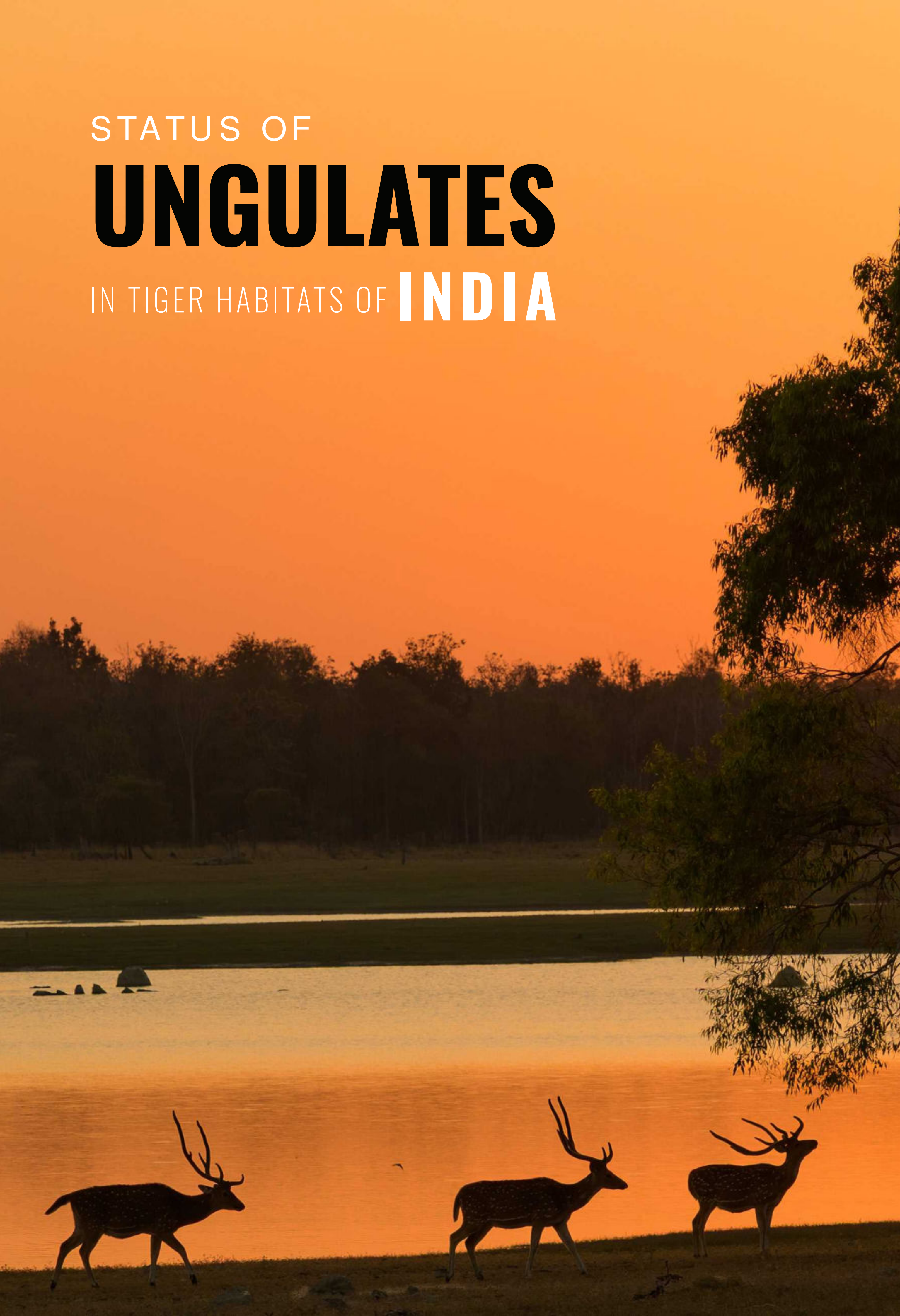
STATUS OF

UNGULATES

IN TIGER HABITATS OF **INDIA**



STATUS OF UNGULATES IN TIGER HABITATS OF INDIA

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SECTION I

Status of Ungulates in India: Introduction and Methods

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I.1. INTRODUCTION

Ungulates, a diverse group of hoofed mammals, are vital components of ecosystems, each playing unique roles in their respective habitats. Ungulates are primarily herbivorous mammals including species such as deer, antelopes, and wild boars. They occupy various ecological niches across India, from grasslands to forests and mountainous regions. Their feeding habits significantly influence vegetation dynamics, nutrient cycling, and regulates soil health. Additionally, they contribute to forest and grassland regeneration through seed dispersal (Ripple *et al*., 2015), which controls vegetation growth, shapes plant community structures, enhances habitat diversity and maintain overall health of ecosystem (Ripple *et al*., 2015). Ungulates play key role in sustaining large (tiger, leopard, dhole) and medium (hyena, jackal) size carnivores. A thriving ungulate population sustains these carnivores (Jhala *et al*., 2025), which in turn play a vital role in regulating the predator-prey dynamic essential for maintaining ecological balance. Prey abundance is the main reason that helped in tiger colonization in past decade in India (Jhala *et al*., 2025). Throughout human history, ungulates have been a primary source of food and resources; and have been prominently depicted in prehistoric art, such as the cave paintings, traditional textiles, carvings, sculptures as well as in folklores and literature. Many ungulate species, such as the blackbuck and nilgai, hold cultural and religious significance in India, with communities in certain regions revering and protecting them due to their association with Hindu traditions and deities, making them central to India's conservation efforts (Diamond, 1998; Zeder, 2008).

Despite their importance, ungulates face significant threats, including habitat loss due to deforestation, urbanization, and agricultural expansion. Poaching for meat, and other traditional uses poses a major threat besides competition with livestock for grazing. Human-wildlife conflicts, particularly crop raiding by nilgai, wild boars and other ungulates, often result in retaliatory killings, exacerbating their population decline. This conflict poses a dual threat: it endangers ungulate populations while also fostering negative attitudes towards wildlife conservation among local communities. Alongside, alterations in climate patterns can significantly affect the distribution of vegetation types that ungulates depend on for food and shelter. Changes in precipitation patterns can lead to droughts or floods that disrupt food availability and breeding success.

Conservation efforts in India have focused on protecting ungulates through the establishment of national parks, wildlife sanctuaries, and conservation reserves. Efforts to mitigate human-wildlife conflicts, including the use of compensation schemes, fencing, and awareness campaigns, have been implemented in various regions. India's ungulate conservation efforts offer valuable lessons for future goals, which includes integrated landscape management (Gopal, 2015), connecting fragmented habitats through wildlife corridors (Qureshi *et al.*, 2014), creating undisturbed habitat patches (Jhala *et al*., 2021) and large scale translocation for reintroduction and augmentation (Jhala *et al*., 2021, Qureshi *et al*., 2023). Strengthening community participation through incentives and sustainable livelihood programs will ensure the coexistence of humans and wildlife. Despite these efforts, ungulate conservation in India faces several challenges. Limited financial resources often constrain the scale of conservation programs, while weak enforcement of wildlife protection beyond protected areas hampers efforts to combat poaching and habitat destruction. Small and isolated populations of species such as Indian rhinoceros, barasingha, wild buffalo, pygmy hog, and hog deer face genetic bottlenecks due to fragmented habitat.

India's diverse geography supports 42 ungulate species belonging to seven families: Bovidae, Cervidae, Equidae, Moschidae, Rhinocerotidae, Suidae, and Tragulidae. Chital, sambar, wild pig, nilgai, barking deer and gaur are the most abundant herbivorous ungulate species and are widely distributed across India, unlike other ungulate species which have much smaller and specialized fundamental niches, with their distribution restricted to particular pockets of the forest. Prominent species of large ungulates which also refered as mega herbivore (> 500 kg) include the Indian rhinoceros (*Rhinoceros unicornis*), wild buffalo (*Bubalus arnee*), and gaur (*Bos gaurus*). Medium – Large ungulates (100 - 500 kg) include sambar (*Rusa unicolor*), nilgai (*Boselaphus tragocamelus*), and barasingha (*Rucervus duvaucelii*). Medium sized ungulates (30 – 100 kg) comprise chital (*Axis axis*), wild pig (*Sus scrofa*), hog deer (*Axis porcinus*), chinkara (*Gazella bennettii*), blackbuck (*Antilope cervicapra*), and chousingha (*Tetracerus quadricornis*). Small ungulates (< 20 kg), include barking deer (*Muntiacus muntjak*), pygmy hog (*Porcula salvania*), and mouse deer (*Moschiola indica*).

For designing, implementing and evaluating the success of any conservation program, it is vital to monitor the status, distribution and trends in the population of the target species. Understanding the spatial ecology and species specific habitat preferences is the foremost need for targeted conservation interventions. This report assesses the status of ungulate species recorded through line transect and camera trap surveys conducted for the "Status of Tigers, Co-predators, and prey in India - 2022." From a conservation and wildlife management standpoint, reliable data on ungulate populations are essential for formulating evidence-based policies and habitat management strategies. This report provides valuable insights into species – wise ungulate abundance, distribution and species specific habitat suitability, contributing to effective conservation planning and management. The findings from this study can enable protected areas to understand the prey – predator relations in the area and maintaining healthy ungulate densities, thus ensuring long-term ecological balance. By prioritizing habitat restoration, scientific research, and innovative conflict resolution strategies, India can secure a thriving future for its diverse and ecologically critical ungulate populations.

I. 2. METHODOLOGY

The methods for estimating ungulate abundance were adapted from the protocol developed for the National Tiger, Co-predator, Prey, and Habitat Estimation (Narain *et al*., 2005; Jhala *et al*., 2005). This protocol was implemented across approximately 395,379 km² of forested areas in India's tiger range states for the nationwide estimation of tigers (Jhala *et al*., 2008, 2011, 2015, 2020, Qureshi *et al*., 2023). The entire tiger-bearing forest was classified into five major landscapes based on biogeography and habitat connectivity factors.

During the National Tiger Estimation exercise, ungulate data was collected in the Phase I survey, which includes (a) ungulate and other prey encounter, (b) habitat assessment, and (c) human impact variables. These tasks were carried out by frontline forest department staff using the M-STrIPES (Monitoring System for Tigers: Intensive Protection and Ecological Status) mobile application. Since the field methodology for status assessments has remained consistent since 2006, wildlife managers have become increasingly proficient in conducting these exercises. These protocols were compiled into a field guide, available in nine regional languages (Jhala *et al*., 2021), and distributed to each frontline staff member (beat guard). The data collection for the All India Tiger Estimation was conducted in three phases.

Phase I – Countrywide field data collection:

Frontline staff of State Forest Departments across all potential tiger-bearing states were trained to collect Phase I data.

Data collection on each of the following components was implemented in:

a. **Carnivore and Mega Herbivore Sign Encounters:** Recorded using Form 1, which involved multiple occupancy surveys in each beat.
b. **Ungulate Abundance:** Assessed using Form 2 through distance sampling on line transects in each beat (Figure I. 1).
c. **Vegetation:** Evaluated with Forms 3A and 3C, which documented canopy cover, tree, shrub, and herb composition, and weed infestation in multiple 15m, 5m and 1m radius plots within transects in each beat.
d. **Human Disturbance:** Monitored using Form 3B where wood cutting, looping, human and livestock presence are recorded on 15m radius plot on line transects in each beat.
e. **Dung Counts:** Conducted using Form 4, which entailed counting all dung and pellets identified to species in multiple 40 m² (20X2m) plots on transects.

