Chapter 5

Identification of ecological corridors for the movement of sloth bears between sanctuaries of Gujarat

5.1 Introduction

Conservation efforts are being made globally towards the subsistence of bears inhabiting not only in protected habitats but also in the forest patches which are legally not designated as PA (Wildlife sanctuary or the National Park) and preserving their distribution range (Garshelis et al. 1999; Jhala et al. 2011; Sathyakumar et al. 2012; Dharaiya et al. 2016). In Gujarat, their habitats have been facing extensive threats due to considerable increase in agricultural activities as well as livestock grazing in and around protected areas which are the major sources of earning for the locals residing in the close vicinity (Dharaiya & Ratnayeke 2009). It has been intimated that if habitat deterioration and fragmentation continue; the species will face a low genetic variation, potentially putting them at the risk to survive in wild (Harris et al. 1992; Dutta et al. 2015). Thus, it is important to maintain a connectivity - an Ecological Corridor between isolated habitats with the areas having potentially good species population. Such corridors are expected to aid the movement and dispersal of species to habitats with poor connectivity (Yoganand et al. 2006). Consequently, developing connectivity between habitats is expected to be helpful in increasing the populations of wildlife in general too.

As 50% of sloth bear populations are surviving in protected habitats facing threats due to fragmentation (Rodgers et al. 2002; Yoganand et al. 2006). The development of ecological Corridor, between them becomes essential. Therefore, establishing ecological corridors have been proposed as one of the few important measures to protect and conserve sloth bears in their natural habitats (Akhtar et

al. 2004; Yoganand et al. 2006; Ratnayeke et al. 2007; Dutta et al. 2015). Ecological corridor is a passage essential for the species movement. It is a functional and structural passageway connecting two neighbouring unconnected, potentially viable habitats (Tischen-dorf & Fahrig 2000; Beier et al. 2008; Koen et al. 2014; Rudnick et al. 2012). These corridors can be developed based on the combined estimation of hindrance as well as facilitation to the animal movements between the identified habitats (Tischendorf and Fahrig 2000). This can be formulated by assessing the impact of environmental factors on the movement and occupancy of targeted species (Merriam 1984). Studies to develop ecological corridors have been undertaken using various approaches relying on geospatial data and tools including software like Linkage Mapper, Habitat Resistance and Circuitscape (Adriaensen et al. 2003; Compton et al. 2007; McRae et al. 2008; Sawyer et al. 2011; McRae et al. 2013; Dutta et al. 2015; Buchholtz et al. 2020) that help in identifying and developing landscape connectivity spatially. Therefore, the present study employs the same approach and tools to identify connectivity between the core identified habitats (Wildlife Sanctuaries) of sloth bears in Gujarat state, India.

5.2 Study Area

For the present objective, the study has been conducted at eastern edge of the Gujarat state encompassing the identified five wildlife sanctuaries spread from North to south directions. Additionally, a buffer zone covering 50 kilometres is included extending into three adjacent states east of Gujarat including Maharashtra, Madhya Pradesh, and Rajasthan. Four out of five sloth bear sanctuaries share their borders with Protected/nonprotected habitats with these neighbouring states with a potential for movement of wildlife across the human defined borders (Figure 5.1.)
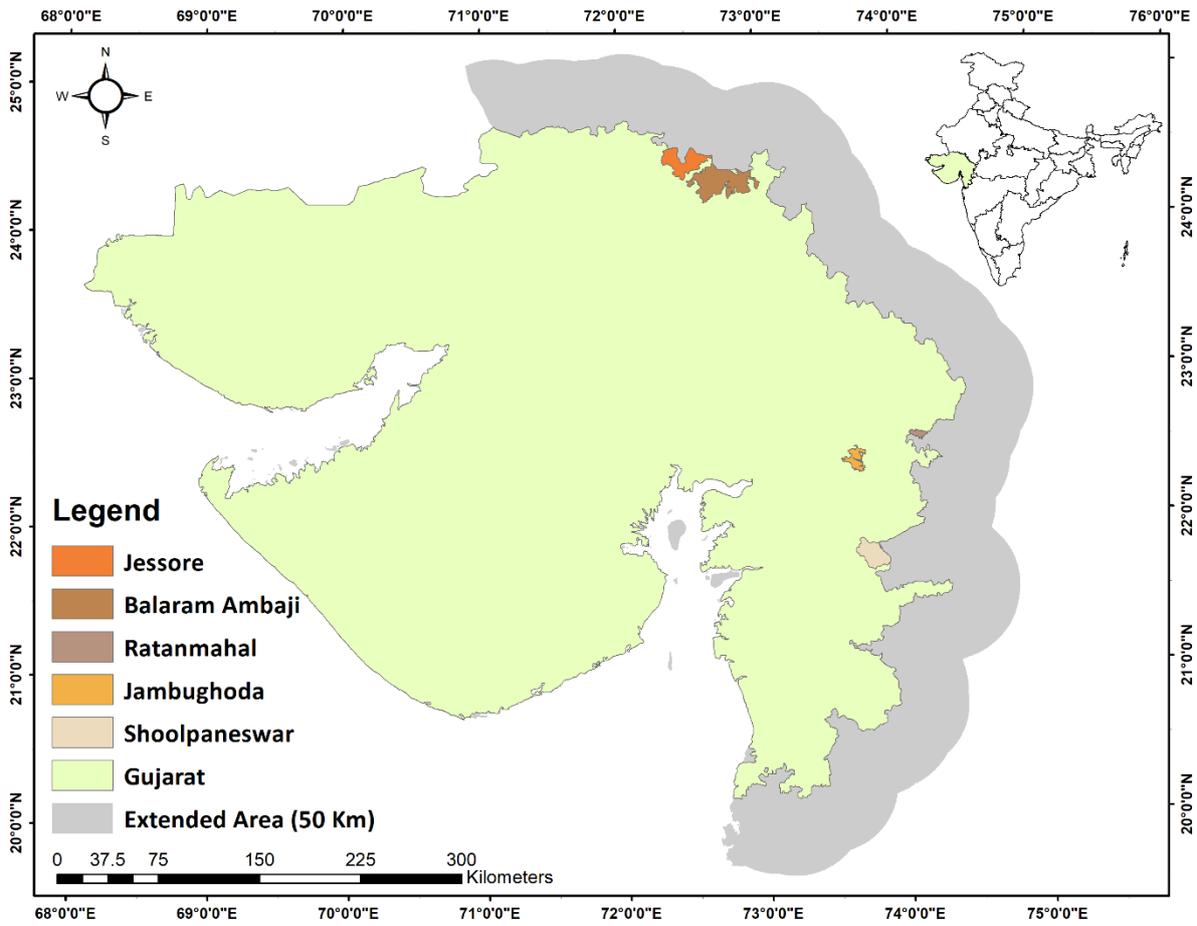
Figure 5.1 Study area representing protected habitats inhabiting sloth bear in Gujarat State

