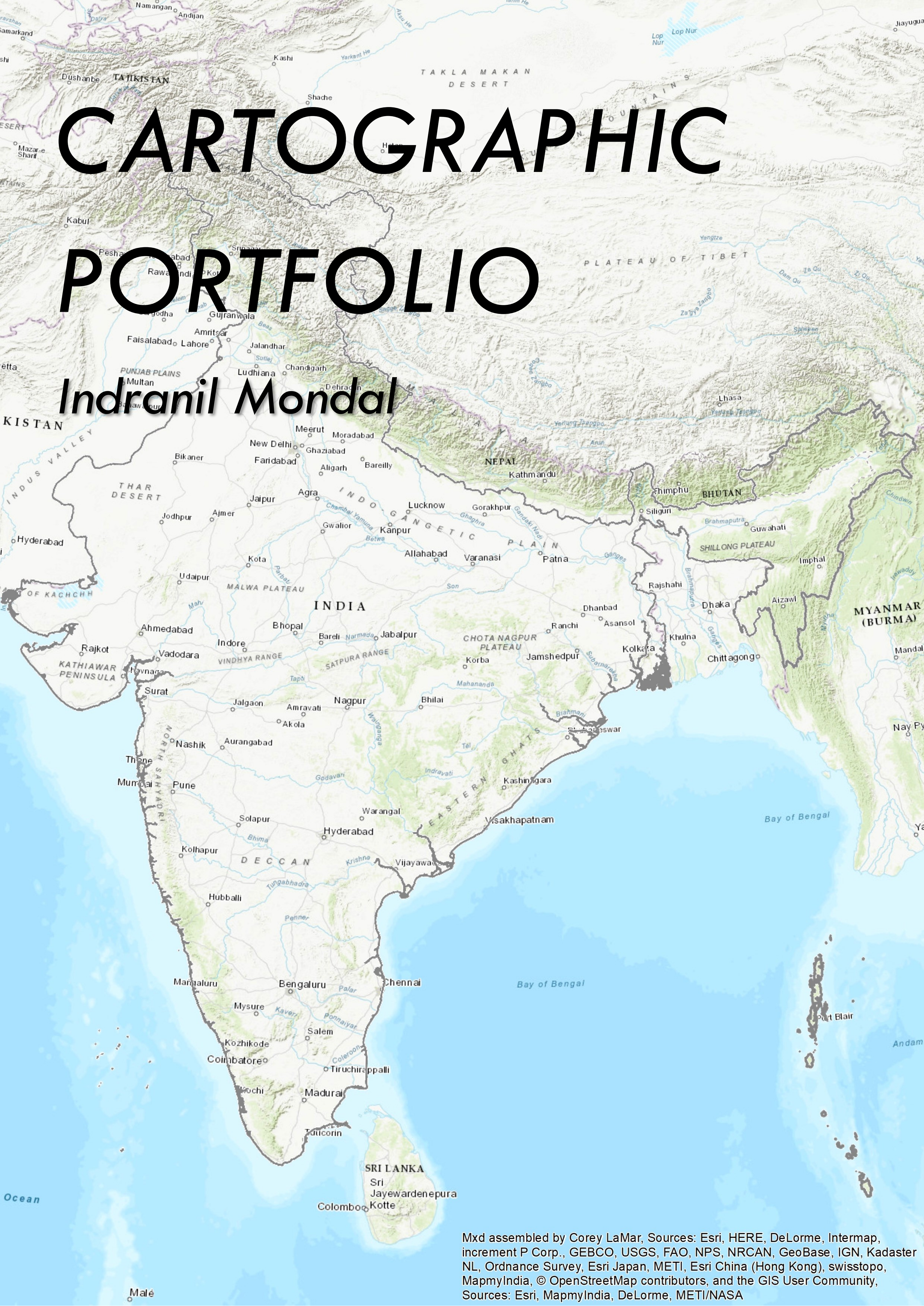
CARTOGRAPHIC PORTFOLIO

Indranil Mondal



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Braided channels and meanders in the Ganges River in the State of Bihar

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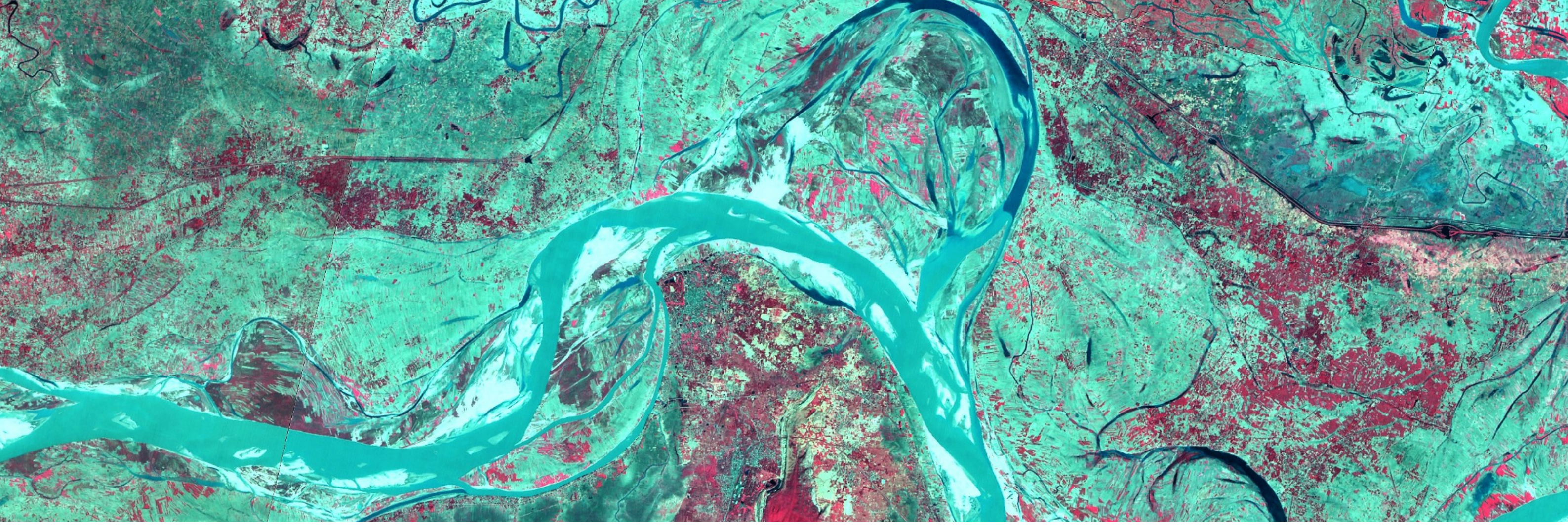
Summary of my research

From the very beginning, the theme of my research has been “the shrinking wild habitats in a developing world, and the need to connect them.” My graduate and post-graduate training in the field of geography and geoinformatics enable me to embrace the knowledge of the people, their land, and their environment and use geospatial technology to address the issues threatening them.

During my Master’s dissertation, I studied how habitat fragmentation effect a small isolated population of a small South-Asian geoemydid, the Tricarinate Hill-turtle. These turtles have a small body size and home range, with very specific habitat requirements and movement patterns. Even the slightest alteration to their habitats could disrupt their movement, and foraging behavior and ultimately affect their life histories. I used an expert opinion model, derived from extensive field observations of these turtles to develop a fine scale connectivity model. The corridors were validated using turtle movement data and found functional. I used a novel technique of low-cost thread-spool tracking to follow their movement within and between fragmented habitat patches. This study helped me appreciate the adverse effects of fine-scale habitat fragmentation that affects small forest dwelling species like the Tricarinate Hill-turtle which often go unnoticed.

Even after my masters, as I started my research career, I followed the same theme. This time I scaled up. Having appreciated the adverse effects of fragmentation on species with a small body size, I started studying one of the most charismatic big cats of the Indian sub-continent, the Bengal Tiger. My study on tiger corridors in India is focused on the Eastern Vidarbha Landscape (EVL), which is situated at the centre of India. It consists of a mosaic of various land uses and a tiger population of 150 -200 individuals. In EVL the prime tiger habitats are inside protected areas (PA) which are like islands in a sea of human-dominated landscape. These PAs are connected by fragmented corridors, which are under high human pressure of resource extraction, grazing, encroachment, land conversion and destruction from developmental activities.

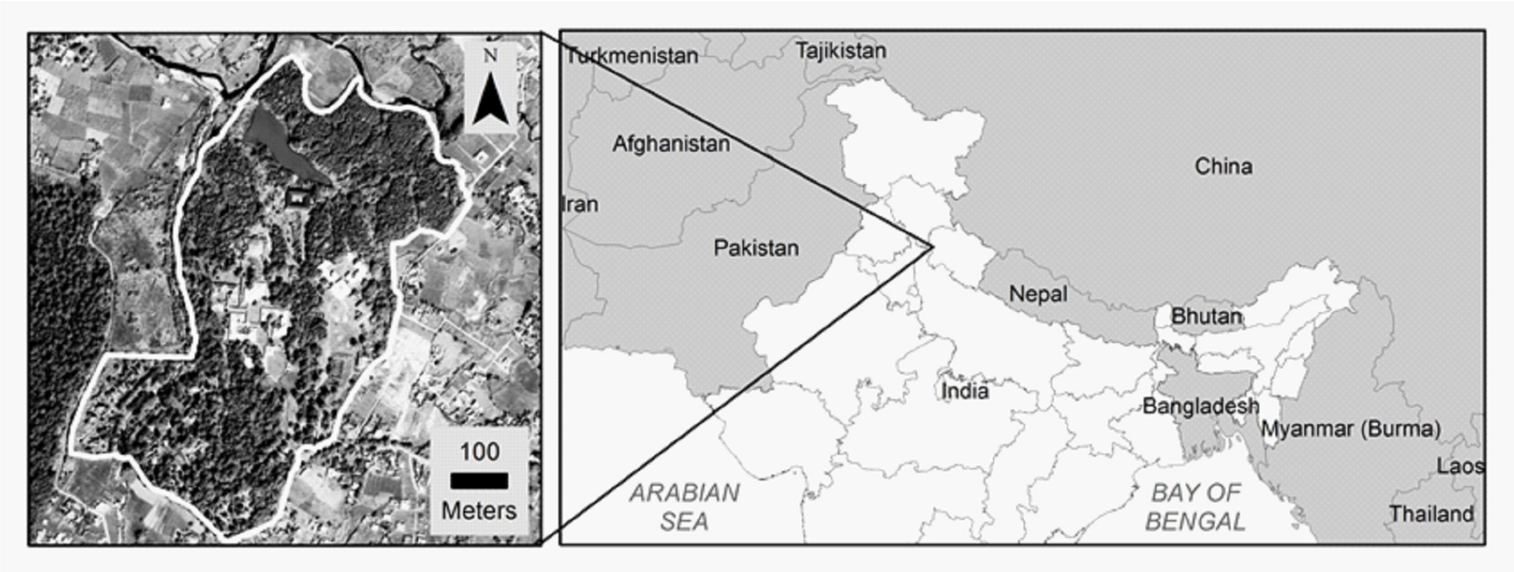


Several studies have established that the only way to save tigers is to connect these isolated habitats. So I use primary and secondary sources of data about tiger presence and data on habitat and disturbance variables to model corridors for tigers in Central India. Since these PAs in EVL have a high turnover rate, a lot of tigers leave these areas, move out and start dispersing through human-dominated areas giving rise to human-tiger conflict. Addressing such conflict is very important since the attitude of local people count towards successful conservation of tigers. Therefore, I also study the spatiotemporal patterns of human-tiger conflict to complement my study on corridors. As an output from my study, I have developed an atlas of the tiger corridors of EVL and a conflict potential map of the landscape. Recently I have been using tracking data from radio-collared tigers to study how the tigers move through the landscape. From the movement data, I was able to model places along corridors that act as a refuge for tigers during the day. The findings of my study help managers pinpoint the location of potential movement corridors, conflict hotspots and degraded pockets needing restoration. Thereby they are able to use precious conservation resources more efficiently and effectively.

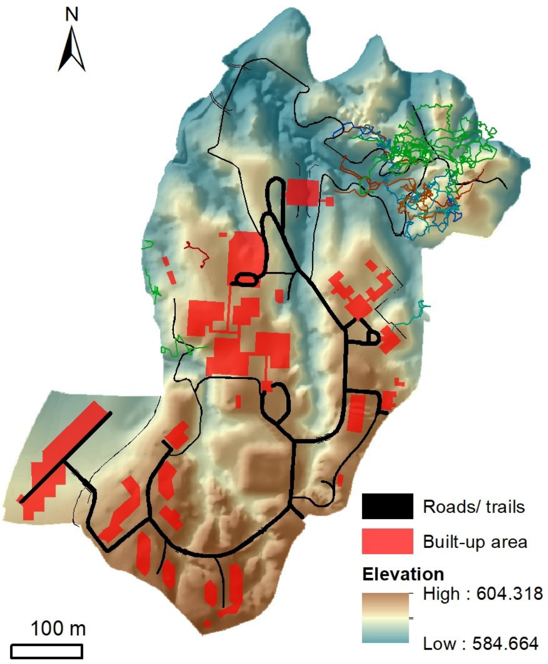
In EVL, farmers illegally electrify the guard fences around their agricultural fields to protect their crops from being raided by wild ungulates. Since they draw the electricity from high voltage transmission lines, wild animals die from electrocution when they come in contact with them. Even dispersing tigers often face the same fate. From my study, I have come up with a map that depicts the potential of electrocution of tigers in the landscape. This map will enable the local forest department and the power transmission companies to conduct joint patrolling operations to curb this menace.