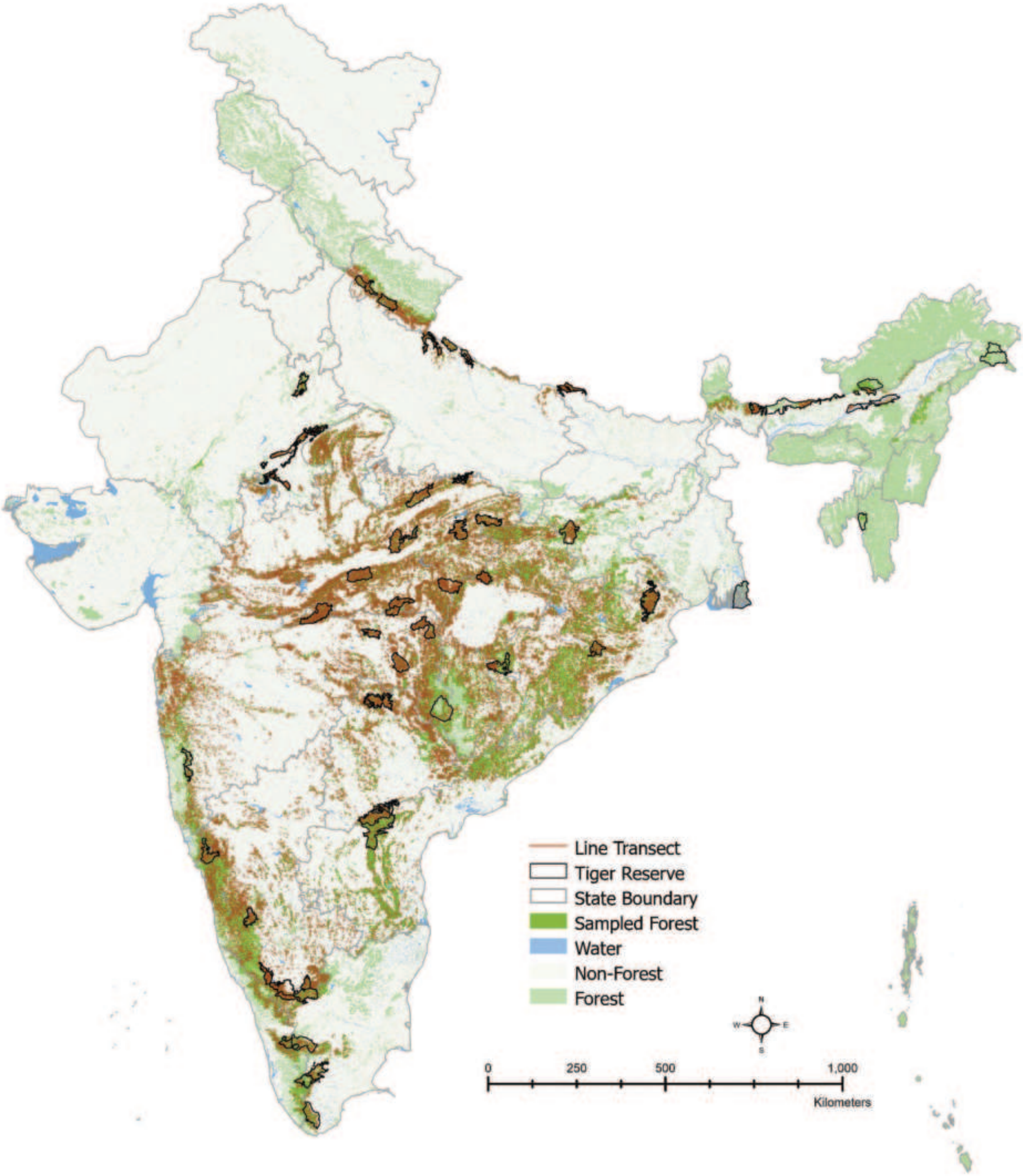

Figure I. 1: Spatial coverage of line transect sampling across tiger bearing areas in India (Phase I) in 2022

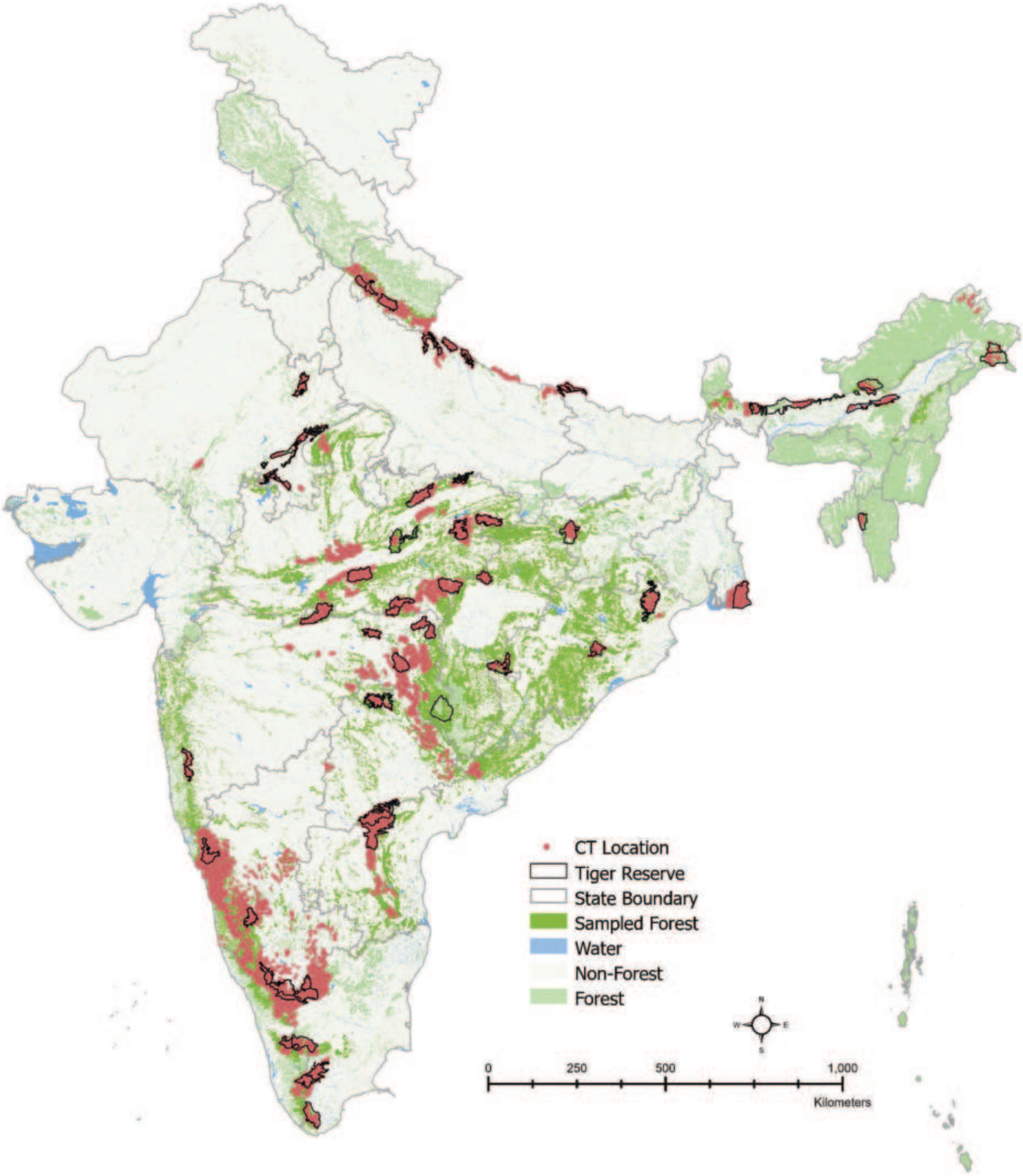

Figure I. 2: Spatial coverage of camera traps sampling across tiger bearing areas in India (Phase III) in 2022

Phase II - Remotely Sensed Spatial and Attribute Covariates:

The distribution and abundance of ungulates are influenced by habitat characteristics and anthropogenic impacts. These covariates were obtained from remotely sensed data and used to model ungulate distribution and abundance in conjunction with Phase I data. Habitat characteristics included vegetation cover (Normalized Difference Vegetation Index (NDVI)) for November and April, their difference as deciduousness, as well as elevation, ruggedness, distance from protected areas, distance from water, distance from built-up areas, distance from open natural ecosystems, aridity, and drainage density (Table I. 1).

Table I. 1: Phase I (field sampling) and remotely sensed data from phase II, used for modelling abundance estimate of ungulate

S. No	Dataset	Source	Spatial Resolution
Species Presence Variables			
1.	Prey Encounter Rate (Chital, Sambar)	Phase-1 Survey, AITE 2022	25km2
Climatic Variables			
2.	Aridity Index	Derived from Landsat - 8 data (Vermote, E., Justice, C., Claverie, M., & Franch, B. (2016). Preliminary analysis of the performance of the Landsat 8/OLI land surface reflectance product. Remote Sensing of Environment, 185, 46-56.)	30m
3.	Land Surface Temperature	Derived from Landsat - 8 data (Vermote, E., Justice, C., Claverie, M., & Franch, B. (2016). Preliminary analysis of the performance of the Landsat 8/OLI land surface reflectance product. Remote Sensing of Environment, 185, 46-56.)	30m
4.	Annual Mean Temperature (Bio1)	Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2.1: new 1-km spatial resolution climate surfaces for global land areas. International journal of climatology, 37(12), 4302-4315.	~1000m
5.	Temperature Seasonality (standard deviation ×100) (Bio4)	Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2.1: new 1-km spatial resolution climate surfaces for global land areas. International journal of climatology, 37(12), 4302-4315.	~1000m
6.	Maximum Temperature of Warmest Month (Bio5)	Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2.1: new 1-km spatial resolution climate surfaces for global land areas. International journal of climatology, 37(12), 4302-4315.	~1000m
7.	Minimum Temperature of coldest Month (Bio6)	Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2.1: new 1-km spatial resolution climate surfaces for global land areas. International journal of climatology, 37(12), 4302-4315.	~1000m
8.	Temperature Annual Range (Bio 7)	Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2.1: new 1-km spatial resolution climate surfaces for global land areas. International journal of climatology, 37(12), 4302-4315.	~1000m
9.	Annual Precipitation (Bio12)	Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2.1: new 1-km spatial resolution climate surfaces for global land areas. International journal of climatology, 37(12), 4302-4315.	~1000m
10.	Precipitation of Wettest month (Bio13)	Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2.1: new 1-km spatial resolution climate surfaces for global land areas. International journal of climatology, 37(12), 4302-4315.	~1000m
11.	Precipitation of Driest Month (Bio14)	Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2.1: new 1-km spatial resolution climate surfaces for global land areas. International journal of climatology, 37(12), 4302-4315.	~1000m
12	Precipitation Seasonality (Coefficient of Variation) (Bio15)	Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2.1: new 1-km spatial resolution climate surfaces for global land areas. International journal of climatology, 37(12), 4302-4315.	~1000m

S. No	Dataset	Source	Spatial Resolution
Habitat variables			
13.	Tree Cover	Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850-53. 10.1126/science.1244693 Data available on-line at: https://glad.earthengine.app/view/global-forest-change.	30m
14.	Normalized Difference Vegetation Index (NDVI) - Pre, Post Monsoon and Difference	Derived from Landsat -8 data (Vermote, E., Justice, C., Claverie, M., & Franch, B. (2016). Preliminary analysis of the performance of the Landsat 8/OLI land surface reflectance product. Remote Sensing of Environment, 185, 46-56.)	30m
15.	Distance from Mixed Savannah	Euclidean distance derived from Mixed Savannah (termed as rangeland) extracted from Sentinel 2 lulc dataset. (Karra, K., Kontgis, C., Statman-Weil, Z., Mazzariello, J. C., Mathis, M., & Brumby, S. P. (2021). Global land use/land cover with Sentinel 2 and deep learning. In 2021 IEEE international geoscience and remote sensing symposium IGARSS, pp. 4704-4707.)	10m
16.	Distance from Forest with canopy cover (more than 10%)	Euclidean distance derived from State of Forest Report (2017). Forest Survey of India, Ministry of Environment, Forest and Climate Change, Government of India	23.5m
17.	Distance from open forest with canopy cover (less than 40%)	Euclidean distance derived from State of Forest Report (2017). Forest Survey of India, Ministry of Environment, Forest and Climate Change, Government of India	23.5m
18.	Distance from dense forest with canopy cover (more than 40%)	Euclidean distance derived from State of Forest Report (2017). Forest Survey of India, Ministry of Environment, Forest and Climate Change, Government of India	23.5m
19.	Distance from Water	Euclidean distance derived from global surface water dataset (Pekel, JF., Cottam, A., Gorelick, N. et.al. High-resolution mapping of global surface water and its long-term changes. Nature 540, 418–422 (2016). https://doi.org/10.1038/ nature20584)	30m
20.	Distance from Open Natural Ecosystem (ONE)	Euclidean distance derived from ONE data. (Madhusudan, M. D., & Vanak, A. T. (2023). Mapping the distribution and extent of India's semi-arid open natural ecosystems. Journal of Biogeography, 50(8), 1377-1387. https://doi.org/10.1111/jbi.14471)	30m
21.	Distance from Seasonal Wetland (Seasonal water available)	Euclidean distance derived from Seasonal wetland data. (Lehner, B., Döll, P. (2004). Development and validation of a global database of lakes, reservoirs and wetlands. Journal of Hydrology 296(1-4): 1-22. https://doi.org/10.1016/j.jhydrol.2004.03.028)	~450m
22.	Grassland area	Derived from Landsat -8 data (Vermote, E., Justice, C., Claverie, M., & Franch, B. (2016). Preliminary analysis of the performance of the Landsat 8/ OLI land surface reflectance product. Remote Sensing of Environment, 185, 46-56.)	30m
23.	Woodland area	Derived from Landsat -8 data (Vermote, E., Justice, C., Claverie, M., & Franch, B. (2016). Preliminary analysis of the performance of the Landsat 8/ OLI land surface reflectance product. Remote Sensing of Environment, 185, 46-56.)	30m
Human disturbance variables			
24.	Distance from Built-Up	Euclidean distance derived from Built-up extracted from Sentinel 2 Land use/ Land Cover dataset. (Karra, K., Kontgis, C., Statman-Weil, Z., Mazzariello, J. C., Mathis, M., & Brumby, S. P. (2021). Global land use/land cover with Sentinel 2 and deep learning. In 2021 IEEE international geoscience and remote sensing symposium IGARSS, pp. 4704-4707).	10m

S. No	Dataset	Source	Spatial Resolution
25.	Distance from cropland	Euclidean distance derived from Cropland extracted from Sentinel 2 Land use/ Land Cover dataset. (Karra, K., Kontgis, C., Statman-Weil, Z., Mazzariello, J. C., Mathis, M., & Brumby, S. P. (2021). Global land use/land cover with Sentinel 2 and deep learning. In 2021 IEEE international geoscience and remote sensing symposium IGARSS, pp. 4704-4707).	10m
26.	Distance from Protected Area Network	Data archived derived from Wildlife Database Cell, WII and Project Tiger database	
27.	Distance from Night Time light	Euclidean distance from night time light dataset. (C. D. Elvidge, M. Zhizhin, T. Ghosh, F-C. Hsu, "Annual time series of global VIIRS nighttime lights derived from monthly averages: 2012 to 2019", Remote Sensing, 2021, 13(5), 922.)	~500m
28.	Human Footprint Index	Mu, H., Li, X., Wen, Y. et al. A global record of annual terrestrial Human Footprint dataset from 2000 to 2018. Sci Data 9, 176 (2022). https://doi.org/10.1038/s41597-022-01284-8	1000m
Topographic/Geographic variable			
29.	Elevation	NASA Shuttle Radar Topography Mission (SRTM) (2013). Shuttle Radar Topography Mission (SRTM) Global. Distributed by Open Topography. https://doi.org/10.5069/G9445JDF.	30m
30.	Terrain Ruggedness Index	Derived from Elevation data	30m
31.	Drainage Density	Derived from Elevation data	1000m

Phase III – Field Survey for Density Estimation:

Phase III involved surveys to estimate the abundance of tigers, leopards, and ungulates. These surveys were conducted in tiger reserves and other key sites. The line transects walked during Phase I (Figure I. 1) were simultaneously used in Phase III to estimate ungulate abundances through distance sampling. Transects were systematically distributed, with each forest beat sampled by one or two transects, depending on the beat's size and habitat type (Jhala *et al.*, 2013). Each transect was walked with a minimum of three temporal replicates during periods of peak herbivore activity. In areas with low sightings, more than three replicates were conducted. Data recorded included: 1) species sighted, 2) group size, 3) the number of adults and young in each group, 4) radial distance to the group center measured with a laser range finder, 5) the group's bearing using a compass, and 6) the walk bearing of the transect.

