Chapter 4

Mapping of potential conflict zones in and around sloth bear habitats

4.1 Introduction

This chapter addresses attacks on human by sloth bears in the Gujarat state (India) where a recorded population of approximately more than 340 individuals subsists as per news articles by 2022. As discussed earlier, the distribution range of this species in the state is restricted to the eastern region of the state extending from north to south in five protected areas connected with territorial forests and the forests in the neighbouring states of Rajasthan, Madhya Pradesh, and Maharashtra. It has been reported that in India most part of sloth bear range is overlapping with human dominated landscapes (Dharaiya et al. 2016; Puri et al. 2023), where in search of food and water, the bears have been observed to move towards non-protected areas, specifically around agricultural fields (Sharp et al. 2022), or when locals move to the forest for collecting forest produce. Such movements frequently trigger bears to attack human in an unexpected encounter. Sloth bear attacks are sudden and defensive rather than predatory, given their opportunistic feeding behaviour (Garshelis et al. 1999; Sharp et al. 2020). In Gujarat, more than 50% attacks have been documented outside the protected areas or near the boundaries (Garcia et al. 2016). Majority of victims recorded have been men, followed by women and children who engage in activities like collection of fruits, fodders, farming, trespassing and livestock rearing making them vulnerable to sudden encounters with sloth bears (Bargali et al. 2005; Ratnayeke et al. 2014; Garcia et al. 2016). Other factors include degraded habitats and sharing forest resources with human, which puts the species of concern in direct competition (Rajpurohit & Krausman 2000; Mewada & Dharaiya 2010; Garcia et al. 2016). Several studies have used species distribution models to understand ecological processes such as interactions between man and wildlife at a fine scale incorporating large data sets, species population dynamics, etc. (Guisam & Thuiller 2005; Elith & Leathwick 2009; Franklin 2010; Wisz et al. 2013). In recent years studies focusing on habitat management of a single focal species have been adapted.

Therefore, to understand occurrence and distribution of sloth bears in and around identified protected areas and to address the conflict situations, the predictive models such as species distribution model (SDM) is used. SDM offers an aid to work with the large datasets and identify patterns that reflects the occurrence of the species in any defined space and time. Earlier, species distribution models were used to work on both presence and absence data. However, due to unreliability of absence data of a species, preference is being given to the models using presence only data (Elith et al. 2006; Hernandez et al. 2006). Hence, in present study, MaxEnt (Maximum Entropy Model), being used to predict the distribution pattern of a species. This software works with the presence data by associating it with the predictor variables (such as human population, land use land cover, transportation network, etc.) affecting the specified geographical space and time (Phillips et al. 2006, 2017). Thus, the objective of the study is to identify the potential areas of interaction between sloth bears and humans in Gujarat. This would help in formulating mitigation strategies to alleviate the human sloth bear conflict in the state.

4.2 Study Area

The study is focussed in the areas that are inhabited by sloth bear populations including protected and non-protected habitats of the Gujarat state (India) (Figure 4.1) as described in earlier chapter (Chapter 2).