Development of linear infrastructures like roads and railways through prime tiger habitats and corridors is also a problem in EVL. I have been part of studies where we have assessed the impact of highway expansion projects and have suggested locations of animal crossing structures after intensive field surveys and GIS modelling.

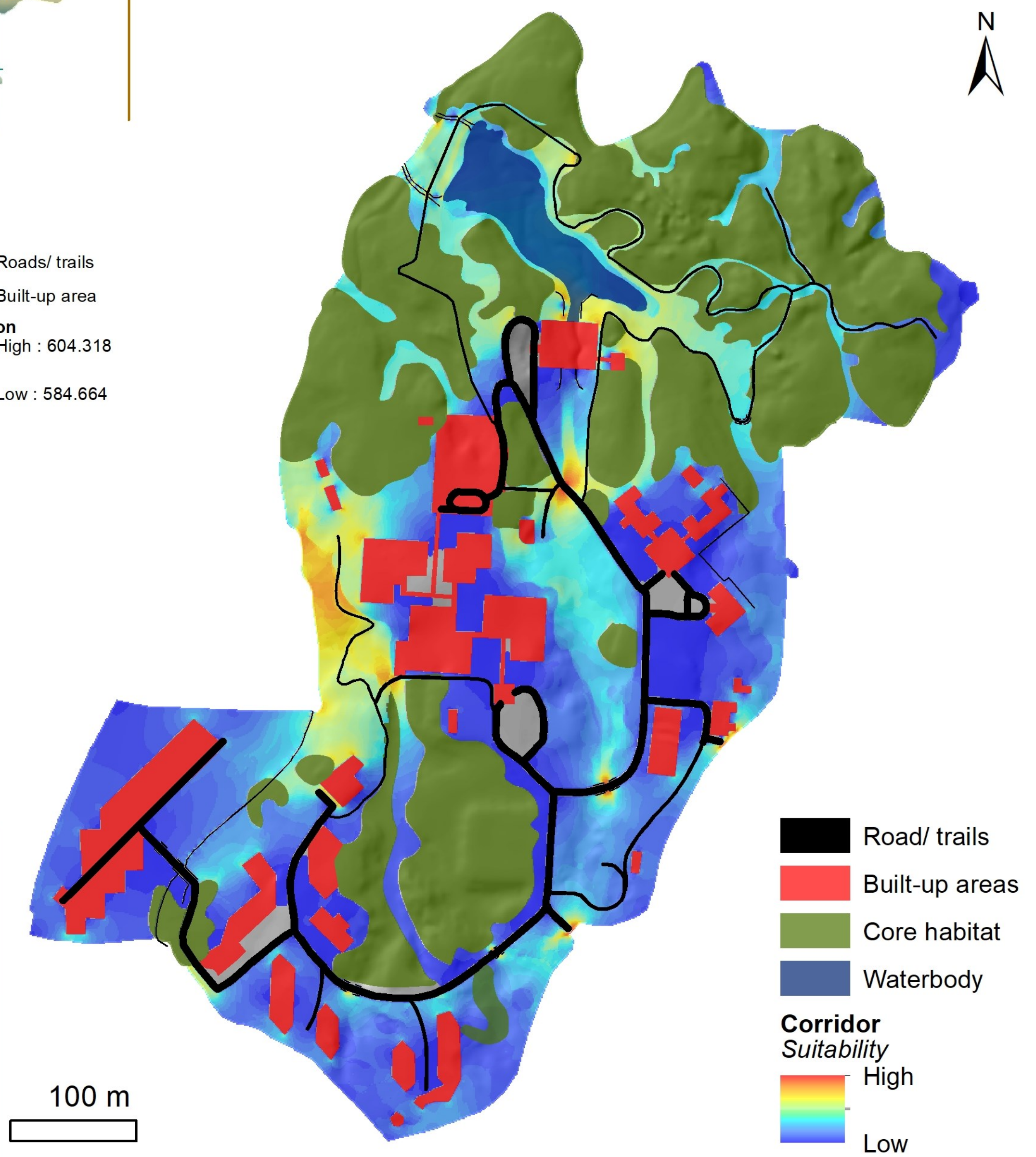
My study on tiger corridors, human-tiger conflict and corridor restoration also forms my Ph.D. thesis. For my post-doctoral study, I want to delve deeper into the field of animal movement in human-dominated landscapes and understand how seasonal differences in the landscape drive their movement.



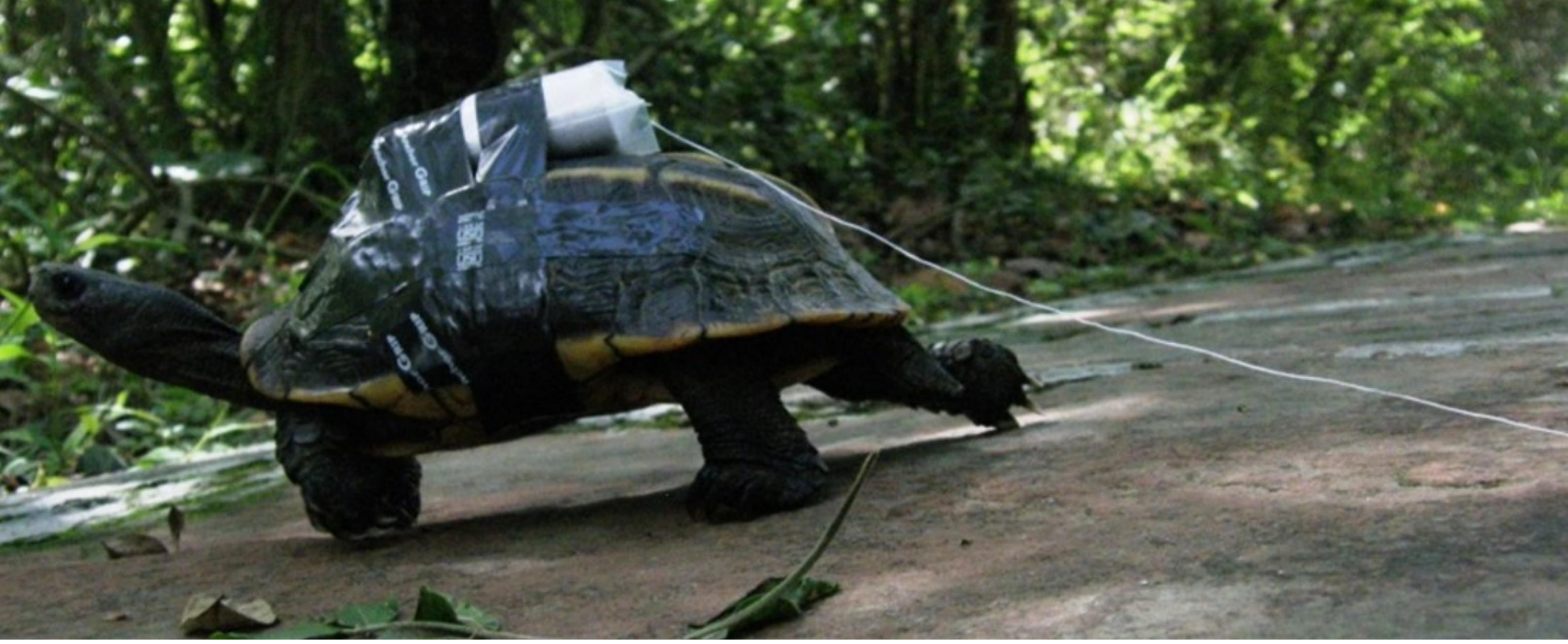
Contextual setting of the study area in the foothills of the Western Himalayas



A relief map of the study area with the layout of built-up areas and roads/ trails. Crooked and colourful lines in the North-Eastern sector of the study area represent turtle tracks.



Corridors modelled using Circuitscpe. Areas with high suitability values indicate sections in the corridors that have more probability of the animal using it for movement.



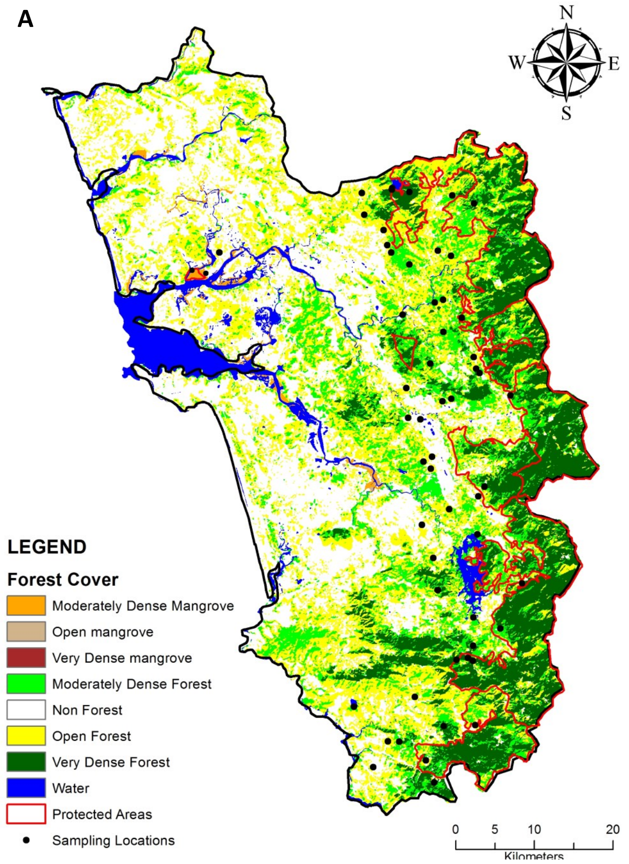
A Tricarinate-Hill Turtle fixed with a thread-spool tracking device.

The present study on a small South-Asian geoemydid, the Tricarinate Hill-turtle (*Melanochelys tricarinata),* focuses on habitat connectivity at a very fine scale. The Tricarinate has a small body size (carapace length: 127–175 mm) and home range (8000 – 15000 m^2), with very specific habitat requirements and movement patterns. We used very high resolution Worldview satellite data and extensive field observations to derive a model of landscape permeability at 1:2,000 scale to suit the target species. We digitized land use classes from the satellite imageries using visual interpretation techniques and quantified vegetation cover type and availability of food resources. Circuit theory was applied to model potential corridors between core habitat patches for the Tricarinate Hill-turtle. The modelled corridors were validated by extensive ground tracking data collected using thread spool technique and found to be functional. Therefore, circuit theory is a promising tool for accurately identifying corridors, to aid in habitat studies of small species.

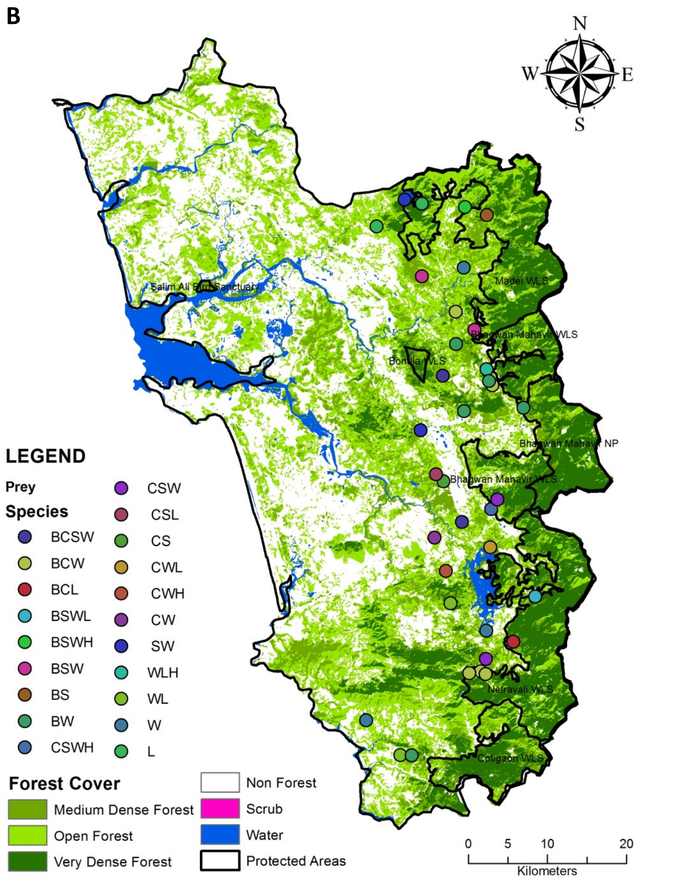
This study was conducted as part of my Master's dissertation thesis inside the campus of the Wildlife Institute of India, serves as a refuge for native floral and faunal species including this turtle. Finding of the study went towards enriching the knowledge base of the campus biodiversity monitoring programme.