The tiger and leopard densities were estimated based on Spatially Explicit Capture Recapture models based on camera traps data, with camera traps placed at 32,803 locations across 175 sites (Figure I. 2). These camera traps were systematically distributed within 2 km² cells, which were subsets of the fixed 25 km² cells, with at least one pair of cameras deployed in each cell (Qureshi *et al.*, 2023, Qureshi *et al.*, 2024). The camera trap surveys also provided data on ungulates and other species, offering an index of relative abundances.

I. 3. ANALYSIS

Density Surface Modelling

The spatial densities of the ungulates were estimated using conventional line transect based distance sampling using Density Surface Modelling (DSM) (Miller *et al.*, 2013). This approach enables managers and researchers to visualize as well as analyze how ungulate densities vary across the habitat in their protected areas for informed and adaptive decision-making. The prey population is estimated only in areas of the tiger range forests that are occupied by prey.

Data processing

Line transects were divided into 250-meter segments. Various spatial covariates were used in the modeling (Table I. 1). A prediction grid (250 m × 250 m) was created in ArcMap (version 10.8.2). The remotely sensed environmental covariates (varying resolutions) were rescaled to 250 m resolution to match the grid size (250 m × 250 m) for ungulate density surface modeling. The site level abundance was estimated at 250 m. resolution and the abundance estimate was summed to 25 km². These estimates are used for training landscape level model. The landscape model incorporates ungulate encounter rate from Phase I data (25 km²).

Data Analysis

Density Surface Models are a two-stage approach designed to estimate the spatial distribution and abundance of wildlife populations. The first stage involves modeling the detection probality using distance sampling methods, while the second stage uses the estimated detectability to model the spatial distribution of the species.

In the first step, the detection probability is modeled using r package distance. The rate of decreasing detectability with increasing distance from transact is modeled in this step (Buckland *et al*., 2001; Miller *et al*. 2013). The function is modeled with uniform, half-normal, and hazard-rate key functions with all three adjustment terms (*i.e.* cosine, simple polynomial and hermite polynomial) and selected the best model using lowest Akaike information criterion (AIC, Akaike, 1974), goodness-of-fit tests (Burnham *et al*., 1980) and visual inspection of the histogram.

In the second step, spatial modeling with environmental covariates was done using the R package DSM (Miller *et al*., 2013). The count method of Hedley and Buckland (2004) was applied, using the number of animals in each segment as the response variable in the density surface model. The number of animals (response variable) for each segment was related to the predictor variables through Generalized Additive Models (GAMs) (Wood, 2017), using a Poisson distribution and a logarithmic link function. Model selection was based on the lowest AIC value while accounting for the deviance explained by each model, ecological plausibility and the P-value of each spatial variable. The abundance of ungulates in the study area (Phase III sampled sites) was estimated as the sum of the predicted abundance in each grid cell of 250 m, relying on the spatial model chosen for inference. Based on the predictions from the density surface model, and taking into account the values of each variable in each grid cell, abundance maps were created in GIS software. Variance for the density estimates from the DSM analysis was obtained through the variance

propagation method described by Bravington *et al*.(2021), which enables prompt variance estimation for both global and sub-area density estimates.

Landscape-level ungulate density estimation was performed by modeling the tiger reserve's DSM prediction as a function of covariates. The ungulate encounter rate from Phase I data and the available suitable habitat, as determined by the habitat mask, were used as covariates in the Generalized Additive Model (GAM) to predict the ungulate density over the landscape.

Model Validation: The ability of the model to predict ungulate density was assessed using a Leave-one-out (LOO) cross validation analysis wherein each value was dropped, re-computed the best model, and it was used to predict the ungulate density of the excluded value (Krebs, 1989). The predictive performance was summarized by the predicted sum of squares R^2 (PRESS R^2) and correlation of LOO model estimated ungulate density with DSM ungulate density (Figure I. 3). The sites where data were not suitable for DSM analysis had their chital and sambar densities predicted using the landscape prediction model. Hence, 25 km^2 density maps are provided.

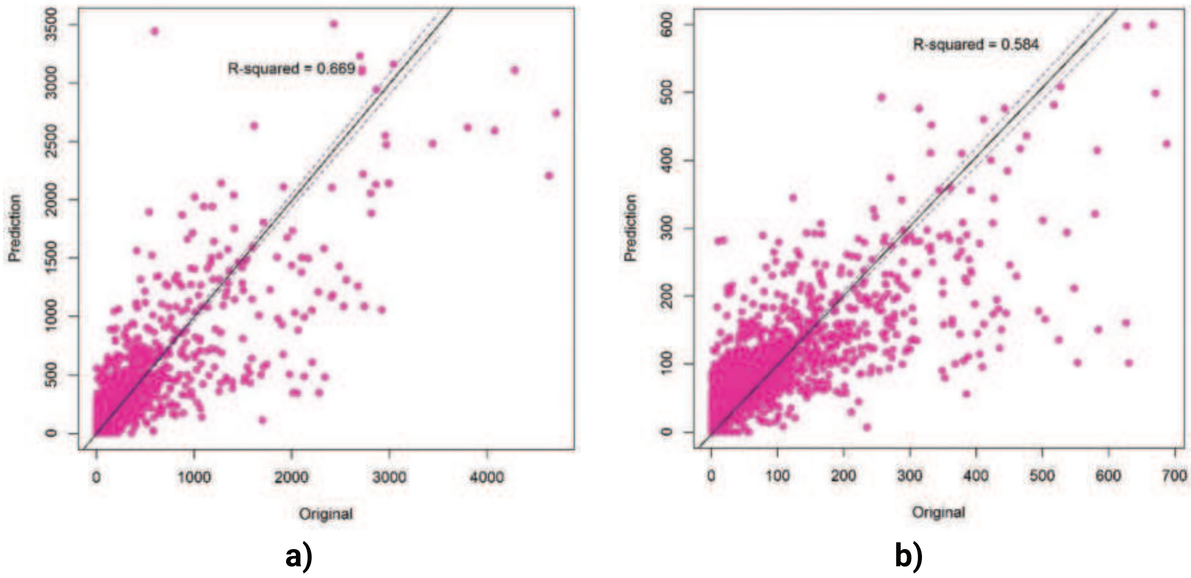

Figure I. 3: Leave one out model validation result a) Chital b) Sambar

Relative abundance estimation using camera trap data

For sites where line transect data was not suitable for DSM analysis, and landscape prediction model was not done, we assessed species distribution and relative abundance using camera trap data. Abundance indices were employed to characterize the spatial distribution and abundance of species, operating under the assumption that these indices scale consistently with actual abundance (Güthlin *et al.*, 2014). The program calculates the number of trap-days for each camera from the time of deployment to retrieval. For each photo capture, the species, date, and location were recorded. Independent events were defined as consecutive photographs of the same species (or individual, if identifiable) taken more than 15 minutes apart at the same camera trap.

The number of independent photo-captures of a species was used to calculate relative abundance indices (RAI) for terrestrial mammals. This is defined as the number of independent photo-captures per 100 trap nights. It is calculated as:

RAI = 100 × (A/N), where A is the number of independent photo captures, and N is the number of trap nights (Carbone *et al.*, 2001; O'Brien *et al.*, 2003).

The RAI map was generated using the Inverse Distance Weighted (IDW) technique by interpolating the RAI values for each ungulate species separately. We extrapolated the RAI values using a constant search radius of 2 km.

Species Distribution modelling

To model the distribution of herbivores, species photo-captures and secondary source data were employed using Maximum Entropy Species Distribution Modelling (MaxEnt, Version 3.4.4) (Phillips and Dudík 2008; Elith *et al.*, 2011; Phillips *et al.*, 2017). MaxEnt, a machine learning software, was used to establish relationships between known occurrence locations and background data with environmental covariates (Table I. 1) related to species ecology. This model was then used to predict the potential distribution of the species across the modeled space (Phillips and Dudík, 2008). Prediction has been done only for those areas where historic presence of the species was recorded. The Linear, Quadratic, Product, and Hinge features of the MaxEnt program have been employed in modelling. For model training, 70% of the data was used, the remaining 30% data was used for test model predictions. This approach aimed to improve the habitat-specific predictions for species potential habitats.

To reduce autocorrelation in the presence of location data, rarefying the location data using the SDM toolbox V2.5 (Brown, 2015) was done, ensuring that the minimum distance between points is approximately 1 kilometre. A Spearman's correlation test is performed using the "corr" package (Wei, 2024) in R (R version 4.3.2). This corelation test is used to select environmental covariates to reduce multi colinearity and retain ecologically meaningful variables for potential habitat of the target species.

SECTION II

Ungulate Ecology and Habitat Suitability in India

Shravana Goswami, Sumandrita Banerjee, Vaishnavi Gusain, Omkar Nar, Dhruv Jain, Abhishek Shukla, Rohan Desai, Stuti Anjaria, Juri Roy, Richard Sangma, Ayan Khanra, Gaurav Shinde, Anshuman Gogoi, Ujjwal Kumar, Vishnupriya Kolipakam , Qamar Qureshi, Yadvendradev Jhala

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II. 1. CERVIDAE (DEER)

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BARASINGHA (*Rucervus duvaucelii*)

Conservation status

Wildlife (Protection) Act, 1972: Schedule I

CITES: Appendix I

IUCN Red List: Vulnerable (VU)

Introduction

The Barasingha, or swamp deer (*Rucervus duvaucelii*), is a deer species native to the Indian subcontinent, belonging to the order Artiodactyla and family Cervidae. Within the genus *Rucervus*, it shares lineage with Eld's deer (*R. eldii*). According to Groves (1982), there are three subspecies of Barasingha, with distribution details further elaborated by Qureshi *et al.* (2004):

- *R. d. duvaucelii* (Wetland Barasingha): Found in the Indo-Gangetic plain north of the Ganges in Nepal and India, but extinct in Pakistan.
- *R. d. branderi* (Hard-ground Barasingha): Native to central India between the Ganges and Godavari rivers.
- *R. d. ranjitsinhi* (Eastern Barasingha): Found in the Brahmaputra plain, likely separated from the nominate subspecies for a long period, occurring in India, and now extinct in Bangladesh (Groves, 1982).

Species Description

The name "Barasingha" refers to its distinct appearance, characterized by twelve tines in its antlers. Barasingha exhibits sexual dimorphism and seasonal changes in coat coloration. Their dorsal fur is typically reddish-brown, fading to creamy or white on the ventral side (Lydekker, 1907; Schaller, 1967; Martin, 1977; Gopal, 1995). Newborn fawns have white spots. Primarily diurnal, barasingha have moderate vision and hearing, but a highly developed sense of smell (Gopal, 1995).

Females reach reproductive maturity at two to three years of age, while males begin breeding after four years (Schaller 1967; Martin 1977; Schaaf 1978; Qureshi *et al*., 1995). Barasingha are monoestrous and give birth to a single fawn after a gestation period of 240 to 250 days (Asdell, 1964). The reproductive rate ranges from 20 to 45 fawns per 100 hinds (Schaller 1967; Martin 1977; Schaaf, 1978; Singh, 1984; Sankaran ,1989; Qureshi *et al*., 1995). Barasingha are polygynous, and both sexes follow a linear dominance hierarchy (Schaller 1967; Martin 1977; Schaaf 1978; Singh 1984; Qureshi *et al*., 1995). Stags establish dominance through sparring and size displays, while females assert dominance by displacing others from preferred feeding and resting areas, often using physical actions such as butting and kicking (Singh 1984; Qureshi *et al*., 1995).

