सूचना का अधिकार
RIGHT TO INFORMATION

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

No. WII/RTI/CPIO/2022-23 (Qtr-IV)/73

Date:19th January, 2023

To,

Mr .Sanjay Kumar
H.No.120 Kailashpuram
Near Govindpuram,
Ghaziabad, Pin:201013
Email id: sanjaychaudhary989@gmail.com

Sub.: Information under RTI Act, 2005–reg.

Ref.: Your RTI No. WLIOI/R/E/22/00056 dated 29/12/2022

Dear Mr. Sanjay Kumar,

Please refer to your application cited above under RTI Act, 2005. In this context, the required information under RTI has been collected from concerned authority and is being furnished below:

Information Sought	**Reply of WII**
Please provide kml of telemetry based tiger corridors of Vidarbha landscape, Maharashtra.	Due to sensitivity of data, the KML file cannot be shared, only report can be shared. The same is being sent at your email id sanjaychaudhary989@gmail.com. (Annexure-1) due to big file size (20 MB) which is not supported online upload.

In case, you are not satisfied with the aforesaid reply, you may appeal to the Appellate Authority as per details given below within 30 days from the date of receipt of this letter.

Dean, FWS
First Appellate Authority & Dean
Address: Wildlife Institute of India, Chandrabani, Dehradun
Phone No.: 01352646202

Thanking you,

Yours faithfully

[Dr. Manoj Kumar Agarwal]
CPIO

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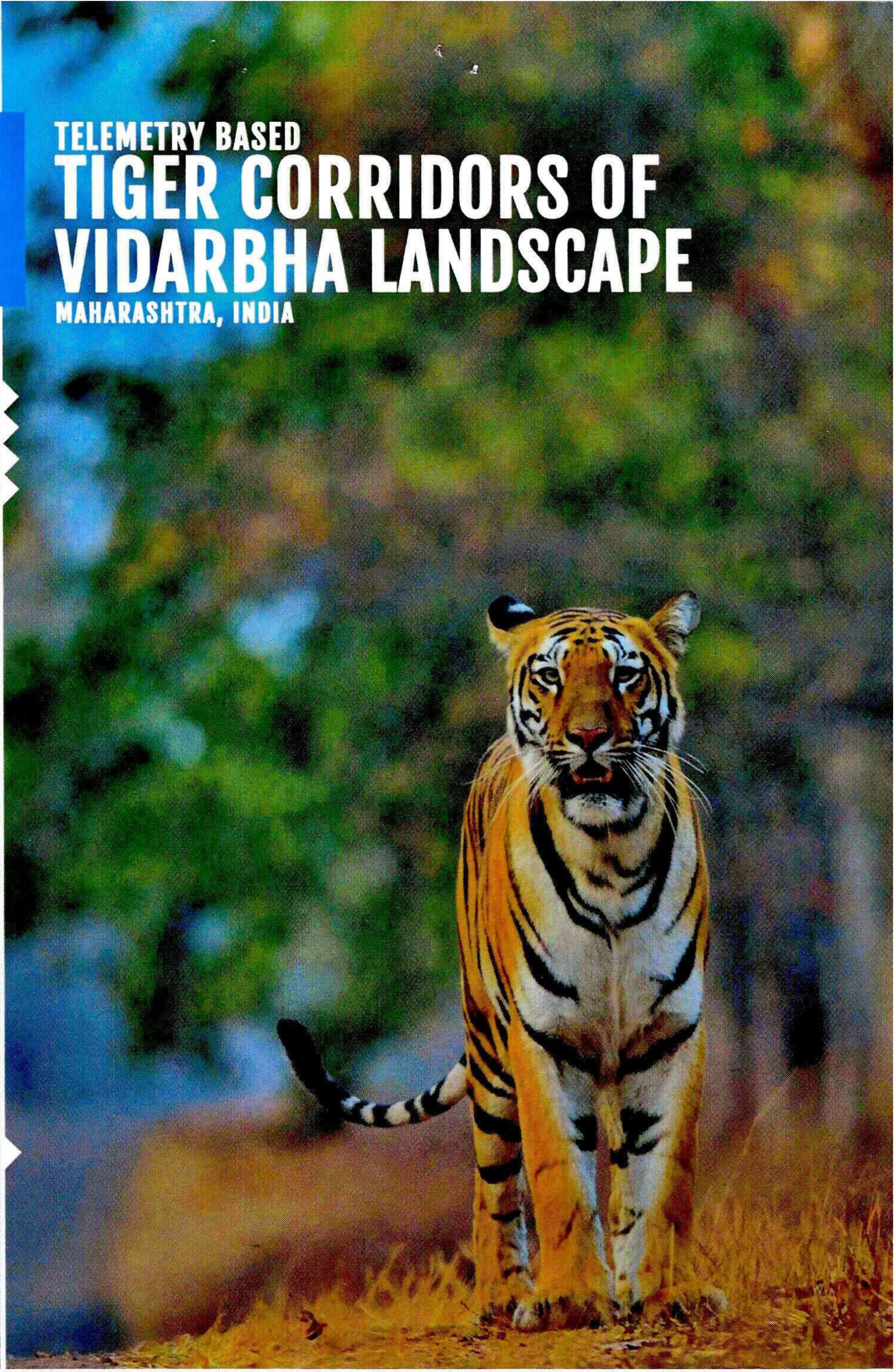
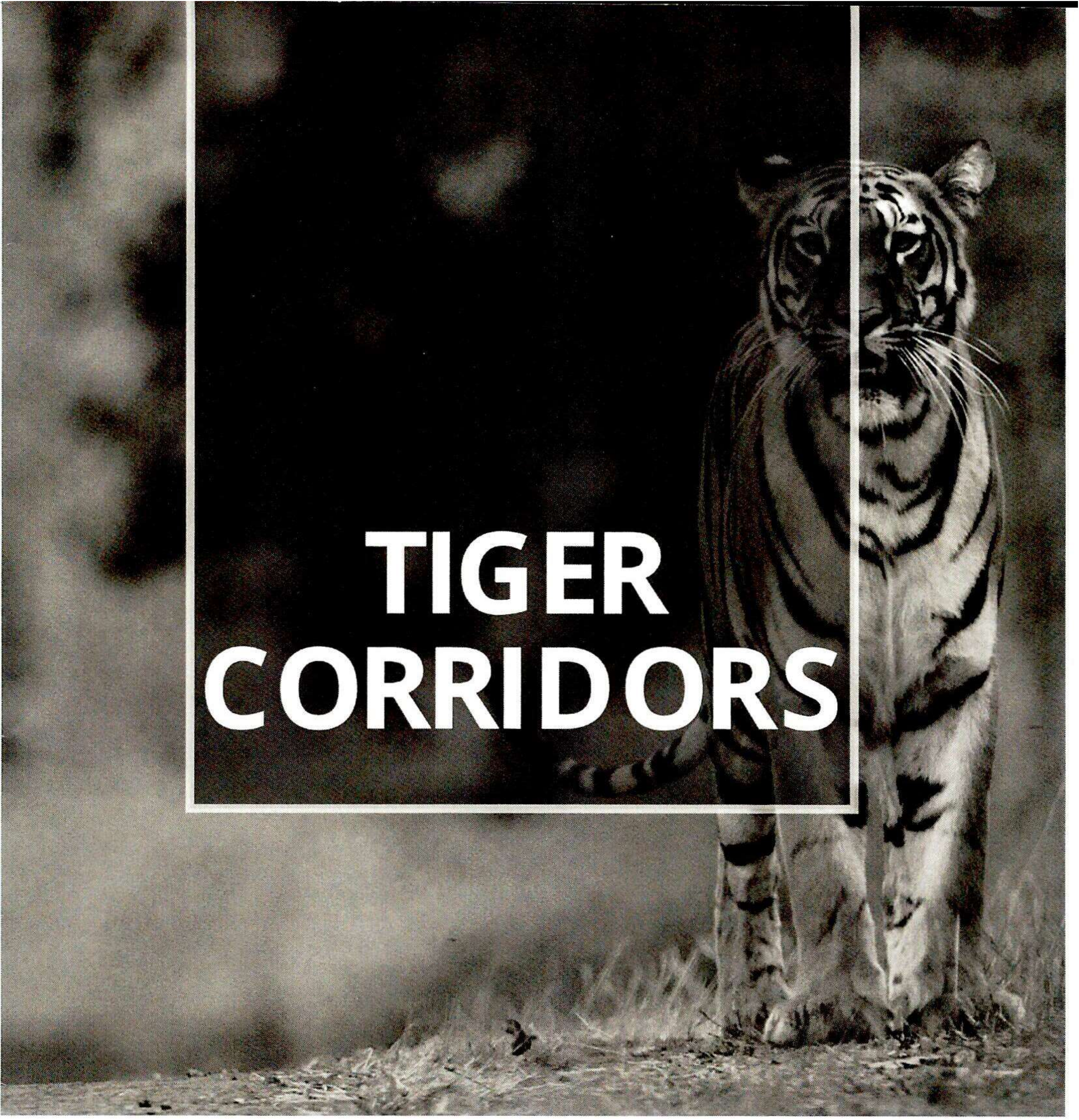
TELEMETRY BASED

TIGER CORRIDORS OF VIDARBHA LANDSCAPE

MAHARASHTRA, INDIA





TELEMETRY BASED

TIGER CORRIDORS OF VIDARBHA LANDSCAPE, MAHARASHTRA, INDIA

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

महाराष्ट्र वन विभाग

MAY 2021

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Note: *The online version of this report shall be available at* https://mahadata.wii.gov.in. The online version of corridor maps shall also be available at same site for interactive use.