Publication

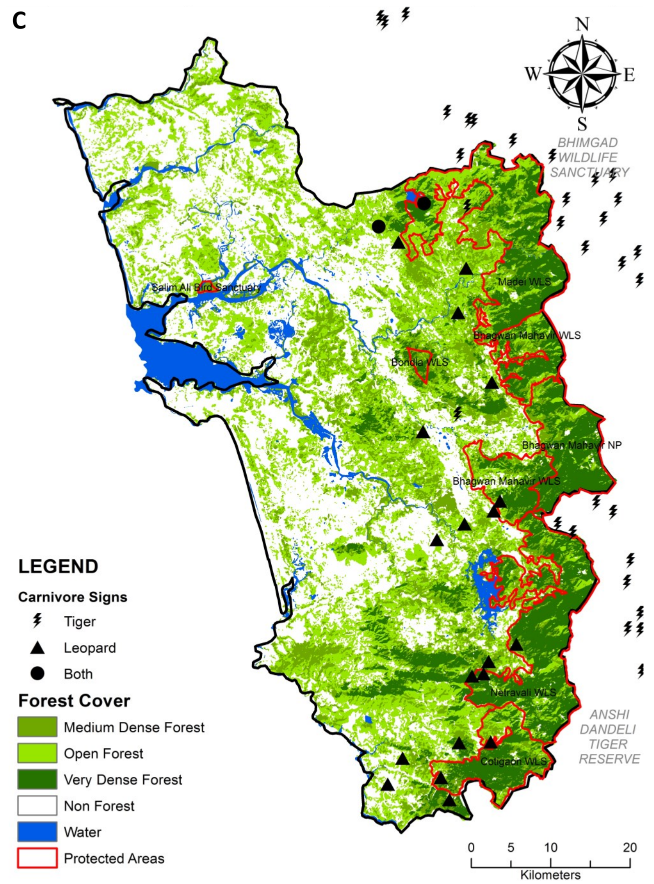
Mondal, I., Kumar, R., Habib, B., & Talukdar, G. (2016). *Modelling Fine Scale Movement Corridors for the Tricarinate Hill Turtle.* ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 719-725. doi:10.5194/isprsarchives-XLI-B8-719-2016



Sampling locations overlaid on Forest Cover map of Goa
(Forest cover data source: Forest Survey of India, 2011)

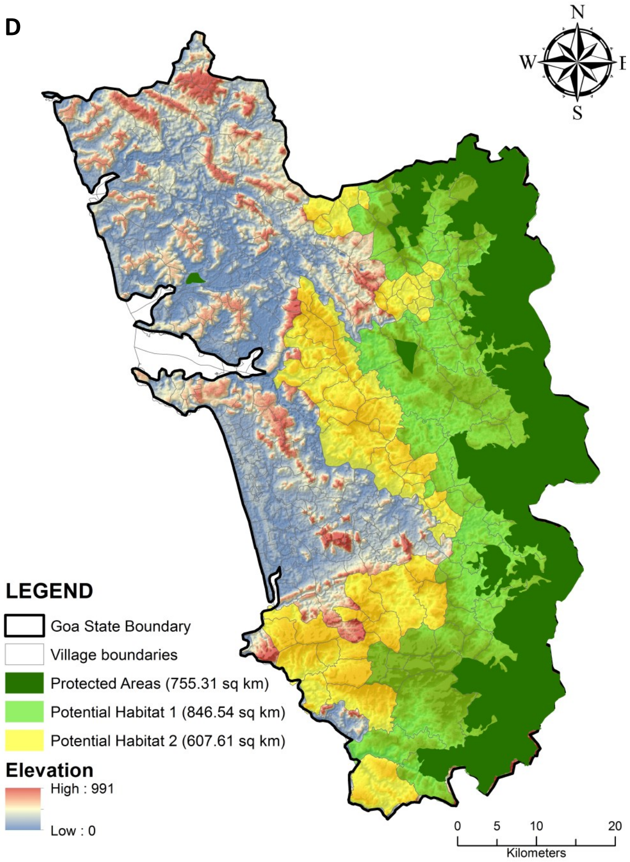


Wild prey signs recorded in Goa
B= Gaur, C=Cheetal, S=Sambar, W=Wild Pig, L= Langur, H= Hare



Carnivore presence locations in Goa and adjoining states of Maharashtra and Karnataka

A Coffee Locust in the forests of Goa



Proposed villages with potential tiger habitat beyond protected areas in Goa

This study was conducted as part of a special committee report that was submitted to the National Tiger Conservation Authority, Ministry of Environment, Forests and Climate Change, Government of India. The aim of this study was to ascertain the spatial presence of tigers, co-predators, prey and the extant of their habitat in the state of Goa, India. This would help the government take a decision about the formation of a eco-sensitive zone around the protected areas in the state to establish mining no-go zones.

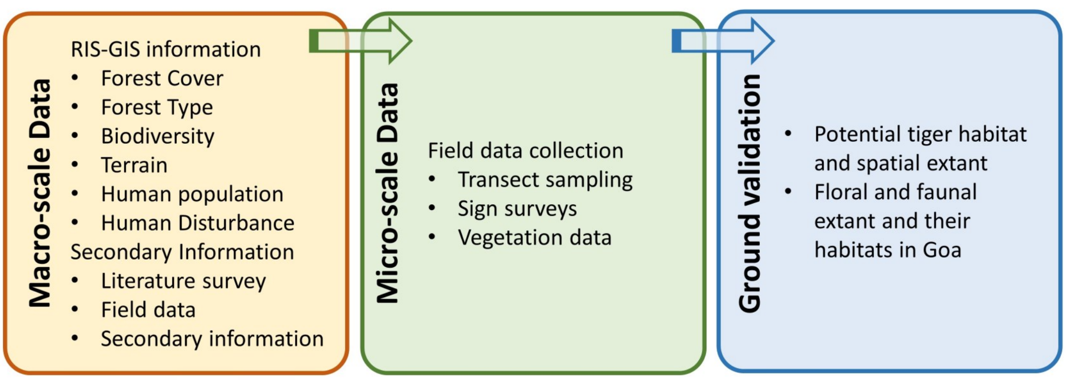
A two pronged multi-scale approach was adopted for in this study. A landscape level approach in GIS and relevant secondary information was used to identify contiguous forest patches in the state of Goa. At a micro - scale, ground information from field visit as well as information from local staff/villagers was used to derive inferences about spatial presence of tiger, co-predator, its prey and extant of their habitat.

A total of 54 **(A)** sampling points were laid with respect to increasing distance (east to west) from Protected Area boundary across North to South of Goa. At each sampling point we recorded direct and indirect evidence of tiger, co-predator **(C)**, prey **(B)**, disturbance and vegetation characteristics using standard methodologies. We calculated prey encounter rates and encounter rates of carnivore signs. Results from vegetation sampling indicated that forest patches outside protected areas in combination with PA's form contiguous habitat harbouring biodiversity and providing cover for wild fauna.

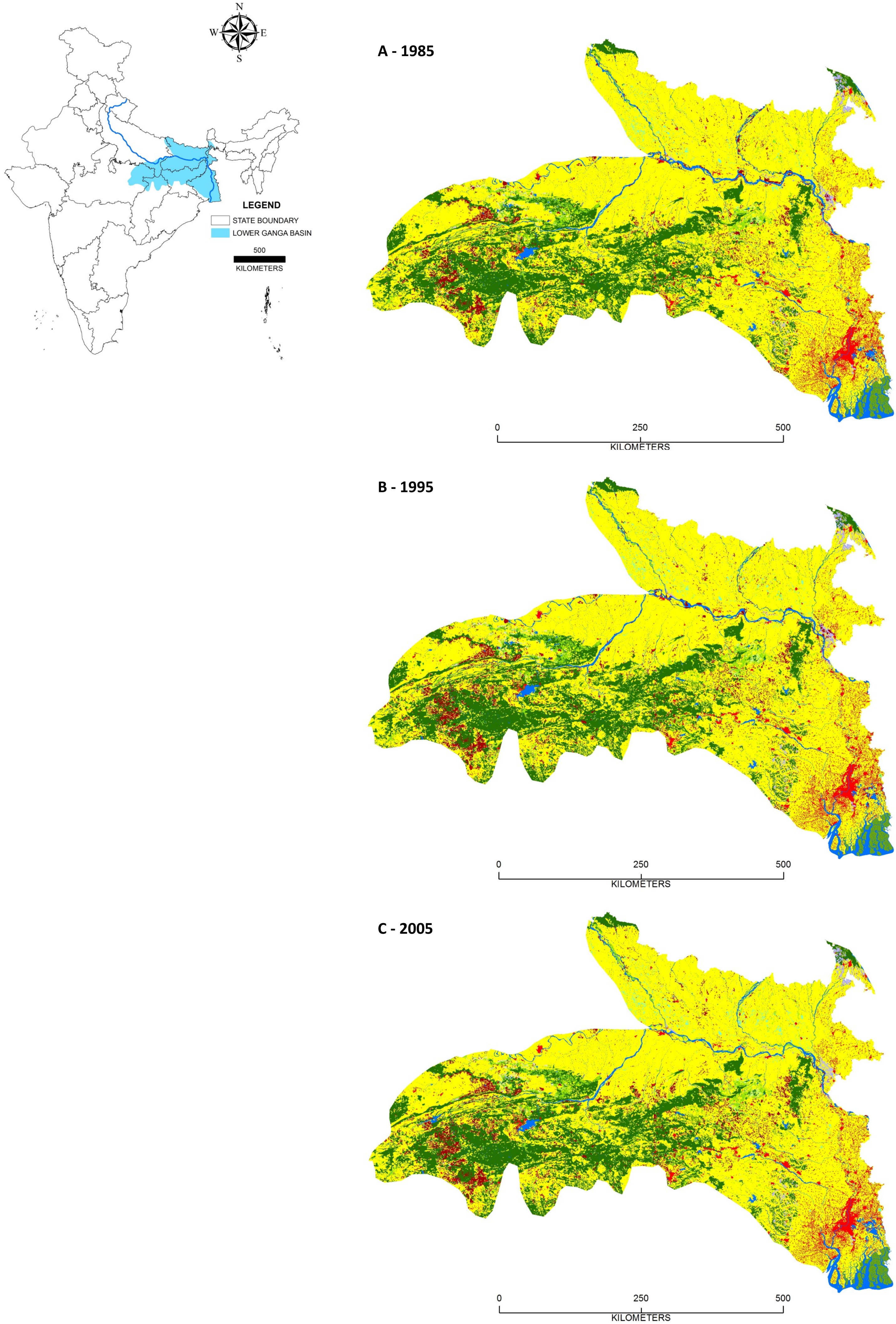
Sign encounter rates of prey/predator species was modelled as function of increasing distance (east – west) from the protected area boundary. It was found that at a distance of 3 – 4 km from PA boundary the occurrence of signs decreased drastically. We therefore used 3.5 km as threshold distance for prioritizing potential tiger areas outside PAs of Goa, which was also comparable to Mean Maximum Distance Moved by tigers from studies conducted in other parts of the country.

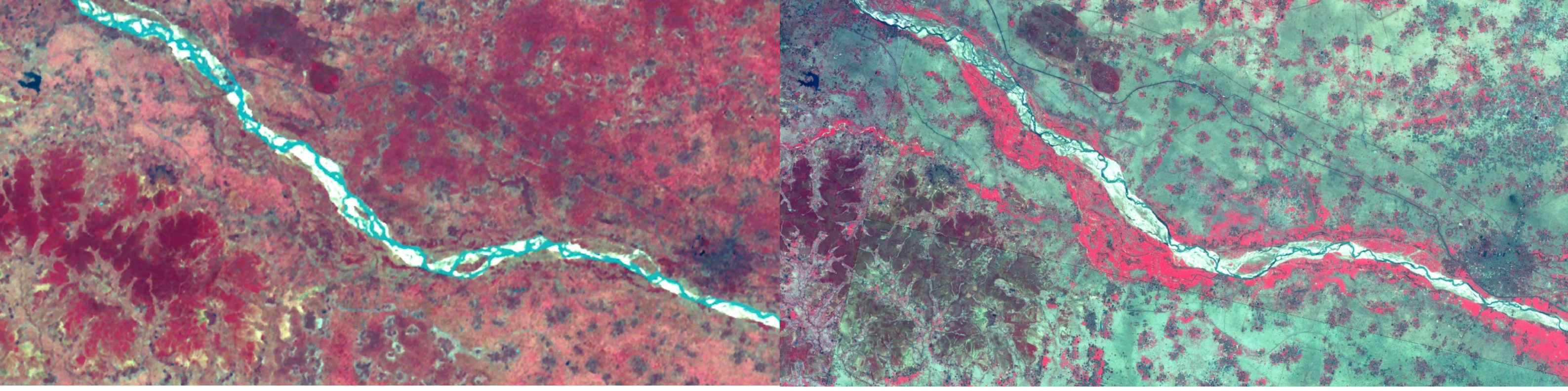
Based on the above information we delineated priority conservation zones in GIS as described below **(D)**. Areas within a distance of 3.5 km from PAs and with a forest cover of dense and moderately dense category covering more than 50% area of a village was selected as Priority 1 potential habitat for tigers. Areas beyond 3.5 km distance and with forest category (Very Dense, Moderately Dense and Open category combined) of 50% or more of the village area was identified as Priority 2 potential habitat for tigers at the village level.