Mating behavior varies between subspecies. In *R. d. duvaucelii* and *R. d. branderi*, mating occurs in winter, with stags entering the rut and hard antler stage by September and beginning their distinctive bugling calls around mid-August (Schaller, 1967; Martin, 1977; Schaaf,1978; Singh, 1984; Qureshi *et al*., 1995). These calls peak between mid-October and November and can extend into April. Rutting begins in August-September for *R. d. duvaucelii*, early December for *R. d. branderi*, and April for *R. d. ranjitsinhii*. Antler shedding follows, with timing varying by subspecies: mid-January, late April, and early October, respectively (Brander, 1923; Finn, 1929; Champion, 1934; Schaller 1967; Prater 1980; Martin, 1977; Schaff, 1978; Singh 1984; Gopal, 1995; Qureshi *et al*., 1995). Stags often mark their territory by rubbing their bodies and necks against tall grasses and engage in dominance battles at wallow sites (Singh, 1984; Qureshi *et al*., 1995). They also carry vegetation on their antlers, potentially enhancing their size appearance (Schaller, 1967; Martin, 1977; Singh, 1984; Qureshi *et al*., 1995). Female behavior during mating season is subtler, as they typically allow only dominant stags to mate.

Fawning periods also vary by subspecies, with *R. d. duvaucelii* fawning from July to August, *R. d. branderi* from September to October, and *R. d. ranjitsinhii* from March to April (Schaller, 1967; Martin,, 1977; Schaff 1978; Singh, 1984; Gopal, 1995; Qureshi *et al.*, 1995). Barasingha is a habitat specialist and an obligate grassland-dwelling herbivore, typically found in open forests with abundant grasses, as well as marshy and swampy grasslands (Schaller, 1967; Martin, 1977; Schaaf, 1978; Singh, 1984; Gopal, 1995; Qureshi *et al.*, 1995). Their diet mainly consists of grasses, aquatic plants, herbs, and shrubs. Group sizes fluctuate seasonally, with smaller groups observed during the rutting period in winter and late monsoon, and larger gatherings in summer when new growth emerges in burnt grasslands (Martin 1977; Schaaf, 1978; Singh, 1984; Sankaran 1990; Qureshi *et al*., 1995). The subspecies *Rucervus duvaucelii branderi* tends to form smaller groups compared to *R. d. duvaucelii* and *R. d. ranjitsinhii*, likely due to differences in grassland structure and habitat management.

Distribution

Historically, the swamp deer (barasingha) had a wide distribution across the Indo-Gangetic plains and the southern lowlands of the Himalayas, covering regions in India, Pakistan, southern Nepal, and Bangladesh (Groves, 1982; Sankaran,1989; Schaller, 1967). However, by the beginning of the 20th century, its current range had contracted to only about 4% of its historical extent (Mukherjee, 1974). Its former range included the marshy areas and grasslands of the Terai and Dooars regions in the northern part of the upper Gangetic plain (Mukherjee, 1974). The species was once abundant in the grasslands of northern India, the upper Sindh, and the swampy plains of the Indus Valley (Finn, 1929; Inglis, 1892). It was also widespread in Assam, extending into the eastern Sundarbans, including Munger in Bihar, and across the forested tracts of Central India (Jerdon, 1874). The barasingha's range stretched across the Central Indian Highlands, including districts such as Hoshangabad, Chhindwara, Balaghat, Seoni, Mandla, Durg, Bilaspur, Raipur, and Bastar in Madhya Pradesh, with reports of their presence in parts of Maharashtra (Forsyth 1889). However, throughout the 20th century, the species experienced significant population decline and range contraction (Duckworth *et al*., 2015). Currently barasingha is present in Kaziranga and Manas in Assam, Dudhwa and Pilibhit in Uttar Pradesh, Kanha, Bandhavgarh (reintroduced) and Satpura (reintroduced) in Madhya Pradsh.

Maxent Result

A total of 401 presence points of Barasingha were used to build up the species distribution model. Data and parameters of the MaxEnt model are provided in Table II. 1 and modelled distribution of Barasingha in the potential distributional range (model extent) are given in Figure II. 1.

According to MaxEnt estimates of the relative contribution of predictor variables (Table II. 1 & Table II. 2), the distance from the PA contributed the most (55.1 & 35.6 %) to the Barasingha habitat models. The response curves for the distance from protected areas (PAs) and the distance from night time light suggest that Barasingha prefers forested habitats, devoid of human disturbance. The response curves for the maximum temperature of the hottest month, minimum temperature of the coldest month, grassland area, and woodland area indicate that they prefer majorly grassland and the fringes between grassland and woodland. The seasonal water and elevation indicate that they prefer lower elevation, non ungulating terrain close to the water.

Table II. 1: Parameters used in MaxEnt setting for modelling of barasingha distribution in forested Landscapes of India

A) Central India landscape

Model setting	Values
Model features	Linear, Quadratic and Product
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity	0.282
Area under the ROC* Curve (AUC)	0.992

B) North East landscape

Model setting	Values
Model features	Linear, Quadratic and Product
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity	0.2227
Area under the ROC* Curve (AUC)	0.976

Table II. 2: Contribution percentage of covariates to the best model explaining barasingha distribution

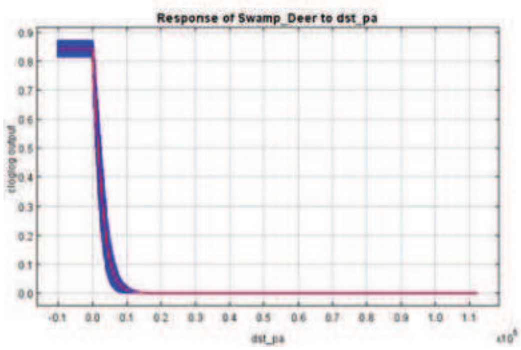
A) Central India landscape

Covariates	Percent contribution	Permutation contribution
Distance from protected area	55.1	93.1
Distance from night time light	15.7	1.7
Grassland Area	13.2	1.4
Min Temperature of Coldest Month (BIO6)	5.1	0.4
Elevation	4.1	1.3
Max Temperature of Warmest Month (BIO5)	3.9	1.5
Woodland Area	1.8	0.3
Distance from seasonal water available	1.2	0.4

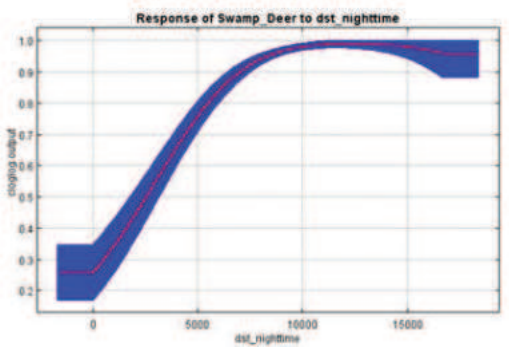
B) North East landscape

Covariates	Percent contribution	Permutation contribution
Distance from protected area	35.6	43.3
Max Temperature of Warmest Month (BIO5)	33.5	8.3
Grassland area	18.1	7
Distance from seasonal water available	4.8	5
Woodland area	4.2	6.3
Min Temperature of Coldest Month (BIO6)	2.7	9.2
Elevation	1.7	20.7

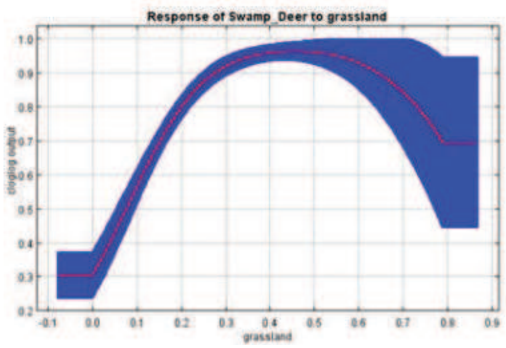
A) Central India landscape



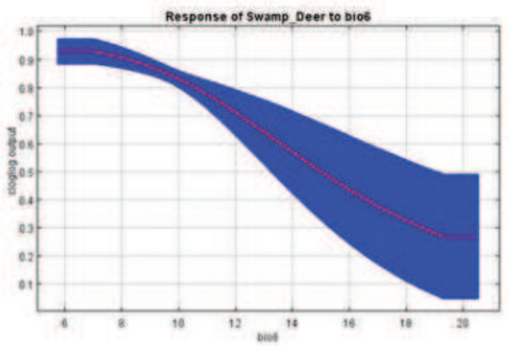
A)



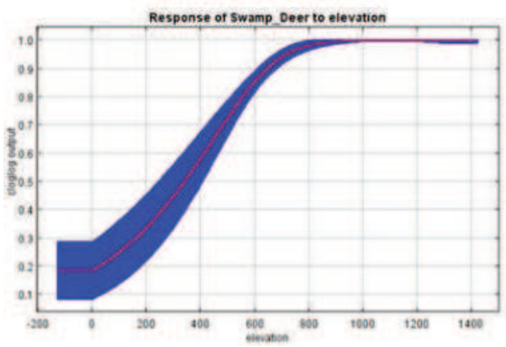
B)



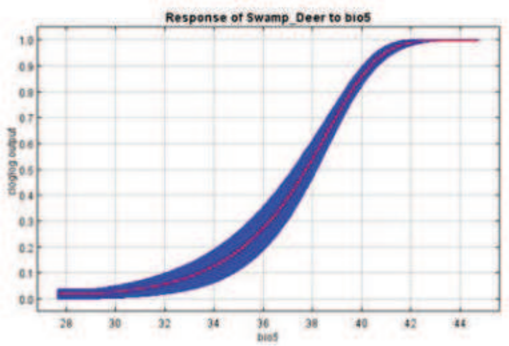
C)



D)

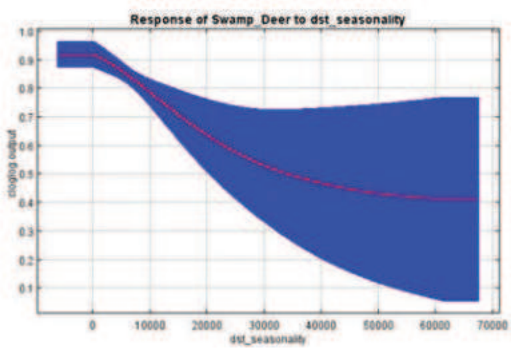


E)



F)

G)



H)

B) Terai and North East landscape

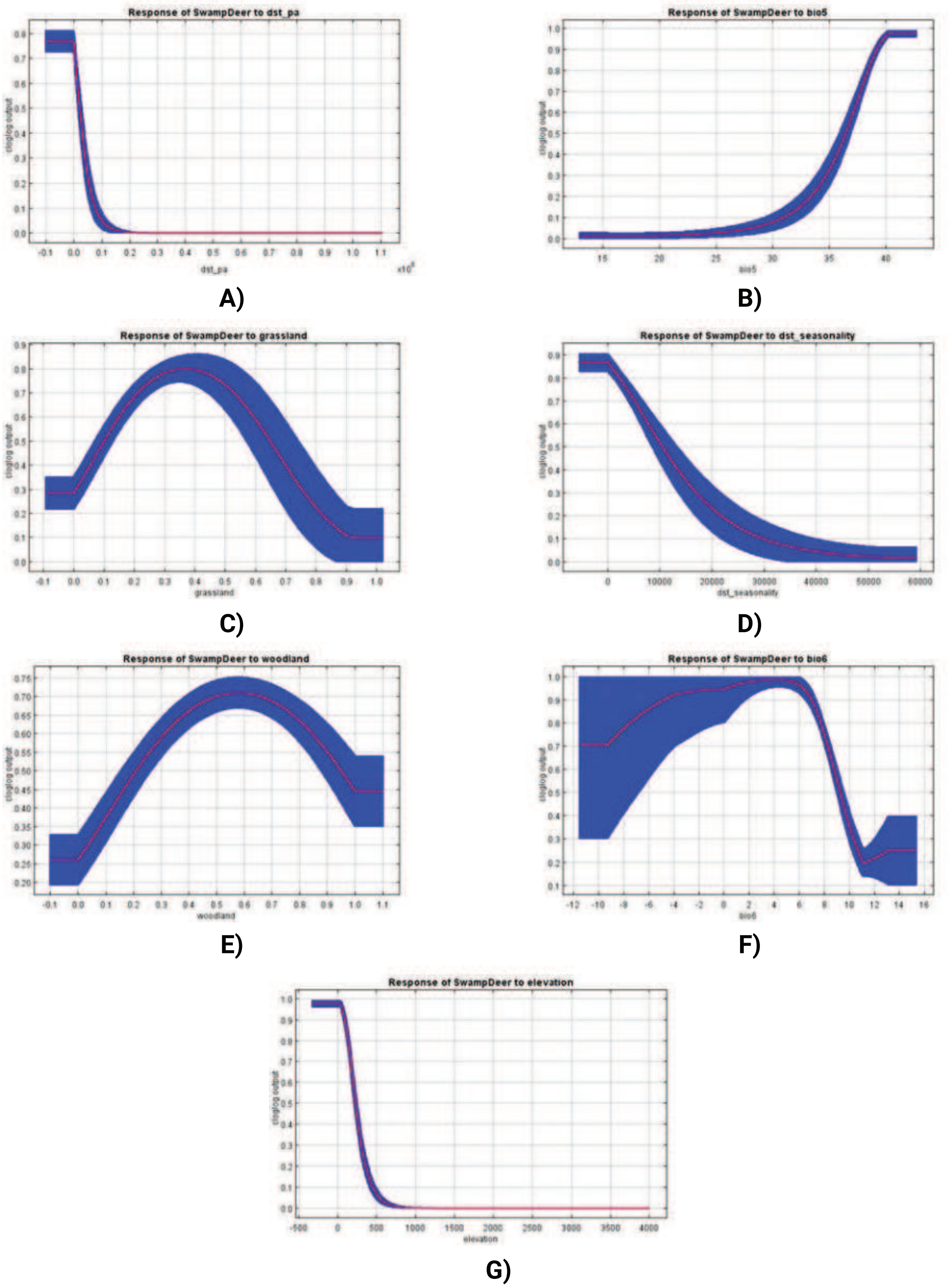


Figure II. 1: Relationship of spatial covariates used in the best fit MaxEnt model explaining barasingha habitat suitability across India