5.3 Methodology

Linking of protected areas is important for the movement of sloth bears. Hence, various environmental and anthropogenic factors considered as variables that influence the movements of bears positively or negatively were identified to evaluate their resistance score based on which ecological corridor can be proposed. This required the acquisition of geospatial data across the habitats identified. The sources of the data used as variables for developing ecological corridors is given below (Table 5.1):

Table 5.1. Environmental and Anthropogenic Data set used for developing habitat resistance layer.

Data layer	Variables	Resistance Score	Data layer	Variables	Resistance Score
Environmental			**Anthropogenic**		
Forest cover	Non forest	4	**Road**	Buffer 1km	45
	Open Forest	2		Buffer 2km	34
	Moderately Dense Forest	4		Buffer 3km	22
	Very dense forest	5	**Rail**	Buffer 1km	37
LU/LC	Barren land	10		Buffer 2km	24
	Agriculture land	100		Buffer 3km	12
	Scrubland	42	**Settlement**	Buffer 1km	67
	Wasteland	42		Buffer 2km	53
Water bodies	Buffer 1km	49		Buffer 3km	40
	Buffer 2km	44		Buffer 4km	27
Slope	Low	40		Buffer 5km	13
	Moderate	40	**Conflict Zone**	Very High	100
	High	13		High	100
				Medium	85
				Low	57

5.3.1 Variables:

The variables considered in present study were divided into two categories, environmental and anthropogenic, for understanding their impact in terms of facilitating or resisting the movement of sloth bears.

5.3.1.1 Environmental Variables:

The first variable considered is forest cover. Based on the density of vegetation, the forest cover was reclassified into four subcategories as mentioned in the table 5.1 (Puri et al. 2015). The Current India State of Forest Report maps from LISS

IIII (Linear Imaging and Self Scanning Sensor) were used to reclassify the raster layer into different categories like open forest, moderately dense forest, and highly dense forest. Further, Land Use/land Cover (LU/LC) layer, which is important to understand the species presence in different landscapes, was used as another variable depicting land use pattern across the study area (Jain et al. 2021). 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). Through field surveys, data was validated on land use pattern such as scrubland, farmland, barren land, and wasteland. Sloth bear habitat in the state represents undulating landscape, hence based on published literature, a raster data for slope was incorporated as an environmental aspect pertaining to species presence recorded in varied habitats (Ratnayeke et al.2007; Jain et al. 2021). Slope was generated from CartoDEM captured by Cartosat I. In addition to these variables, waterbodies as a combined layer including ponds, dams, wetlands, and rivers were considered as one of the variables (Jain et al. 2021; Paudel et al. 2022). National wetland inventory data was utilised to retrieve data on water bodies including man-made and natural, in the area at 1:50,000 scale (NWA 2011).

5.3.1.2 Anthropogenic Variables:

To estimate the resistance on any type of bear movement and impact of human presence, secondary information on human- sloth bear conflict reported between 2008-2020 was acquired from the Gujarat State Forest Department. Here, any encounter or incident with sloth bear leading to an attack, injury or death was considered as a conflict. The information gathered was further confirmed with the victims and villagers. Along with that, geo-tagged location of the sloth bear attacks was recorded using GPS (Garmin etrex10).