Publication: *Ascertaining the Spatial Presence of Tiger, Co-Predators, Prey and Extant of their Habitat in Goa* (2013). Wildlife Institute of India, Dehradun and National Tiger Conservation Authority, New Delhi. *Committee Report.*



Flowchart of the methodology used to develop the map of proposed villages as potential tiger habitat


N
W
E
S
LEGEND
STATE BOUNDARY
LOWER GANGA BASIN
500
KILOMETERS
A - 1985
0
250
500
KILOMETERS
B - 1995
0
250
500
KILOMETERS
C - 2005
0
250
500
KILOMETERS



Seasonal landuse change in Lower Gangetic Basin depicted in standard false colour composite image.

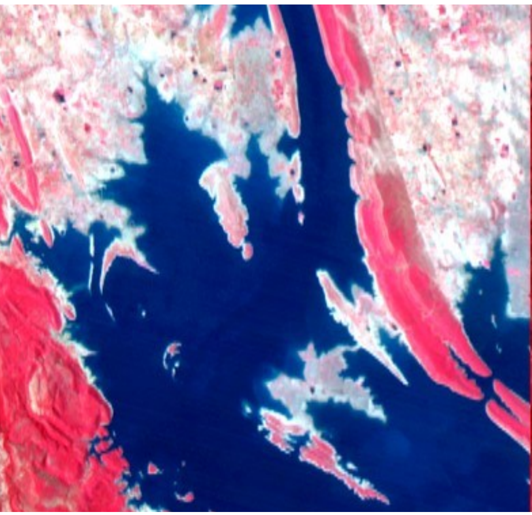
Monsoon (Left) and Summer (right)

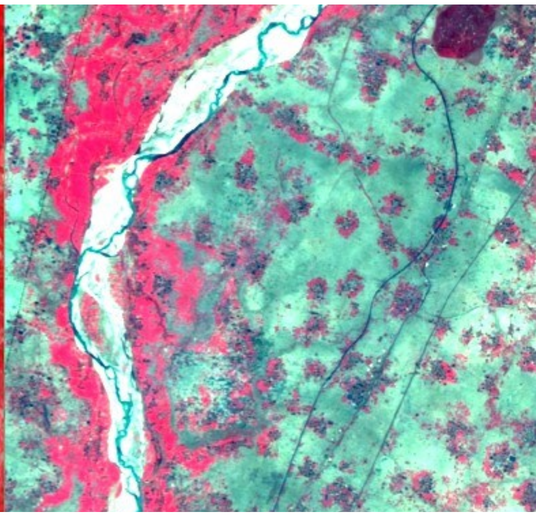
The Lower Gangetic Basin is one of the most highly populated areas of India, covering an area of 286,899 km^2 with a population density of 720 persons per km^2. 64% of the area is covered under agriculture which is supported by the highly fertile alluvial soil. Landuse and landcover (LULC) changes due to an ever increasing human population, natural disasters induced by climate change can alter agricultural productivity which in turn can affect the food security of the region. The current study found out the change in LULC over a span of 20 years (1985-2005), and identified the factors driving this change. LULC data was generated from geo-corrected satellite data of LANDSAT-MSS, IRS LISS-I and IRS LISS-III for pre monsoon and post monsoon seasons for the years 1985-86, 1994-95 and 2004-05 respectively, using onscreen visual interpretation at 1:250,000 scale. We used cross-tabulation matrix to investigate landuse and landcover transformation. The most significant transformation has been to built-up category, contributed by agricultural land (515 km^2) and scrubland (53 km^2). The other notable transformations are from agriculture to plantation (247 km^2), fallow to scrubland (838 km^2) and from water body to scrubland (407 km^2). We generated change no-change matrix and analyzed it using logistic regression to investigate the drivers of LULC change. We identified availability of water for irrigation, literacy, sex ratio and the availability of different sources of livelihoods, as the major drivers of LULC change in the Lower Gangetic Basin.

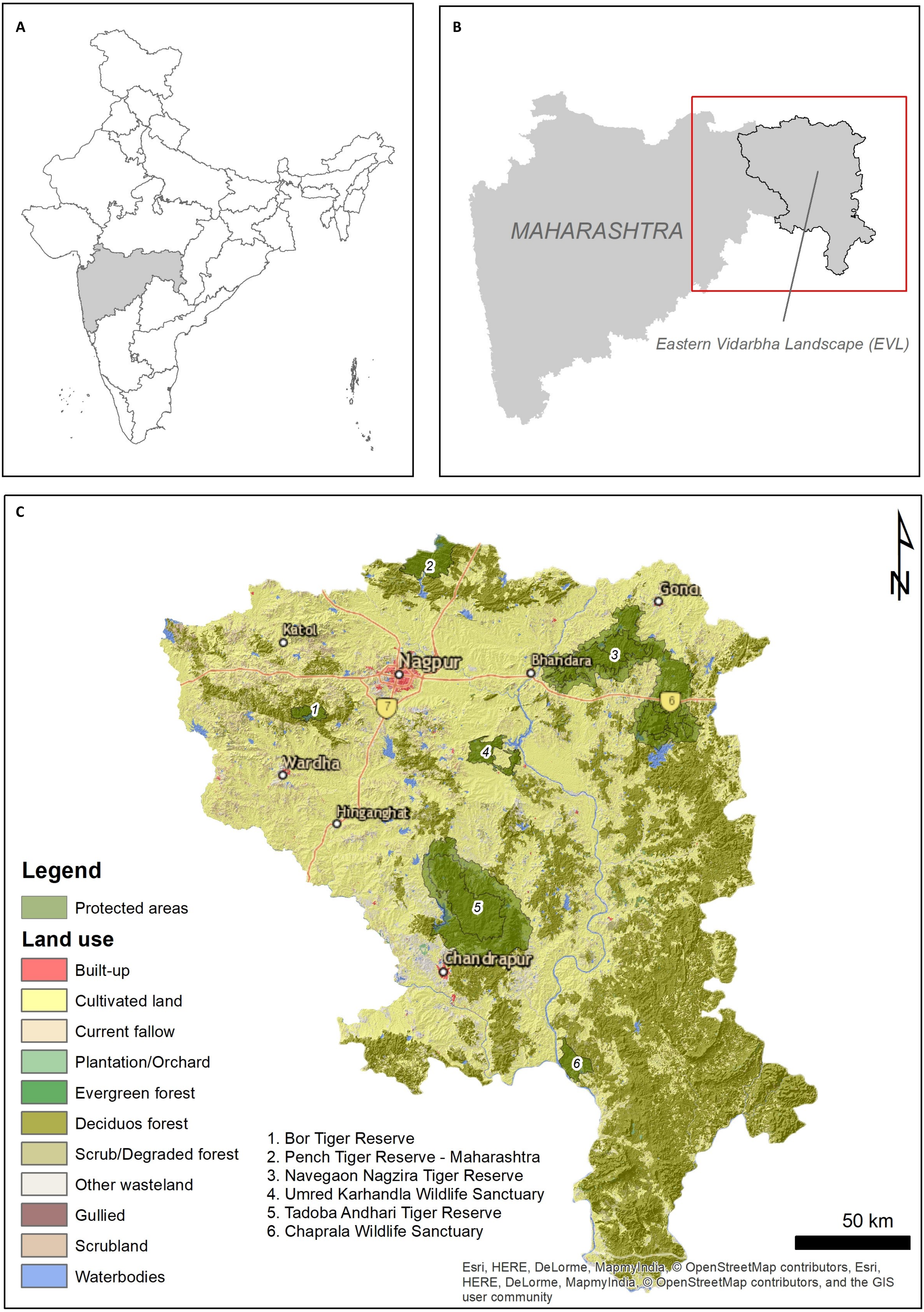
Publication

Mondal, I., Srivastava, V., Roy, P., & Talukdar, G. (2014). *Using logit model to identify the drivers of landuse landcover change in the Lower Gangetic Basin, India.* The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 40(8), 853. doi:10.5194/isprsarchives-XL-8-853-2014

Mondal, I., and Talukdar, G., (2013). *Landuse Landcover Dynamics and Impact of Human Dimensions in Lower Ganga Basin.* Wildlife Institute of India, Dehradun. *Technical Report No. TR 007/2014*






A
B
MAHARASHTRA
Eastern Vidarbha Landscape (EVL)
C
Katol
Nagpur
Bhandara
Wardha
Hinganghat
Chandrapur
1
2
3
4
5
6
7
Legend
Protected areas
Land use
Built-up
Cultivated land
Current fallow
Plantation/Orchard
Evergreen forest
Deciduos forest
Scrub/Degraded forest
Other wasteland
Gullied
Scrubland
Waterbodies
1. Bor Tiger Reserve
2. Pench Tiger Reserve - Maharashtra
3. Navegaon Nagzira Tiger Reserve
4. Umred Karhandla Wildlife Sanctuary
5. Tadoba Andhari Tiger Reserve
6. Chaprala Wildlife Sanctuary
N
50 km
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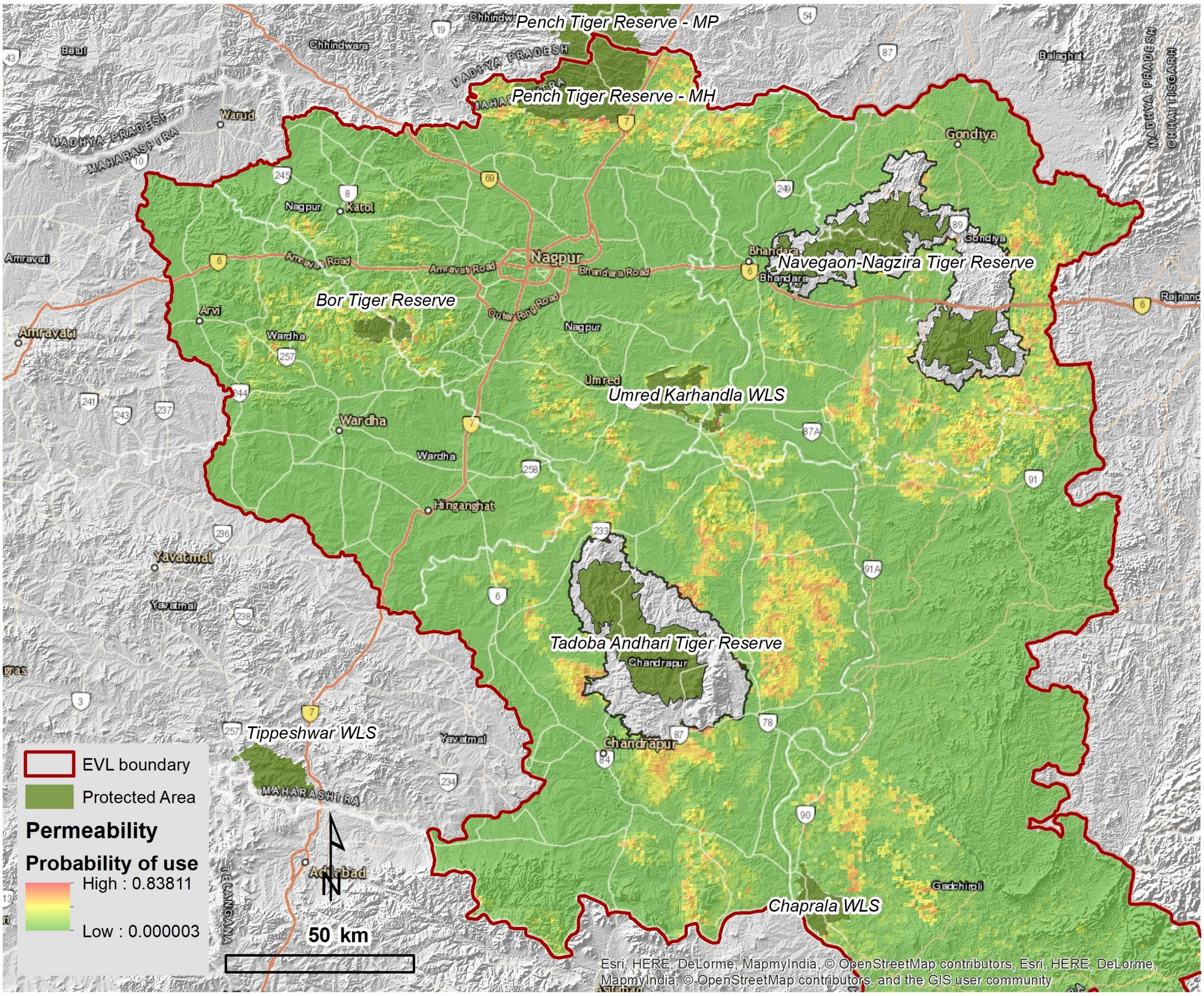
Inviolate forested areas inside Tadoba Andhari Tiger Reserve (top right).

