HABITAT SUITABILITY ANALYSIS OF TIGERS USING DECISION SUPPORT SYSTEM OF INDIAN BIO-RESOURCE INFORMATION NETWORK (IBIN) PORTAL

Amrapali Tiwari[1,2], Sameer Saran[1], Kirti Avishek[2]
[1]Geoinformatics Department, Indian Institute of Remote Sensing Dehradun India,
Amrapali Tiwari, IIRS, ISRO Dehradun,
Email: tiwariamrapali61294@gmail.com
Sameer Saran IIRS ISRO Dehradun,
Email: sameer@iirs.gov.in
[2] Department of Civil and Environment Engineering BIT Mesra, Ranchi, India
Kirti Avishek, BIT Mesra, Ranchi,
Email: kavishek@bitmesra.ac.in

KEY WORDS: MCDA, GIS, Remote Sensing, weighted overlay.

ABSTRACT: India has the highest population of Bengal tigers (Panthera tigris tigris) in the world (70%). Conservation of big cats like tigers is crucial owing to their lower frequencies and the fact that they belong to the top of the food chain as top consumers. In India, tiger population is threatened and belonged in IUCN category of endangered species thereby requiring immediate attention. With advancement in satellite remote sensing and GIS processing techniques numerous avenues of research has unfastened in the field. This study performs a site suitability analysis for tigers in and around Jim Corbett tiger reserve, India using several variables influencing presence of tigers in an area. Ecological factors are used as variables for e.g., remotely sensed variables like vegetation types and proximity from drainage, roadways and settlement etc. The criteria are given relative importance using AHP, a multi-criteria decision analysis (MCDA) and areas that are not suitable, moderately suitable and highly suitable for tigers are delineated.

1. INTRODUCTION

Bengal tiger is a subspecies Panthera tigris called Panthera tigris tigris (Kitchener, 2017) and one of the largest mammal carnivore to live today. It is native to Indian subcontinent. Tigers are the top carnivores and belonging at the top of the food chain making them crucial for regulating and continuing ecological processes (Sunquist et al. 1999). Safeguarding top carnivores ensures biodiversity as well as appropriate working of the ecosystems (Qureshi et al., 2014). It has been incorporated as world's charismatic megafauna (Sankhala, 1978), and it is also used as flagship species by conservationists. Tiger population is threatened and belong in the IUCN category of endangered species thereby requiring immediate attention There are six global priority tiger conservation landscapes for durable conservation significance in the Indian subcontinent (Dinerstein et al., 2007; Qureshi et al., 2014) sustaining more than 60% of the worldwide genetic variation in them (Mondol et al. 2009). Being the only country with largest population of Bengal tigers in the world it is essential for India to incorporate commandments concerning wildlife protection especially pertaining to tigers in India. An increase in poaching activities and habitat loss due to various natural and anthropogenic reasons has confined their population in small patches. This is attributed to the past century hunting of tigers for commercial gain as well as for showcasing bravery. Even in ancient times, carnivores and humans have been at loggerheads for resources leading to deaths of carnivores (Gittleman et al., 2001). Climate change and deforestation has also adversely affected them by influencing prey population and destroying habitat of their home ranges which in turn increases human animal conflict. Over the years, continuous urban development has contributed in habitat fragmentation and patches of tiger habitat have become disconnected (Crooks., 2002, Proctor et al., 2005). In traditional medicinal sciences, body parts of tigers were used leading to clearing out of the population in huge numbers (Nowell, 2000 ; Check., 2006). Tigers are considered as umbrella species in the ecosystems because in all ten biogeographical zones present in India and tigers are inhabited in almost every one of them from the mountains to swamps, grasslands, to dry and moist deciduous forests, and also to evergreen forest systems (Kumar, 2021). Key elements of tiger habitats include area with rich ungulate population and dense and undisturbed vegetation along with water availability (Sunquist et al. 1999; Karanth and Sunquist 1995). It is observed that in continental environments where its primary prey involves larger ungulates, body size of tigers is larger, sometimes twice the size of tigers found in islands e.g., Sunda land. Difference between tigers of island and tigers of mainland is that mainland tigers with higher body mass and bigger sizes are more equipped with catching preys with larger sizes while island tigers are efficient for preying on smaller ungulates (Seidensticker and McDougal, 1993).