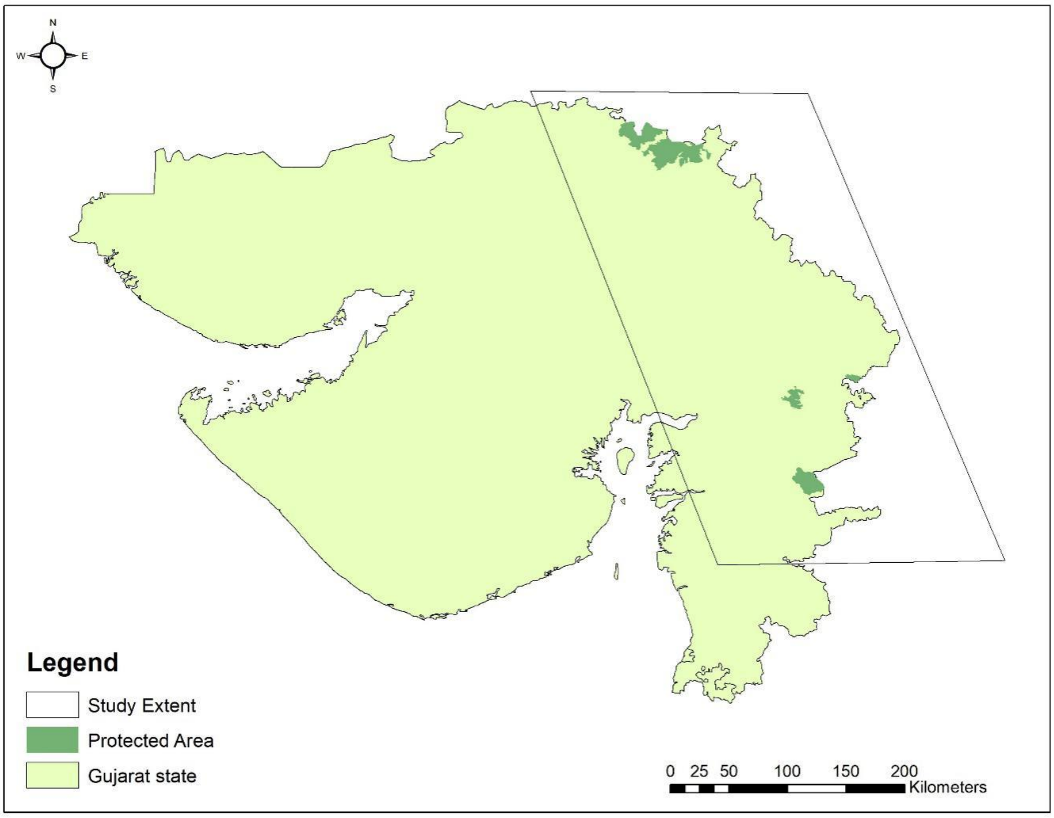


Figure 4.1. Map of Gujarat with an extent representing the study area

4.3 Methodology

4.3.1 Predictor variables and their sources

To evaluate the potential conflict zones between human and sloth bears in the study area, six predictor variables were identified based on the published literature. These variables are, distance to protected areas, land use/land cover patterns, human settlements, road network, human population density and waterbodies. The large part of sloth bear population is found in protected habitats, hence the five sanctuaries inhabiting sloth bear were considered for the analysis. The shapefiles of these sanctuaries (Figure 4.1) were acquired from the Gujarat Forest Department, Government of Gujarat and secondary data on human sloth bear conflict was collected from the same department. As in majority of regions, sloth bear habitats overlapped with human dominated landscape, LISS III (Linear Imaging and Self Scanning Sensor) images were procured to generate Land

Use/land Cover raster layer (Figure 4.2a) by using hybrid classification as is described by Kumar et al. (2013). For this, Bhuvan portal (https://bhuvan-app1.nrsc.gov.in) was accessed to acquire information on LU/LC images generated by National Remote Sensing Centre (NRSC). LISS III images with 1:50,000 scale was procured for 2016-17 cycle to generate Land Use/land Cover raster layer by using hybrid classification as is described by Kumar et al. (2013). This approach is a combination of both supervised and unsupervised classification (Dharaiya & Singh 2017). Through field surveys, data was validated on land use pattern such as scrubland, farmland, barren land, and wasteland. The categories considered are Agricultural land (Kharif, Rabi and Zaid), built-up area, Fallow land, plantation/orchards, Forests (Degraded and deciduous), scrubland and wasteland. Also, human constructed infrastructure such as road network was given emphasis for the analysis. Here only rural road network was considered based on conflict records occurring near rural or tribal settlements. Open street map (www.openstreetmap.org,) was used to acquire data for human settlements (Figure 4.2b) and rural road networks (Figure 4.2c). Impact of human presence on sloth bear occupancy was reflected by collecting data on human population density, which was acquired from Socioeconomic Data and Application Centre, SEDAC (https://sedac.ciesin.columbia.edu/) (Figure 4.2d). Studies have shown repetitive occurrence of sloth bears near water bodies (Figure 4.2e), hence, they are considered as another individual variable under assumption that they influence the occupancy of sloth bears. The shapefiles for waterbodies were procured at 1:50 000 scale from the National Wetland Inventory data (NWA 2011).