The Eastern Vidarbha Landscape (EVL, **B**) or the Nagpur Division is one of six administrative divisions of Maharashtra State **(A)** in India. Nagpur is the easternmost division in the state, with an administrative headquarters in the city of Nagpur. It lies between 18° 11’ 20.69” N to 21° 43’ 15.79” N and 78° 03’ 37.09” E to 80° 54’ 09.42” E. It encompasses an area of 51,000 km^2 covering the six districts of Bhandara, Chandrapur, Gadchiroli, Gondia, Nagpur, Wardha. It houses a human population of 11,754,434 people, and at the same time has a forest cover of about 20,000 km^2. This patch of forest is very important as it harbours a population of about 150 tigers and forms the connecting link between the central and southern Indian tiger populations. It plays a pivotal role in exchange of individuals and thereby facilitates gene flow between these two populations increasing the viability of tiger populations in India. There are 6 protected areas or wildlife divisions where these tigers live, but these refuges are scattered like islands in a sea of human dominated landscape. So knowing the locations of tiger movement corridors and probable areas of human tiger conflict is very important for a wildlife manager.

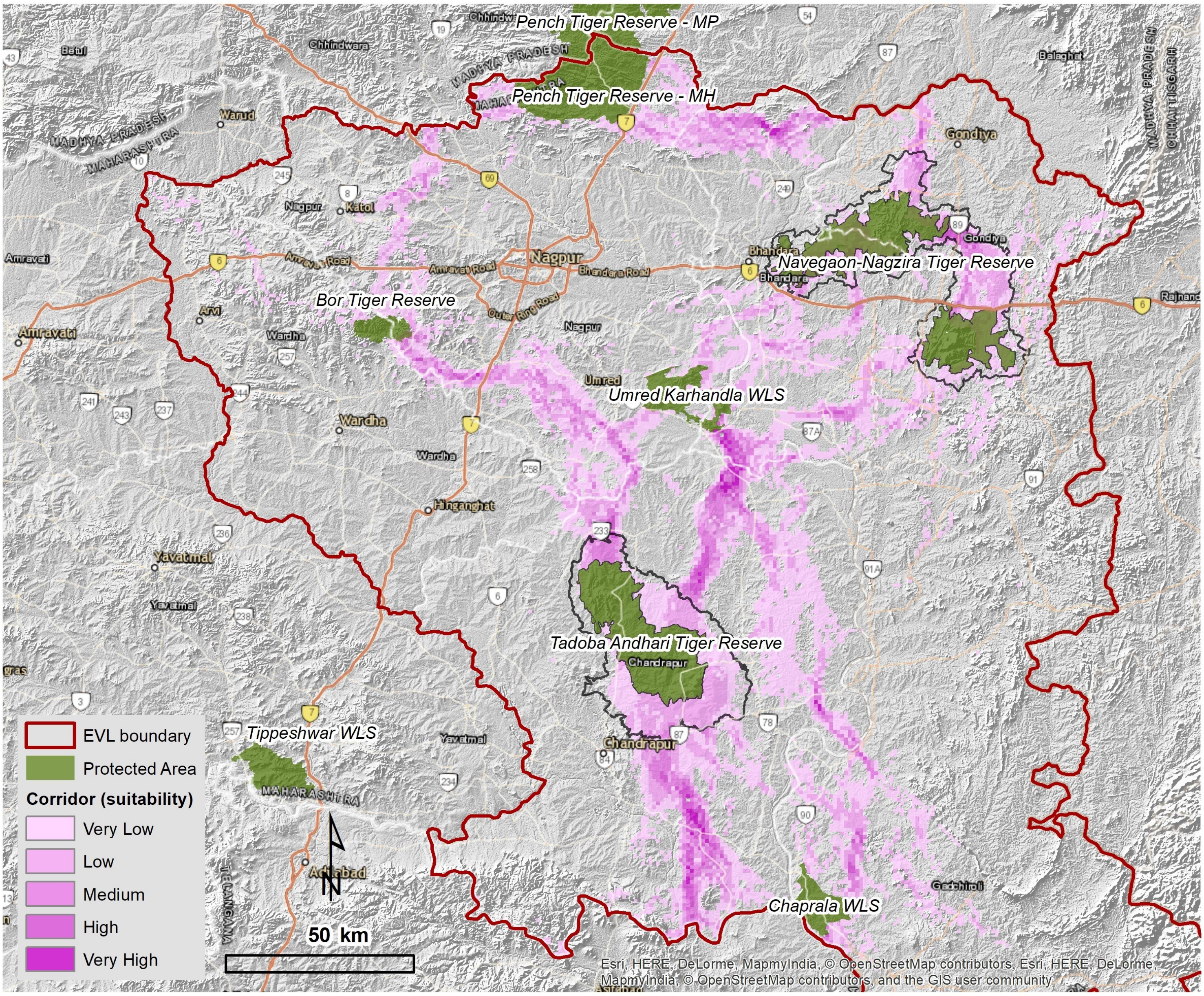
Figure C shows the land use map of EVL, draped on a hillshade layer. Both the land use and elevation data have been obtained from National Remote Sensing Centre, Department of Space, Government of India.

All the following GIS work will showcase maps from my PhD study focused on tiger corridors in the human dominated areas in EVL.



Map showing permeability for tiger movement in EVL, as derived from MAXENT modeling. Values for PAs and Tiger reserve buffers have been masked .

Tiger presence data was recorded during occupancy surveys and sign surveys in the corridor areas of EVL. Presence locations were also obtained from locations of camera traps deployed by the forest department and from direct opportunistic sightings and indirect signs. We used presence data of tiger and associated remotely sensed eco-geographical variables (forest type, night light, distance from roads, distance from drainage, distance from PAs, and distance from forests outside PAs) to build a MAXENT model using Maxent version 3.3.1. to delineate areas that may be preferred by tiger across the landscape for movement. The MAXENT output may also be treated as a cost surface for movement in the landscape and was further used to model tiger corridors using the software Circuitscape.



Map of tiger corridors of EVL modelled after using the permeability surface in Circuitscape

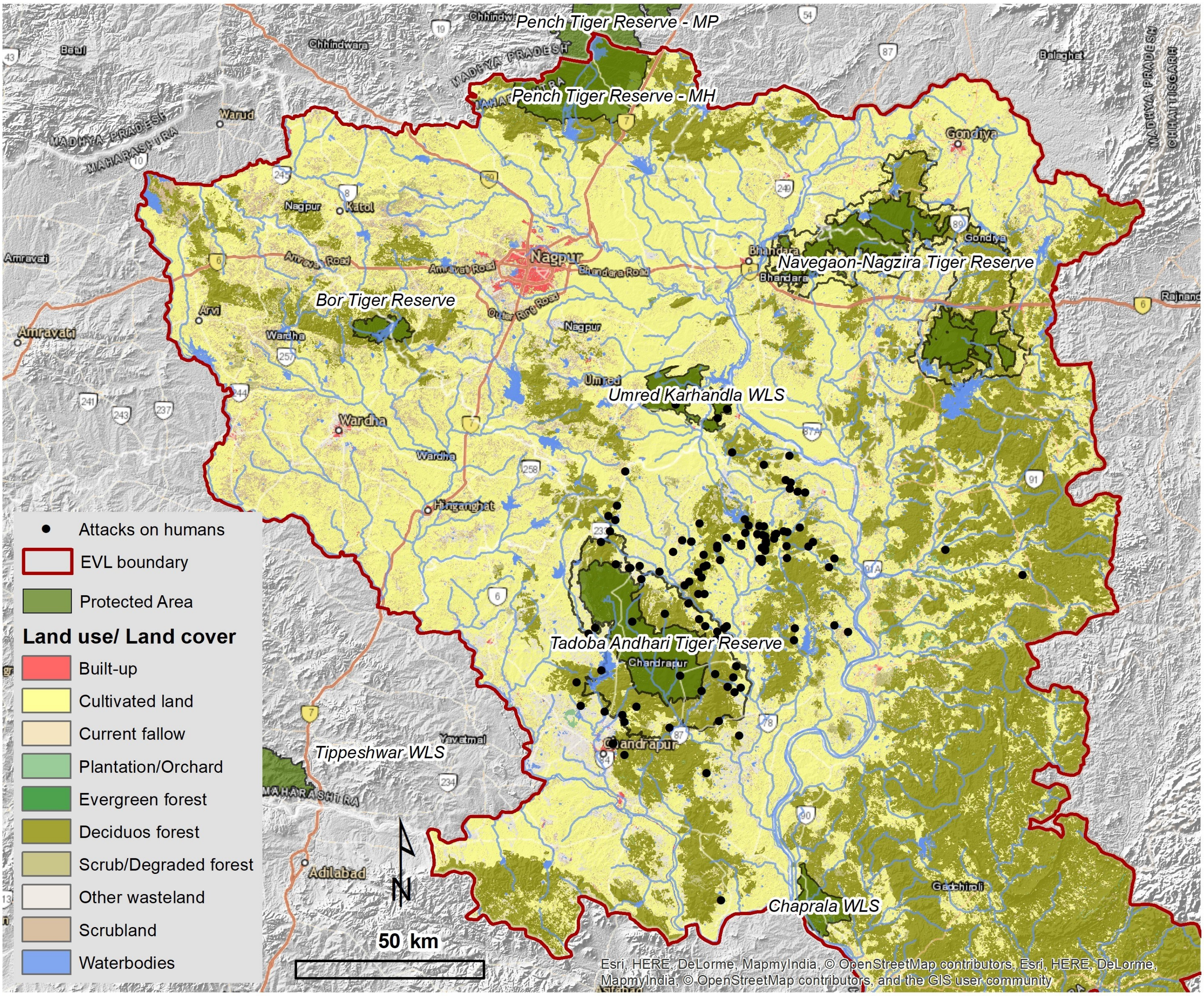
Circuitscape considers the landscape as an electronic circuit board and each suitable habitat patch as a node. Here the flow of electric current is analogous to the movement of a tiger. In the model, a current of one ampere is passed between the nodes, following all possible pathways made up by combining different landscape circuit linkages between the source and sink nodes. This operation assigns a current value to each landscape raster cell equivalent to the amount of current flowing through it, which yields a current map depicting the distribution of current values across the landscape. Places with high current values depicts areas, which are favored by the tiger for movement between habitat patches as compared to the low values. The current values in the Circuitscape output were classified into five classes (very low, low, medium, high and very high) using Jenks Natural Breaks Optimization. This implementation was done using the software Circuitscape 4.0 .

Through this analysis we identified 9,370 km^2 of tiger corridors in EVL, which was further categorized into 5 classes from very low (5,953 km^2), low (2,247 km^2), medium (862 km2), high (249 km^2) to very high (59 km^2) indicating the importance of that pathway or corridor.

We designed an atlas out of these results, providing village level maps and data for tiger corridors in EVL that will be helpful for the wildlife managers to take proactive measures on the ground for an effective tiger conservation in the landscape.

Publication

Mondal, I., Habib, B., Nigam, P. and Talukdar, G. (2016). *Tiger Corridors of Eastern Vidarbha Landscape.* Wildlife Institute of India, Dehradun and National Tiger Conservation Authority, New Delhi. *Technical Report No. TR 2016/009.* Pp 447.