Over the last century ecological landscape has changed drastically resulting in isolation of tigers to small patches enclosed by agricultural land and human settlements (Dinerstein et al., 2007). Fragmentation of habitat resulting in loss of preys brutally affects existence of tigers in the habitat. Elimination of tigers from their habitat results in an explosion in number of prey species particularly ungulates and small predators consequently, misbalancing the dynamic of ecosystems (Seidensticker and McDougal, 1993).

Remote Sensing and GIS are very useful tools for habitat suitability analysis. The availability of open source, reliable and multi temporal datasets derived from remote sensing satellites, and geospatial techniques for classifying land cover types aids the examination of landscape structure (Crowley and Cardille, 2020) for study of habitats of wildlife . The multiple sensor capabilities of remote sensing satellites like Landsat-8 OLI and Sentinel-1A provides multi-scale information on landscape composition and its configurations. It also assists in studying the effects of landscape structure and landscape change over time on biodiversity and population dynamics (Gillanders et al., 2008). It is also used to gather variables affecting the habitat such as roadways, drainages, location of water bodies and settlements. With accessibility of high resolution satellite imagery vegetation analysis can also done. Emerging techniques of hyperspectral remote sensing can are used in vegetation type identification (Zhang et al., 2021) which is used as an essential criteria for habitat suitability analysis especially in case of wildlife (Buruso, 2018). Various ecological and geospatial modelling tools have been developed over the years for habitat suitability and site suitability analysis. Weighted overlay analysis is a geospatial tool used widely in such decision making (Firoz et al., 2018). IBIN portal provides a platform for computing weighted the analysis in any part of India. In this study, a habitat suitability analysis is concluded on and around Jim Corbett national park/ tiger reserve. Numerous factors affecting the habitat of tigers are taken into account and weighted overlay analysis is done based of multiple criteria decision analysis method of analytical hierarchy process (AHP) using spatial decision support system of Indian Bio resource Information Network (IBIN) portal. IBIN portal is a national repository on bio-resource information developed by Indian Institute of Remote Sensing (ISRO) funded by Department of Biotechnology of Government of India. (Saran et al., 2019). A great deal of information on biotic resources of India in accessible form is available in the portal (https://betaibin.iirs.gov.in)The portal also provides various modelling applications with respect to biotic resources of India. Spatial decision support system is one such modelling application which uses remotely sensed variables like drainages, settlements, roadways and vegetation types of the study area, as inputs for habitat suitability analysis in the area. Details about background of weighted overlay analysis used in the study is provided in next section.

1.1 Spatial decision support system - weighted overlay analysis

It is a geospatial technique used in decision making particularly in site suitability and habitat suitability analysis. It is based on intersection of weighted layers. In this study, weighted overlay analysis is done on spatial decision support system of Indian bio-resource information network. All the criteria are weighted as not suitable, moderately suitable, suitable and highly suitable. Weighted overlay is computed based on suitability and AHP to give site suitability analysis.

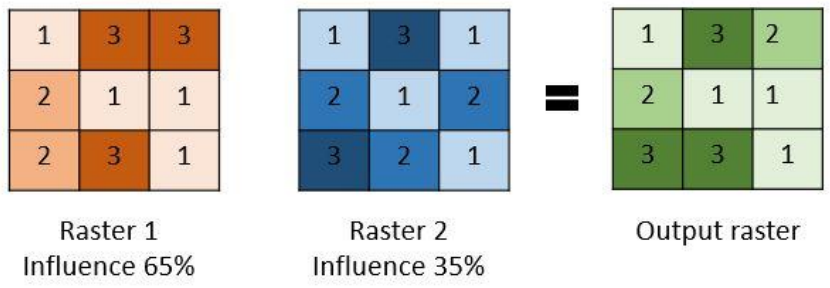

Fig 1: Diagram showing working of weighted overlay (Adapted from desktop.arcgis.com)

In Fig 1, the input rasters are reclassified to a common measurement scale of 1 to 3. Percentage influence is given to each input raster. Suppose first raster is given percentage influence of 65% and second raster is given percentage influence of 35%. For calculating the value of output raster percentage influence is multiplied with the value of first raster and added with percentage influence multiplied with value of second rasters as shown in Fig 1.