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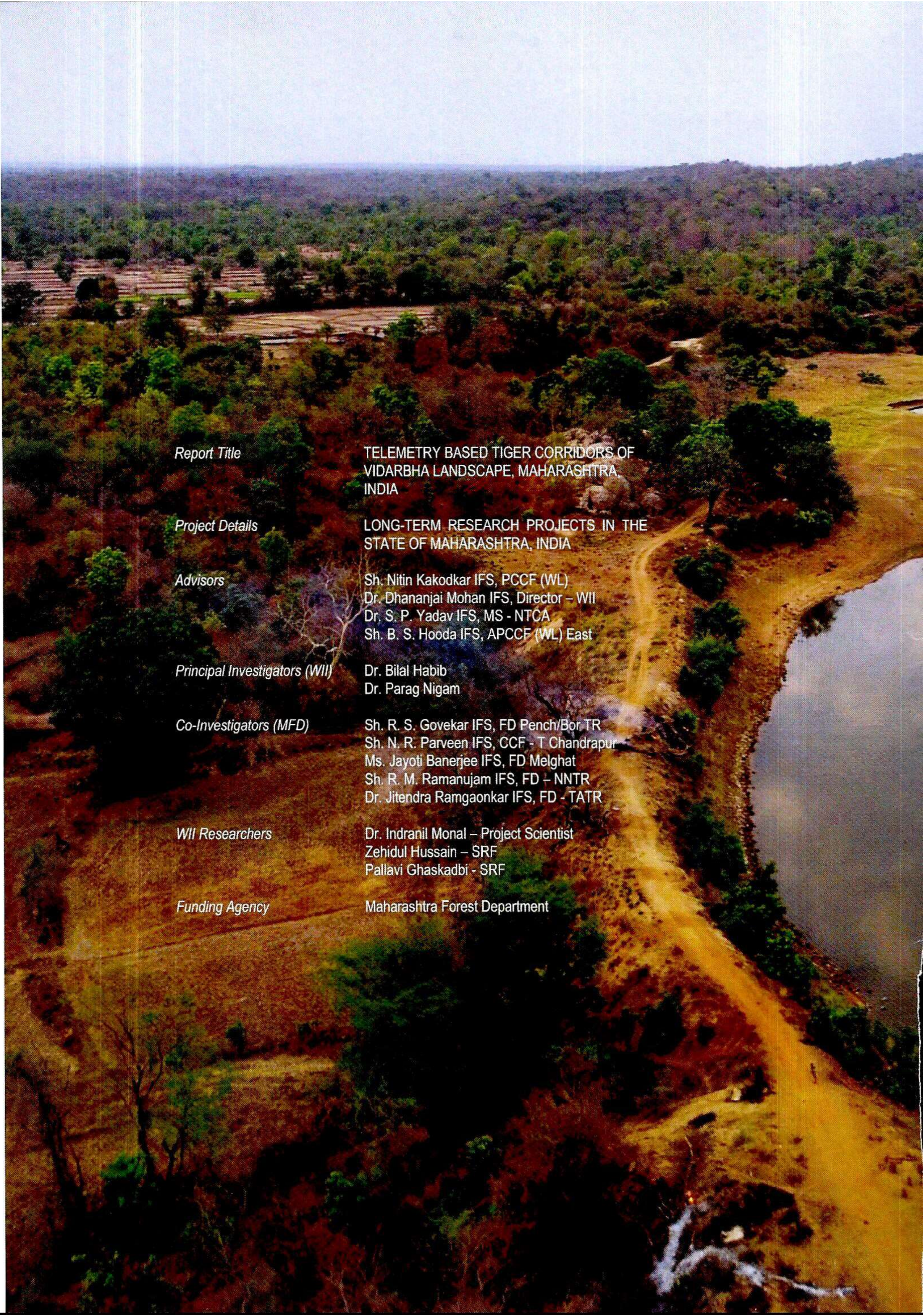

Report Title	TELEMETRY BASED TIGER CORRIDORS OF VIDARBHA LANDSCAPE, MAHARASHTRA, INDIA
Project Details	LONG-TERM RESEARCH PROJECTS IN THE STATE OF MAHARASHTRA, INDIA
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We thank our field assistants for their tireless efforts during the filed especially while tracking tigers.

HIGHLIGHTS

First corridor study based on tiger telemetry data in India.

Habitat permeability for tigers is favoured by Southern Dry Mixed Deciduous Forest (5A/C3), followed by Very Dry Teak Forest (5A/C1). Such forests in the landscape needs protection.

Of the total area of landscape 97,321 km^2, study identified 37,066.94 km^2 of tiger corridors, which was further categorized into 5 classes according to tiger use into very low (10,289.19 km^2), low (18,727.69 km^2), medium (5,689.63 km^2), high (1,418.25 km^2) to very high (942.19 km^2). Attempt should be made to bring these identified areas under corridor management plan and enhanced protection.

Vidarbha landscape is dissected by roads totalling a length of 84,202 km. Pre-emptive mitigation needs to be drawn at places where such roads cross important tiger corridors.

PREFACE

India houses sixty percent of the global population of tiger in seven percent of their historic range. These tigers are present in tiger reserves that are mostly geographically aloof from each other. They are separated by landscapes of intensive human occupation including expanding agriculture and urbanization. This problem of isolation is further aggravated by aggressive infrastructural development which is fuelled by a national aspiration to 8% economic growth and without the presence of a comprehensive land-use policy. Moreover, these reserves that contain these isolated meta-populations are in themselves not enough to sustain a sizeable tiger population. Under such circumstances it is imperative that these habitats or Protected Areas be connected, and corridors are the best available measure that the global conservation community unanimously vouches for. In India, all tiger corridors are heavily affected by anthropogenic pressures, which is exerted by human population of 1.25 Billion people increasing at a rate of 1.7% annually (Census of India 2011). This demands the immediate attention of all respective wildlife managers. This report is about the delineation/identification of critical tiger corridors in Vidarbha Landscape of Maharashtra India using actual tiger movement (telemetry) data. This is the first ever study in India where actual tiger movement data has been used to identify the tiger corridors. We shall be continuously updating these corridors with generation of more and more scientific information. We hope this will be useful for the managers to take proactive measures in field for long-term conservation of tigers in the State of Maharashtra. The soft copy and interactive maps of this report are available at https://mahadata.wii.gov.in. This is an online web portal developed as a dissemination platform for outcomes of research projects in the State of Maharashtra.

Introduction

Protected areas (PA) were established in India to provide wild animals with a refuge in the face of habitat loss due to escalating anthropogenic pressures from an ever-growing human population in the country. Some of these PAs were later rechristened as tiger reserves (TR), under Project Tiger Scheme in 1973, with the intension of providing further protection to all the wild species present, under the umbrella of the Tiger (*Panthera tigris tigris*). The presence of viable populations of tigers is an indicator of the integrity, sustainability, and health of larger ecosystems. Tiger landscapes support tigers, co-predators, their prey, and a vast amount of biodiversity. They also contribute to human wellbeing, locally and globally, through the provision of many ecosystem services such as water harvesting, carbon sequestration, plant genetic materials, food security, medicinal plants, and opportunities for community-based tourism.

Most PAs and TRs appear as isolated patches of forest in a sea of human dominated landscapes. In such a scenario, habitat connectivity is extremely essential to prevent species extinction by isolation of population and or restriction of gene flow. Loss of habitat connectivity in close proximity to a tiger source area, owing to Landuse Landover change due to various reasons, leads to straying of tigers near human dominated areas in the landscape (NTCA 2013). Besides, tigers dispersing from one landscape (source) to another (sink) traverse modified landscapes using agricultural fields and similar cover along river courses, feeding on livestock or native wild prey. Dispersing tigers utilize habitats with varying degree of human disturbance and varying Landuse. After leaving the natal areas, the animals get noticed either by people or by forest department in an area, which probably is not conducive for their movement (chance encounter of either sign or direct encounter with humans increase). Therefore, tiger conservation in India solely depends on identification of structural and functional dispersal corridors and on mitigation of conflicts with humans along these.

Habitat loss and fragmentation have been recognized throughout the world as a key issue facing the conservation of biological diversity (IUCN 1980). As the global population increases, less and less of Earth's surface remains free from human interference. Human activities have modified the environment to the extent that the most common landscape patterns are mosaics of human settlements, farmland, and scattered fragments of natural ecosystems. Destruction and degradation of natural habitats are widespread and profound and their implications for the conservation of biological diversity and the sustainability of natural resources are of global significance (Bennett 1999). Closely coupled with the issue of broad-scale loss of natural habitats is the challenge of maintaining and conserving biodiversity in landscapes now dominated by human land use. In many such landscapes, large natural tracts are becoming scarce or no longer exist.

Remnants of the natural environment increasingly occur as a mosaic of large and small patches, survivors of environments that have been carved up to develop new forms of productive land use for humans. Together they provide the habitats upon which the conservation of much of the flora and fauna in developed landscapes ultimately depends.

Under such scenario, the connectivity of such isolated fragments becomes important. This can be achieved by linking these fragments by a corridor of similar suitable habitat, which will impart a greater conservation to this new arrangement (Diamond 1975; Wilson and Willis 1975). This initial recommendation was based entirely on theoretical considerations, primarily stemming from island biogeographic theory. Subsequently, protection or provision of continuous corridors of habitat to link isolates such as nature reserves, woodlands or patches of old-growth forest have been widely recommended as conservation measures to counter the impacts of habitat reduction and fragmentation. Besides, the concept of corridors as a conservation measure has been phenomenally successful in catching the attention of planners, land managers and the community.

In the face of habitat fragmentation, persistence of wildlife populations depends, at least in part, on their ability to move through modified landscapes. Such movements allow individuals to forage over multiple habitat patches, rescue local populations from extinction, or recolonize local populations after extinction. The interaction between animal movements (set by physiology and behaviour) and landscape structure (set by landscape composition and configuration) will determine the ability of an animal to move through a landscape. (Merriam 1984) referred to the landscape property resulting from this interaction as "connectivity".

Landscape connectivity was later defined as "the degree to which the landscape facilitates or impedes movement among resource patches" (Taylor et al. 1993) and is both species-specific and landscape-specific (Tischendorf and Fahrig 2000b). Understanding the impact of landscape change on landscape connectivity is essential for predicting the impact of landscape change on a species (Goodwin and Fahrig 2002).

A wildlife corridor is an area of habitat connecting wildlife populations separated by human activities (such as roads, development, or logging). This allows an exchange of individuals between populations, which may help prevent the negative effects of inbreeding and reduced genetic diversity (via genetic drift) that often occur within isolated populations. Corridors may also help facilitate the re-establishment of populations that have been reduced or eliminated due to random events (such as fires or disease). This may potentially moderate some of the worst effects of habitat fragmentation (Goodwin & Fahrig 2002). The negative response of landscape connectivity to large inter-patch distance suggests that measures like decreasing isolation, through corridors (Merriam 1991; Noss 1993; Rosenberg et al. 1998), have the potential to increase landscape connectivity.

Connectivity depends on the characteristics of the habitat patches and the distance between patches (Ewers and Didham 2006) but also on the suitability and permeability of the matrix (Powney et al. 2011; Vergara 2011). Landscape connectivity is also dependent on some landscape characteristics, which modify interspecific relationships (Ewers and Didham 2006; Wakano et al. 2011) and mortality risks (Tischendorf & Fahrig 2000a). Thus, species success or failure depends on features of landscape patches and landscape characteristics that need to be taken into account when estimating connectivity (Kadoya 2009; Sawyer et al. 2011). Using movement data to estimate connectivity within a species' territory requires very important logistical and economical resources (Zeller et al. 2012), which become even more important when multi-species connectivity is considered. Goodwin & Fahrig (2002) showed that landscape structure was strongly correlated to connectivity, especially habitat area and inter-patch distance.