To recognize the impact of humans on developing ecological connectivity, data on human settlements is important (Dutta et al. 2016; Jain et al. 2021), hence it is also considered. Further, transportation networks, such as rail and road, were also included as man-made variable potentially impacting the linkage between the protected habitats. These variables are important as they hinder the sloth bear movement across the two neighbouring habitats creating an unfavourable environment for the target species. As movement of sloth bear can be random, buffer zones were created around the settlement, transport network and waterbodies. Open street map (www.openstreetmap.org,) was used to acquire data for human settlements and transport network including railway and road networks. 1 to 5 km buffer zone was considered for road, rail and settlement data. The data obtained in the form of line, point or polygon was used to generate buffer zones (Figure 5.2). These multiple buffers were subsequently allotted resistance scores as mentioned in the table 5.1. Multiple buffers were given resistance values in the decreasing order under the assumption, the closer the corridor to unsuitable cells, high resistance it will provide.

5.3.2 Habitat Resistance

To delineate the potential paths for developing the ecological corridors, it is important to generate a habitat resistance layer based on the variables discussed above. This was generated using Gnarly landscape utilities tool. For this, each feature or subcategories is assigned a value to estimate the relative resistance. It allows software to create additional grid cell values for the suitable habitat for a species to move through, ultimately avoiding grid cells of the features contributing high resistance (McRae et al. 2013). Gnarly utilities tools function by adding up the resistance values to identify the grid cells with suitable and non-suitable areas in the final output.

In order to develop the resistance model, ranks are assigned to all the variables mentioned above based on the literature available as well as the opinions of

experts and scientists (Akhtar et al. 2004; Ratnayake et al. 2007; Dharaiya et al. 2016). Further, Analytical Hierarchical Process (AHP); a decision-making process structured to analyse multiple alternatives of a problem was used. In this process alternatives are given ranks based on their assigned weightages and contributions with the help of pair-wise matrix (Saaty 2004; Boroushaki & Malczewski 2008) with the help of AHP, weighted sum values were obtained to further multiply with the assigned ranks to each category of individual layers to calculate resistance score (Saaty 2004).

The resistance score obtained varies between 0-100 from no resistance to maximum as given in the table 5.1. This data was further used to develop habitat resistance layer using Gnarly utilities toolbox (version 0.1.0) that functions by adding up the resistance scores for individual variables to estimate the habitat resistance as a final output (McRae et al. 2013).

5.3.3 Least Cost Path Analysis

The least cost path represents the passage for wildlife with minimum difficulty, energy expense and less risk of mortality. It is estimated using Linkage Pathways Tool in GIS. It utilises the core habitats and habitat resistance to develop the connectivity between the core habitats (McRae & Kavanagh 2017). Hence, to develop the connectivity between the sloth bear habitats, core areas are identified. Here, the term 'core' represents the five protected areas inhabited by the sloth bears in Gujarat (Figure 5.1).

Thus, least cost path (LCP) approach was used to calculate the Cost Weighted Distances (CWD) between these identified cores. The cost weighted distance estimates the cumulative expense or cost of movement of a species from a cell to the nearest core. The estimated CWD was combined to generate corridor as an output using LCP. The most feasible linkage paths were determined by obtaining the ratio of cost-weighted distance to Euclidean distance (CWD: EucD) and cost-weighted distance to the length of the least-cost path (CWD: LCP). Furthermore,

Circuitscape theory in ArcGIS (McRae 2012) was used to estimate the importance of individual cores. It is an algorithm that treats core habitats as nodes and injects 1 Amp current through these nodes, calculating the cumulative current flow indicating the importance of each habitat in maintaining the connectivity network (Dutta et al. 2015; McRae et al. 2016).