1.2 Analytical hierarchy process

The AHP is a concept of measurement with pairwise comparisons and depends on the decision of experts to develop priority scales which are used to measure intangibles in comparative terms (Saaty, 1980). Comparisons are made as how one element dominate other with respect to each given attribute.

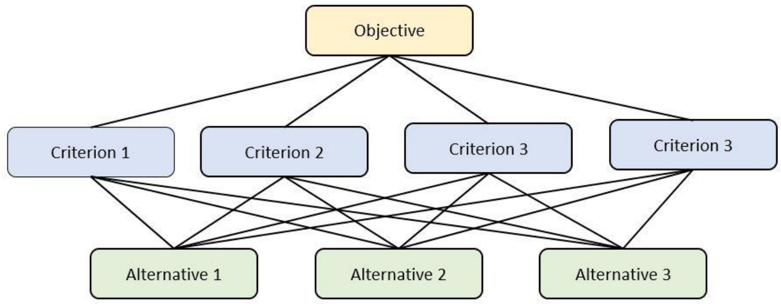

Fig 2: AHP process (Adapted from Saaty, 1980)

AHP relies on subjective inputs on multiple criteria. Based on these inputs, evaluation of each of the possible alternatives is done. AHP helps decision makers to organise their thoughts and proclaim them in a presentable form. AHP rationalise the decision making process by synthesising all the information about them in a systematic manner (Handfield et al., 2002). Overall, AHP is a suitable tool when the objective of the decision is clearly defined. There are series of steps involved in AHP starting from definition of the problem, structure and hierarchy of the problem from a broad perspective, construction of a set of pairwise comparison matrices and finally using the priorities generated from comparisons to give weights to the priorities immediately below. These steps are repeated for each element. Overall priorities are obtained by adding weighed values of each element (Saaty., 1980). In this study AHP is used to generate weights to be given to the criteria used in habitat suitability analysis of tigers. Criteria used in this particular study are distance from waterbodies, distance from roadways, distance from settlements, vegetation types and land use. These weights are given as inputs in weighted overlay analysis.

2. MATERIAL AND METHODS

2.1 Description of study area

This study was carried out in and around Jim Corbett National park, located in Haldwani district of Uttarakhand, India. It is spread over an area of 1318.54 sq km, of which 520 sq km is the main area, and the rest is buffer. National park is spread over the attractive landscapes of Pauri Garhwal, Almora, and Nainital. This national park has the most number of tigers in the country counted to 231 tigers.