There is very little information about which animal species actually use vegetation corridors during dispersal (Arnold et al. 1991; Bentley and Catterall 1997; Cale 1990; Desrochers and Hannon 1997; Hinsley et al. 1995; Saunders and De Rebeira 1991), or about how effective differently connected landscapes may be for species with a range of different dispersal behaviors. For example, a landscape with corridor gaps (discontinuities) of 100 m may be perfectly satisfactory for a large parrot that needs only visual contact to move from patch to patch (Saunders and De Rebeira 1991), but useless for a small arboreal lizard if that lizard never moves far from the safety of trees (Sarre et al. 1996).

(Graves et al. 2007) identified primary habitat and functional corridors across a landscape using Global Positioning System (GPS) collar locations of brown bears (Ursus arctos) on the Kenai Peninsula, Alaska. Dispersal corridors used by wide-ranging carnivores have been accurately modeled using GIS techniques (Cushman et al. 2006; Walker and Craighead 1997) including American martens (Broquet et al. 2006; Wasserman 2008).

Earlier, most tiger ecological research efforts have focused on investigating behavioral aspects such as communication, territoriality, land tenure, dispersal and social organization within a few protected areas (Karanth and Sunquist 2000; Seidensticker 1976; Smith 1993; Sunquist 1981). These basic studies of tiger behaviour formed the foundation of more advanced population level studies. Although ecological studies of large carnivores within a modern scientific framework began forty years ago with George Schaller's pioneering work in Kanha National Park (Schaller 2009) and have advanced tremendously thereafter as a result of research by other scientists (Karanth et al. 2003). Major scientific advances in understanding tiger ecology were made in the 1973-1985 period through radio telemetry studies in Chitwan, Nepal under the Smithsonian Tiger Ecology Project (Seidensticker 1976; Seidensticker and McDougal 1993; Smith et al. 1987; Smith 1993; Sunquist and Sunquist 2002). During the 1990s, long-term ecological studies in Nagarahole (Karanth and Stith 1999; Karanth and Sunquist 1992, 1995, 2000), Panna (Chundawat et al. 1999) and other areas of India and Nepal (Biswas and Sankar 2002; Karanth and Nichols 1998; Karanth et al. 2004; Karanth et al. 2000; Karanth et al. 2003; Wegge et al. 2004) that employed modern techniques such as radio-telemetry, camera trapping, dietary analyses and prey density estimation, generated substantial new knowledge about wild tigers. Recent initiatives by NTCA, State Forest Departments along with Wildlife Institute of India for long term monitoring of Tigers in Kanha Tiger Reserve, Pench Tiger Reserve, Sundarbans, Panna Tiger Reserve, Ranthambore Tiger Reserve and Bhandavgarh Tiger Reserve have produced enough information vital for long term conservation of wild tigers and co-predators in India. Landmark population estimation exercise at national Level by NTCA and Wildlife Institute of India (Jhala 2011; Jhala et al. 2008, 2011, 2015, 2020) identified the critical tiger populations for long term monitoring in India.

Graph structures have been shown to be a powerful and effective way of both representing the landscape pattern as a network and performing complex analysis regarding landscape connectivity (Pascual-Hortal and Saura 2006). Different ecological applications of graph theory focusing especially on connectivity analysis of heterogeneous landscapes for conservation have been recently reported (Bunn et al. 2000; Jordán et al. 2003; Keitt et al. 1997; Ricotta et al. 2000; Urban and Keitt 2001). A graph is a set of nodes (or vertices) and links (or edges) such that each link connects two nodes; it may be used for quantitatively describing a landscape as a set of interconnected patches (Ricotta et al. 2000; Urban and Keitt 2001; Jordan et al. 2003). Nodes represent patches of suitable habitat surrounded by inhospitable habitat (non-habitat) (Urban and Keitt 2001). The existence of a link between each pair of patches implies the potential ability of an organism to directly disperse between these two patches, which are considered connected.

Maharashtra Forest Department in collaboration with Wildlife Institute of India has initiated long-term study to understand the landscape use by dispersing tigers. As a part of the study, movement corridors have been modelled based on the actual movement data of tigers. This is the first study in India to delineate tiger corridors based on actual movement data of tigers.

Study Area

Vidarbha is the North-eastern region of the Indian state of Maharashtra, comprising Nagpur Division and Amravati Division. It occupies 31.6% of the total area and holds 21.3% of the total population of Maharashtra. It borders the state of Madhya Pradesh to the north, Chhattisgarh to the east, Telangana to the south and Marathwada and Khandesh regions of Maharashtra to the west. It lies between 18° 40′ 21.42″ N to 21° 38′ 58.23″ N and 75° 59′ 24.90″ E to 80° 53′ 49.03″ E. It encompasses an area of 97,321 km^2 covering the 11 districts of Akola, Amravati, Bhandara, Buldana, Chandrapur, Gadchiroli, Gondia, Nagpur, Wardha, Washim, and Yavatmal (Figure 1). It houses a human population of 2,30,03,179 people (Census of India, 2011), and at the same time has a forest cover of about 26775.06 km^2 (27.5%) (FSI, 2019).

Vidarbha lies on the northern part of the Deccan Plateau. Unlike the Western Ghats, there are no major hilly areas. The Satpura Range lies to the north of Vidarbha region in Madhya Pradesh. The Melghat area of Amravati district is on the southern offshoot of the Satpura Range. Large basaltic rock formations exist throughout Vidarbha, part of the 66-million-year-old volcanic Deccan Traps. Bhandara and Gondia district are entirely occupied by metamorphic rock and alluvium, making their geology unique in Maharashtra. Buldhana has the Lonar crater created by impact of an asteroid. The eastern districts of Gondia, Bhandara, Gadchiroli and Nagpur are in earthquake zone 1, which has the least seismic activity in India, while other districts are in zone 2.

Wainganga is the largest river in Vidarbha; along with its major tributaries, the Wardha, Kanhan, and Painganga, its waters flow south into the Godavari River. In the north, five small rivers–Khapra, Sipna, Gadga, Dolar and Purna–are tributaries of Tapti river.

The Vidarbha Landscape (VL) is very important as it harbours a population of about 331 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 8 protected areas or wildlife divisions where these tigers live, but these refuges are scattered like islands in a sea of human dominated landscape. Therefore, knowing the locations of tiger movement corridors and probable areas of human tiger conflict is especially important for a wildlife manager.

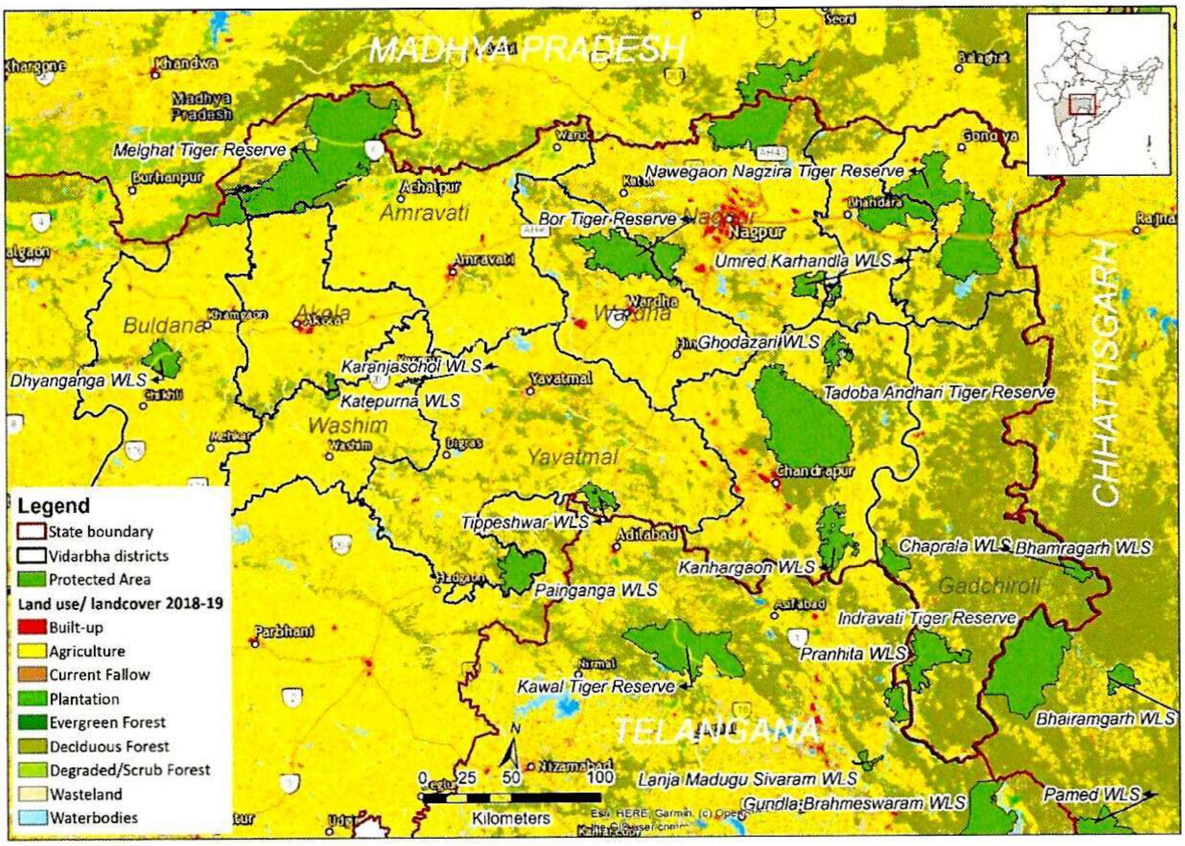

Figure 1: Vidarbha landscape showing the location of PAs with respect to landuse/landcover.

Materials and Methods

Capture and radio-collaring

Overall, 15 tigers were radio-collared and monitored from 2015 - 2020 for their movement through human dominated landscape in the State of Maharashtra. The animals were fitted with GPS collars that were programmed to take fixes at different intervals (Table 1). The GPS data was downloaded from satellite links (Iridium) as well as UHF ground download receiver. The animals were intensively tracked in the field using VHF ground tracking. The captured tigers were initially identified for collaring by field-based monitoring and camera trapping. After identification, the individuals were tracked and immobilized using combination of Medetomine hydrochloride, Ketamine hydrochloride, and Xylazine (dosages based on the body weight, age, and sex). Dosage was injected remotely using an air-pressurized Dan-Inject projector (Model IM) from an open top vehicle, and the immobilized animal was approached.