To achieve that, Central Mapper tool was applied on the network of connectivity developed through LCP. It allows to develop a linkage depicting the most important areas of the network by allowing the current to flow through the least cost paths (McRae and Kavanagh 2011; Carroll et al. 2012).
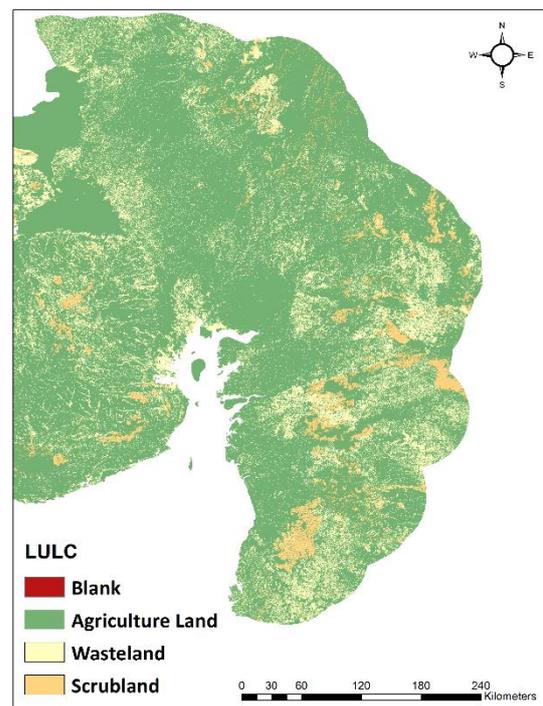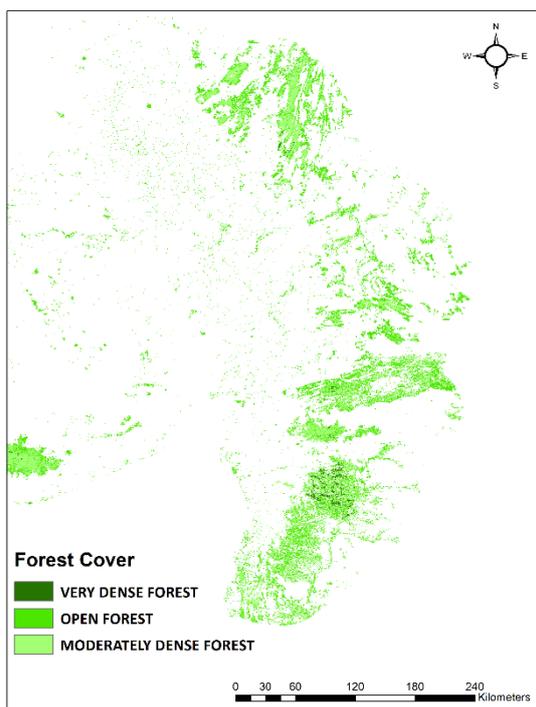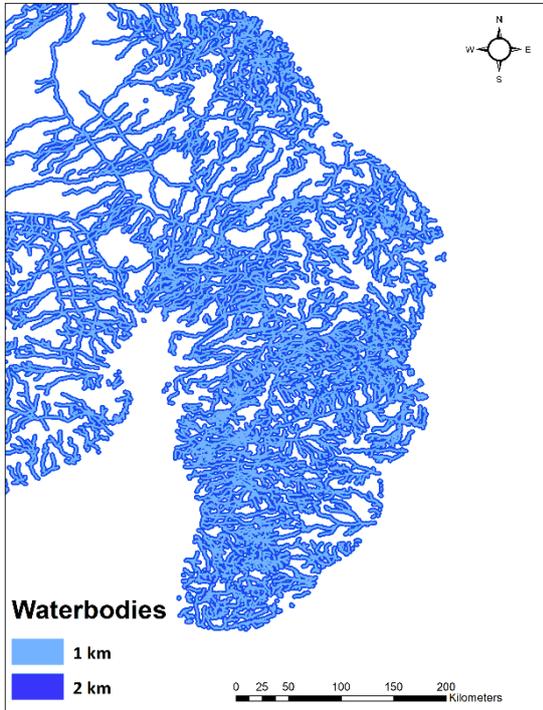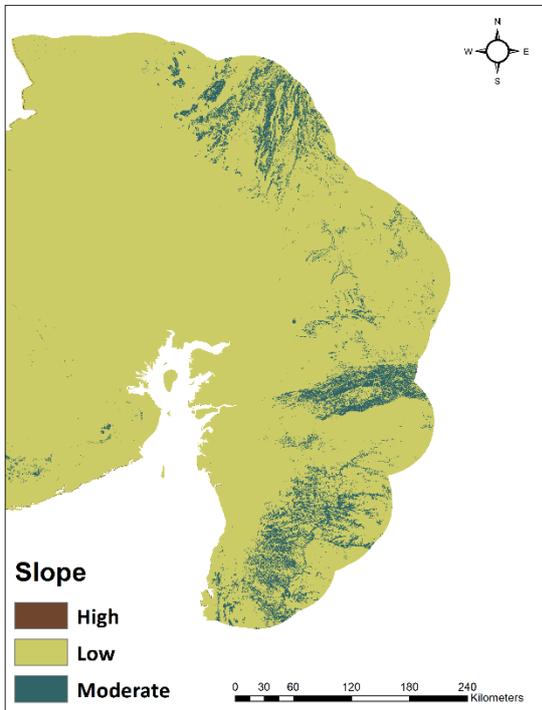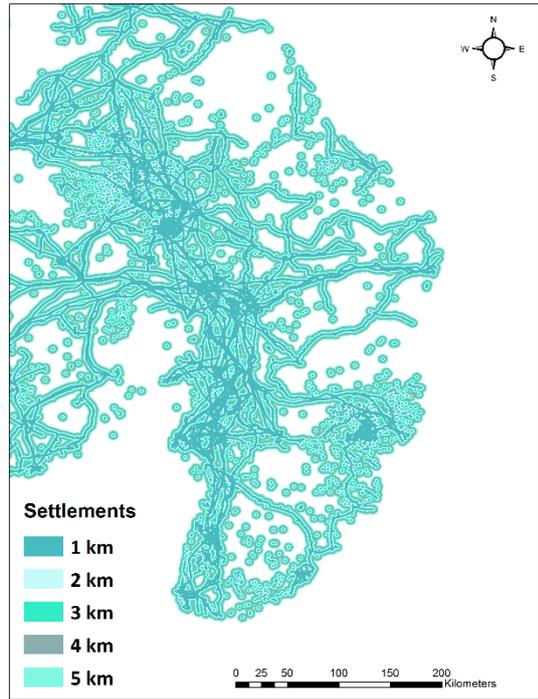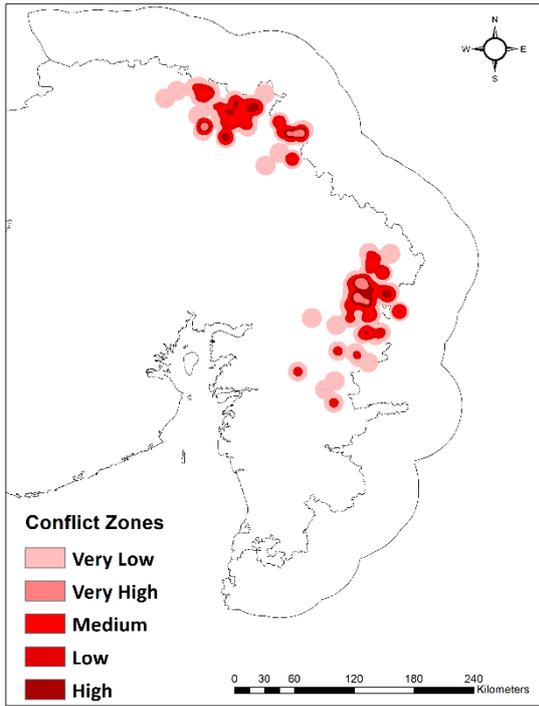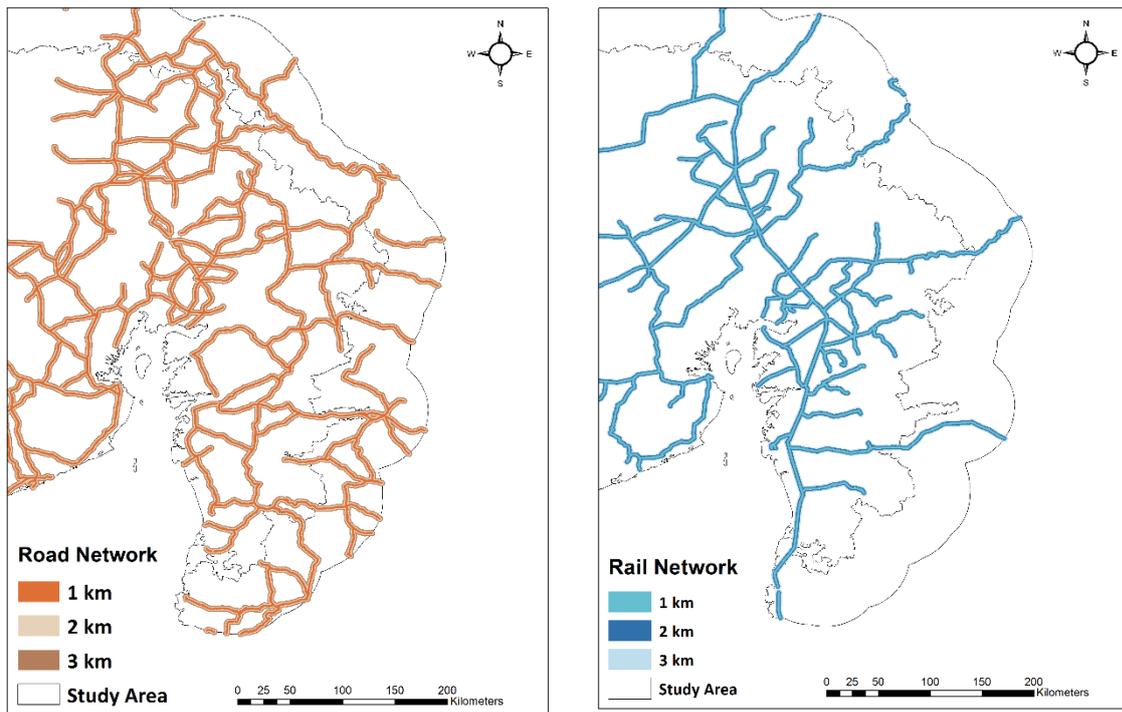
Figure 5. 2 Environmental and Anthropogenic variables used for estimating resistance layer. a). forest cover categorised into three types b). land use land cover map c) Conflict locations recorded (2008-2016) ranging from high to low frequency of occurrence d). Settlements map with buffers (1-5 km) e). Slope map f). Water bodies with buffers (1-2 km) g). Rural and urban roads map with buffers (1-3 km) h). Railway network map with buffers (1-3 km)