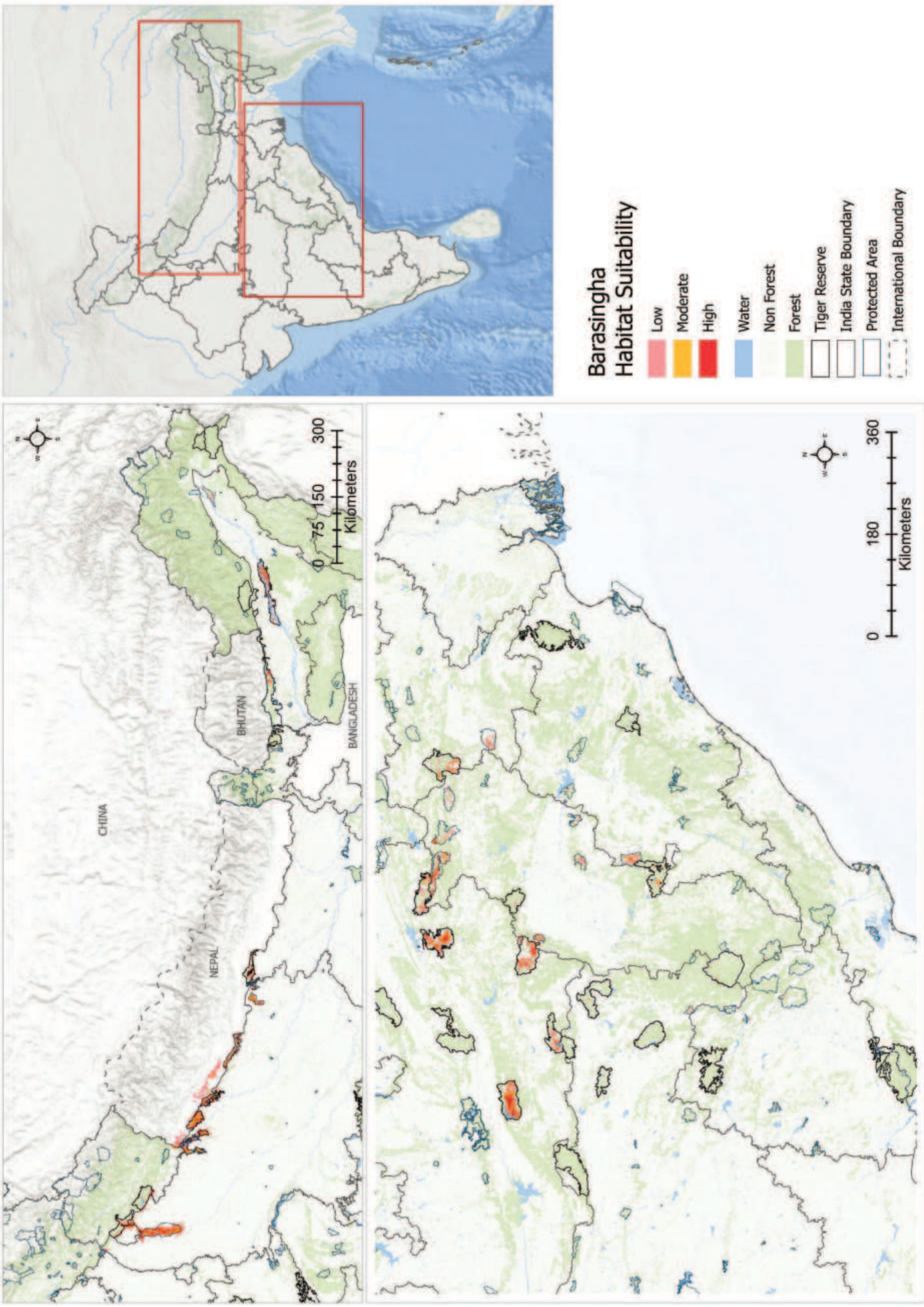


Figure II. 2: Modelled habitat suitability of barasingha across the India using MaxEnt

BARKING DEER (*Muntiacus muntjak*)

Conservation status

Wildlife (Protection) Act, 1972: Schedule I

IUCN Red List: Least Concern (LC)

Introduction

Barking deer or Indian Muntjac is one of the smallest deer of the Indian subcontinent. It has the lowest recorded chromosome in mammals. The barking deer is known as the most primitive member of the Cervidae family, (Barrette, 1977; Colber, 1969). Barking deer belongs to the genus *Muntiacus*, with three different subspecies of muntjac previously recognized based on morphological and geographic variation (Cahalene and Whitehead, 1972; Singh *et al*., 2021):

- *Muntiacus muntjac vaginalis* (Mainland red muntjac) – It has the widest distribution among all the subspecies. It is found across north, north east & central India.
- *Muntiacus muntjac aureus* (Himalayan red muntjac) – Found in the North, & North-Western part of India (*i.e.*, Uttarakhand, Punjab, and Himanchal Pradesh).
- *Muntiacus muntjac malabaricus* (Western Ghats & Srilankan red muntjac) – Restricted to southern India and Western Ghats.

Recent phylogenetic studies suggest that these are not subspecies but genetically distinct species. Martins *et al*., (2017) identified three major mitochondrial lineages among red muntjacs, while Singh *et al*., (2021) confirmed the Himalayan red muntjac (*M. aureus*) as a distinct lineage that diverged from the mainland form around 1.01 million years ago. A species of leaf muntjac (*Muntiacus putaoensi*), commonly found in Indo-Malayan eco-zone has been recorded in hill forests of Arunachal Pradesh and Nagaland (Datta *et al*., 2003; Choudhury, 2007). These findings support their recognition as separate species, highlighting the need for region-specific conservation strategies.

Species Description

Barking deer can be easily identified by their distinctive bony, hairy pedicels that form dark ridges along the sides of their faces, earning them the nickname "rib-faced deer." Males have small, unbranched antlers that grow to about 15 cm in length, while females possess bony ridges with tufts of hair in place of horns. They have a reddish-brown coat and greyish-white underparts; their coat gets darkened with age. Their long tongues and canines in the upper jaw are used by males for fighting. When alert, they raise their tails, revealing a white scut (Bahuguna and Mallik, 2010).

Barking deer measure between 89-135 cm (35-53 in) in length, with adult males standing 55-65 cm (21-25 in) at the shoulder and females measuring 40-57 cm (15-22 in). Their weight ranges from 20 to 25 kg (Bahuguna and Mallik, 2010). Barking deer are primarily diurnal and tend to be solitary, though they may form pairs during the breeding season or be seen with mothers and their young. Female barking deer reach breeding age between 8 to 10 months and can breed year-round, with a gestation period of 210 days and a weaning period of 70 days (Menon, 2014). In the wild, barking deer have a life expectancy of less than 17 years (Huffman, 2004; Tacutu *et al.*., 2018).

Barking deer make distinctive, sharp dog-like barking calls in the presence of potential danger. These alarm calls can be made singly or combined into long sequences and may be heard from more than a kilometer away (Wiles and Weeks, 1981). The bark of a male is deeper than that of a female. The loud and hoarse mating call can be distinguished from the alarm call, which is a series of sharp and short barks (Bahuguna and Mallick, 2010).

Barking deer are not territorial. However, males have home ranges of 6-7 km^2 that they scent mark (Menon, 2014). The males engage in sparring (harmless combat between unequal individuals or between males with short antlers) as well as aggressive fighting (generally between large antlered males) (Barrette, 1977).

As nibblers, barking deer prefer feeding on tender leaves, twigs, seed pods and shrub fruits (Barrette, 1977). Their forage sites are associated with a higher density of trees and shrubs whereas bed sites have significantly taller and larger canopy for better concealment (Teng *et al*., 2004) as dense cover can minimize detection (Geist, 1974, Mysterud & Østbye, 1995).

Distribution

Barking deer is distributed throughout peninsular India, terai, north-east and the slopes of Himalayas. They inhabit tropical and subtropical deciduous forests, grasslands, savannah, scrub forests and co-exists with chital, sambar, hog deer. They also occur at higher elevations (Jhala *et al*., 2020). Like other small forest-dwelling ungulates, barking deer prefer thick cover to avoid predation (Jarman, 1974; Geist, 1974). The species is adaptable enough to survive in disturbed and fringe forest areas or near crop plantations.

Maxent Result

A total of 7749 presence points of barking deer were used to build up the species distribution model. Data and parameters of the MaxEnt model are provided in Table II. 3 and Table II. 4 and modelled distribution of barking deer in the potential distributional range (model extent) are given in Figure II. 4.

According to MaxEnt estimates of the relative contribution of predictor variables (Table II. 4), the distance from the forest contributed the most (34%) to the barking deer habitat model. The response curves for the distance from protected areas (PAs) and the human footprint index (26.4%) suggest that barking deer prefer forested habitats, can tolerate low levels of human disturbance, but avoid highly disturbed areas. The response curves for the maximum temperature of the hottest month (30.7%), NDVI pre-monsoon (6.5%), elevation (2%), and annual precipitation (0.5%) indicate that they prefer dense forests with moderate rainfall and hilly terrain, while avoiding arid and cold regions like those in Rajasthan, Gujarat, and the Upper Himalayas.

Table II. 3: Parameters used in MaxEnt setting for modelling of barking deer distribution in forested landscapes of India

Model setting	Values
Model features	Linear Quadratic and Product
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.4631
Area under the ROC* Curve (AUC)	0.722

Table II. 4: Contribution percentage of covariates to the best model explaining barking deer distribution

Covariates	Percent contribution	Permutation contribution
Distance from forest	34	59.5
Max Temperature of Warmest Month (BIO5)	30.7	6
Human foot print index	26.4	16.4
NDVI pre-monsoon	6.5	13
Elevation	2	3.5
Annual Precipitation (BIO12)	0.5	1.6

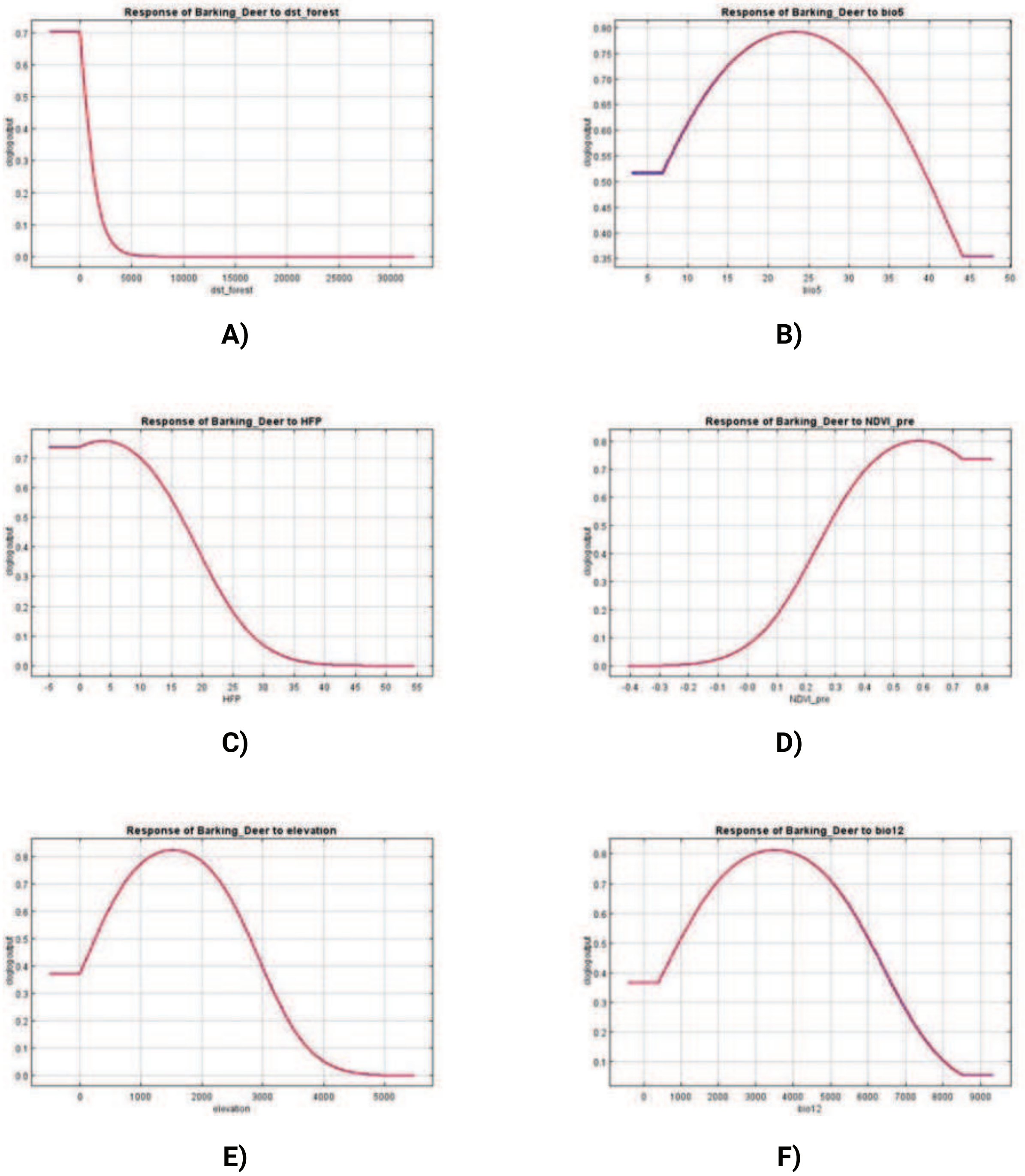


Figure II. 3: Relationship of spatial covariates used in the best fit MaxEnt model explaining barking deer habitat suitability across India.