Table 1: Details of tiger monitoring from 2015 to 2020 in the State of Maharashtra, India

Individual ID/Sex	Age	Habitat/ System	GPS location acquired	Monitoring days	Monitoring Period	Collar type
Bor /Female	Sub-adult	PA	3307	78	29.07.2017 to 14.10.2017	Iridium, VHF/Activity
E1 Melghat/ Female	Sub-adult	PA	1479	63	01.07.2019 to 01.09.2019	Iridium, VHF/Activity
T01/Male	Adult	PA	1097	217	15.09.15 to 19.04.16	Iridium, VHF/Activity
T7-C2/Male	Sub-adult	PA	1532	183	09.06.18 to 08.12.19	Iridium, VHF/Activity
T7-C1/Male	Sub-adult	PA	4268	358	10.06.18 to 02.06.19	Iridium, VHF/Activity
Shivanjhari Female	Sub-adult	PA	3256	680	06.03.2017 to 14.01.2019	Iridium, VHF/Activity
T09/Male	Sub-adult	PA	5615	717	17.03.2016 to 03.03.2018	Iridium, VHF/Activity
T10/Male	Sub-adult	PA	3194	227	17.03.2016 to 29.10.2016	Iridium, VHF/Activity
Tipu/Male	Sub-adult	PA	3595	287	25.02.2019 to 08.12.2019	Iridium, VHF/Activity
Walker/Male	Sub-adult	PA	5604	396	27.02.2019 to 28.03.2020	Iridium, VHF/Activity
Brh F/Female	Sub-adult	Outside PA	823	155	03.06.2016 to 04.11.2016	Iridium, VHF/Activity
E3/Female	Sub-adult	Outside PA	3750	329	02.01.2019 to 26.11.2019	Iridium, VHF/Activity
E4/Female	Sub-adult	Outside PA	160	333	01.03.2019 to 27.01.2020	Iridium, VHF/Activity
Brh M/Male	Sub-adult	Outside PA	833	155	03.06.16 to 04.11.16	Iridium, VHF/Activity
E1 Brh/Female	Sub-adult	Outside PA	1311	93	28.02.2019 to 31.05.2019	Iridium, VHF/Activity

Analysis of tiger movement data

Tiger movement data was analyzed and pockets in the landscape outside PAs were identified where they were spending a considerable amount of time while dispersing or exploring. The eco-geographical characteristics of these pockets were extracted and based on this information it was extrapolated to other areas of the landscape to derive a model of habitat permeability for the movement of tigers in the landscape outside PAs. The habitat permeability surface was used in Circuit Theory framework to model tiger corridors (Figure 2)

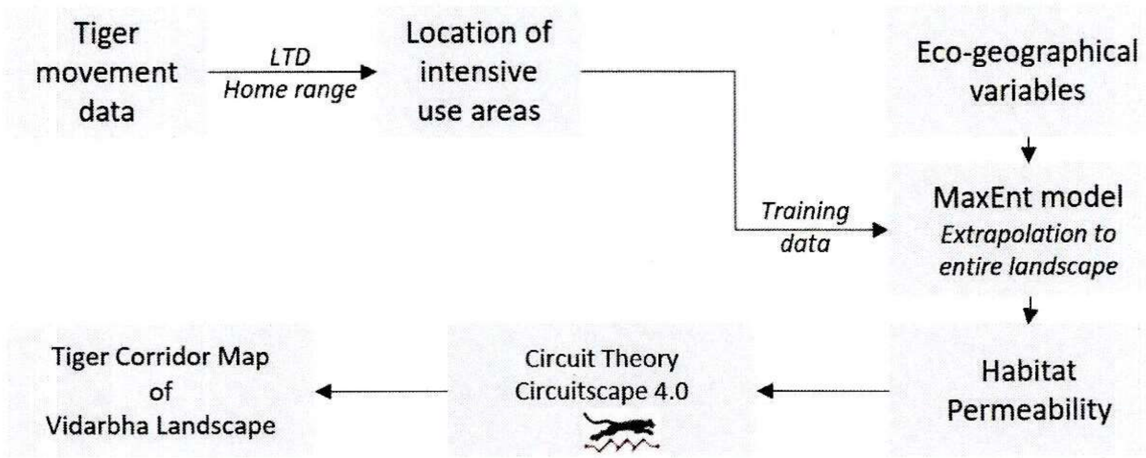

Figure 2: Flowchart of methodology for modelling tiger corridors using telemetry data.

Between September 2015 and 2020, 15 tigers were tracked with radio collars and a total of 39,824.00 GPS fixes were recorded outside PAs. Location information from these GPS fixes were further used to derive a model of habitat permeability for the movement of tigers in the landscape outside PAs.

Use of the landscape by tigers during movement

Movement Ecology Tools for ArcGIS (ArcMET) 10.2.2v3 was used for this analysis (Wall et al., 2013). Using this tool on the GPS fixes of the tiger collars the Linear Time Density (LTD) Home Range was calculated. The LTD tool calculates the percentage of time spent per grid cell based on the approximated, straight-line movement by the animal from one recorded position to the next. Although it is well understood that animals rarely travel in straight lines, it is nonetheless a useful approximation in this situation. The landscape was divided into 500 X 500 m grids (which is more than the mean displacement/hr of a tiger in this landscape i.e. 312.20 m) (Habib et al. 2021) and the LTD values were calculated along the path of tiger movement. The LTD values were then sub-divided into ten bins using Jenks Natural Break Optimization, the grids which fell in the four highest bins were selected and centroid points of these selected grids were generated. Using

SDMToolbox in ArcGIS 10.2, a heterogeneity layer of the eco-geographical variables was generated, and the centroid points were spatially rarefied, in the process removing spatially autocorrelated ones. Spatially rarefied locations were then used as a training dataset to train a MaxEnt model to generate a surface of habitat permeability.

MaxEnt Modelling of habitat permeability.

The diverse set of 18 climatic and eco-geographical variables were considered: annual mean temperature, isothermality, temperature seasonality, annual precipitation, precipitation seasonality, compound topographic index, elevation, distance from drainage, forest, protected areas and roads, evapotranspiration, livestock population, land use, normalized difference vegetation index, human population, terrain roughness, and slope position. Autocorrelation was checked between these set of 18 climatic and eco-geographical variables and 15 were retained which were not auto-correlated at a Pearson's R of 0.4 and 0.5. 250 locations (training dataset) and 15 variables were used to build initial MaxEnt models with default settings, using a random test percentage of 25%, with ten times cross-validation. Based on jackknife test of variable importance in the initial models, we further filtered 9 climatic and eco-geographical variables which was used in the final model.

Modelling of corridors using Circuit theory

Circuit Theory considers the landscape as an electronic circuit board and each suitable habitat patch as a node (Figure 3). 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 favoured 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 following Jenks, (1967). This implementation was done using the software Circuitscape 4.0 (McRae, 2006; McRae and Beier, 2007; McRae et al., 2008; Shah and McRae, 2008).

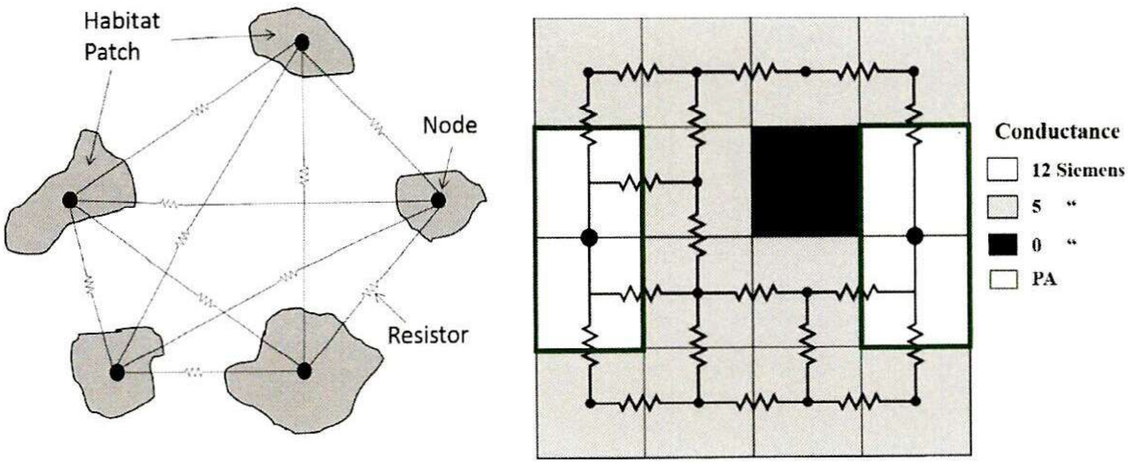

Figure 3: A landscape as depicted in Circuit Theory

Results

MaxEnt Modelling of habitat permeability

Using the methodology as described in section 3.3, a MaxEnt model was built to derive a model of habitat permeability for the movement of tigers in the landscape outside PAs, using 15 eco-geographical variables. After a jackknife test of variable importance, out of 15 variables only 9 were retained to build the final model. As shown in Figure 4, the final model was influenced most (28.4%) by the annual mean temperature (Figure 5 - Corresponding to rugged areas with remnant natural vegetation (woody-scrubland/grassland) on very poor quality stony, detrital, and shallow soil (Champion and Seth, 1968)), followed by distance from PAs and forests (19.3%), annual precipitation (16.6%) (Figure 6) and elevation (6.5%). The model was influenced by livestock population (3.9%), landuse (5.4%), distance from roads (2.3%) and NDVI (1%), to a lesser degree. The response curves in Figure 7 shows how each eco-geographical variable affects the MaxEnt prediction. The curves show how the logistic prediction changes as each eco-geographical variable is varied, keeping all other eco-geographical variables at their average sample value. The output probability surface from MaxEnt which indicates the probability that a tiger may pass through was treated as the habitat permeability surface to be fed into Circuitscape.

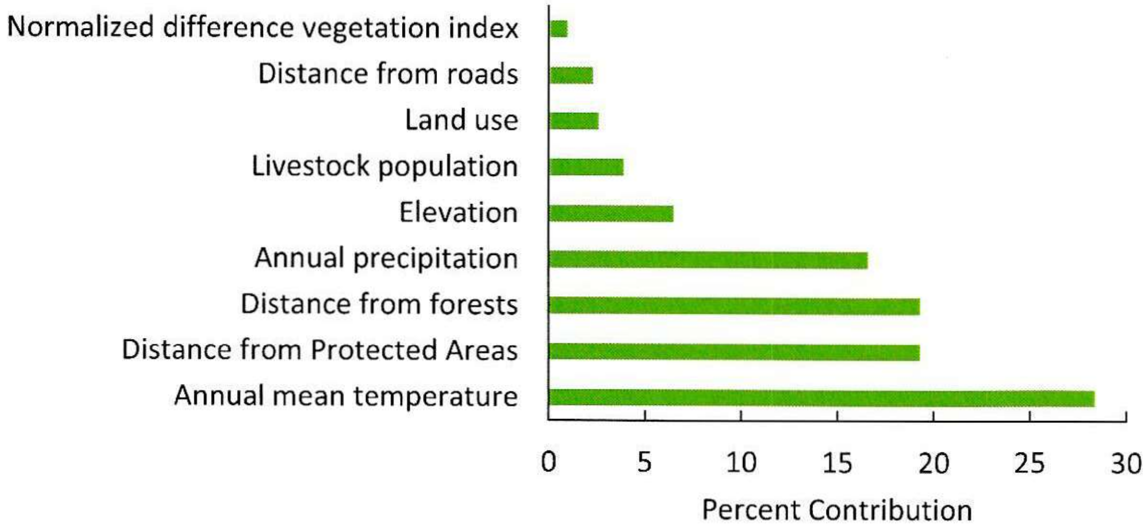

Figure 4: Relative contribution of response variables to the final model.