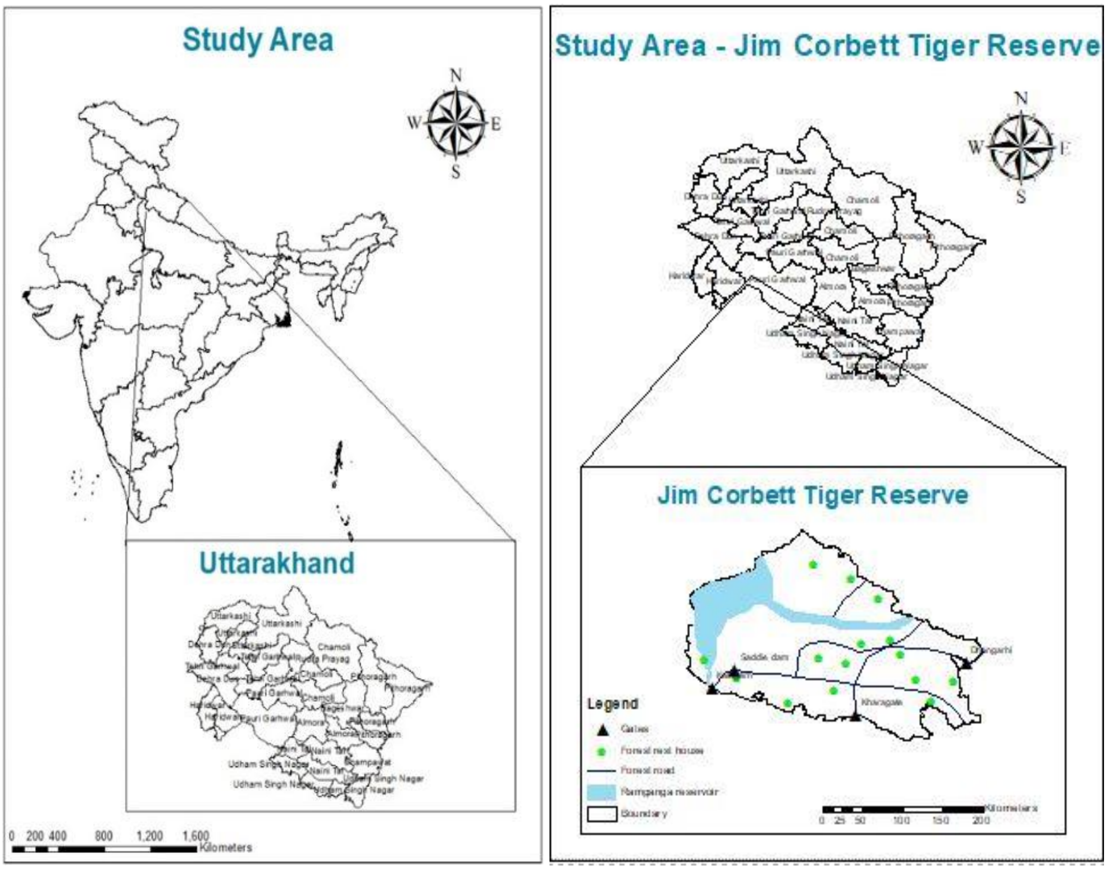

Fig 3: Map of study area

2.2 Data and software requirements

Satellite data from Sentinel-2 is used for study area demarcation and processing of variable for suitability analysis. ArcMap 10.5 is used for study area map preparation, IBIN portal is used for carrying out weighted overlay analysis and occurrence data was downloaded from GBIF for accuracy assessment.

2.3 Methodology

In this study, spatial decision support system feature of Indian bio-resource information network (IBIN) portal is used. Criteria used for habitat suitability for tigers are distance from drainage, distance from roads, distance from settlements and types of vegetation. They were ranked on the basis of suitability for tigers and weighted overlay was computed and final suitability map was generated.

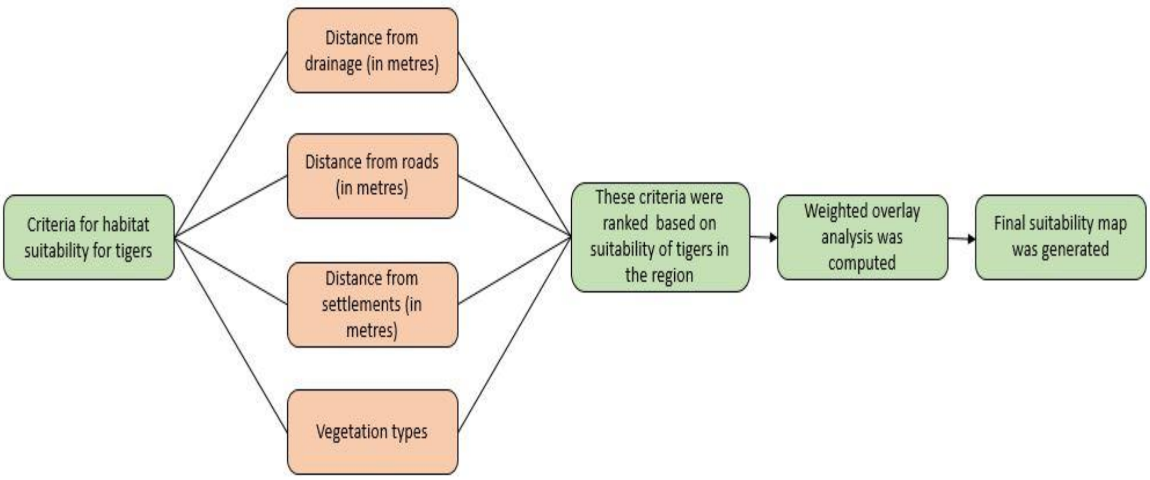

Fig 4: Methodology used in the study

On the study area, drainages were delineated using spatial decision support system (SDSS) of the Indian Bioresource Information Network (IBIN) portal. Distance from drainages were given rating based on suitability of tigers. Distance of 1000 m is regarded as highly suitable because drainages are primary source of water for wildlife and their presence in close proximity of drainages is highly likely. Distance between 1000m to 2000m is suitable, 2000m to 3000m is considered as moderately suitable and 3000m to 4000m is considered as least suitable as shown in Fig 5.