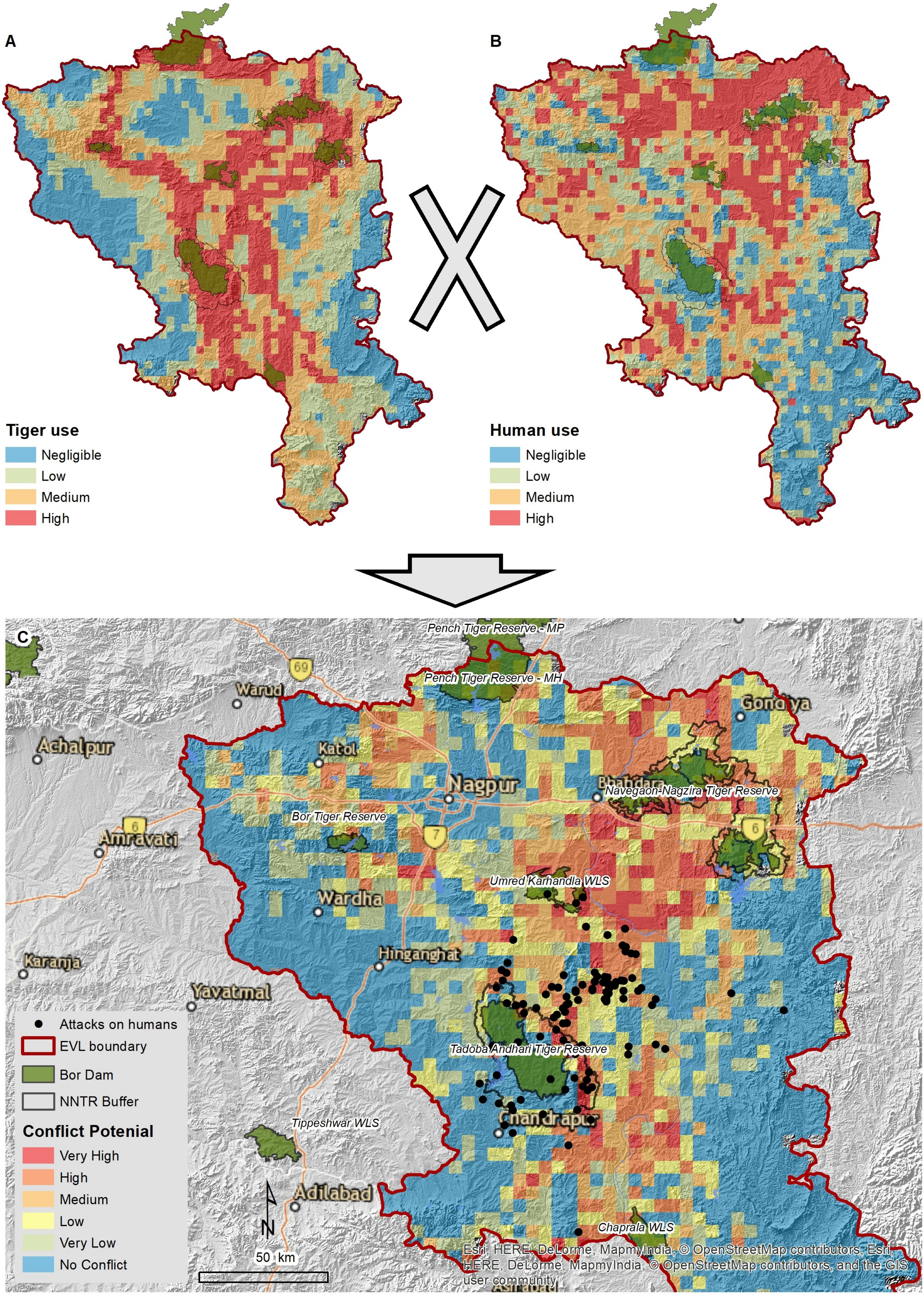


Map showing permeability for tiger movement in EVL, as derived from MAXENT modeling. Values for PAs and Tiger reserve buffers have been masked .

Human-tiger conflict forms one of the main challenges for tiger conservation in human dominated landscape. This is because in such landscapes tiger populations are housed inside PAs which are surrounded by densely populated areas and are always at the mercy of the local communities. Under such circumstances it is always important to earn the goodwill of local people and to take them within the folds of conservation initiatives. Therefore understanding of the dynamics of human-tiger is critical for conflict mitigation and formulation of effective management strategies for the long term survival of the tigers in this landscape.

We formed a null hypothesis (H_0)where we assumed that when areas of high human use and high tiger use overlap the chances of human-tiger conflict is high. We used the modelled corridor surface as a surrogate to indicate the use of the landscape by tigers **(A)**. Village-wise population density surface was used as a surrogate for human use of the landscape **(B)**. Information of tiger use and human use from the above layers were summarized at 5 X5 km grids across the landscape. Then we categorized these grids into four bins using Jenks Natural Break Optimization ranking each bin from 0 to 3 in increasing order of the intensity of use. We then multiplied these two ranking (one based on tiger use and the other on human use) to obtain our surface for a null model of human-tiger conflict potential **(C)**.

To test H_0 we did a chi-square test where in each conflict potential category we compared the proportion of grids expected to have human-tiger conflict against the grids from which actual incidents were reported. The chi-squared test results indicate that with an increase in conflict potential in each category, we have also seen a significant rise in actual conflict incidents in each category, χ^2 (6) = 36.9780, $p < 0.001$


A
B
Tiger use
Negligible
Low
Medium
High
Human use
Negligible
Low
Medium
High
C
Pench Tiger Reserve - MP
Pench Tiger Reserve - MH
Warud
Gondiya
Achalpur
Katol
Nagpur
Bhandara
Navegaon-Nagzira Tiger Reserve
Bor Tiger Reserve
Amravati
Umred Karhandla WLS
Wardha
Hinganghat
Karanja
Yavatmal
Tadoba Andhari Tiger Reserve
Chandrapur
Tippeshwar WLS
Adilabad
Chaprala WLS
50 km
N
Attacks on humans
EVL boundary
Bor Dam
NNTR Buffer
Conflict Potenial
Very High
High
Medium
Low
Very Low
No Conflict
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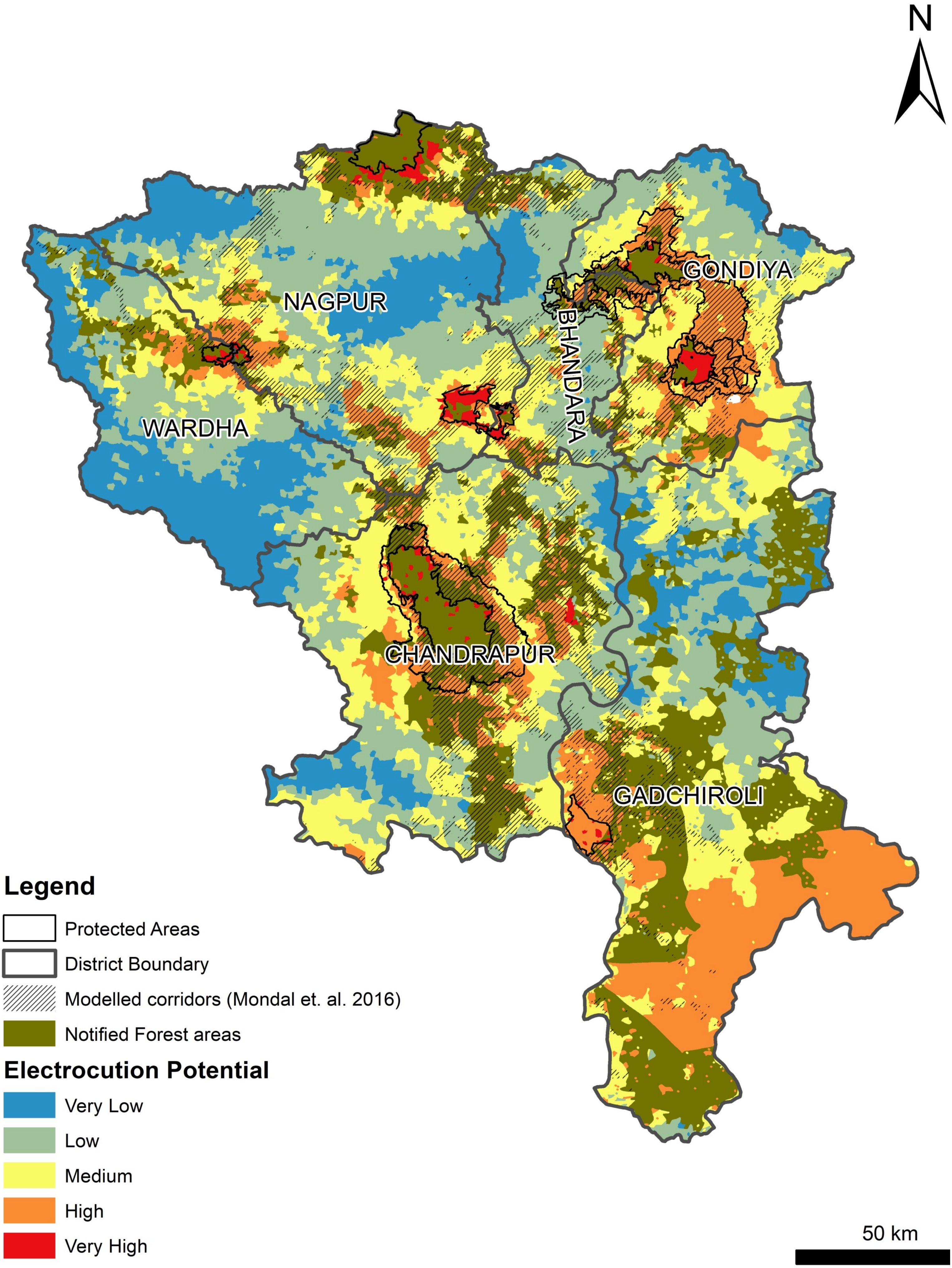

N
NAGPUR
GONDIYA
BHANDARA
WARDHA
CHANDRAPUR
GADCHIROLI
Legend
Protected Areas
District Boundary
Modelled corridors (Mondal et. al. 2016)
Notified Forest areas
Electrocution Potential
Very Low
Low
Medium
High
Very High
50 km

A forest agriculture edge in EVL (top right).

A great part of the tiger corridors in EVL lies outside the PA network and under different land ownership tenures. It is in such areas that the poor farmers, in a desperate attempt to prevent herbivores from destroying their crops, the often set up illegal high-voltage electrical fences around their fields drawing power from electrical lines meant for home or agricultural use. Subsequently, tigers using human dominated landscape like agriculture fields to move about, are at a great risk when they encounter such fences. Illegal electric fencing by farmers to protect their crops is non-selective in nature, wide spread and will have devastating effect on the long-term conservation of the tiger populations in India. The objective of this study is to identify potential villages for effective mitigation and to raise awareness about the issue.

We calculated average landscape permeability for the movement of the tiger from the corridor layer into the village polygons. We also calculated average distance of each village polygon from PAs. Zonal statistics tool in ArcGIS 10 was used to do both these analysis. We then calculated the amount of forest cover in each village polygon using tabulate area tool in ArcGIS 10. Value of each of these variables that was extracted at the village level was standardized using Z-scored standardization technique. The electrocution potential of each village was then calculated using the following equation:

Habitat permeability – distance from PA + proportion of forest …….. equation (i)

The following assumptions were made while forming equation (i):

- Higher the value of habitat permeability, higher is the chance of a tiger being present or moving there.
- Higher the distance of the village from Pas, lower is the chance that people will use electrified fences to protect their crops.
- Higher the proportion of forested area in a village polygon, higher is the chance that people will use electrified fences to protect their crops and higher chances of animal being electrocuted.

We defined this as the electrocution potential of the landscape. Higher the values more chances of animals being electrocuted. After calculating the values of electrocution potential for each village, we have classified them into 5 risk groups (Very Low, Low, Medium, High and Very High) using Jenks Natural Breaks Optimization following Jenks 1967.

Publication: Habib, B., Nigam P., **Mondal, I.**, Ghaskadbi, P. and Hussain, Z. (2017): *ENSURING SAFETY IN THE KILLER FIELDS: Identifying potential villages for measures to reduce electrocution of Tigers and associated species in Eastern Vidarbha Landscape, Maharashtra, India.* Wildlife Institute of India, Dehradun, National Tiger Conservation Authority and Maharashtra Forest Department. Pp 115. *TR No. 2017/014.*

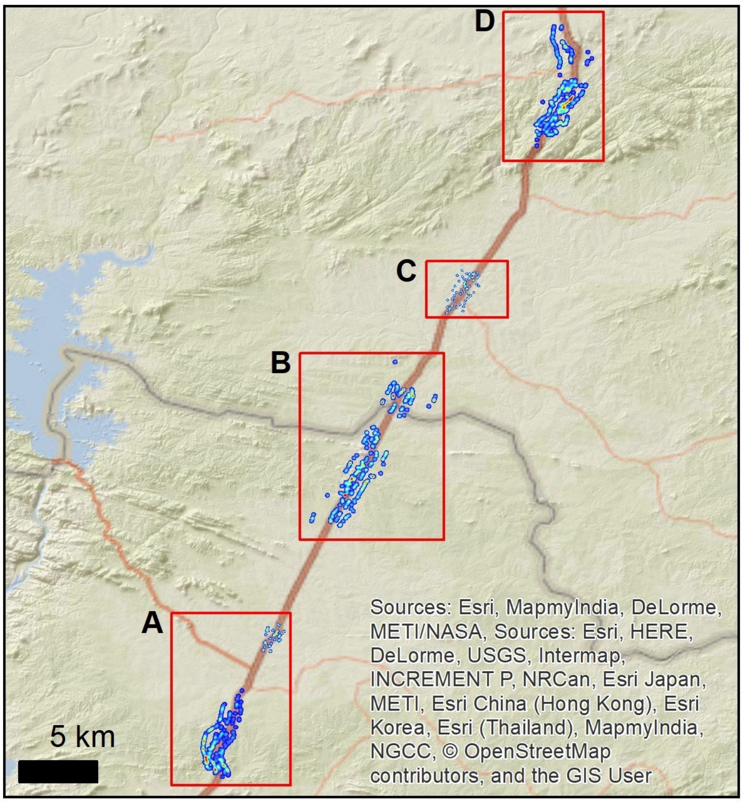
This study was undertaken to aid the Government of India and the National Highway Authority of India (NHAI) in mitigating the negative effects of the widening of National Highway No.7. It is one of the two arterial highways of India and it cuts through important wildlife corridors in Central India **(Picture, top left)**. The main aim of this study was to identify specific animal crossing zones on NH 7 passing through vital wildlife corridors and to suggest feasible locations for making underpasses. We conducted sign surveys along multiple transects parallel to the highway and in increasing distance from the highway to identify Animal Crossing Zones. We also conducted vehicle transects to identify hotspots of animal death (road kills).