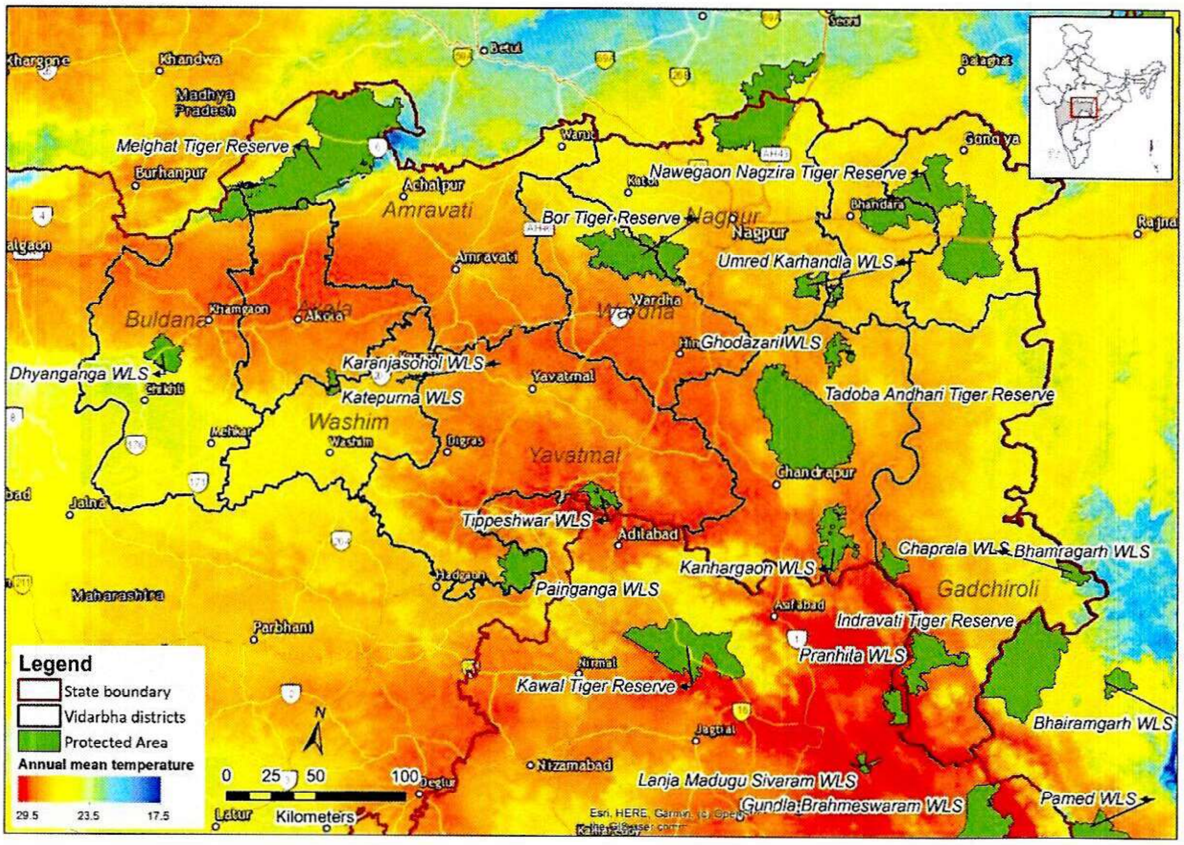

Figure 5: Variation of annual mean temperature across Vidarbha Landscape, Maharashtra, India

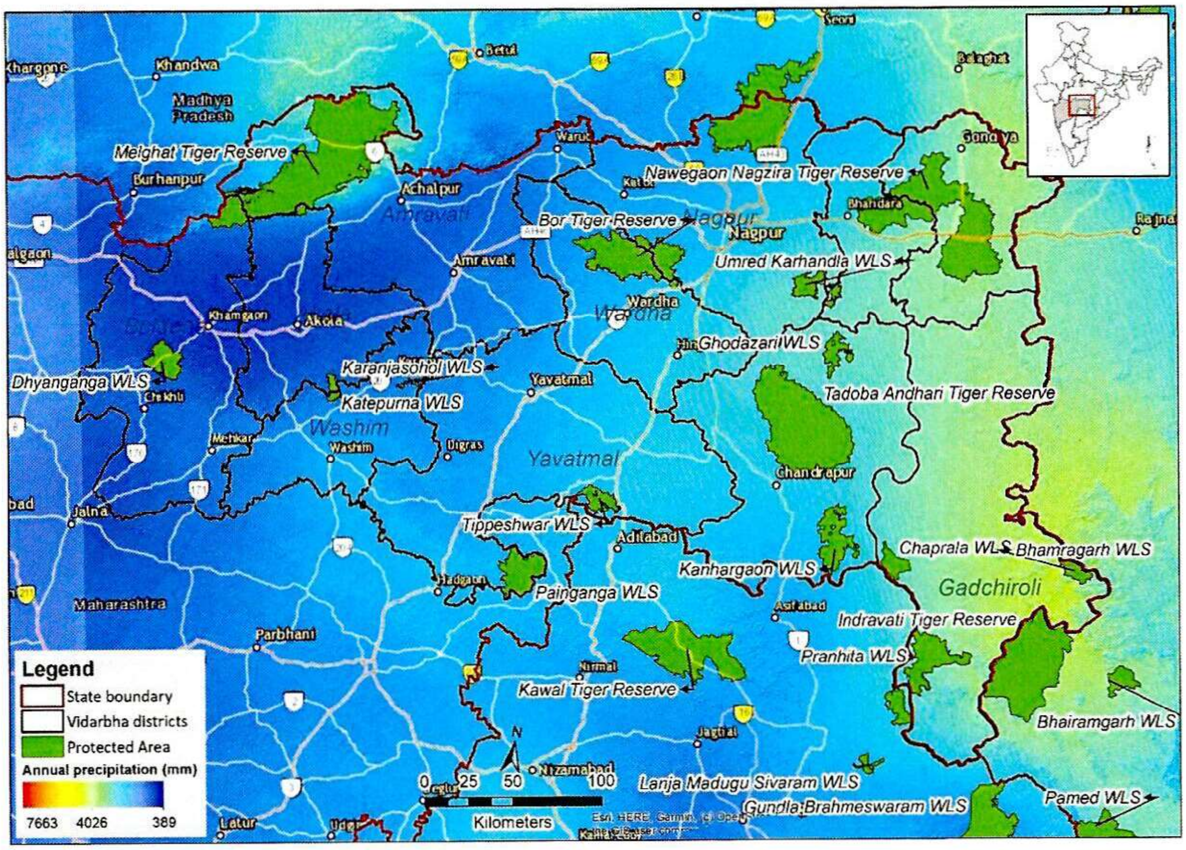

Figure 6: Variation of annual precipitation (mm) across Vidarbha Landscape, Maharashtra, India

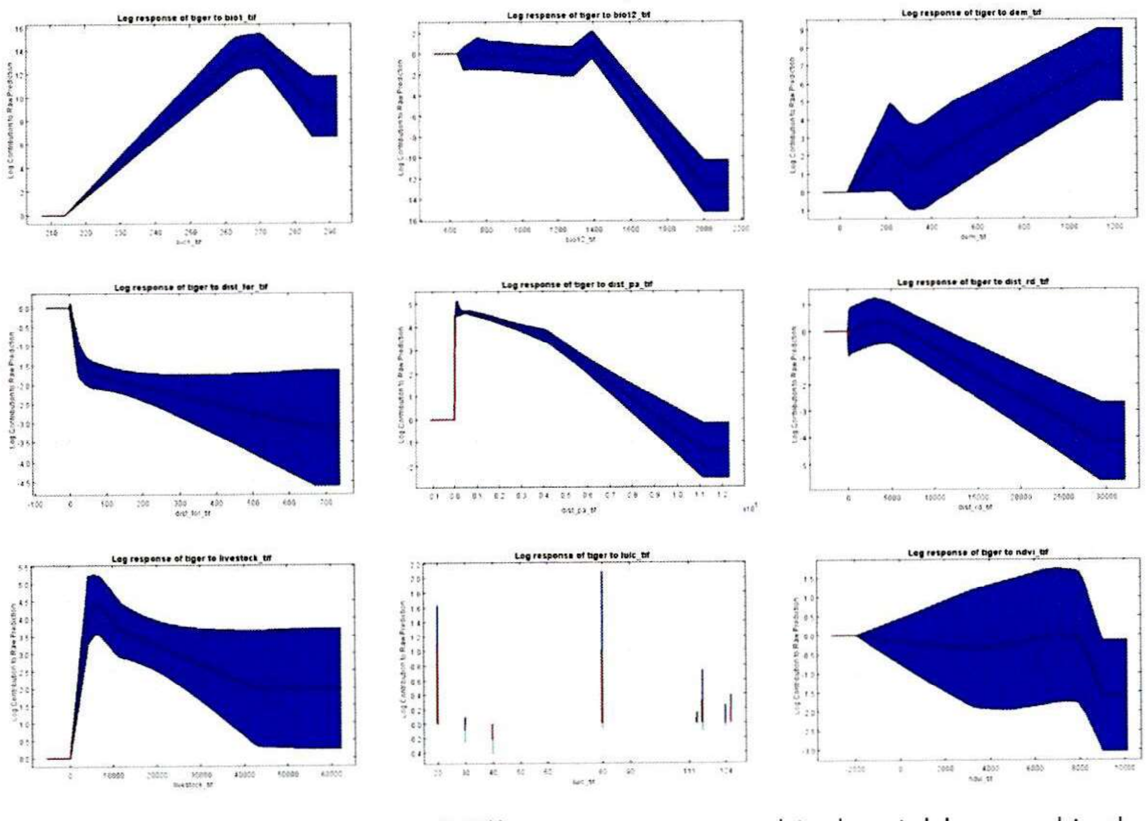

Figure 7: Response curves of different eco-geographical variables used in the MaxEnt model.