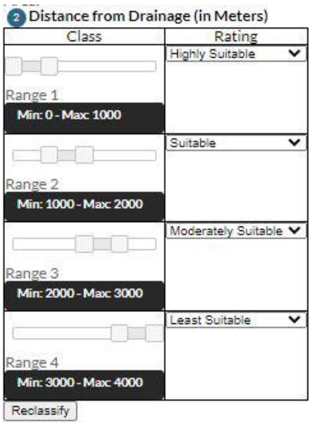

Fig 5: Suitability distance from drainage with respect to habitat of tigers

Similarly, roadways were also delineated using spatial decision support system (SDSS) of the IBIN portal. Distance from roadways were given rating based on probability of presence of a tiger in the region. Distance of 1000 m is regarded as least suitable because it is highly unlikely that roadways would be ideal habitat for tigers. Distance between 1000m to 2000m is moderately suitable, 2000m to 3000m is considered as suitable and regions as far as 3000m to 4000m are regarded as highly suitable as shown in Fig 6.

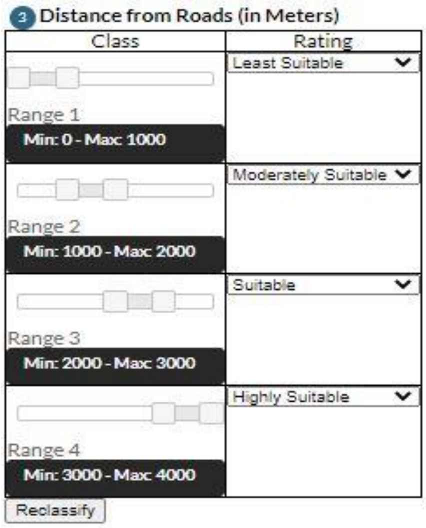

Fig 6: Suitability distance from roads with respect to habitat of tigers

Likewise, settlements were delineated using spatial decision support system (SDSS) of the IBIN portal. It is believed that most favoured habitats of tigers include dense vegetation, grasslands or wetlands (Sunquist et al. 1999; Kumar, 2021). It is only when natural habitat of tigers are disturbed and fragmented they appear in settlement area and prey on humans and livestock of humans (Seidensticker and McDougal, 1993; Dinerstein et al., 2007) which also results in death of tigers. Therefore, Distance of 1000 m is regarded as least suitable for them. Distance between 1000 m to 2000 m is moderately suitable, 2000 m to 3000 m is considered as suitable and regions as far as 3000 m to 4000 m are regarded as highly suitable as shown in Fig 7(a).On the basis of study area, vegetation type of the area is deduced using spatial decision support system (SDSS) of IBIN portal. In the study area, there are eight types of vegetation found namely agricultural land, forest plantations, grasslands, Himalayan moist temperate, Pine and mixed Pine, Sal and mixed Sal, waterbodies and wetlands and non-forest vegetation. Forest plantations, grasslands, Sal and mixed Sal and wetlands were considered highly suitable, Pine and mixed pine were regarded as suitable, Himalayan moist temperate forest is regarded as moderately suitable and agriculture and non-forested vegetation were put in least suitable category (Singh, Velmurugan and Dakhate, 2009; Xiaofeng et al., 2011) as shown in Fig 7(b).

Suitability map generated is overlaid on the occurrence data for species in the area downloaded from GBIF for basic accuracy assessment of the habitat suitability analysis as shown in Fig 9.

4 Distance from Settlements (in Meters)

Class	Rating
Range 1 Min: 0 - Max: 1000	Least Suitable
Range 2 Min: 1000 - Max: 2000	Moderately Suitable
Range 3 Min: 2000 - Max: 3000	Suitable
Range 4 Min: 3000 - Max: 4000	Highly Suitable

Reclassify

5 Vegetation Type

Vegetation Type	Rating
Agriculture	Least Suitable
Forest Plantations	Highly Suitable
Grasslands	Highly Suitable
Himalayan Moist Temperate	Moderately Suitable
Non Forest	Least Suitable
Pine and Pine mixed	Suitable
Sal and Sal Mixed	Highly Suitable
Water Bodies and Wet Lands/grasslands	Highly Suitable

Reclassify Vegetation Type

Fig 7(a): Suitability distance from settlements with respect to habitat of tigers. 7(b) Suitability based on vegetation types

3. RESULTS AND DISCUSSION

The weighted overlay analysis is executed on the above-mentioned layers on SDSS feature of IBIN portal. Percentage importance to each layer relative to other layers was given based on AHP. The final habitat suitability map for tigers in Jim corbett national park / tiger reserve is given Fig 8.