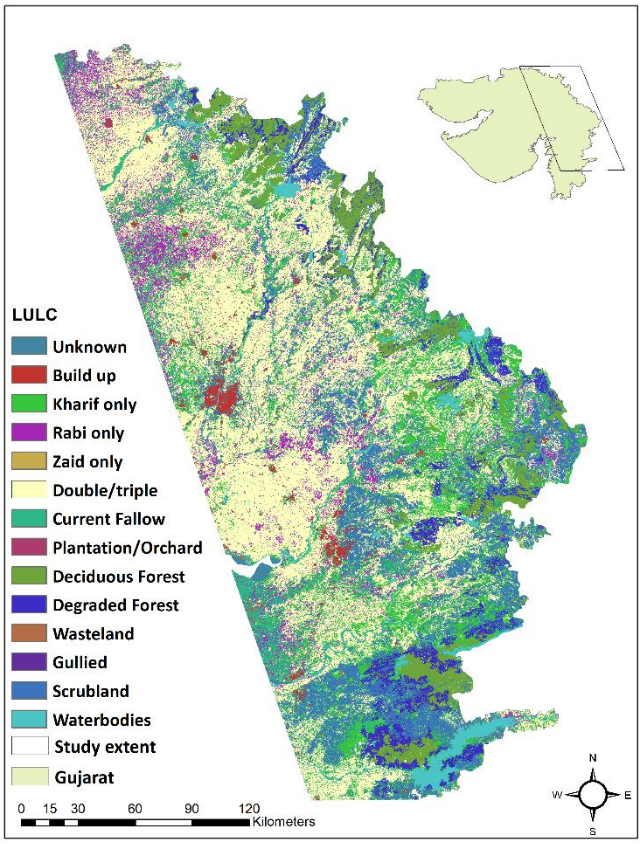
4.3.2 Data Preparation

A study extent as shown in Figure 4.1. was generated using ArcGIS© defining the study area restricted to sloth bear distribution in the state. Before subjecting the data set in to the MaxEnt software the variables discussed above were preprocessed. Initially the projection of all the layers for Land use/ land Cover, human population density, waterbodies and Human settlements were changed from Geographic Coordinate System to Universal Transverse Mercator (UTM) Coordinate System using ArcGIS. Further, all layers were clipped using study area extent to reduce the processing time. These layers were rasterised to estimate the Euclidean distance in ArcGIS©. The distance of each feature including human settlements, road, waterbodies, and human population density (Figures 4.2 b, c, d, e) were computed using Euclidean Distance Spatial Analysis Tool that converts them into continuous dataset. Land use/ land cover was used under the categorical data with all the classes shown in Figure 4.2a. These layers were subsequently converted from GeoTIFF to ASCII files which is the acceptable format for the input files in MaxEnt (Zvidzai et al. 2023). The secondary data on conflicts was cleaned by removing missing features, unfitting GPS locations and incorrect information in Microsoft excel that revealed 169 locations across the state in and around sloth bear habitats. A bias file was generated to limit the background sample points for the model within the extent of study area as described by Philips et al. (2006).

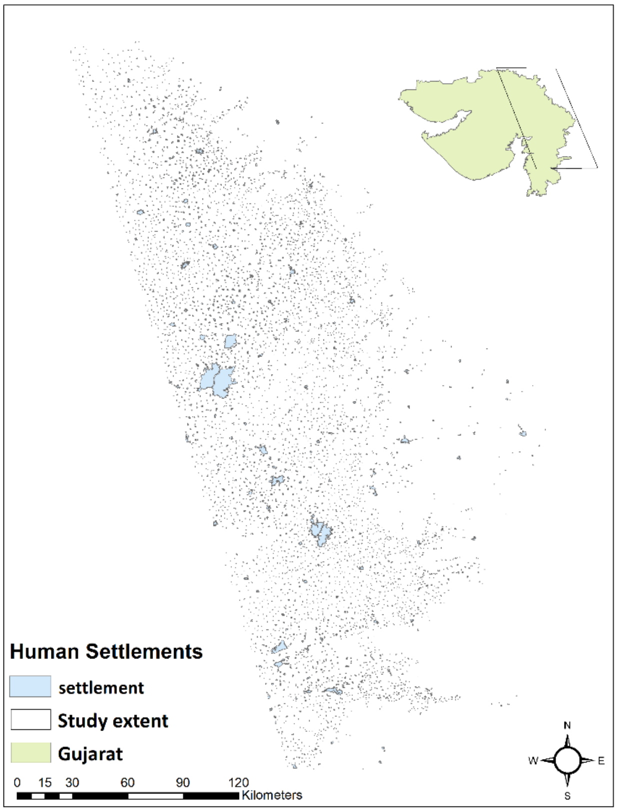
4.3.3 Maximum Entropy Model (MaxEnt)

The analysis of data collected for this study was performed in MaxEnt version 3.4.0, a presence only species distribution modelling techniques (Philips et al. 2017), to develop the potential zones of conflict throughout the study extent. MaxEnt, estimates distribution probabilities of unknown points by generating values for predictor variables at known points. The approach attempts to reach maximum entropy of human bear conflict distribution – which is closest to the uniform distribution. This is achieved on the basis of the constraints imposed by known values of the observed conflict distribution and respective predictor variables (influencers and inhibitors) of the study extent.

Reports indicate that MaxEnt is well suited to predict model based on ecological interactions (Phillips and Dudík 2008, Baldwin 2009, Elith et al. 2011). Here, the software is used to evaluate human sloth bear interactions based on the previous conflict records. To simplify the model for identifying potential zones for human-sloth bear conflicts, default values integrated in the software were used, except for a few tweaks like 1000 iterations were used to maximise the prediction accuracy while keeping random test percentage at 25% of data for testing whereas 75% for training.