Modelling of corridors using Circuit theory

After running Circuitscape in pairwise mode, where it passes current between every possible pair of PAs following every possible pathway in the landscape, the generated output is displayed in Figure 8. Through this analysis 37,066.94 km^2 of tiger corridors were identified in VL, which was further categorized into 5 classes from very low (10,289.19 km^2), low (18,727.69 km^2), medium (5,689.63 km^2), high (1,418.25 km^2) to very high (942.19 km^2) indicating the importance of that pathway or corridor.

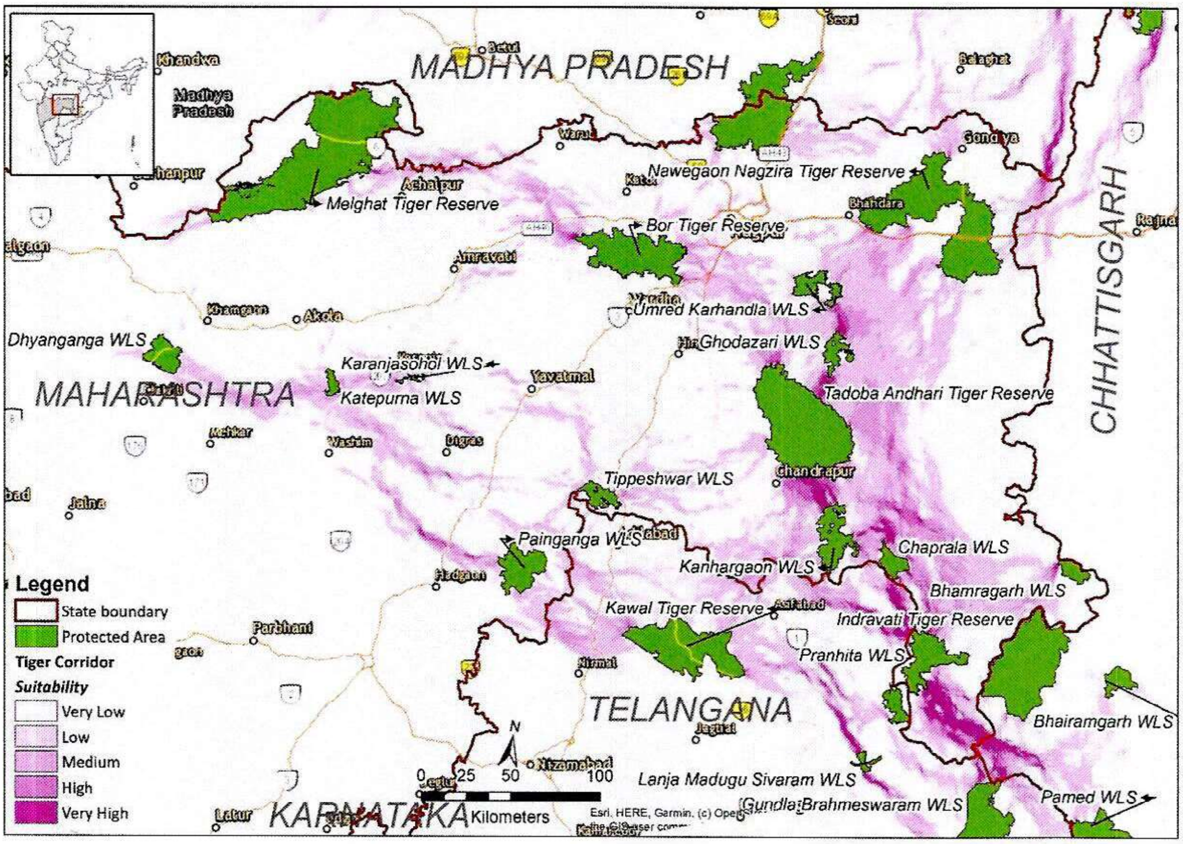

Figure 8: Telemetry based tiger corridors of Vidarbha and adjoining landscape in the State of Maharashtra, India.

Figures 9 – 12 show the corridor map of the Vidarbha and surrounding landscape, with rest to natural drainage, forest cover and landuse categories. The connectivity is classified from very low to very high. The very high values indicate good connectivity where is very low values indelicate low connectivity. All these connectivity maps are based on the telemetry data. With more information about the tiger movement from the landscape, we shall keep on revisiting these maps for better conservation and management of the tigers in the landscape. Figure 13 and 14 shows 3 categories (Very High, High and Medium) and 4 categories (Very High, High, Medium and Low) of suitability on forest cover map of the landscape. The telemetry based tiger movement has been reported from the suitability categories including very low suitability category.

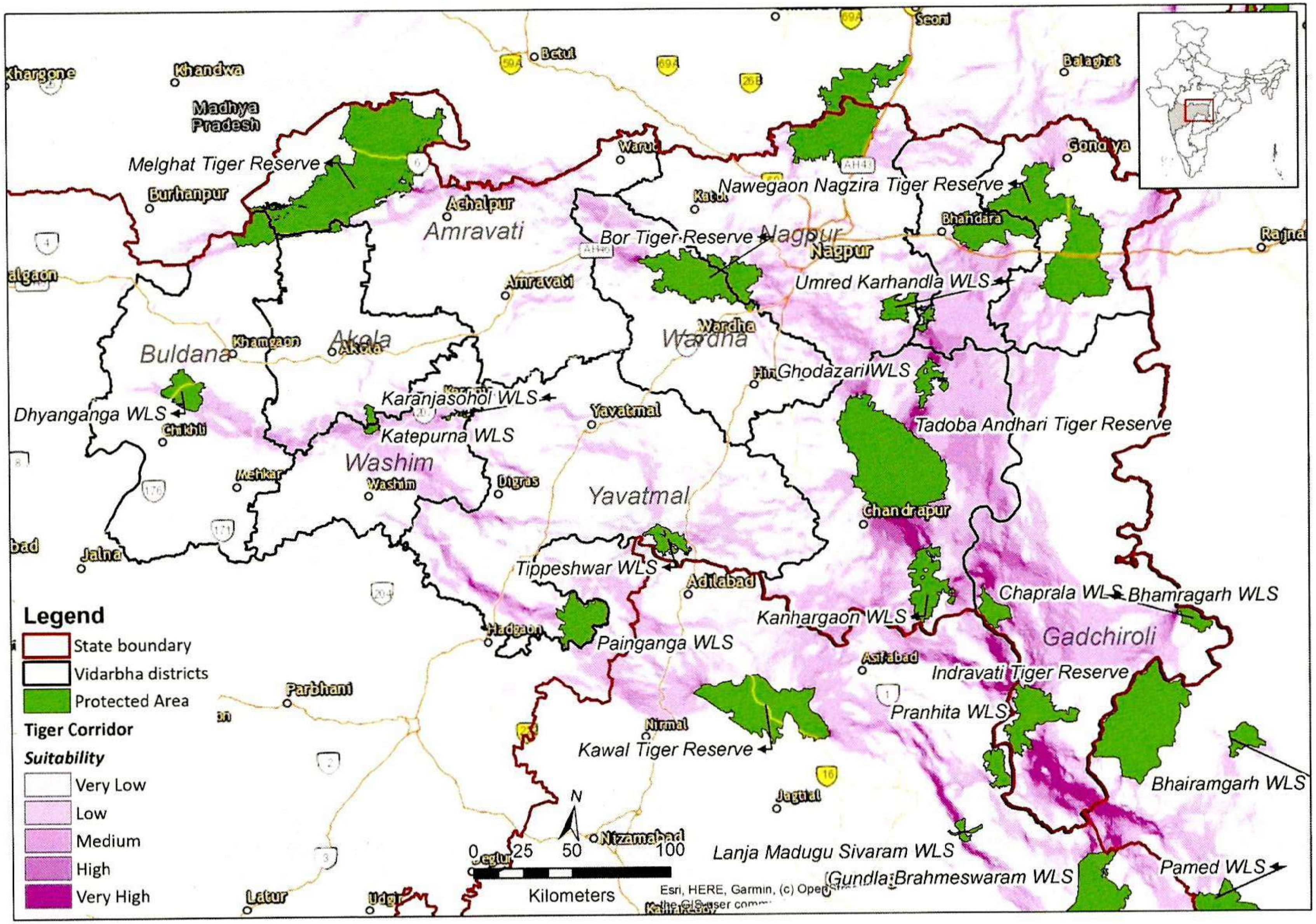

Figure 9: Telemetry based tiger corridors of Vidarbha (boundary) and adjoining landscape in the State of Maharashtra, India.