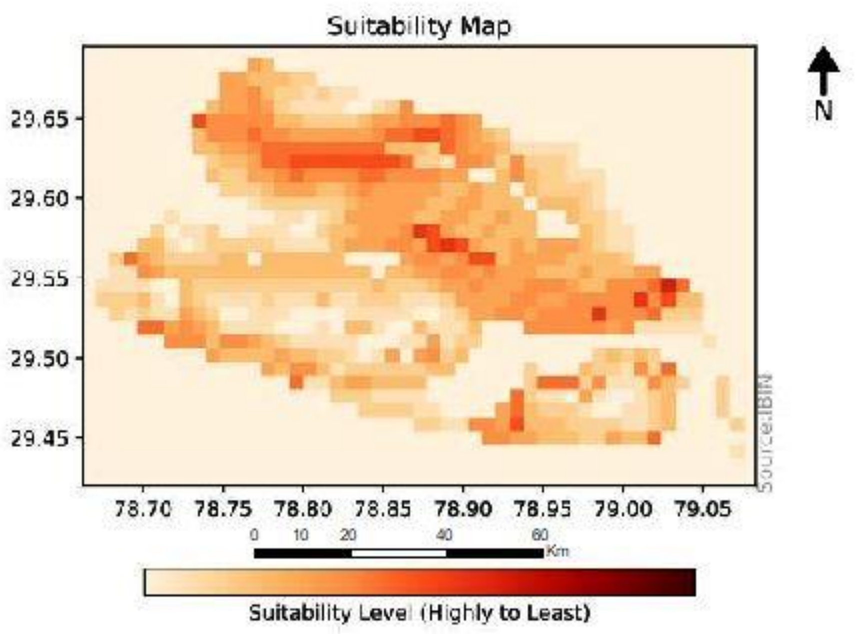

Fig 8: Habitat suitability map of *Panthera tigris tigris* in Jim Corbett national park

After the overlay analysis of separately weighted layers, finally habitat suitability map is generated for Panthera tigris tigris. As shown in Fig 8 areas shown in dark is least suitable for tigers in the region and areas in lighter shades correspond to highly suitable areas for tigers. Highly suitable areas are mostly stretched from centre of the tiger reserve to the western end of it. Habitat suitability analysis of tigers in Jim Corbett tiger reserve is calculated based on four factors, drainages, roads, settlements, and vegetation types. It has been made sure while giving suitability criteria, that presence of tigers is more likely at a distance away from the roads and settlements while they are more likely to be found near waterbodies and drainage areas. As discussed, earlier tigers are found in dense forests, grasslands, wetlands etc. Therefore, these categories were marked most suitable for the species. While agriculture and non-forest areas were considered as least suitable for the species. For accuracy assessment tiger occurrence points downloaded from GBIF database is overlaid on the suitability map. Twelve points were identified on the study area where tigers were spotted in the study area. As shown in Fig 9 out of twelve points eight points coincide with highly suitable areas for tigers while four points are found in less suitable areas giving accuracy of 66 percent and uncertainty of 33 percent.