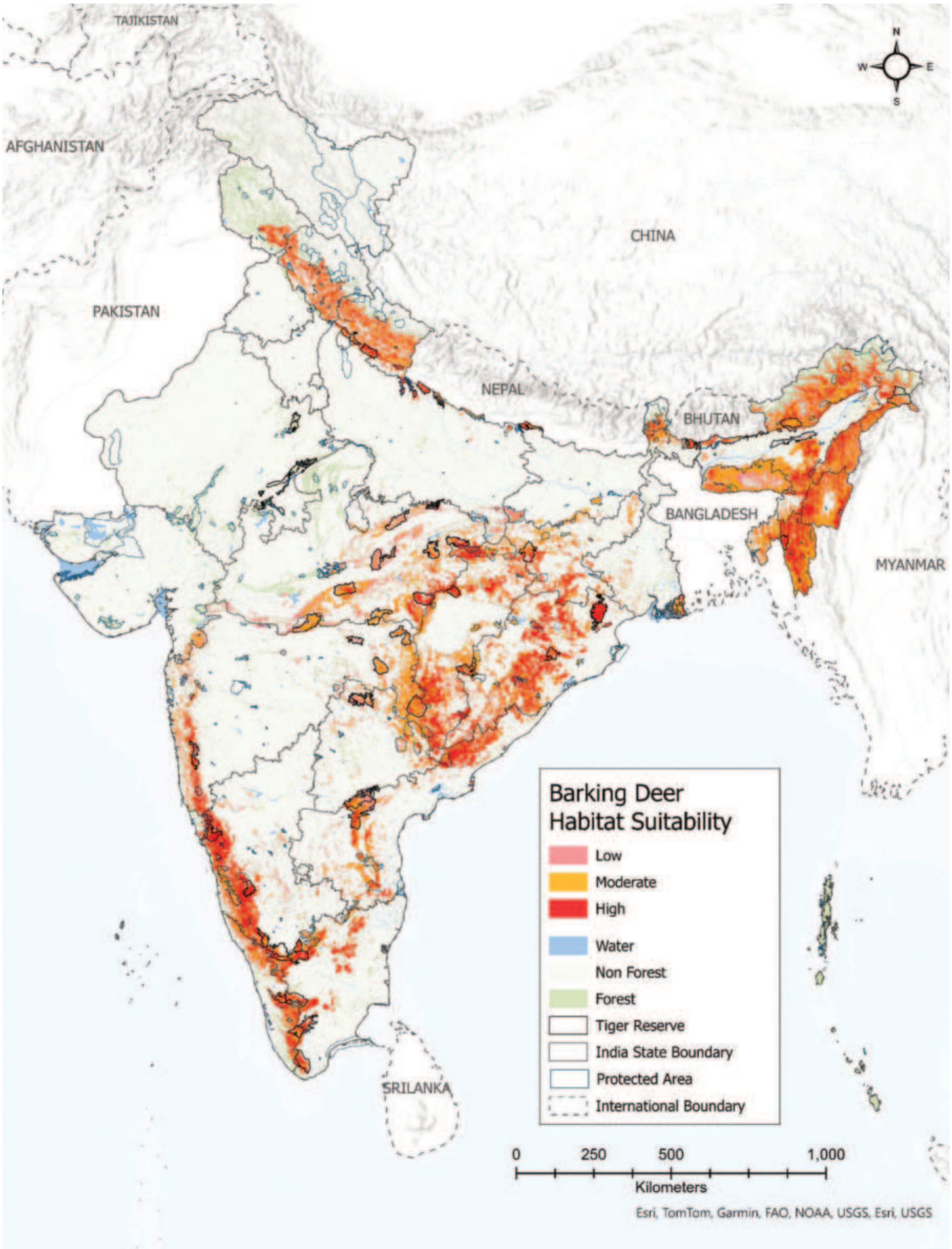


Figure II. 4: Modelled habitat suitability of barking deer across the India using MaxEnt

CHITAL (*Axis axis*)

Conservation status

Wildlife (Protection) Act, 1972: Schedule II

IUCN Red List: Least Concern (LC)

Introduction

The chital is classified under genus *Axis*, which includes four species, of which two occur in India, the hog deer (*Axis porcinus*) and chital (*Axis axis*).

Species Description

Chital, is a medium sized deer with a bright reddish-brown coat that have scattered white spots. Unlike other cervids the spots of chital (and sika deer) are retained throughout their life. These spots help them camouflage in Indian forests (Iverarity, 1895). Adult males have darker coat colour than female and feature black facial markings. The underparts, including the underside of the tail, are white, and there is a white "bib" on the upper throat. Males have large antler, although comparatively smaller than other cervids. The first set of antlers in yearlings consists of simple spikes, usually less than 5 inches long. Their body sizes generally range between 40 to 60 kg, although large, well-grown stags may weigh more than 90 kg. Female chital are almost 35% lighter than male (Ables, 1977). Adult males reach a height of 90 cm and female 75 cm (Graf and Nicholes, 1966).

Chital live in social groups and may even form temporary herds of 100-200 individuals during periods of high forage abundance. The basic group composition is a matriarchal family group with females and their fawns from the current and previous year. A typical herd comprises a few family groups along with individual deer of mixed ages and sexes. An interesting association between langur and chital is observed where langurs feed in trees, and chital frequently gather beneath to pick up the leaves and fruits dropped by these langurs (Newton, 1989).

Seasonality is observed in chital rutting and fawning behaviour, primarily influenced by resource availability. The gestation period for females is 227 days, after which they give birth to one fawn, though rarely twins are also observed. Chital is the most abundant ungulate species in India. Being a prolific breeder (Prater, 1965) their population grows exponentially under favourable conditions. Chital prefers open forests and grasslands (Mishra, 1982) and avoids steep terrains and evergreen forests (Mishra and Wemmer, 1987). Chital are preferential grazers (Dinerstein, 1980; Tak & Lamba, 1984; Mishra & Wemmer, 1987). Grasses constitute more than 60% of their diet in Kanha, Central India (Schaller, 1967, Awasthi, 2020). However, chital also readily browse on leaves from various trees, shrubs, vines, and seasonal fruits (Dinerstein 1979; Johnsingh & Sankar, 1991). Rodgers (1988) has categorized chital as a generalist feeder that takes grass, forbs, and woody plants in its diet while Hofmann (1985) classified them as intermediate/mixed feeders based on morphophysiological ruminant feeding types. Chital are most active in the morning and late afternoon, resting in shaded areas during the midday heat.

Distribution

The chital is found across India, Nepal, Bhutan, Bangladesh, and Sri Lanka (Grubb, 2005; Raman, 2013). Its western range extends to eastern Rajasthan and Gujarat. The northern boundary follows the bhabar-terai belt along the Himalayan foothills to western Assam. The eastern limit runs from western Assam to the Sundarbans in West Bengal and Bangladesh. Sri Lanka marks its southernmost range (Gee, 1964; Schaller 1967; Raman, 2013). In peninsular India, chital populations are sporadically distributed in forested areas (Sankar and Acharya, 2004). They have also been introduced to the Andaman Islands, Argentina, Armenia, Australia, Brazil, Croatia, Moldova, Pakistan, Papua New Guinea, Ukraine, Uruguay and the USA.

Maxent Result

A total of 6742 presence points of chital were used to build up the species distribution model. Data and parameters of the MaxEnt model are provided in Table II. 5 & Table II. 6 and modelled distribution of chital in the potential distributional range (model extent) are given in Figure II. 6.

According to MaxEnt estimates of the relative contribution of predictor variables (Table II. 6), the distance from the forest contributed the most (39.3%) to the chital habitat model. The response curves for the distance from forest, treecover (5.4%) and the distance to nightlight (0.5%) suggest that chital prefer wilderness, can tolerate low levels of human disturbance, but avoid highly disturbed areas. The response curves for precipitation of the wettest month (31.7%), the maximum temperature of the warmest month (10.9%), annual precipitation (3.1%), ruggedness (4.9%) and elevation (4.2%) indicate that they prefer open forested area, grassland with moderate rainfall and flat terrain. They avoid very dense forest and semi-desert or desert.

Table II. 5: Parameters used in MaxEnt setting for modelling of chital distribution in forested landscapes of India

Model setting	Values
Model features	Linear Quadratic and Product
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.63
Area under the ROC* Curve (AUC)	0.754

Table II. 6: Contribution percentage of covariates to the best model explaining chital distribution

Covariates	Percent contribution	Permutation contribution
Distance from Forest	39.3	72.5
Precipitation of Wettest Month (BIO13)	31.7	3.2
Max Temperature of Warmest Month (BIO5)	10.9	2.4
Treecover	5.4	3.1
Ruggedness	4.9	8.3
Elevation	4.2	2.6
Annual Precipitation (BIO12)	3.1	6.6
Distance from Night time light	0.5	1.4

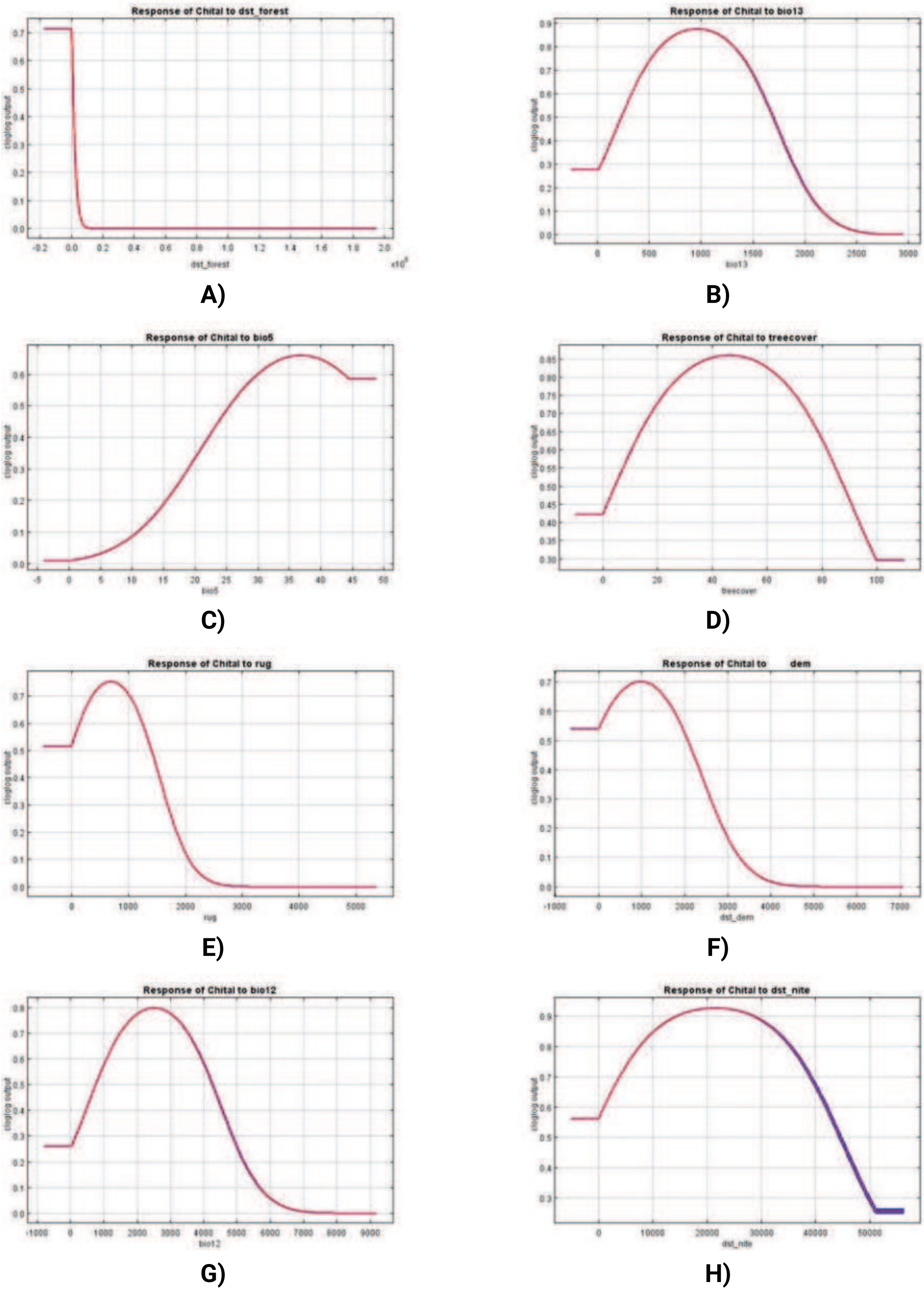


Figure II. 5: Relationship of spatial covariates used in the best fit MaxEnt model explaining Chital habitat suitability across India