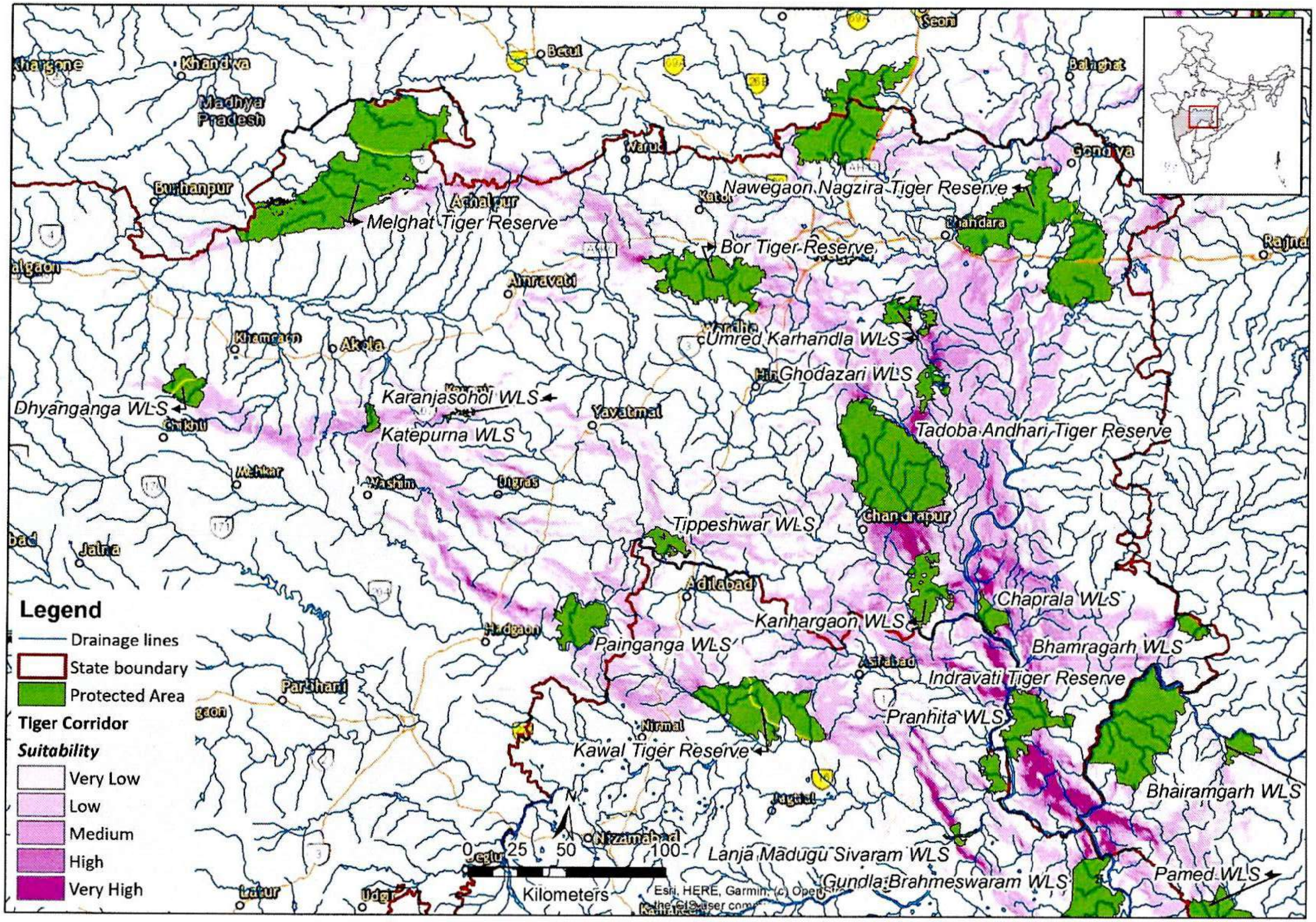

Figure 10: Telemetry based tiger corridors of Vidarbha and adjoining landscape with respect to natural drainages in the State of Maharashtra, India.

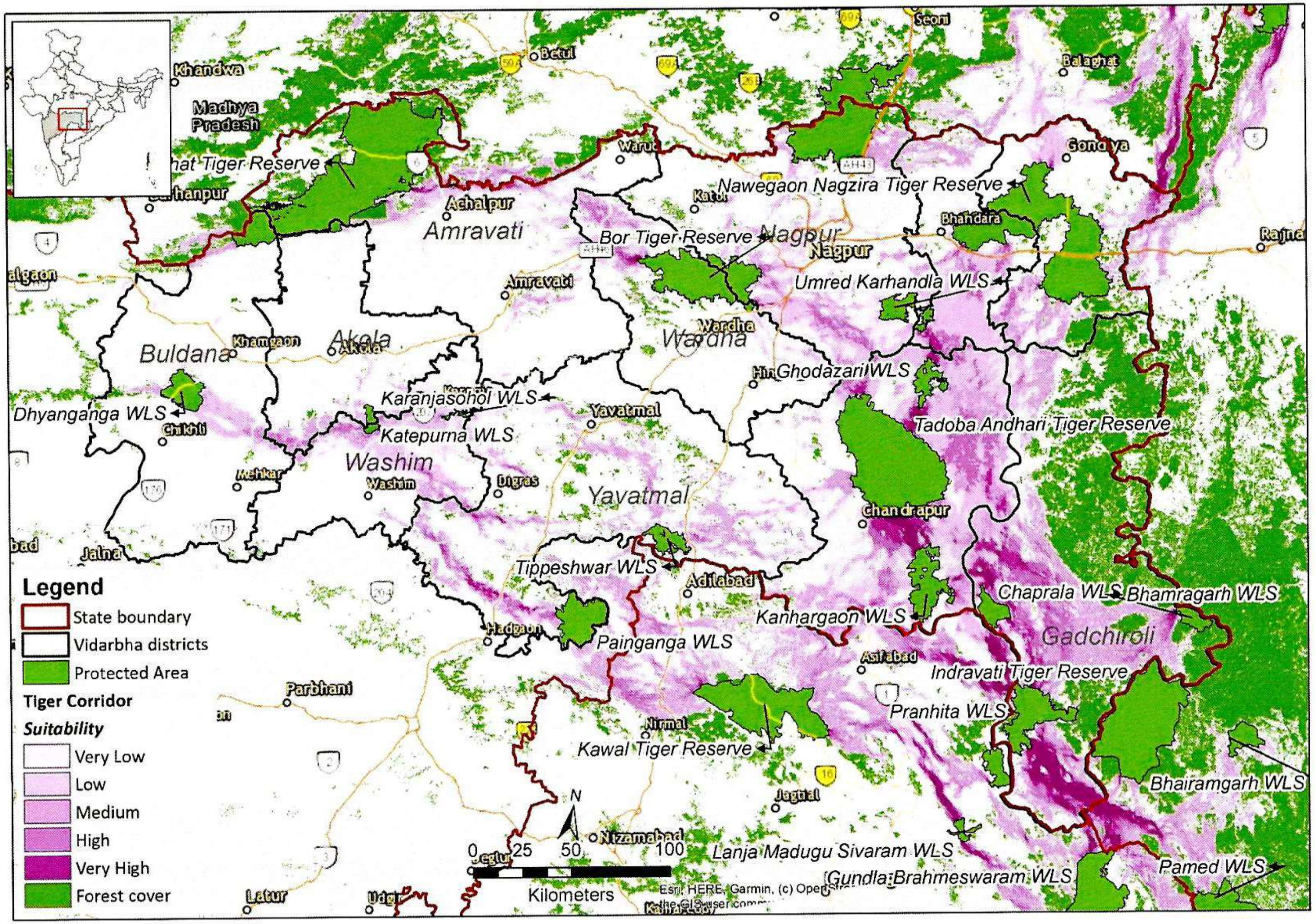

Figure 11: Telemetry based tiger corridors of Vidarbha and adjoining landscape with respect to forest cover in the State of Maharashtra, India.

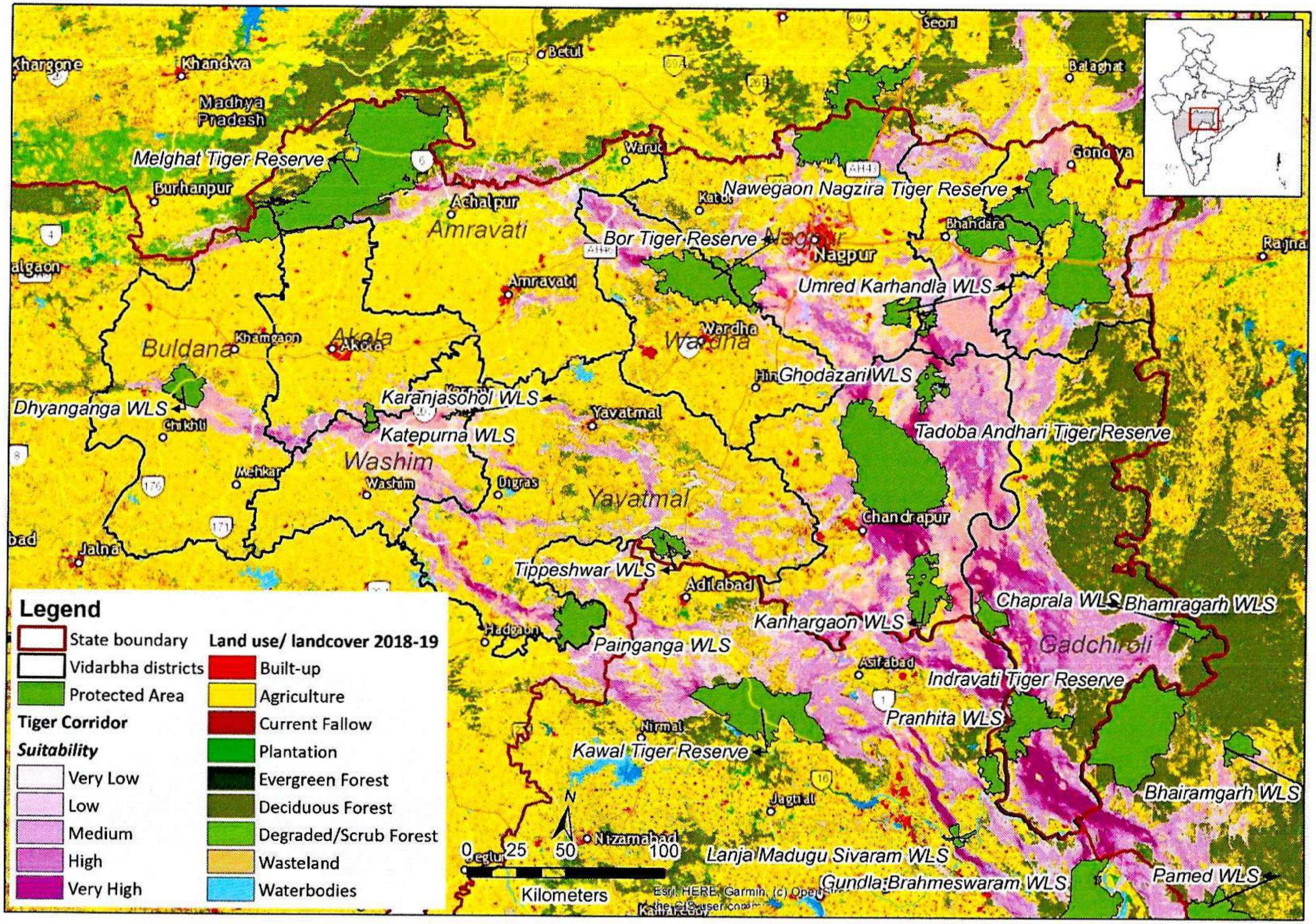

Figure 12: Telemetry based tiger corridors of Vidarbha and adjoining landscape with respect to landuse in the State of Maharashtra, India.

