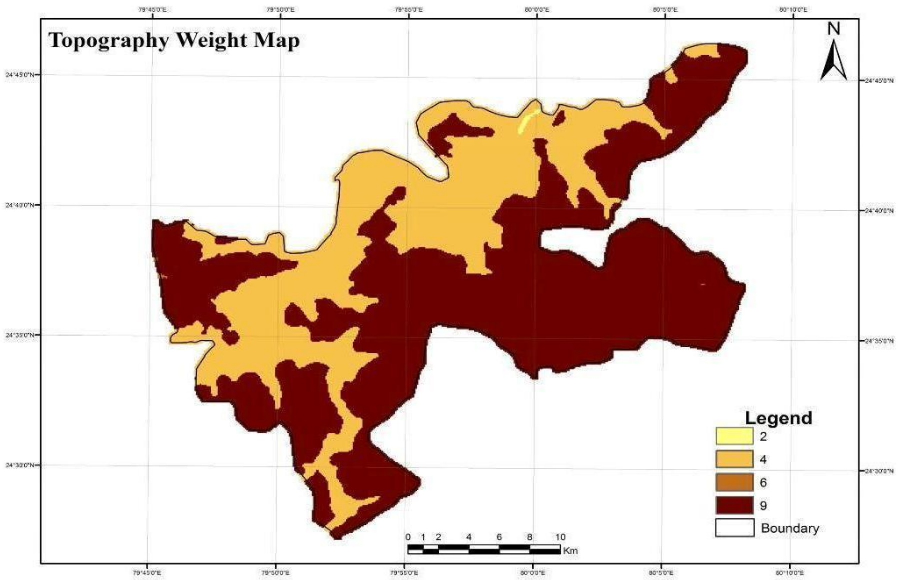

Fig. 13: Topography Weight Map for Tiger

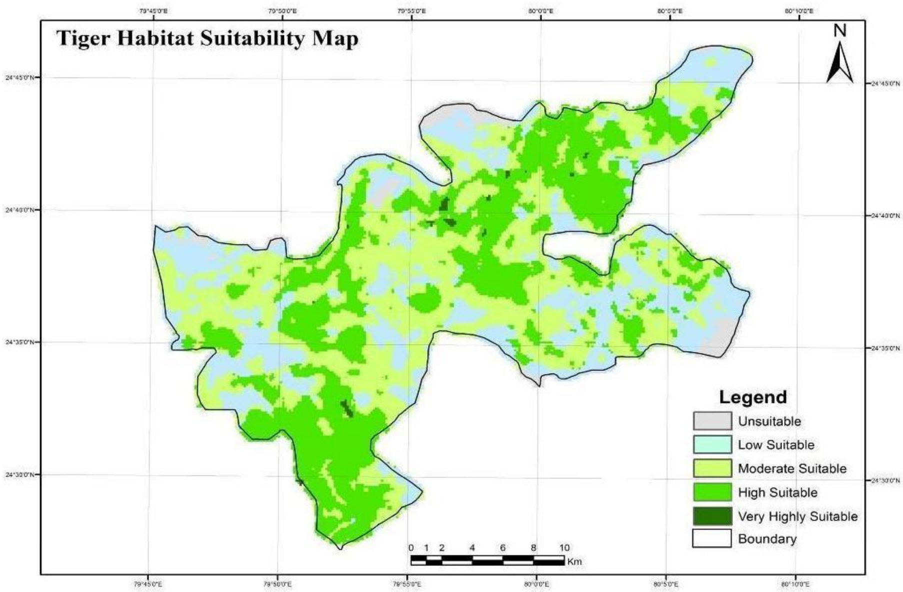

Fig. 14: Tiger Habitat Suitability Map

Water availability is a critical requirement for survival of wild animals in the study area. In the study area landscape, there are an only Ken River is the perennial water sources; water becomes particularly scarce during the summer months. At such times, prey populations also converge at water sources providing predators with hunting opportunities. Movement into areas proximate to perennial water sources would therefore be favored.

Human settlements areas are usually avoided by wild animals. The denser and more populous an area, the more formidable it is as a movement barrier. Tigers, under normal circumstances, avoid traversing through such areas. Tiger's preferred prey includes in the study area, this group is commonly represented by chital (Axis axis), sambar (Cervus unicolor), wild-boar (Sus scrofa), barking deer (Muntiacus muntjak), and nilgai (Boselaphus tragocamelus) were also encountered. Within the forest habitat show preferences for different habitat conditions imposed by the structure and composition of forest.

Table 3. Influences and weightage of different thematic layers for contributing habitat for Tiger in Panna Tiger Reserve.

Raster Layer	Influence % (Theme Weight)	Feature Classes or Buffer Distance	Feature Class Weight
Vegetation	**15**	**Vegetation Type**	
		Misc forest with grassland	7
		Mixed Forest	9
		Teak & bamboo plantation.	4
		Teak Forest	4
		Pure Sal	5
		Salai Forest	2
		Non Forest	1
Forest Cover	**15**	**Forest density**	
		Dense	6
		Moderate Dense	9
		No Forest	1
River & WB	**15**	**River & WB Buffer**	
		0-500m	9
		500-1000 m	8
		1000-2000m	6
		2000-3000	4
		Above 3000 m	2
Slope	**10**	**Slope Gradient in Degree**	
		0-2 %	2
		2-5 %	3
		5-10 %	9
		10-15 %	7
		15-20 %	5
		20-30 %	4
		Above 30 %	1
Topography	**10**	**Elevation in M**	
		0-400m	7
		400-500 m	9
		500-600 m	6
		600-700 m	5
		700-800 m	4
		800-900 m	3
		Above 900m	2
Drainage density	**10**	**Drainage Density**	
		Very high	2
		High	4
		Moderate	9
		Low	5

Road & Rail	2	**Distance to Road & Rail**	
		0-100 m	1
		100-500 m	3
		500-1000 m	5
		1000-2000 m	7
		Above 2000m	9
Human Settlement	**3**	**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	**25**	**Prey Availability**	
		High	9
		Moderate	6
		Low	4
		Least	1

4. CONCLUSION

This study has attempted to prepare habitat suitability model for the Panna national park. The Dry Forest habitat of Panna is an area occupied by two different kinds of ungulate populations which have evolved in different environments - one in open habitats and the other in forest. The distribution of tigers in Panna is closely related to high prey density areas, as has been found in other areas (Sunquist and Karanth, 1999). It is clear from the results of the study that tiger distribution is more closely related to two prey species of deer - chital and sambar. In habitats such as Panna national park, which form over 40% of the tiger habitat in the subcontinent. An area having a high density of road would be avoided by wild animals as compared to an area with few or no roads because there is a high traffic and constant noise. Tiger (*Panthera tigris*) prefer core habitats, generally avoid area with high edge density. In the study area landscape, perennial water sources ken river surroundings area prefer by the Prey species of tiger due to this occupancy of prey species the tiger is also occupied in this area.

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