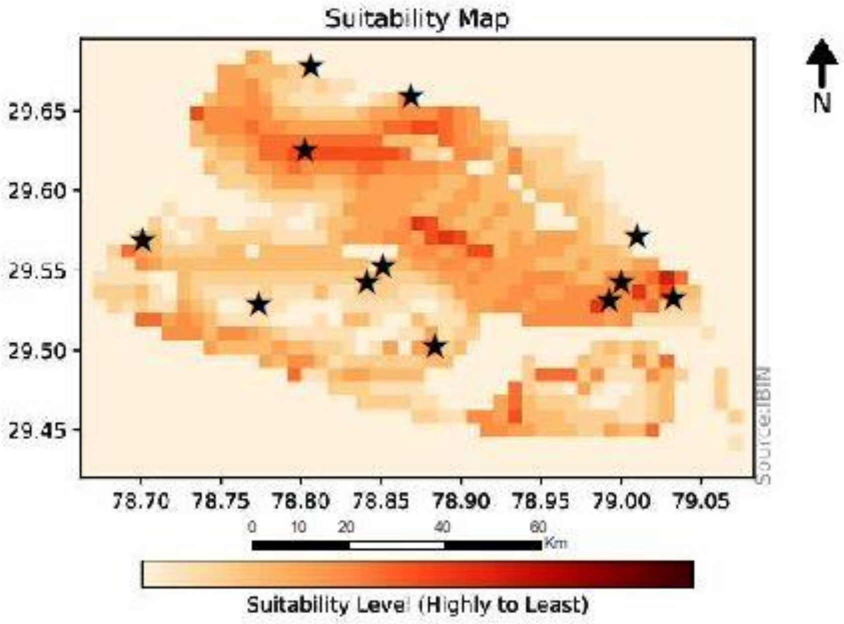

Fig 9: Occurrence points of tigers overlaid on habitat suitability map

4. CONCLUSION

Habitat suitability analysis of organisms can be considered as a powerful tool for understanding the landscape and drivers that affect animal behaviour. This study is particularly beneficial for umbrella species like tigers because they belong at the top of food chain and their population regulates the population of species even at lower level of food chain.

In India, population of tigers are confined in small patches thus, they are prone to local extinctions. Conservation of such species require meta-population framework requiring habitat connectivity (Yumnam et al., 2014). According to wildlife institute of India, till now, under Project Tiger, 50 tiger reserves have been developed covering 72,749 km2 of area which is about 2.21% of geographical area of India. Some of the tiger reserves have habitat corridors which facilitate movement of tigers within them (Yumnam et al., 2014). Yet there are many tiger reserves, where fragmentation and anthropogenic disturbances are challenging the sustainability of landscape structure and functions. Increase in number of protected areas are essential for conservation. However, a comprehensive conservational approach requires a thorough understanding of its behavioural aspect, habitat and ecological interactions etc. It has attracted a considerable amount of research in the field. Modelling of tiger population based on habitat and climate and prediction based on number of other factors are done by researchers (Rather, Kumar and Khan, 2020). Similarly, in this study habitat suitability is modelled using spatial decision support system of Indian bio-resource information network showing suitable areas for tigers in Jim Corbett national park of Uttarakhand state of India. This study would act as a pioneer step in many conservation-based studies for tigers. Results of this study can be used in developing various conservation strategies in the area. It would act as a powerful input for decision makers to adopt better policies for the future of tigers in India.

REFERENCES

Ahmad, F., Goparaju, L. and Qayum, A., 2018. Wild life habitat suitability and conservation hotspot mapping: Remote Sensing and GIS based decision support system. AIMS Geosciences, 4(1), pp.66-87.

Buruso, F. H. (2018) 'Habitat suitability analysis for hippopotamus (H. amphibious) using GIS and remote sensing in Lake Tana and its environs, Ethiopia', Environmental Systems Research, 6(1). doi: 10.1186/s40068-017-0083-8.

Dinerstein, E. et al. (2007) 'The fate of wild tigers', BioScience, 57(6), pp. 508–514. doi: 10.1641/B570608.

GBIF.org (19 September 2021) GBIF Occurrence Download https://doi.org/10.15468/dl.dr3uzv

Handfield, R. et al. (2002) 'Applying environmental criteria to supplier assessment: A study in the application of the Analytical Hierarchy Process', European Journal of Operational Research, 141(1), pp. 70–87. doi: 10.1016/S0377-2217(01)00261-2.

Imam, E., & Tesfamichael, G. Y. (2013). Use of remote sensing, GIS and analytical hierarchy process (AHP) in wildlife habitat suitability analysis. Journal of Materials and Environmental Science, 4(3), 460-467.

Jain, D., Areendran, G., Raj, K., Gupta, V.D. and Sahana, M., 2021. Comparison of AHP and maxent model for assessing habitat suitability of wild dog (Cuon alpinus) in Pench Tiger Reserve, Madhya Pradesh. In Spatial Modeling in Forest Resources Management (pp. 327-363). Springer, Cham.