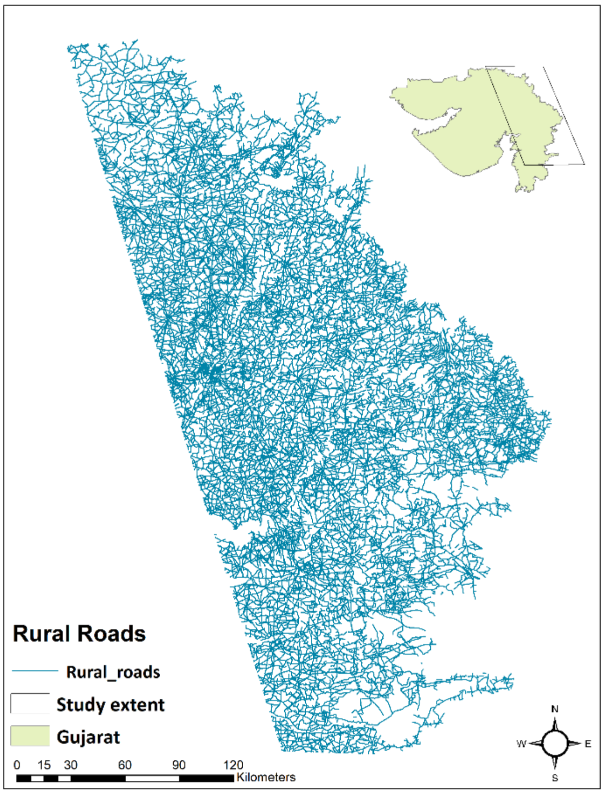


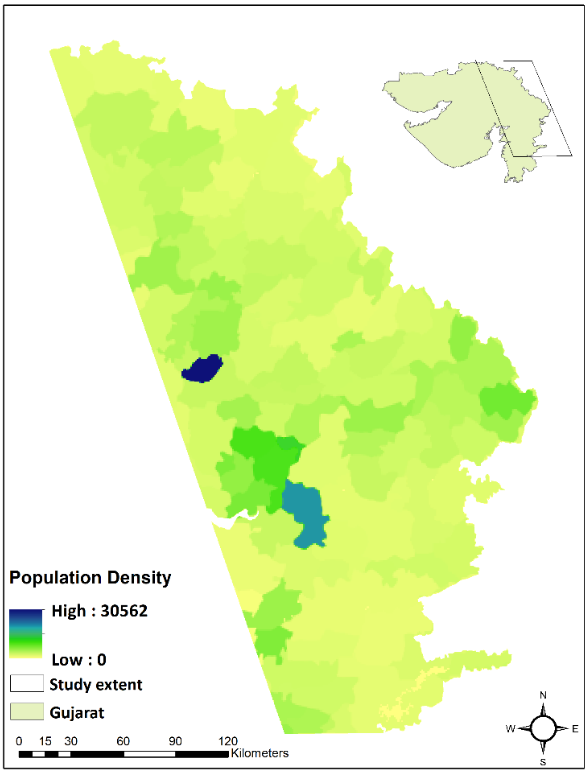
a. Landuse/Landcover



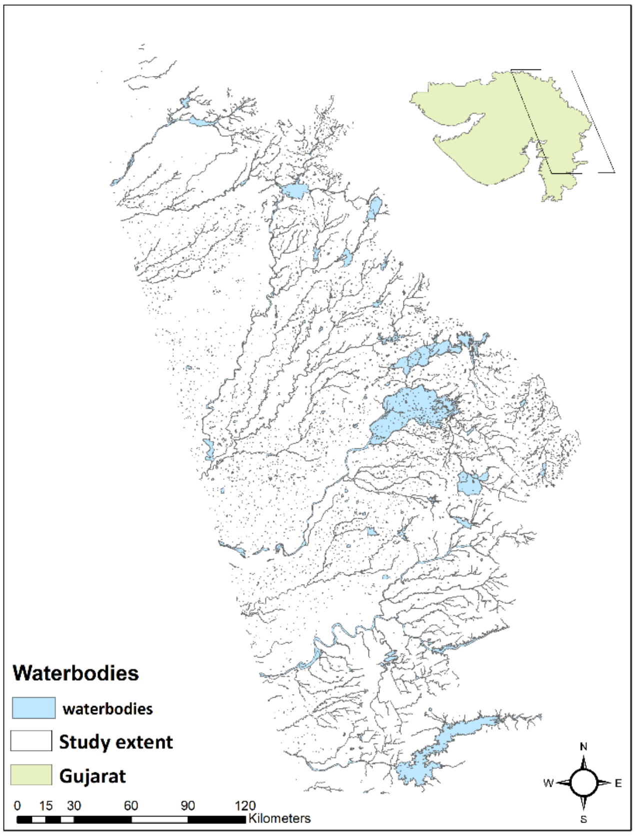
b. Human settlements

c. Road network





d. Human Population density



e. Waterbodies

Figure 4.2. Variables used for identifying potential human sloth bear conflict zones. a) Land use Land cover, b) Human settlements, c) Rural Road network, d) Human population density e) Waterbodies

This allows the software to generate 25% random sample points out of the conflict records to conduct simple statistical testing whereas the training data set (conflict records) is set aside to train the model to identify the distribution of potential areas for human-sloth bear conflicts. Further, the software was run using K-folding technique which creates number of repetitions of human sloth bear conflict records to optimise the use of conflict data. This was done using the in-built cross-validation features 'splits' and 'folds', where maxent software creates splits in the conflict data set, dividing them into separate groups equal in size identified as folds.