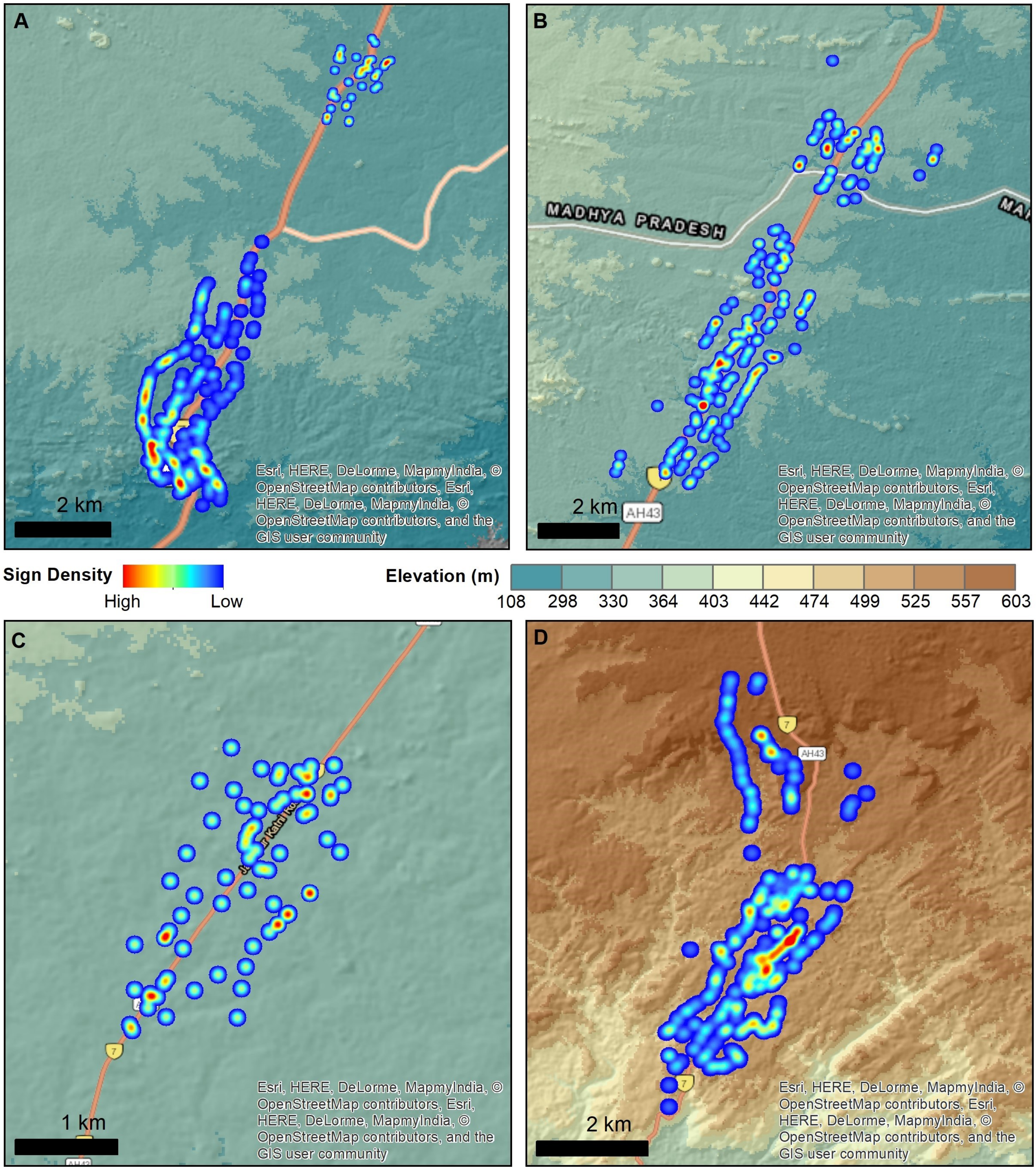
Locations of animal signs collected in field were plotted in GIS domain and sign occurrence density per unit area was calculated using Home Range Tools extension for ArcGIS. We used Kernel analysis which is a non-parametric statistical method for estimating probability densities from a set of points. The method begins by centering a bivariate probability density function with unit volume (i.e., the "kernel") over each recorded point. A bivariate kernel probability density estimator (i.e., a "utilization distribution") is then calculated using the probability density estimates at each sign. The resulting kernel probability density estimator will have relatively large values in areas with many observations and low values in areas with few. Intensity use area estimates were indicated by using colour shading, with light colour showing low sign densities and darker shades indicating higher sign densities.

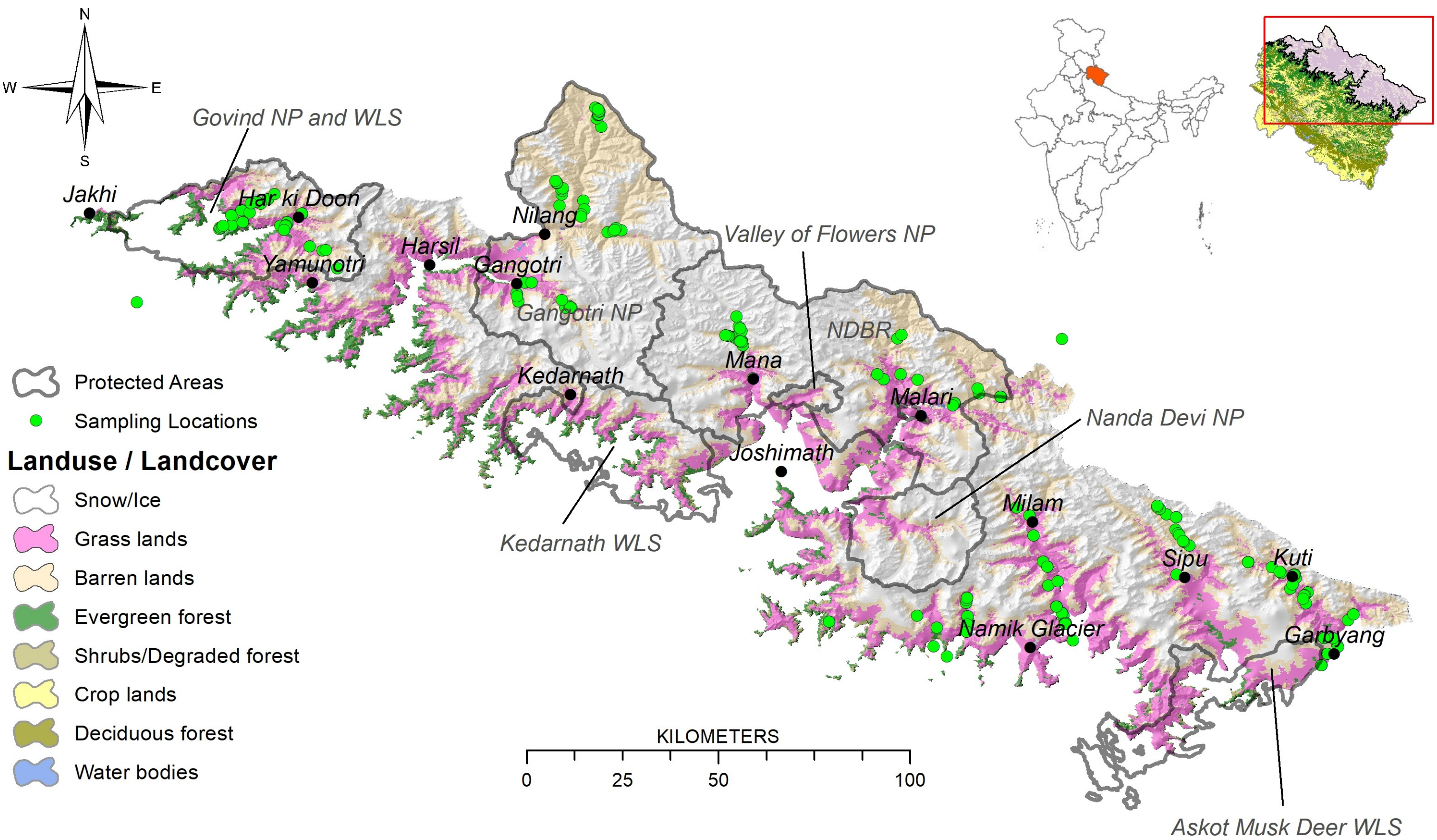
This colour variation define intensity use areas at different probability levels, based on which we identified multi-species animal crossing zones along the respective road stretches **(A, B, C, D)**. Following our recommendations The NHAI is constructing flyovers for vehicles which will leave ample passage for animal to move below **(Picture, top right)**.

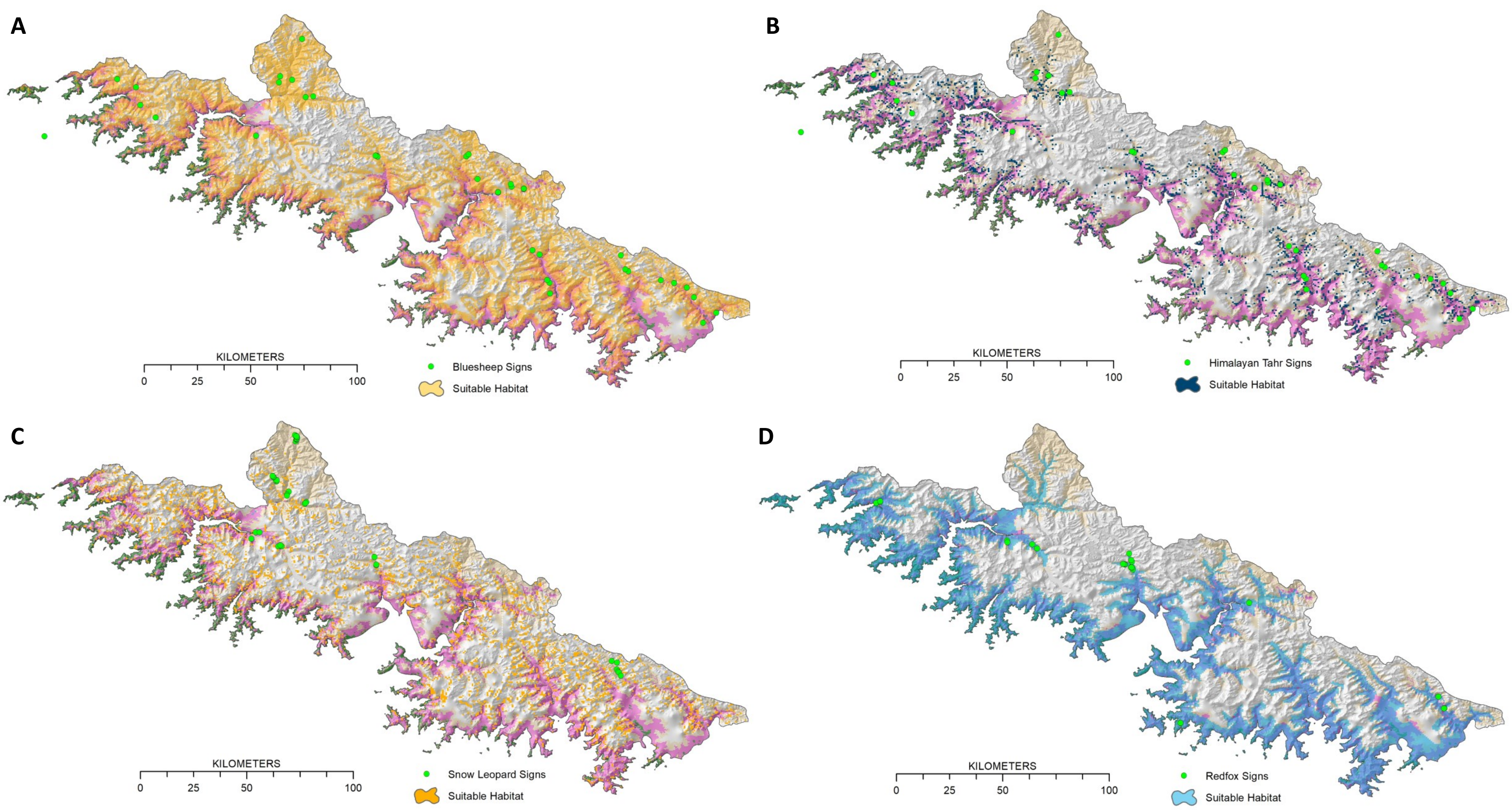
Publication

Habib, B., Saxena, A., **Mondal, I.,** Rajvanshi, A., Mathur V.B. and H.S. Negi, H.S. (2015). Proposed *Mitigation Measures for Maintaining Habitat Contiguity and Reducing Wild Animal Mortality on NH 6 & 7 in the Central Indian Landscape*. Technical Report, Wildlife Institute of India, Dehradun and National Tiger Conservation Authority, Govt. of India, New Delhi, pp 104. *TR 2015/006.*




A
2 km
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community
B
MADHYA PRADESH
MA
2 km
AH43
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community
Sign Density
High
Low
Elevation (m)
108
298
330
364
403
442
474
499
525
557
603
C
7
1 km
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community
D
7
AH43
7
2 km
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


N
W
E
S
Govind NP and WLS
Jakhi
Har ki Doon
Nilang
Harsil
Yamunotri
Gangotri
Gangotri NP
Valley of Flowers NP
NDBR
Mana
Kedarnath
Malari
Nanda Devi NP
Joshimath
Kedarnath WLS
Milam
Sipu
Kuti
Namik Glacier
Garbyang
Askot Musk Deer WLS
Protected Areas
Sampling Locations
Landuse / Landcover
Snow/Ice
Grass lands
Barren lands
Evergreen forest
Shrubs/Degraded forest
Crop lands
Deciduous forest
Water bodies
KILOMETERS
0
25
50
100


A
KILOMETERS
0
25
50
100
Bluesheep Signs
Suitable Habitat
B
KILOMETERS
0
25
50
100
Himalayan Tahr Signs
Suitable Habitat
C
KILOMETERS
0
25
50
100
Snow Leopard Signs
Suitable Habitat
D
KILOMETERS
0
25
50
100
Redfox Signs
Suitable Habitat

This study documents the detail of the first attempt of wildlife population estimation for the Trans-Himalayan and adjoining Greater Himalayan regions of the state of Uttarakhand, India. The output from this study would assist the local forest administration to formulate conservation policies based on scientific data. This region has a variety of rare kinds of animals species. The notable species include Snow Leopard, Common Leopard, Himalayan Brown Bear, Asiatic Black Bear, Blue Sheep/ Bharal. Himalayan Tahr, Serow and Himalayan Musk Deer.