Jain, P., Ahmed, R., Sajjad, H., Sahana, M., Jaafari, A., Dou, J., & Hong, H. (2021). Habitat suitability mapping of sloth bear (Melursus ursinus) in the Sariska Tiger Reserve (India) using a GIS-based fuzzy analytical hierarchy process. In Remote Sensing and GIScience (pp. 205-227). Springer, Cham.

Kanagaraj, R., Wiegand, T., Kramer-Schadt, S., Anwar, M. and Goyal, S.P., 2011. Assessing habitat suitability for tiger in the fragmented Terai Arc Landscape of India and Nepal. Ecography, 34(6), pp.970-981.

Kumar, A. (2021) 'Conservation Status of Bengal Tiger (Panthera tigris tigris)- A Review', Journal of Scientific Research, 65(02), pp. 01–05. doi: 10.37398/jsr.2021.650201.

Mehlich, R., 2005. A Preliminary Habitat Suitability Analysis for the Restoration of South China Tigers in the Hupingshan Reserve, China. Atlas of Maine, 2005(2), p.13.

Mishra, A., Sarup, J. and Gupta, D.C., Geo spatial approach for tiger habitat suitability mapping: A case study of Bandhavgarh national park, Madhya Pradesh, India

Nowell, K. (2000) 'Far from a cure: the tiger trade revisited', TRAFFIC International, (June), p. 100. Available at: https://www.changewildlifeconsumers.org/site/assets/files/1104/far_from_cure.pdf.

Qureshi, Q. et al. (2014) 'Connecting tiger populations for long-term conservation', National Tiger Conservation Authority, pp. 6–9.

Rather, T. A., Kumar, S. and Khan, J. A. (2020) 'Multi-scale habitat modelling and predicting change in the distribution of tiger and leopard using random forest algorithm', Scientific Reports, 10(1), pp. 1–19. doi: 10.1038/s41598-020-68167-z.

Roy, P.S., Ravan, S.A., Rajadnya, N., Das, K.K., Jain, A. and Singh, S., 1995. Habitat suitability analysis of Nemorhaedus goral–a remote sensing and geographic information system approach. Current Science, pp.685-691.

Saran, S., Padalia, H., Ganeshaiah, K. N., Oberai, K., Singh, P., Jha, A. K., ... & Kumar, A. S. (2019). Indian Bioresource Information Network (IBIN). In Remote Sensing of Northwest Himalayan Ecosystems (pp. 251-264). Springer, Singapore.

Seidensticker, J. and McDougal, C. (1993) 'Tiger predatory behaviour, ecology and conservation', Symposium of the Zoological Society of London, (65), pp. 105–125.

Singh, G., Velmurugan, A. and Dakhate, M.P., 2009. Geospatial approach for tiger habitat evaluation and distribution in Corbett Tiger Reserve, India. Journal of the Indian Society of Remote Sensing, 37(4), pp.573-585.

Singh, G., Velmurugan, A. and Dakhate, M. P. (2009) 'Geospatial approach for tiger habitat evaluation and distribution in Corbett Tiger reserve, India', Journal of the Indian Society of Remote Sensing, 37(4), pp. 573–585. doi: 10.1007/s12524-009-0052-4.

Singh, R., Joshi, P.K., Kumar, M., Dash, P.P. and Joshi, B.D., 2009. Development of tiger habitat suitability model using geospatial tools—a case study in Achankmar Wildlife Sanctuary (AMWLS), Chhattisgarh India. Environmental monitoring and assessment, 155(1), pp.555-567.

Tang, T., Li, J., Sun, H. and Deng, C., 2021. Priority areas identified through spatial habitat suitability index and network analysis: Wild boar populations as proxies for tigers in and around the Hupingshan and Houhe National Nature Reserves. Science of The Total Environment, 774, p.145067.

Xiaofeng, L. et al. (2011) 'Habitat evaluation of wild Amur tiger (Panthera tigris altaica) and conservation priority setting in north-eastern China', Journal of Environmental Management, 92(1), pp. 31–42. doi: 10.1016/j.jenvman.2010.08.001.

Yumnam, B. et al. (2014) 'Prioritizing tiger conservation through landscape genetics and habitat linkages', PLoS ONE, 9(11). doi: 10.1371/journal.pone.0111207.

Zhang, Y., Migliavacca, M., Penuelas, J. and Ju, W., 2021. Advances in hyperspectral remote sensing of vegetation traits and functions.