Further, the available conflict-location geolocations were used to retrain models, that resulted in an optimized averaged output (Phillips et al. 2006; Phillips and Dudik 2008). The Jack-knifing technique, integrated in the software was also used, to estimate relative influence of each predictor variable in model training (Pearson et al. 2007). The output generated from Jackknife highlights the importance or contribution of individual variable with, or without, and in combination with other variables to achieve test gains in the model (Padalia et al. 2014; Wang et al. 2017). The model performance was assessed using Area Under Curve (AUC) and Receiver Operating Character (ROC) features (Philips et al. 2006, Padalia et al. 2014). These features are used to provide statistical output to evaluate the model performance in case of 'presence data' (Proosdij et al. 2016) used for the study conflict records too. The performance of the model generally lies between the range of 0 to 1; values closer to 1 implies a good performance (Phillips et al. 2006; Sharma et al. 2020). The correlation between potential conflict locations and variables was evaluated by generating response curves. The response curve feature was checked before running the model in the maxent software. The generated Clog log output was in the default format to assess the potential human bear conflict areas (Philips 2005; Sharma et al. 2020). This was further converted into raster format using ArcGIS software.

4.4 Results

The output shows the value for area under the curve (AUC) is 0.887 (Figure 4.3) with a standard deviation estimated to be 0.033 revealing a good performance of the model run for identifying potential areas for human-bear conflict in the MaxEnt software.

The output generated using 6 predictor variables (Figure 4.4) show the test omission rate and predicted area as a function of the cumulative threshold, averaged over the replicate runs. This further forsees that the six variables used to predict human sloth bear conflict in Gujarat explain 89% spatial variability to delineate the probable areas with high-risk of bear-human conflict.

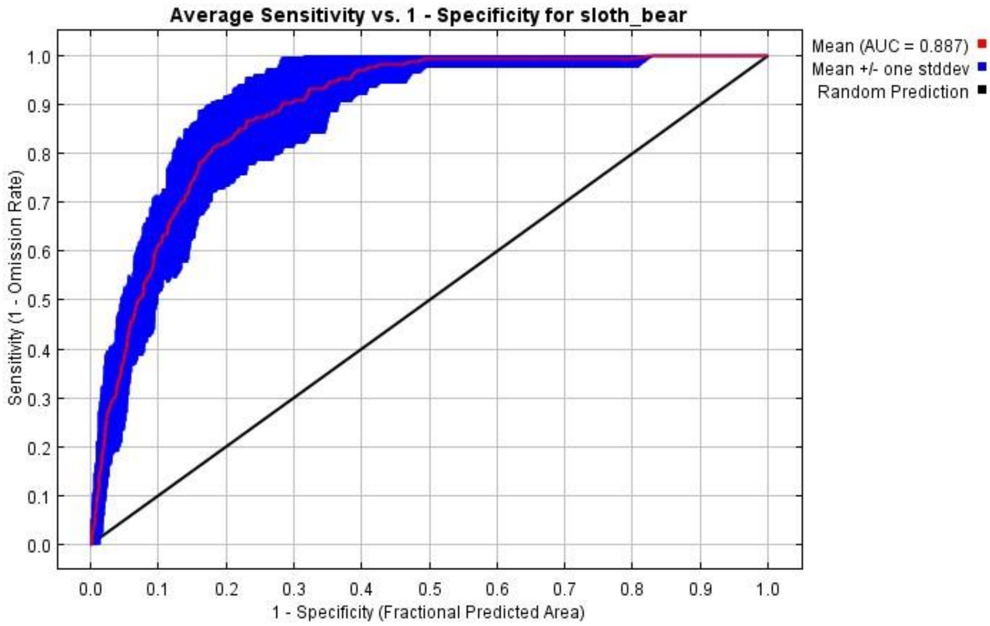


Figure 4.3. The output of Area Under the Curve to test the efficiency of model in the present study, y-axis represents sensitivity test of how well the data predicts and x-axis shows the specificity of how correctly the absences are predicted.