5.4 Results

All the variables (Table 5.2) used to calculate the resistance score revealed that the area of the forest cover sprawled estimated over the state to be 23,843.9 km^2 (Figure 5.2a). Majority of the forest composition accounted was for open forest (62.3%) followed by significant area covered by moderately dense forest (36%) and least percentage is calculated for the very dense forest (1.63%). It was observed that the dense forest cover is largely limited to the eastern boundary of the state. A large part of the state's geographical region (91,259.07 km^2) is occupied by different land use patterns. Under LU/LC, Agricultural lands make up most of the geographical area accounting for 79.4% whereas, the least area is

estimated for barren land (0.002%). The other two categories, wasteland covers 16.1% followed by barren land with 4.5% area (Figure 5.2b.). On the basis of all the variables recorded (Figures 5.2a, b, c, d, e, f, g, h) the developed resistance model shows that highly resistant areas were located near the anthropogenic variables - human settlements, conflict's locations, roads, and railway networks (Figure 5.3).

Based on the AHP analysis, the two highest resistance score (Table 5.1) were attributed to conflict zones (23.02%) and landuse/landcover (19.52%). The resistance scores were validated by calculating the consistency ratio of AHP (0.06) for all the variables used. The ratio estimated was less than 0.1, hence verifying the Analytical Hierarchical Process (Annexure II).
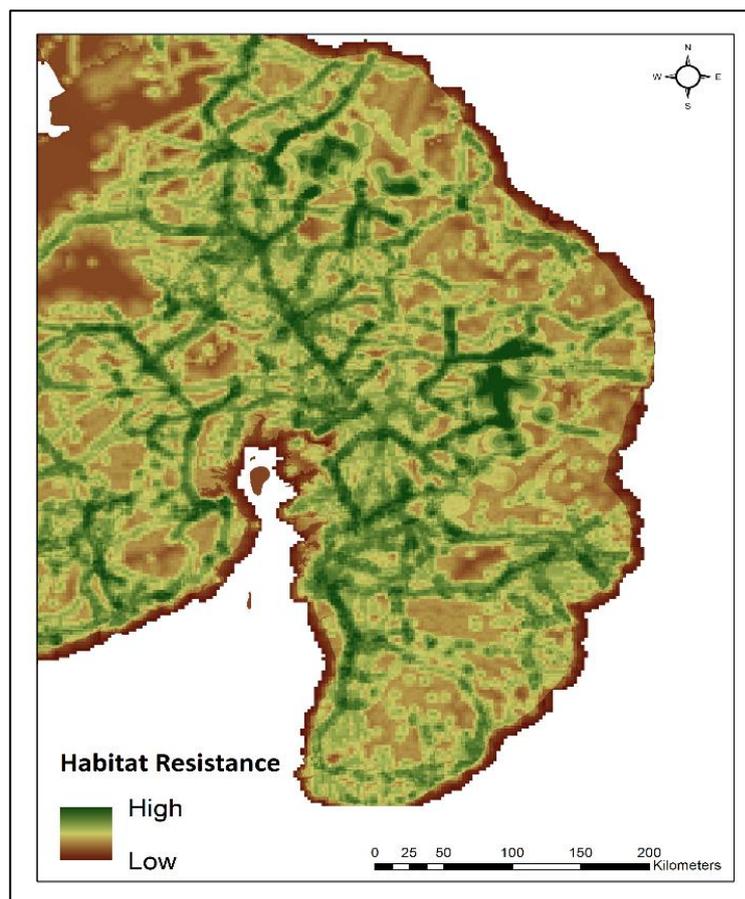

Figure 5.3 Habitat resistance for connectivity between the core habitats of sloth bears based on the weighted sum scores of all the variables shown in Fig 5.2.

The connectivity analysis generated six links between the targeted protected areas (Table 5.2, Figure 5.4). In north Gujarat, two sanctuaries i.e. Jessore and Balaram Ambaji were linked with single connectivity mapped between them. The Euclidean distance, least cost path and cost weighted distance for the linkage was found to be lowest with values estimated to be 1.96 km, 3.54 km, and 836.49 km respectively. Another connecting linkage between Ratanmahal WLS-Jambughoda WLS was estimated with a lower Euclidean distance of 34.92km followed by Jambughoda WLS-Shoolpaneshwar WLS with EucD 49.12km. However, the other two links mapped between Balaram Ambaji-Jambughoda and -Ratanmahal were found with high Euclidean distances, 204.82km and 212.78 km respectively.

Table 5.2. Least cost path and cost weighted distance calculated by connectivity analysis for Identified protected areas of Gujarat.

Protected Area 1	Protected Area 2	Euclidean Disatnce (EucD, Km)	Cost Weighted Distance (CWD, Km)	Least Cost Path (LCP, km)	CWD: EucD	CWD: LCP	Centrality (Amps)
Jessore	Balaram Ambaji	1.96	836.49	3.54	427.65	236.03	4.07
Balaram Ambaji	Ratanmahal	212.78	18206.93	342.98	85.56	53.08	2.35
Balaram Ambaji	Jambughoda	204.82	18143.17	239.16	88.58	75.86	2.36
Ratanmahal	Jambughoda	34.92	6109.68	49.44	174.95	123.57	2.40
Ratanmahal	Shoolpaneshwar	83.58	6275.42	108.30	75.07	57.94	2.45
Jambughoda	Shoolpaneshwar	49.12	5806.22	70.10	118.20	82.83	2.54

In the present study, the link between Balaram Ambaji-Ratanmahal WLS was found to be having minimum ratio (53.08) of CWD: LCP. Along with that another suitable link with minimum hindrance to the animal movement was estimated for Ratanmahal WLS-Shoolpaneshwar WLS (57.94). Conversely, high value was

recorded for building the network connecting Jessore-Balaram Ambaji. The ratio of CWD:EucD and CWD: LCP for this link was estimated to be 427.65 and 236.03 respectively resulting in maximum resistance