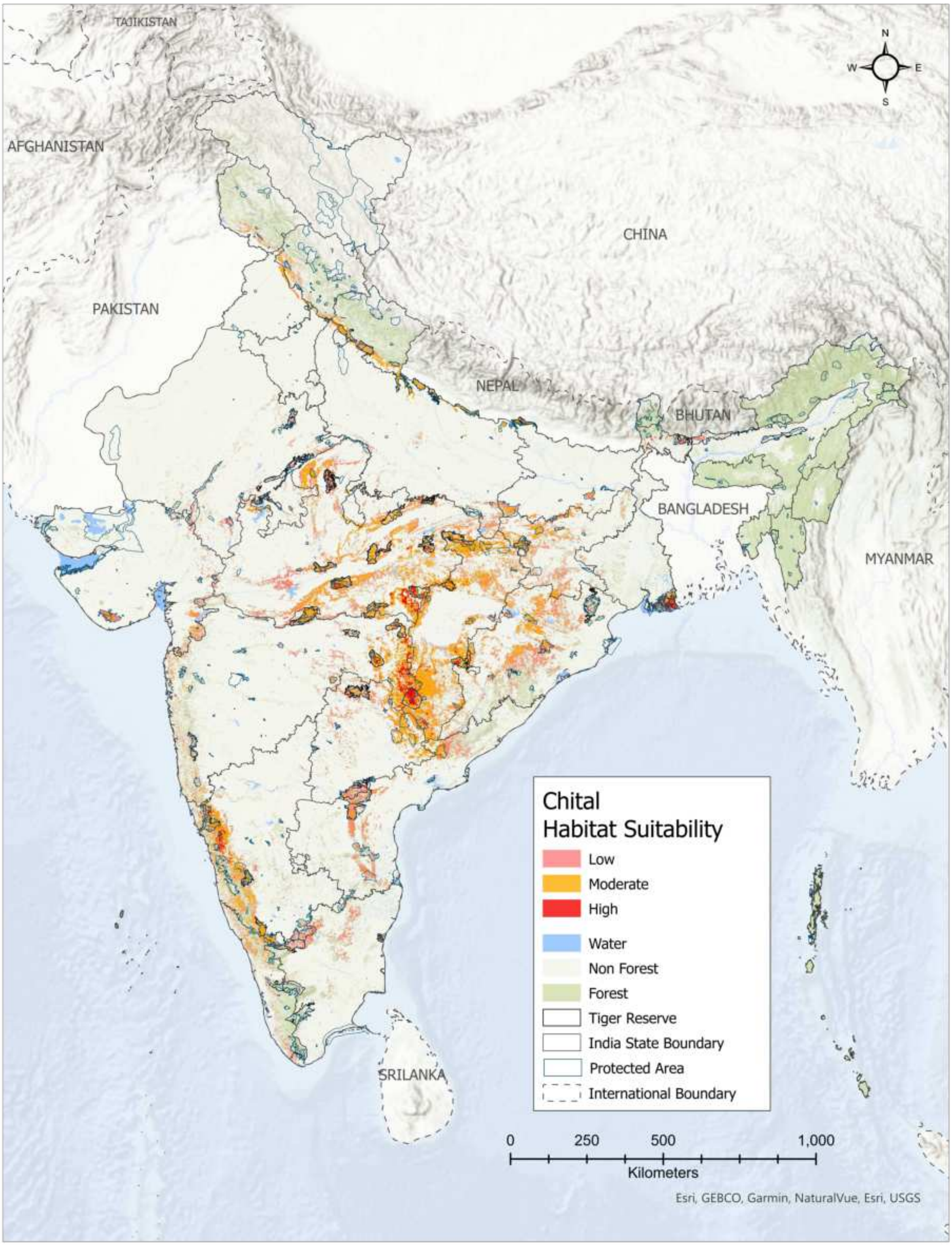


Figure II. 6: Modelled habitat suitability of chital across the India using MaxEnt

HOG DEER (*Axis porcinus*)

Conservation status

Wildlife (Protection) Act, 1972: Schedule I

CITES: Appendix I

IUCN Red List: Endangered (EN)

Introduction

The hog deer (*Axis porcinus*), a member of the Cervidae family, is a medium-sized grassland deer that serves as important prey for large carnivores, playing a vital ecological role within its ecosystem (Stoen & Wegge, 1996; Lovari *et al*, 2015).

Species Description

The hog deer is a grassland obligate species, primarily threatened by habitat degradation or loss and illegal hunting (Dhungel & O'Gara, 1991; Odden *et al*, 2005). It is more robust with shorter legs compared to chital, presenting a bigger and rounder shape than the barking deer. Though similar in size and shape to the compact barking deer, the hog deer is generally larger. Its stout rump and lowered forequarters contribute to a pig-like appearance.

During winter, the hog deer's coat becomes darker and glossier, while in summer, it exhibits a yellowish hue with faint white or pale brown spots. These patches may be along the median dorsal line or distributed across the body. Males from the north-eastern regions tend to be darker than those from the west. The hog deer lacks a neck ruff, and its facial glands are less developed. The underside of its body is white, and the broad, rounded ears have white fringes. The antlers are shorter than those of other large deer species but longer than its head and relatively thick. Additionally, it has a brown tail with a white underside, similar to that of the chital and barking deer (Menon, 2014).

In terms of body size, male hog deer have a head-to-body length of 140-150 cm, while females measure around 130 cm. The shoulder height for male ranges from 65 to 75 cm, and for females, it is between 55 and 65 cm (Menon, 2014). Males typically weigh 40 to 55 kg, while females weigh around 30 to 40 kg (Menon, 2014). The gestation period is approximately 220 to 230 days (Dhungel & O'Gara, 1991; Sheng & Ohtaishi, 1993), with females usually giving birth to a single calf (Dhungel & O'Gara, 1991). In the wild, hog deer can live up to 20 years (IUCN, 2015).

In undisturbed environments, hog deer are primarily active during the crepuscular period, with significant daytime activity observed, particularly in hot and wet seasons (Dhungel & O'Gara, 1991). However, in Cambodia, they have adapted to nocturnal activity and solitary living due to increased hunting pressure (Timmins, 2000). The main social unit is a female with her fawn. Larger groups do not form strong bonds and scatter when disturbed. Groups of up to 20 have been observed in Chitwan feeding on post-fire regrowth (Dhungel & O'Gara, 1991). Home ranges vary between five to 70 hectares (Dhungel & O'Gara, 1991; Odden *et al*., 2005). Most hog deer in Chitwan are sedentary (Dhungel & O'Gara, 1991), but farming cycles influence their movements in agricultural areas like Sri Lanka (McCarthy & Dissanayake, 1992). They migrate to higher grasslands during monsoon floods in India, Myanmar (Peacock, 1933). The rut occurs from September to October in Nepal and India, extending to February in China. Fawning occurs between April and May in Nepal and from April to October in China (Dhungel & O'Gara, 1991; Sheng & Ohtaishi, 1993). Weaning occurs at six months, and fawns reach sexual maturity by eight to twelve months, with a maximum lifespan of 20 years (IUCN, 2015).

The hog deer typically inhabits moist tall grasslands near rivers, reaching its highest densities in floodplain grasslands (Seidensticker, 1976; Dhungel & O'Gara, 1991; Karanth & Nichols, 2000; Odden *et al.*, 2005). It avoids closed-canopy forests and prefers grasslands (Peacock, 1933) dominated by *Imperata cylindrica* (Johnsingh *et al.*, 2004; Biswas, 2004). Primarily a grazer, the hog deer feeds on young grasses like *Imperata cylindrica* and *Saccharum spp*., as well as herbs, flowers, fruits, and browses (Bhowmik *et al*, 1999; Dhungel & O'Gara, 1991; Biswas, 2004; Wegge *et al*., 2006). It can cause damage to crops in scrub and cinnamon gardens in Sri Lanka (McCarthy & Dissanayake, 1992).

Distribution

Hog deer typically inhabit moist grasslands near rivers (Biswas & Mathur, 2000) and historically ranged widely across Southeast Asia, from Pakistan to southern China. However, its distribution has significantly diminished, leading to isolated and fragmented populations. The hog deer has experienced a considerable decline in recent decades, making it one of the most endangered large mammals in parts of its range. Primary threats to the species include hunting, habitat loss, and degradation, with hog deer being particularly vulnerable to hunting compared to other deer species in the region. Their wetland habitats have been largely lost due to agricultural expansion and urban development.

Historically, hog deer roamed from Pakistan through northern and northeastern India, including the Himalayan foothills, into non-Sundaic Southeast Asia and marginally into southern China. Currently, the species is nearly extinct east of Myanmar and is considered extinct in Thailand, where it has been reintroduced, and almost certainly in Vietnam and Laos (Humphrey and Bain, 1990; Duckworth *et al*., 1999; Tordoff *et al*., 2005). Recently, small populations have been discovered in Bangladesh and five areas of Cambodia (Khan, 2004; Maxwell *et al*., 2007; Timmins and Sechrest, 2010; Brook *et al*., 2015). Hog deer was introduced to Australia, the United States, and possibly Sri Lanka also (Moore and Mayze, 1990; Grubb, 2005; Vishvanath *et al*., 2014).

In Pakistan, isolated riverine grasslands along the Indus Valley and its tributaries serve as the primary habitat for hog deer, with smaller subpopulations found near the Indus mouth and north of Sukkur (Roberts, 1977). Although hog deer are listed in several protected areas, recent data on their populations are scarce. In India, they inhabit the Terai grasslands and floodplains of the Ganges and Brahmaputra rivers, from Punjab to Arunachal Pradesh, with significant populations in Dudhwa tiger reserve and the Pilibhit tiger reserve (Johnsingh *et al*., 2004; Tandon, 1989; Biswas, 2004). In Bangladesh, hog deer are now rare, primarily residing in protected areas like the Chittagong hill tracts (Khan, 2004), while in Cambodia, they survive in the floodplains and grasslands of Kratie Province (Timmins and Sechrest, 2010).

Maxent Result

A total of 667 presence points of Hog Deer were used to build up the species distribution model. Data and parameters of the MaxEnt model are provided in Table II. 7 & Table II. 8 and modelled distribution of hog deer in the potential distributional range (model extent) are given in Figure II. 9.

According to MaxEnt estimates of the relative contribution of predictor variables (Table II. 8), the distance from protected areas (PAs) contributed the most (76.7%) to the hog deer habitat model. The response curve for distance to PAs, along with distance from the forest (2.8%), suggests that hog deer prefer wilderness and areas devoid of human disturbance. The response curves for elevation (15.5%), maximum temperature of the warmest month (3%), NDVI post-monsoon (1.6%), and surface temperature (0.6%) indicate that hog deer primarily prefer open, warm, moist grassland areas at lower elevations, mainly found in the Tarai landscape and Brahmaputra floodplain areas. Being grazers, they primarily avoid open bare land and highly dense forest patches.

Table II. 7: Parameters used in MaxEnt setting for modelling of hog deer distribution in forested landscapes of India

Model setting	Values
Model features	Linear, Quadratic, Product and Hinge
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.1092
Area under the ROC* Curve (AUC)	0.967

Table II. 8: Contribution percentage of covariates to the best model explaining hog deer distribution

Covariates	Percent contribution	Permutation contribution
Distance from protected area	76.7	76.1
Elevation	15.5	9.2
Max Temperature of Warmest Month (BIO5)	3	7.1
Distance from forest	2.8	6.4
NDVI post-monsoon	1.6	0.9
Temperature	0.6	0.3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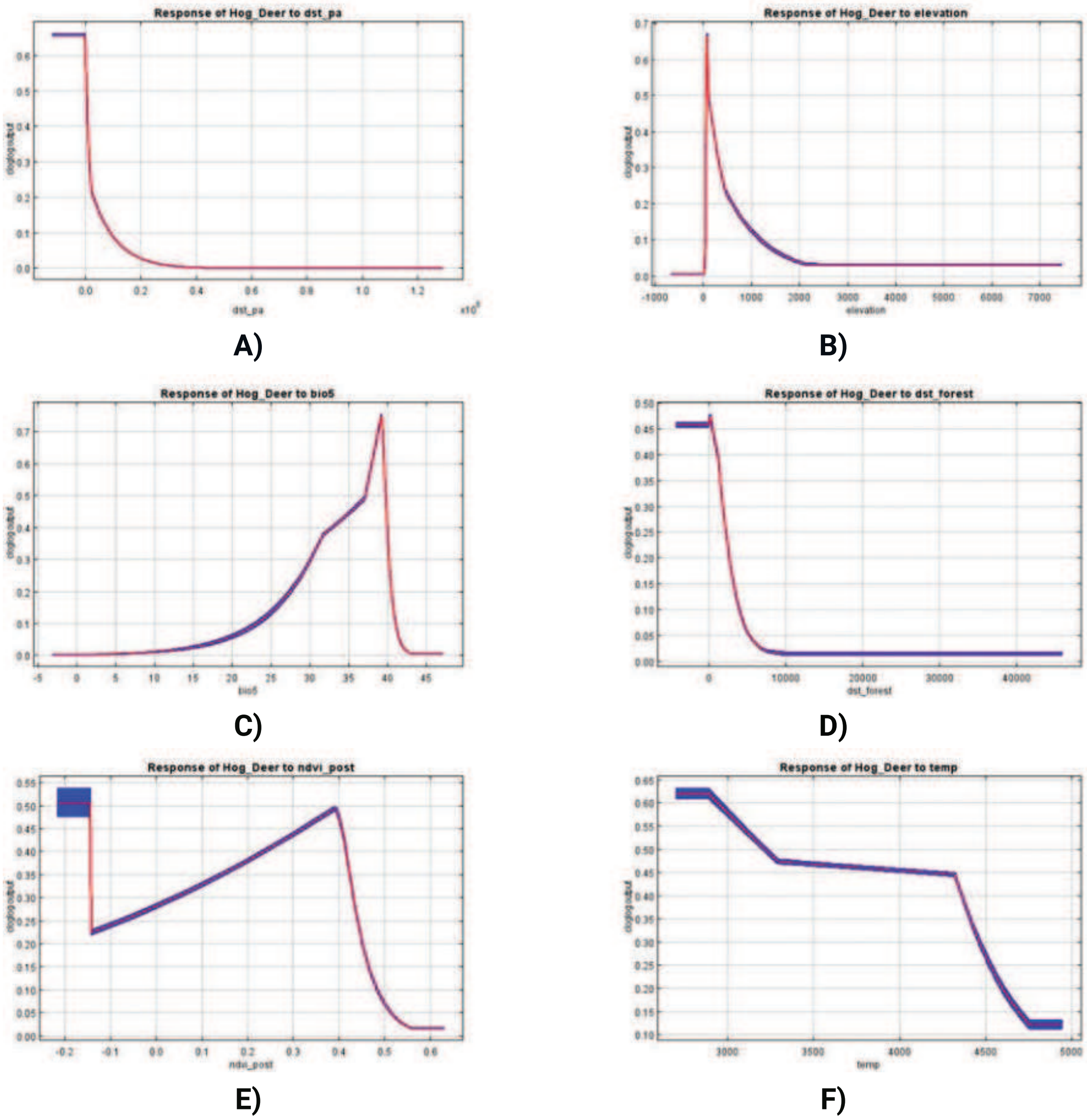