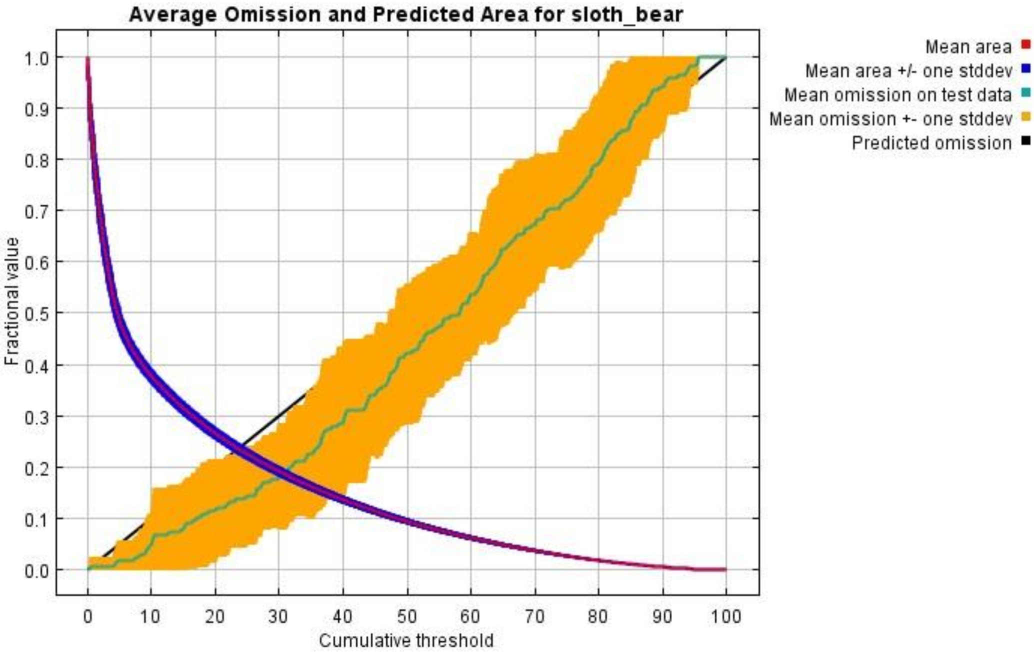


Figure 4.4. The graph shows the omission rate and predicted area averaged over replicated runs as a function of the cumulative threshold.

The final output for delineating potential areas of human sloth bear conflicts shows the variable distance to sloth bear protected habitats (five wildlife sanctuaries) as the most influencing predictor variable with a contribution of 53.1 %, followed by the variable -distance to human settlement estimated at 16.6%. Other variables including land use land cover (11.5 %), human population density (10 %), and distance to waterbodies (4.8 %) were relatively less influential as predictor variables with distance to rural roads (4%) being the lowest. According to Jack-knife test also, distance to protected areas was most significant variable when used in isolation (Figure 4.5) holding substantial information that influences the occurrence of human sloth bear conflict which is lacking in other variables reducing the gain obtained significantly when all other variables were used. Other variables that were found to be influencing the gain significantly were distance to settlement, population density and land use land cover. While distance to roads and water bodies showed a weaker effect on the prediction of human bear conflict locations.

Figure 4.5. A Jackknife test of variable importance measured in regularised training gain. Bars in blue representing the level of gain when used in isolation and green-blue bars showing the drop of gain by removing a particular variable compared to red bar.

The response curves predicted that the probability of human sloth bear conflict was concentrated around the boundaries of protected areas and as expected reduces with increase in distance from the protected areas (Figure 4.6a). A weak correlation was estimated with distance to settlements (Figure 4.6c) and roads (Figure 4.6d) in developing the high-risk zones. However, with a continuous variation noticed in the response curve, the probability of risk increases with increasing distances from human settlements (Figure 4.6c) up to certain distance. Though, risk probability for human bear encounter is potentially high close to waterbodies (Figure 4.6f). Thus, different categories of land use land cover had a varied influence on predicting potential risk zones with deciduous forest, scrublands, and waterbodies being the most influential for the human bear conflict areas (Figure 4.6b).