8981.23 km^2 spreading over 16 valleys was covered in 15 days in an expedition mode by multiple teams consisting of researchers, scientists and Forest Department staff. Spending 5760 man hours, 64 grids were sampled, where 128 transects (640km) was walked and 67 points were sampled (with a total of 647 replicates). The survey recorded the evidence of 19 species of mammals.

Geospatial analysis was done to evaluate availability of suitable habitat for species in the Uttarakhand Trans-Himalayan Region. During the survey the detection of species was effected because of rainfall, extraction season of *Ophiocordyceps sinensis* or for the presence of pastoralists. Because of the absence of enough sighting records, rule based modelling was carried out for four species - Blue Sheep, Himalayan Tahr, Red Fox and Snow Leopard. Habitat masking was done using GIS for the abovementioned species to delineate their suitable Habitat in Uttarakhand Trans-Himalayan and adjoining Greater Himalayan region. The raster layers used for habitat suitability mapping were elevation and slope. The upper and lower limit of elevation range and preferred slope for each of the four species were used from available literature. Suitable Habitat for each species was calculated from the area of overlap between the suitable elevational and slope ranges.

The identified suitable habitat for Blue Sheep was 8545 km^2**(A)**, while for Himalayan Tahr **(B)**, Snow Leopard **(C)** and Red Fox **(D)** it was 927, 1520 and 5217 km^2 respectively.

Publication

Habib, B., Mohan, D., Bhattacharya, A., Shrotriya, S., **Mondal, I.,** and Rawat G.S. (2016) *Status of Wildlife in Trans-Himalayan Region of Uttarakhand State, India.* Uttarakhand Forest Department and Wildlife Institute of India, Dehradun. *Technical Report.* Pp. 44.

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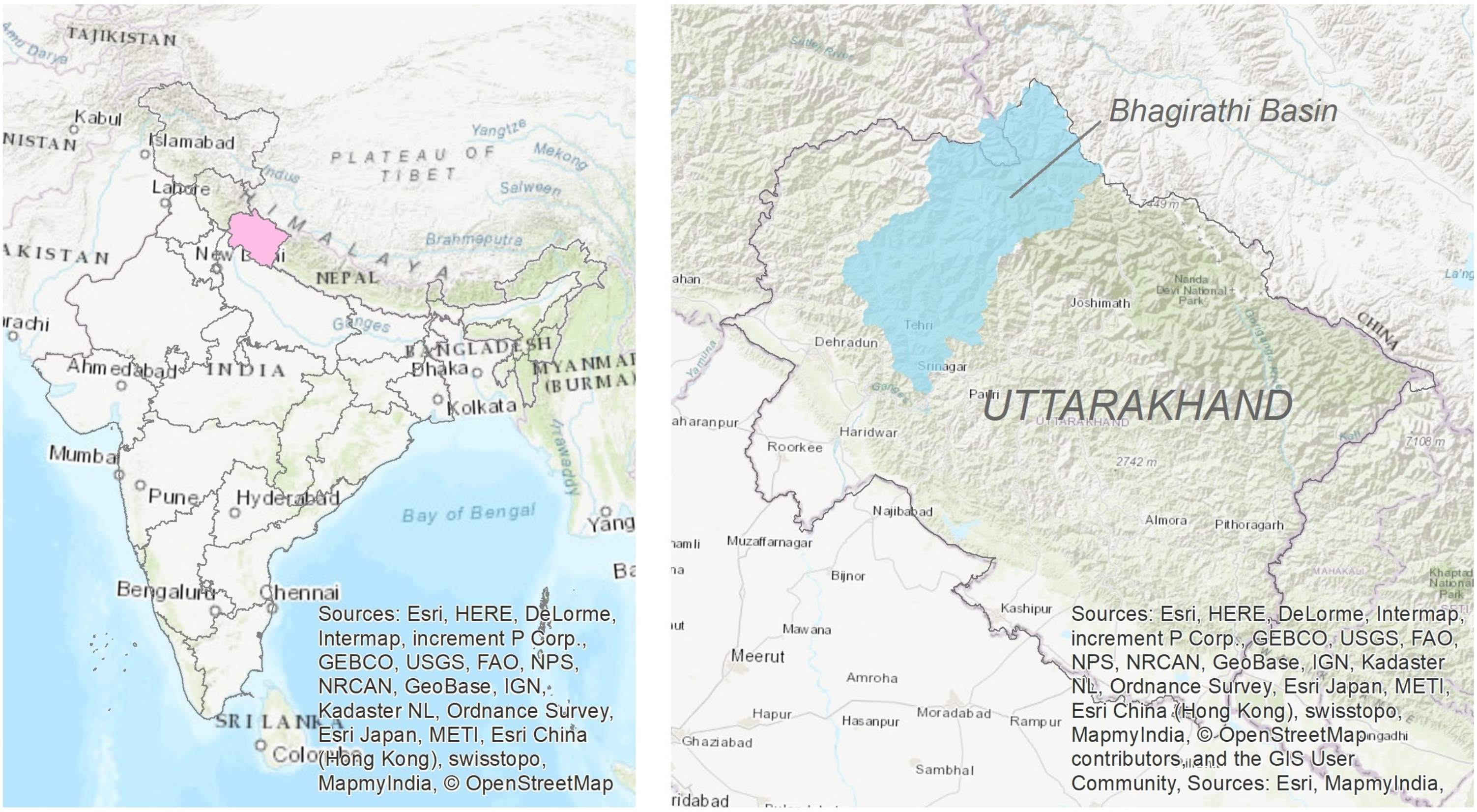
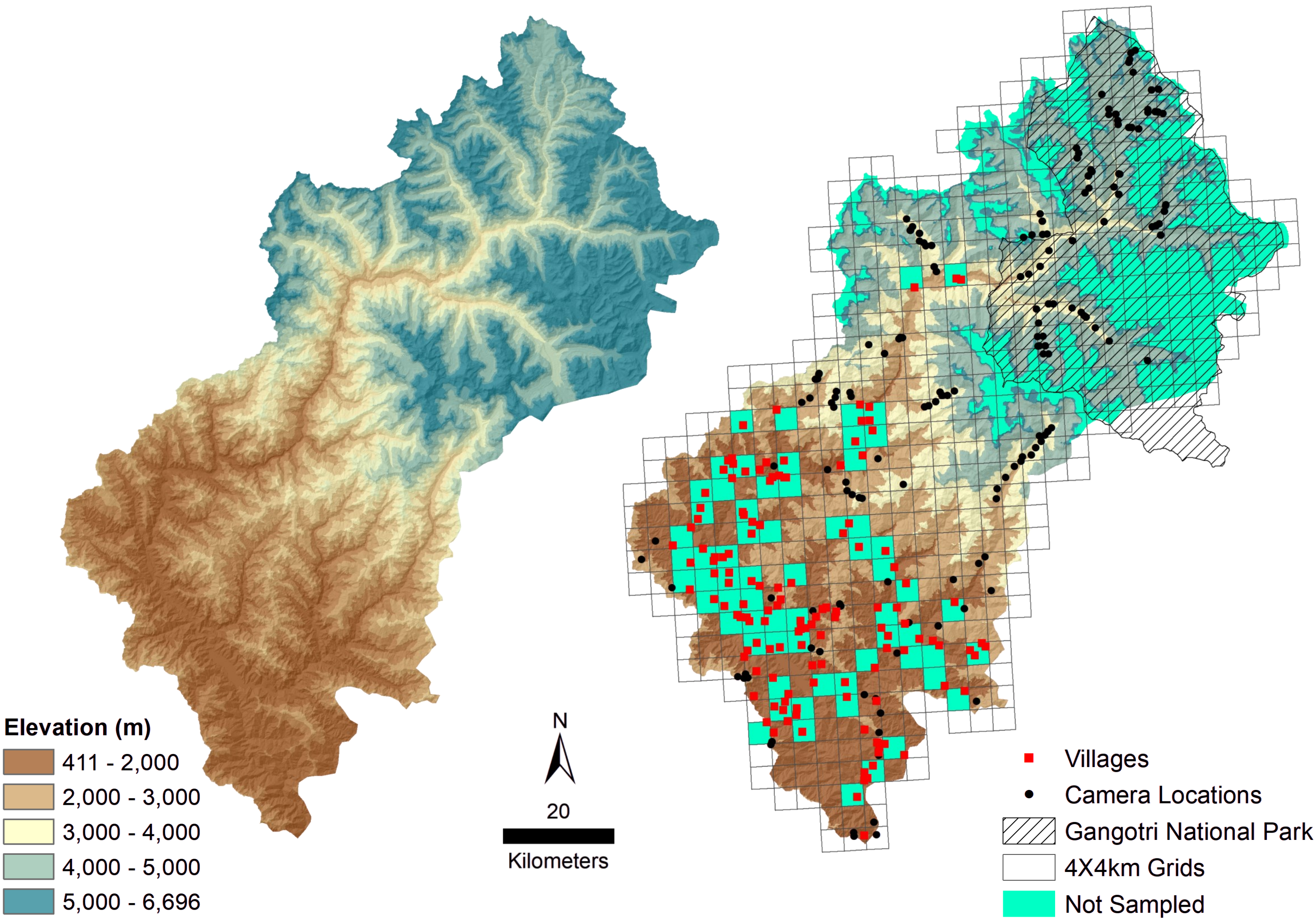

TAJIKISTAN
Kabul
Islamabad
Lahore
New Delhi
NEPAL
PLATEAU OF TIBET
INDIA
Ahmedabad
Mumbai
Pune
Hyderabad
Bengaluru
Chennai
Kolkata
Dhaka
BANGLADESH
MYANMAR (BURMA)
Bay of Bengal
SRI LANKA
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap
Bhagirathi Basin
UTTARAKHAND
Dehradun
Tehri
Srinagar
Pauri
Joshimath
Haridwar
Roorkee
Najibabad
Muzaffarnagar
Bijnor
Almora
Pithoragarh
Kashipur
Meerut
Amroha
Hapur
Hasanpur
Moradabad
Rampur
Ghaziabad
Sambhal
CHINA
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community, Sources: Esri, MapmyIndia,


Elevation (m)
411 - 2,000
2,000 - 3,000
3,000 - 4,000
4,000 - 5,000
5,000 - 6,696
N
20
Kilometers
Villages
Camera Locations
Gangotri National Park
4X4km Grids
Not Sampled

Map shows the effort of two year camera trapping survey done along an elevation gradient of 500m to 5000m in the Bhagirathi basin (~ 7000 km^2) of Uttarakhand, Western Himalaya. The survey was part of a study which aims at generating baseline faunal database to study the effects of climate change in the Indian Himalaya. The survey was done using camera traps to generate baseline information on species distribution. For the survey, the entire Bhagirathi basin was subdivided into 38 cells of 256 km^2 (16 km x 16 km) according to the average home range of the largest mammal found in the area-the Himalayan brown bear. Each of these 38 cells were further subdivided into 4 km x 4 km grids and camera units were deployed in at least 3 such 4 km x 4 km grids within each 256 km^2 cells Camera trapping was done in different habitat types along the altitudinal gradient. Glacial moraines, rocky outcrops, alpine meadows were covered at higher elevation (>3800m). Middle elevation (2000 m - 3800 m) comprising of stunted tree line vegetation (*Rhododendron* spp., *Betula utilis*), subalpine mixed conifer forests (*Abies pindrow, Cedrus deodara* and *Pinus wallichiana*) and temperate mixed broad-leafed forest and oak patches (*Quercus semicarpefloia* and *Quercus floribunda*).

In total, 209 locations were sampled from October 2015 to June 2017. Map also shows the area/ grids that were not covered (above 5000m and human settlements).

Alpine and sub-alpine habitats of the Gangotri Valley (top right)