There is high anthropogenic pressure in the northern region with increasing record of conflict cases increasing the cost of developing the corridor. The centrality tool run on mapped corridor to identify the importance of individual habitats show maximum value 4.07 amps for centrality flow between Balaram-Jessore connecting the foothills of Aravalli (Figure 5.5, Table 5.2). The link mapped between Ratanmahal-Shoolpneshwar and Jambughoda-Shoolpneshwar revealed both having similar values for the centrality flow (2.54 amps). The value for link between Ratanmahal- Jambughoda was found to be 2.40 amps.
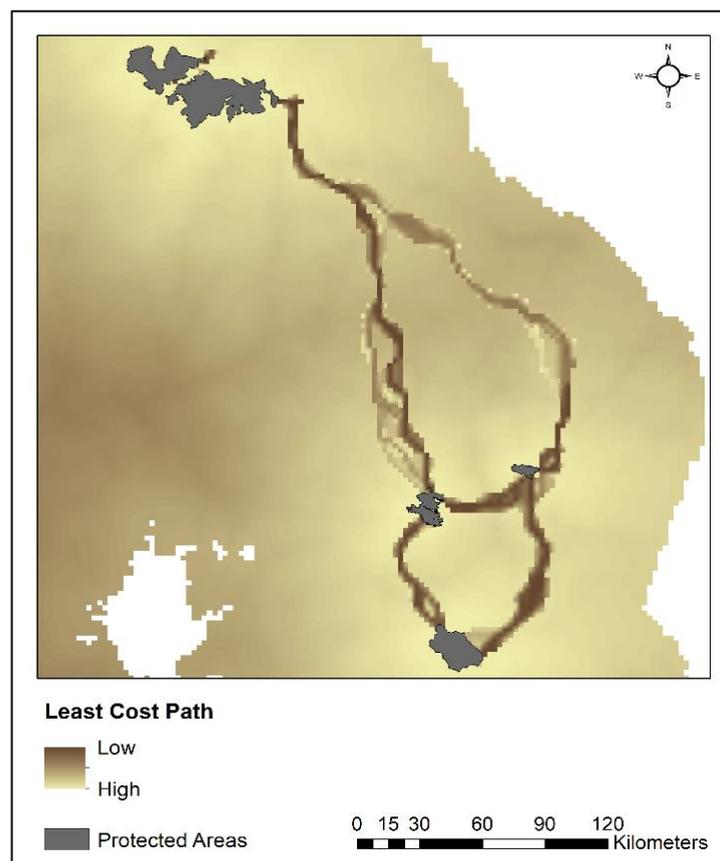

Figure 5.4 Least cost paths identified between the core habitats of sloth bears. Low resistance paths are represented by the darker colour and lighter colour represents high resistance for least cost path

These links can serve as a potential corridor for increasing the gene flow of sloth bears towards Jambughoda wildlife sanctuary. Lowest centrality flow was estimated for the links connecting Balaram Ambaji to Jambughoda and to Ratanmahal. The ecological connectivity between the three sanctuaries i.e. Ratanmahal, Jambughoda and Shoolpaneshwar depicts an essential network for sloth bear movements. The link mapped between Ratanmahal-Shoolpneshwar and Jambughoda-Shoolpneshwar revealed both having similar values for the centrality flow (2.54 amps). The value for link between Ratanmahal- Jambughoda was found to be 2.40 amps. These links can serve as a potential corridor for increasing the gene flow of sloth bears towards Jambughoda wildlife sanctuary. Lowest centrality flow was estimated for the links connecting Balaram Ambaji to Jambughoda and to Ratanmahal. The ecological connectivity between the three
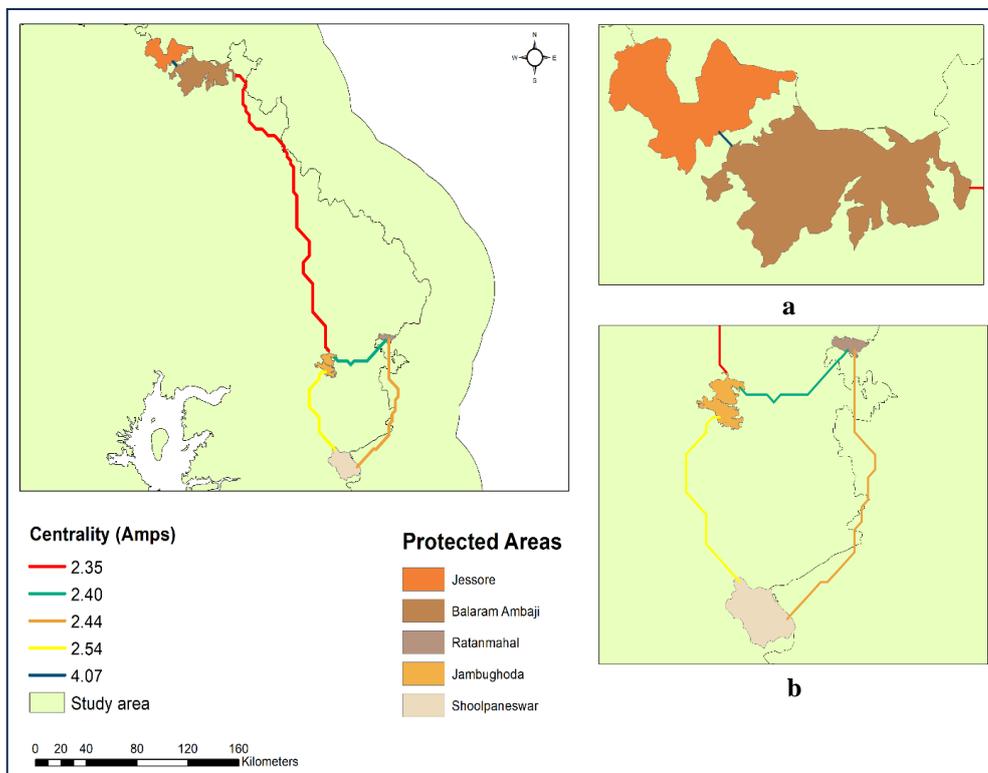

Figure 5.5. Centrality flow (in Amps) for each linkage (a.) High centrality flow between Jessore (left) and Balaram Ambaji (right). Centrality flow between Ratanmahal (right), Jambughoda (left) and Shoolpaneshwar (lower).

sanctuaries i.e. Ratanmahal, Jambughoda and Shoolpaneshwar depicts an essential network for sloth bear movements.