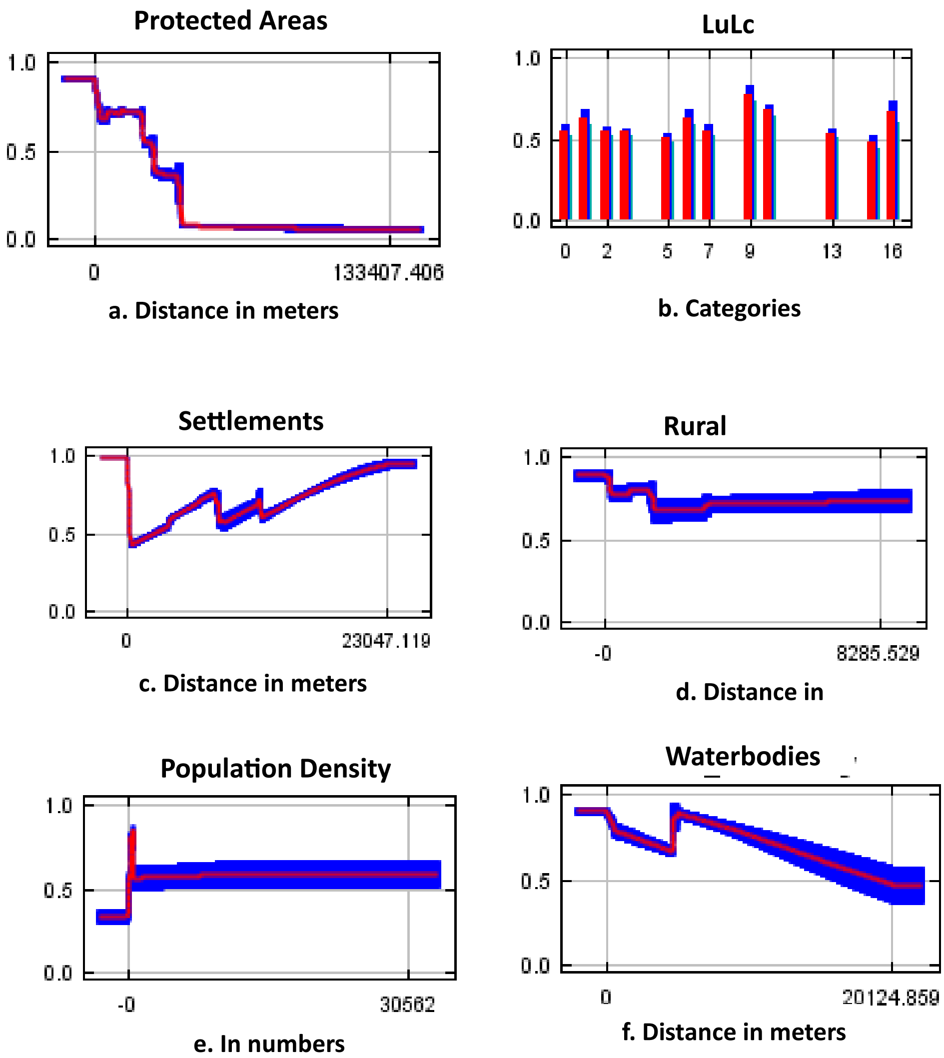


Figure 4.6. The relative importance of six variables in modelling the predicted probability of occurrence. Each variable measured over the entire spectrum of values when other variable kept constant at their average. The y-axis showing the occurrence could be completely predicted based on the particular variable alone, the x-axis represents the weighted number of pixels.

The final clog log output shows values between 0 to 1 where the values above 0.8 are considered as high-risk zones for human-sloth bear conflicts (Figure.4.7). In Present study approximately 30% of areas are identified as high-risk zone for the same. Highly potential areas are restricted to, in and around protected as well as non-protected sloth bear habitats. Banaskanatha, Mehsana and Sabarkanatha districts in North Gujarat are more susceptible to human sloth bear conflicts as predicted by the final output (Figure.4.6). Whereas Dahod district also represents significant areas predicted as potential zones for human sloth bear encounters. Relatively low areas were identified in Chhota Udepur, Vadodara and Narmada districts mainly towards the eastern border of the state boundary.

4.5 Discussion

The distribution of risk zones for potential conflicts has been limited in and around the protected habitats of sloth bears as well as human settlements. The area identified is concentrated to eastern boundary of the Gujarat state border encompassing six districts. The northern region of the state is known to harbour high density of sloth bears in the state (Gujarat Forest Department).

Sloth bears in the area are known to be widely inhabiting protected and non-protected forests interspersed with human settlements therefore, increasing the chances of sudden encounters with bears (Dharaiya 2009). Between 1968 to 2008 almost 36% percent conflicts have been reported from this region in the state. Garcia et al. (2016) also accounted for 71 victims who suffered sloth bear attacks from the Banaskantha, Mehsana and Sabarkantha districts as per the records.

Density of forest is essential in determining the suitable habitats when used as a predictor variable (Puri et al. 2015); and Gujarat is endowed with dry deciduous forest cover which is preferred habitat for sloth bears. Also, their movements have been frequently reported from the scrublands at lower elevation (Dharaiya 2009; Mewada 2015; Dharaiya et al. 2016). These two covariates have depicted a strong association to potential risk zones for human bear face offs for the predicted model. This is concurrent with the reports of studies on people residing in proximity to natural habitats of the bears (Garshelis et al. 1999; Ratnayeke et al. 2007). These people are majorly forest dwellers sustaining livelihood through collecting forest produce. Locals were attacked while collecting natural resources such as timber, flowers, and fruits (Dharaiya 2009; Garcia et al. 2016; Dhamorikar et al. 2017). Similar cases have been identified from the central India where encounters with sloth bears have been reported from non-protected forested patches far from the villages (Rajpurohit & Krausaman 2000; Bargali et al. 2005). It is widely established that ecological processes are greatly impacted by the human activities (Crutzen 2006).