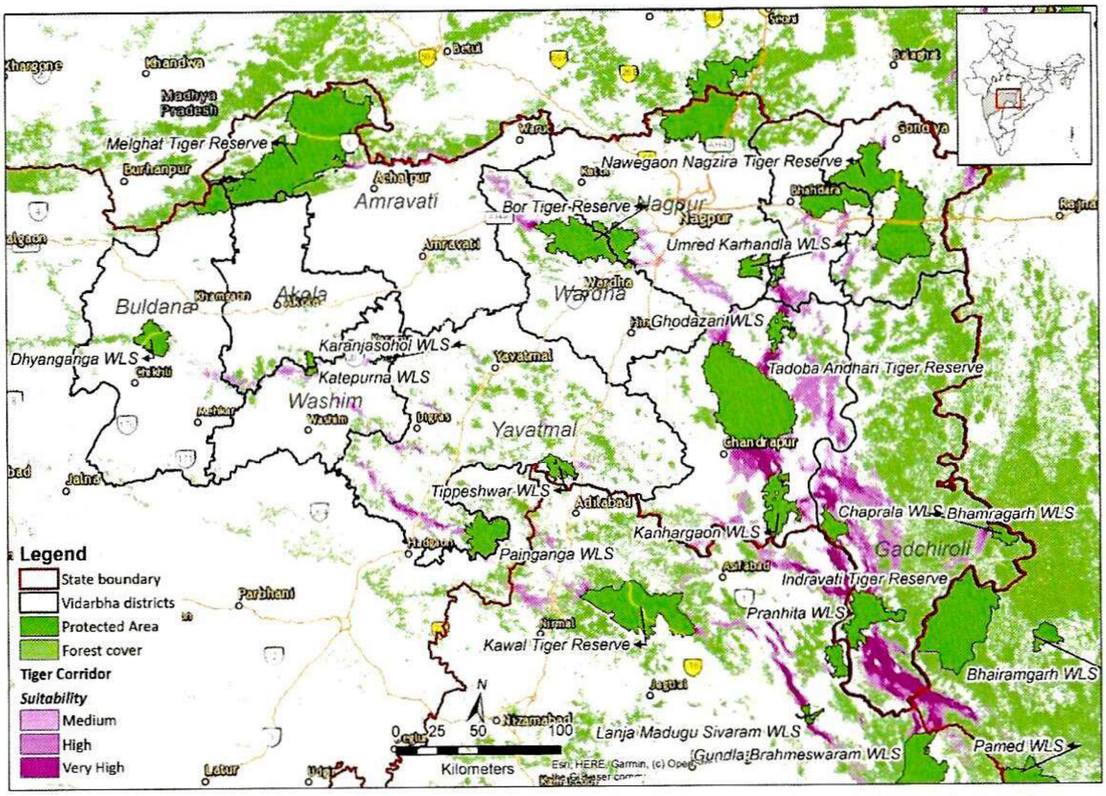

Figure 13: Telemetry based tiger corridors (Very High, High and Medium Suitability) of Vidarbha and adjoining landscape with respect to forest cover map in the State of Maharashtra, India.

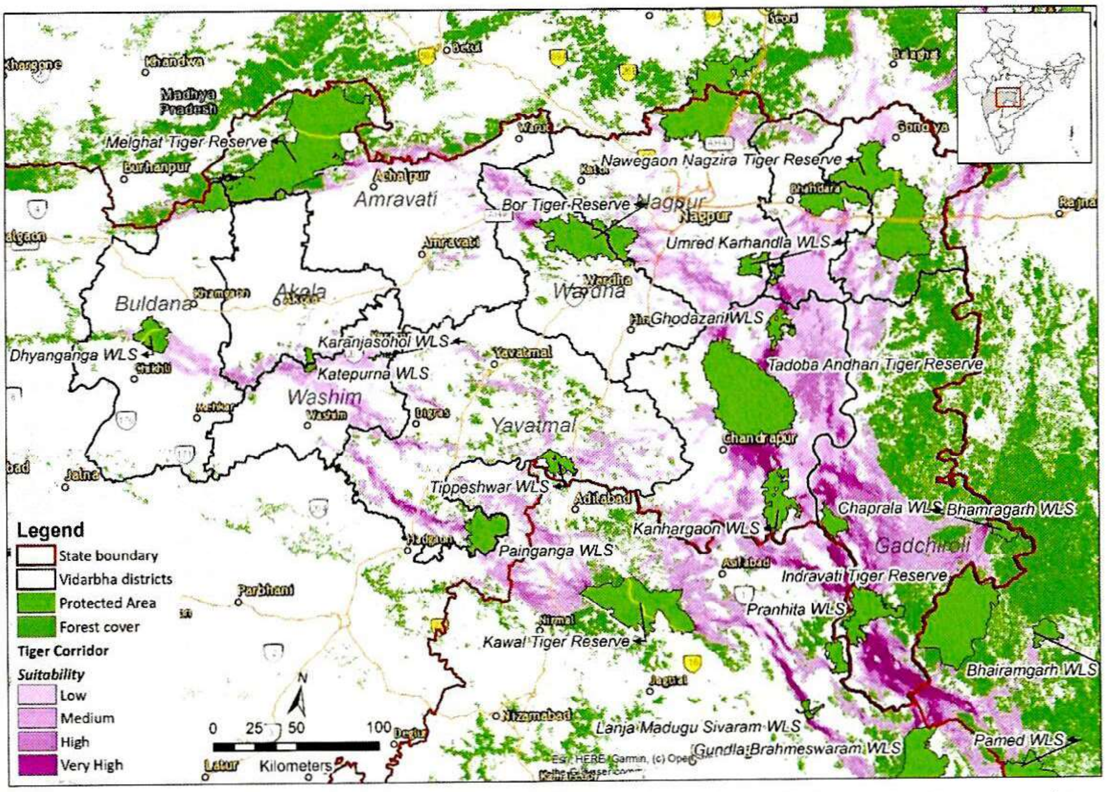

Figure 14: Telemetry based tiger corridors (Very High, High, Medium and Low Suitability) of Vidarbha and adjoining landscape with respect to forest cover map in the State of Maharashtra, India.

Figure 15 shows the percentage of different LULC categories present in the five classes of corridors that were segregated. It was obtained after calculating zonal statistics on the LULC data obtained from NRSC at 1:250,000 scale. The statistics show that the maximum area in all the classes is covered by Deciduous Forests, which indicates that the best parts of the corridors are through forested tracts where there is good cover for tigers all throughout the year. It is followed by areas of agriculture (mainly monsoon and double/ triple crops) and to some extent by wasteland areas (read: scrubland in monsoon). This is contrary to popular belief that tigers use only forested areas for movement. The proportion of agricultural land increases as we move from more to less suitable areas in the corridors. The modelling approach adopted in this study was able to capture more corridors than Qureshi et al., (2014), due to the use of tiger telemetry data from outside PAs as against using a coarse scale occupancy model using data on tiger presence and also due to fine scale of eco-geographical variables used in this study.

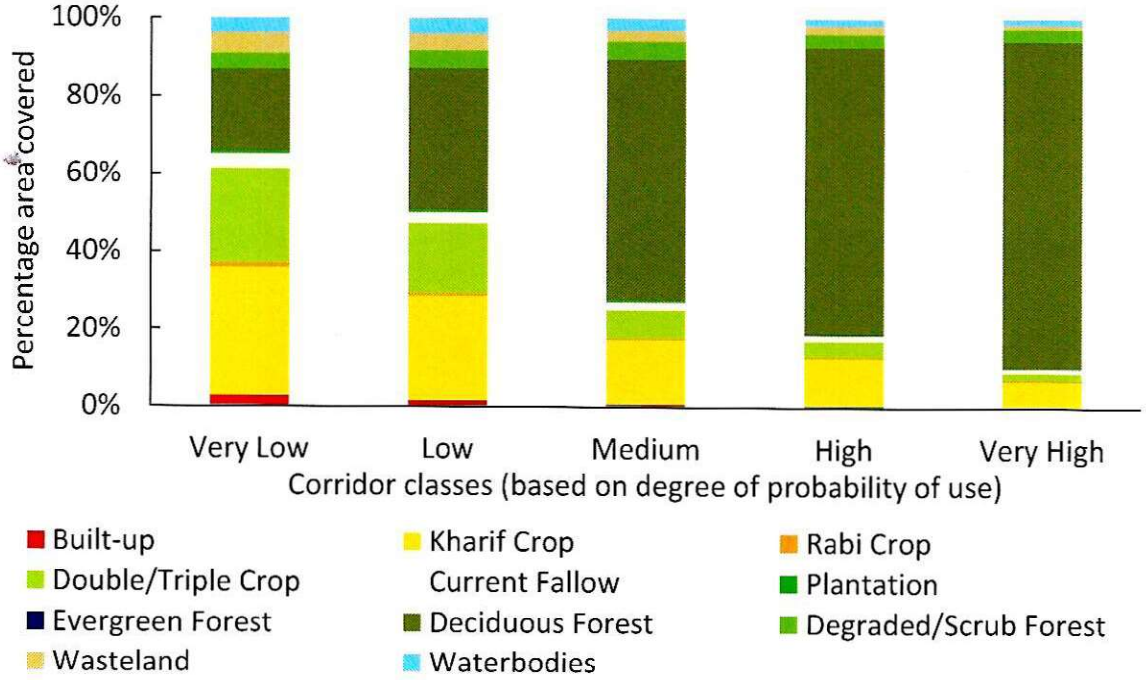

Figure 15: Proportion of landuse available in the telemetry-based tiger corridor's in Vidarbha and adjoining landscape of Maharashtra, India.

Conclusions

Improvement of habitat connectivity for wild animals in fragmented landscapes is increasingly being used as a strategy to mitigate the effects of habitat fragmentation, land-use dynamics and climate change (Doerr et al., 2011). However, movement data are yet to be systematically incorporated into assessments and prioritization of connectivity (Sawyer et al., 2011; Zeller et al., 2012). This study uses movement data to quantify habitat use outside PAs and incorporate the same information into connectivity modelling. This is first such study in India.

The findings of this study indicate that tigers in VL are using a much wider swathe of the landscape outside PAs for movement than earlier known. It extends well beyond forested structural corridors or the least cost corridors modelled by earlier studies (Qureshi et al., 2014). Not only that, but data from collared dispersing tigers have also shown extensive use of agricultural lands for movement. In such cases they have used whatever small fragment of forest patch/ or a parcel of cultivated land with standing crops was available, to seek refuge during the daytime. Tiger in this landscape were seen pushing their boundaries of human tolerance, ready to accept the risks of exploring a human-dominated landscape. Such findings from this study not only add to our knowledge of tiger movement ecology but has tremendous management implications on the ground. It changes the quantum of management efforts for creating awareness related to human-tiger conflict management and mitigation, connectivity conservation, etc. It provides directions as to where to focus management interventions on the ground to make the corridors more permeable and aid successful tiger dispersals.

The purview of tiger conservation, which till date was thought to be restricted to lands under the jurisdiction of the forest management, now seems to extend beyond such boundaries and into a realm where a successful conservation effort should necessarily include a much diverse array of stakeholders. The local people, the district administration, local NGOs and various developmental agencies should now work in tandem with the forest management. The findings of this report may provide clues to managers so as to target proactive and pre-emptive management interventions for conflict prevention/ mitigation and connectivity conservation. The report is also timely for the development agencies to design their future plans while considering tiger movement corridors in the landscape.

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