5.5 Discussion

Potential pathways promoting wild animal movements between two habitable areas can be developed by understanding landscape suitability and connectivity (Dutta et al. 2016; Garcia et al. 2016; Ketting 2020), especially for the animals like sloth bears preferring to remain solitary in varied habitats. In Gujarat, an ecological connectivity is essential for the scattered habitats of sloth bears mainly limited to eastern border of the state spreading from north to south. These habitats are characterized with dry deciduous forests interspersed with farmlands and villages (Mewada and Dharaiya, 2010; Mewada et al. 2019) that are degrading and fragmenting the surroundings. Therefore, the connectivity suggested between these habitats identified based on hindrance/resistance provided by ecological and anthropogenic parameters impacting species movement becomes important. In the present study, habitat resistance layer has shown maximum resistance in the areas with high anthropogenic disturbances. The variable 'human settlements', is identified as an important parameter considering its negative impact on the sloth bear movement by obstructing the pathway between the two potentially suitable habitats (Bargali et al. 2012; Kaminski et al. 2013; Jain et al. 2021). The man-made structures such as transportation networks including roads and railways are strongly associated with creating hindrances for connectivity (Jain et al. 2021). Being an opportunistic feeder, sloth bears often venture into human inhabited areas in search of food/water (Bargali et al. 2005; Mewada & Dharaiya 2010; Mewada et al. 2019). In the present study though not very close to human habitations, sloth bears have frequently marked their presence in close vicinity of water bodies. Thus, the factors affecting sloth bears occupancy became important in generating the habitat resistance for the present study (Figure 5.3).

Further, with the help of resistance layer, six potential linkages are established between Jessore-Balaram Ambaji sanctuaries, Balaram Ambaji- Ratanmahal, Balaram Ambaji- Jambughoda, Ratanmahal-Jambughoda, Ratanmahal-Shoolpaneshwar and Jambughoda-Shoolpaneshwar. The potential pathway linking Balaram Ambaji with two sanctuaries (Figure 5.4) located in the central part of Gujarat, across the Polo forests in Vijaynagar, is passing through the districts in adjoining state of Rajasthan is also suggested by Jangid et al. (2016). The longest ecological corridor identified between Balaram Ambaji and Ratanmahal in present study with Euclidean distance of 297.98 km is much longer when compared to the home ranges of sloth bears; reported by Yoganand et al. (2005) and Baskaran et al. (2015) 85 km^2 for males and 20 km^2 for females with cubs. It has been reported that with the increasing Euclidean distance, the linkage quality decreases due to high influence of anthropogenic variables (Dutta et al. 2016).

However, the pathway connecting Jessore and Balaram Ambaji with Euclidean distance of 1.96 km is found to be an important link to preserve the high density of sloth bears in the area. This is a potential corridor as both the sanctuaries are also geographically connected with Mount Abu and Fulwari ki Nal in Rajasthan (Singh 2008). This can be further corroborated with the distribution study of rusty spotted cat in Mount Abu (Rajasthan) indicating the possible movement between the adjoining habitat of Jessore (Gujarat) (Mukherjee et al. 2017; Singh and Kariyappa 2020). The landuse pattern of Jessore sloth bear sanctuary is mainly characterized by dense forest patch centrally concentrated with sporadically distributed villages around the edges. On the contrary, forest cover in Balaram Ambaji is fragmented, overlapped with farmlands and villages. Studies have reported sloth bears frequenting agricultural lands and water resources in these villages (Dharaiya 2008).

Based on centrality mapper analysis, Balaram Ambaji has been identified in the present study as a significant zone connecting three sloth bear habitats one in north-west (i.e. (Jessore) and two in Central Gujarat (Ratanmahal and Jambughoda) which further can be elongated in south to Shoolpaneshwar (Figure 5.5). Two protected habitats in central Gujarat, Jambughoda and Ratanmahal are mapped with a single link with a Euclidean distance of approximately 35 km. The ecological corridor passes through the Chhota Udepur district, a reserve forest geographically located closer to Ratanmahal sloth bear sanctuary. This area was previously proposed as a potential corridor facilitating the migration of large mammals like sloth bears and leopards (Singh 2008; Vyas and Upadhyay 2014). The southern region shows link with these two habitats of central region through two separate connectivity formed between Shoolpaneshwar - Jambughoda and Shooploaneshwar-Ratanmahal (Figure 5.4). This has been recognised as a potential passage for large mammal movement (Kumar & Ramana 2017). However, it is important to note that Narmada River traversing this area probably is a hindrance to mammals migrating through this area (Singh 2008). This study presents potential ecological corridors aiding migration of large mammals to move towards a suitable habitat to access the natural resources as well as avoiding human contacts. It is recommended that the functionality of these corridors should be studied through intensive ground survey using camera traps, DNA study, radio telemetry. Further, study suggests that future research work should be carried out to study potential links connecting neighbouring states allowing migration of animals.