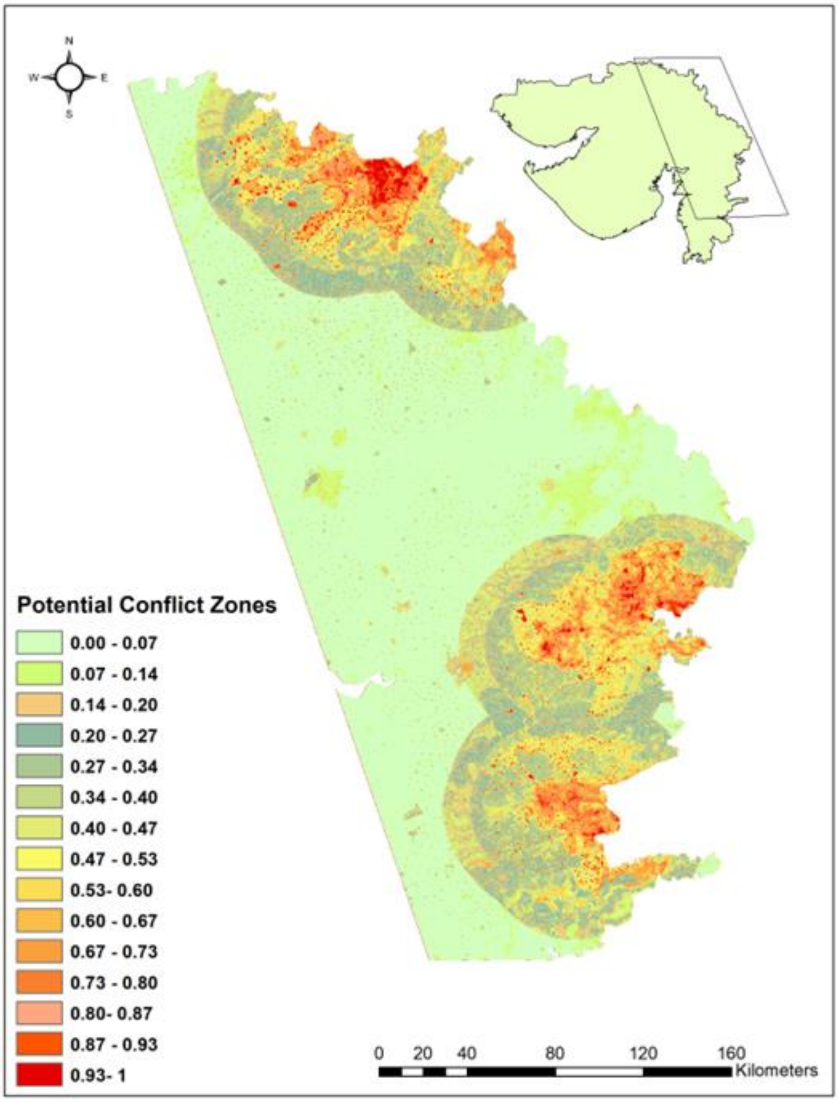


Figure 4.7. Potential human sloth bear conflict zones in Gujarat state varying between the values 0 to 1.

Large scale overlapping of sloth bear habitats and human settled areas potentially lead to increase in the human-sloth bear encounters (Puri et al. 2015). Interestingly, the human population density has not been identified as a strong predictor impacting the risk zones in the current study. Though, encroachment due to continuous land expansion is the leading cause of fragmentation isolating important patches of bear habitats. Ultimately, converting the forests into cultivating land, developing road network, etc, drives the bear towards human dominated landscapes increasing the chances of encounters between the two (Koirala et al. 2015; Acharya et al. 2017; Malik et al. 2023). It is consistent with results from this study, where risk zone is susceptible by the short distance from human settled areas. In the habitat suitability modelling, short distances to settlements and roads were found largely influential for sloth bears occupancy (Ratnayeke et al. 2007; Ghimire & Thapa, 2015). On the contrary, in densely forested areas of Mudumalai Tiger Reserve, occurrence of sloth bear was not strongly associated with distance to settlements (Ramesh et al. 2012).

Considerably, the sloth bear habitats in Gujarat are situated within the range of areas densely populated by humans leading to its degradation and fragmentation. Here, sloth bears have been threatened by rising incidences of human bear encounters (Joshi et al. 2015). The present model notifies that amongst the categories of different land use patterns, scrublands were relatively influential towards the predicted risk zones in the studied area. Occupancy studies have analysed that terrain heterogeneity influences the bears presence in an area allowing sloth bears to avoid human presence (Puri et al. 2015).

The proximity to waterbodies has been an important aspect for developing the occupancy models. In North Gujarat sloth bear's presence around the waterbodies has been reported (Malik et al. 2018). Due to scarcity of water in dry periods, sloth bears are reported to frequent nearby villages in search of water resources (Singh et al. 2018; Sharp et al. 2020). In the current study, it was noted that up to 5000 meters distance to waterbody (Figure 4.6f) there is sharp increase towards the occurrence of human-bear encounters, that further diminishes with the increase in distance. This is also corroborated in other studies where water bodies were mildly influential parameter in predicting sloth bear occupancy (Akhtar et al. 2007, Sahlen et al. 2011; Ketting 2020).

In conclusion, the present model states that potential high-risk zones for human sloth bear conflicts in Gujarat lies in the fragmented regions between transitional zones around protected areas with human settlements. Majority of potential human sloth bear conflicts identified in the non-protected areas frequented by both the humans and the bears. Nevertheless, a concentrated zone was revealed inside the Balaram Ambaji sanctuary, which is a disturbed area due to various developmental activities supporting a renowned temple and tourism associated with it. However, an insight can be gained by comprehending human-bear conflicts relationship with associated ecological parameters that can help in developing effective measures to reduce potential conflict situations (Frank 2016; Frank and Glikman 2019; Long et al. 2020; Khattak et al. 2021).