Figure II. 8: Relationship of spatial covariates used in the best fit MaxEnt model explaining hog deer habitat suitability across India

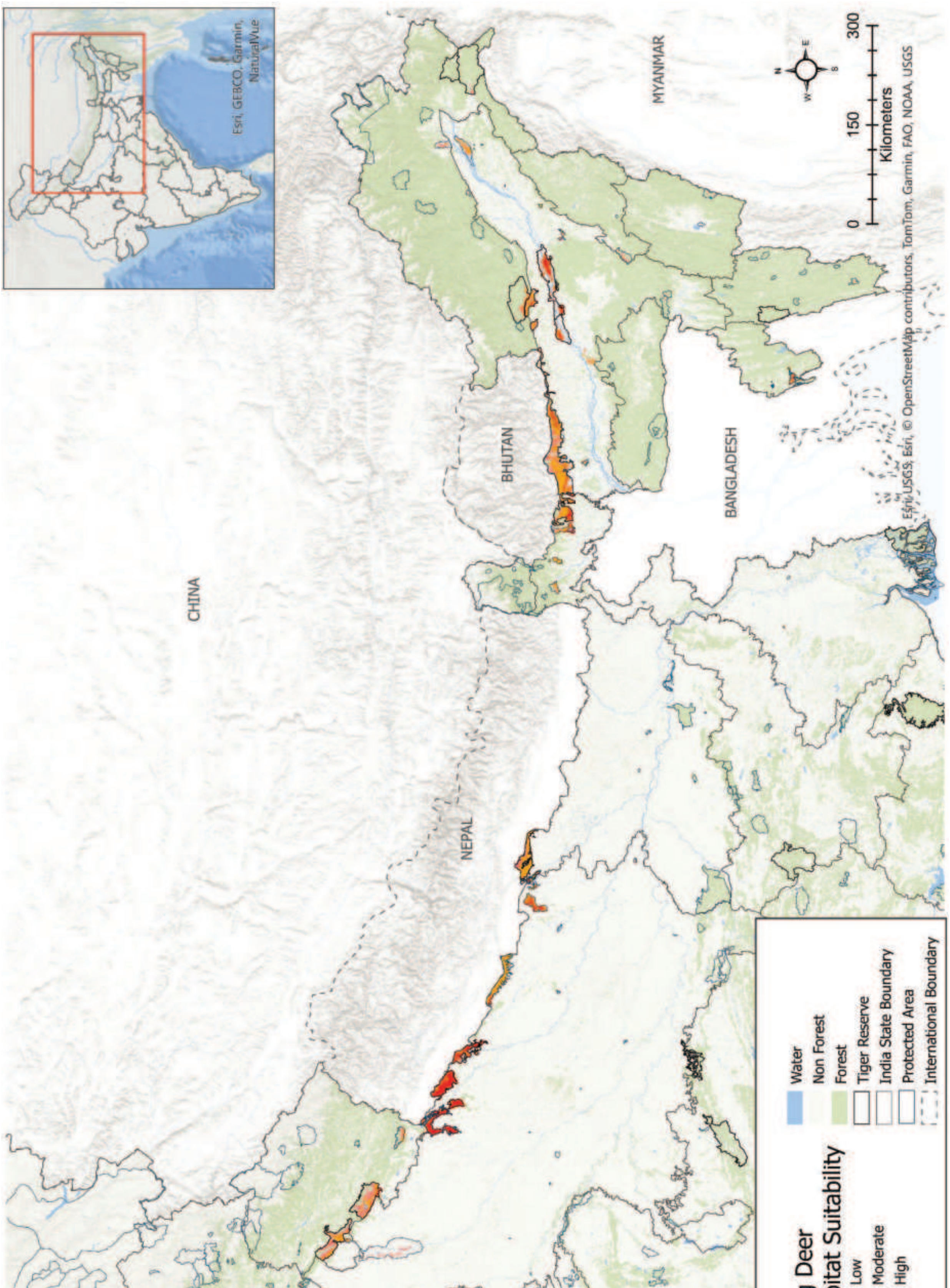


Figure II. 9: Modelled habitat suitability of hog deer across the India using MaxEnt

SAMBAR (*Rusa unicolor*)

Conservation status

Wildlife (Protection) Act, 1972: Schedule I

IUCN Red List: Vulnerable (VU)

Introduction

The Sambar deer (*Rusa unicolor*), is the largest and most widespread deer species in South Asia (Corbet *et al.*, 1992). Historically classified as *Cervus unicolor,* it was reclassified into the genus *Rusa* by Grubb in 1990 (Timmins *et al.*, 2015). Sambar has most widely but highly scattered distribution throughout the Indian subcontinent (Timmins *et al.*, 2015).

Species Description

Sambar have a head and body length ranging from 162 to 246 cm, a tail length of 25 to 30 cm, and a shoulder height of 102 to 160 cm (Nowak, 1999). Males typically weigh between 225 and 320 kg, while females weigh less than 225 kg (Sankar and Acharya, 2004). They have broad obovate ears that measure about half the length of the head, whitish at the base and inside (Lydekker, 1915; Brander, 1923; Schaller, 1967) and a black-tipped tail that is whitish underneath (Atkeson *et al*., 1988). Sambar has coarse and shaggy pelage, which exhibits considerable colour variation, ranging from yellowish-brown to brown, and can appear almost black or dark salty grey (Blanford, 1898). The belly often matches the colour of the rest of the body or is even darker, with some individuals displaying chestnut or whitish hues on the inner side of the buttocks and underparts (Lydekker, 1898; 1915). Females and young sambar deer have lighter body colours, with young individuals characterized by very light to no spots and a dark dorsal line (Brander, 1923). Males develop an “unkempt ruff” of long hairs on their throat and neck, sometimes tipped in gray (Blanford, 1898; Schaller, 1967). A distinctive feature of the sambar is the presence of a “sore spot,” a glandular structure measuring about 10-15 cm located on the throat, surrounded by a whorl of hair, which often exudes a whitish oily or watery substance from a blood-red spot (Davar, 1938; Geist, 1998; Kurt, 1978; Pocock, 1933; Schaller, 1967; U Tun Yin, 1967). Adult males possess antlers that are unique among cervids, exhibiting an ancestral condition with typically thirteen points that are rough and robust, featuring an anterior brow tine that emerges at an acute angle from the main beam (Blanford, 1898; Pocock, 1933). Although about 10% of males may have a fourteen-point antler (Ward, 1896; Brander, 1923) the average antler length is recorded at 109.8 cm (Leslie, 2010).

Sambar is mostly crepuscular, with significant nocturnal activity (Schaller, 1967; Duckworth pers. comm., 2008). They are known to be solitary, more often than in temporary congregations, with groups mostly formed of family associations (Schaller 1967; Karanth and Sunquist, 1992). However, during peak summer, groups of up to 80-100 individuals can be seen in close proximity of large water bodies, as is common in Pench tiger reserve (Kumar, 2008). Being generalist herbivore ruminants, sambar incorporates a variety of dietary components as per availability (Geist, 1998; Schaller, 1967), including grasses and herbs as well as a great variety of shrubs and trees (Khan *et al.*, 1994; Schaller *et al.*, 1967; Srivastava *et al.*, 1990).

Sambar breed seasonally in most areas (Timmins *et al.*, 2015) and exhibit a polygamous male-dominance system within dispersed facultative mating territories (Leslie, 2011). The rutting period of sambar is characterised by the presence of hard antlers, sore patches, territoriality wallowing as well as courtship (Rai *et al.*, 2021), swollen necks, strong odour, everted periorbital glands and increased aggression (Leslie, 2011). After a gestation period of approximately 259 ± 12 days (Dahlan and Dawend, 2013), the female usually give birth to a single fawn. Peak fawning occurs during the summer months of March to June (Rai *et al*., 2021). In the wild, sambar deer have a lifespan of about 12 years (Berwick, 1974).

Sambar inhabit a variety of forest types in India, ranging from thorny arid forests of Gujarat and Rajasthan to the deciduous forests of peninsular India, pine and oak forests of the Himalayan foothills the evergreen and semi-evergreen forests of northeastern India and the Western Ghats (Schaller, 1967; Sankar, 2004). They are observed to thrive best in well-watered moist deciduous forest landscape, across most of their range.

The sambar population is stable within protected areas but outside their population is low and declining (Qureshi *et al.*, 2023). The increasing severity of hunting pressures, coupled with ongoing habitat loss, has led to a substantial decline in sambar populations (Wani *et al.*, 2020).

Distribution

The native range of the sambar extends from the Indian subcontinent, including India and Sri Lanka, eastward along the southern Himalayas through Nepal and Bhutan, and further into South China, Taiwan, Bangladesh, and mainland Southeast Asia, including Myanmar, Thailand, Laos, Cambodia, Vietnam, and Malaysia, as well as the main islands of Indonesia and Borneo (Grubb, 2005). The species has also been introduced to the United States, New Zealand, and Australia (Rai *et al.*, 2019).

Maxent Result

A total of 14270 presence points of Sambar were used to build up the species distribution model. Data and parameters of the MaxEnt model are provided in Table II. 9 & Table II. 10 and modelled distribution of sambar in the potential distributional range (model extent) are given in Figure II. 11.

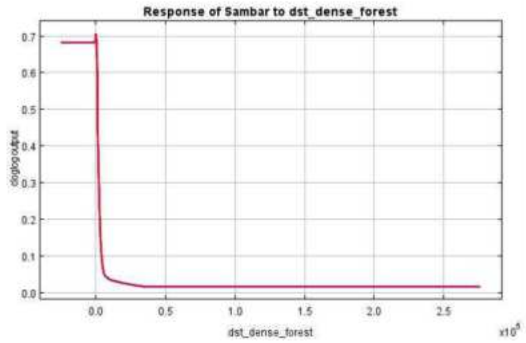
According to MaxEnt estimates of the relative contribution of predictor variables (Table II. 10), the distance from dense forest (90.8%) to the Sambar habitat model. The response curves of the distance from dense forest and human footprint index (4.1%) suggest that Sambar prefer dense vegetation and wilderness, and as human disturbance increases the suitability decreases. The response curves for the Minimum temperature of coldest month (3.7%), ruggedness (1.3%), NDVI pre monsoon (0.1) indicate that they can inhabit wider verity environmental conditions from semi-arid to evergreen, but increases toward dense moist forested area, and undulating terrain till some extent.

Table II. 9: Parameters used in MaxEnt setting for modelling of sambar distribution in forested landscapes of India

Model setting	Values
Model features	Linear Quadratic and Product and Hinge
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.54
Area under the ROC* Curve (AUC)	0.675

Table II. 10: Contribution percentage of covariates to the best model explaining sambar distribution

Covariates	Percent contribution	Permutation contribution
Distance from Dense forest	90.8	77.4
Human footprint index	4.1	8.8
Min temperature of coldest month (Bio6)	3.7	10
Ruggedness	1.3	2.7
NDVI pre monsoon	0.1	1.1



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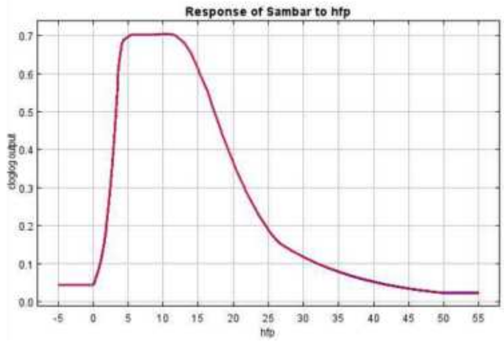

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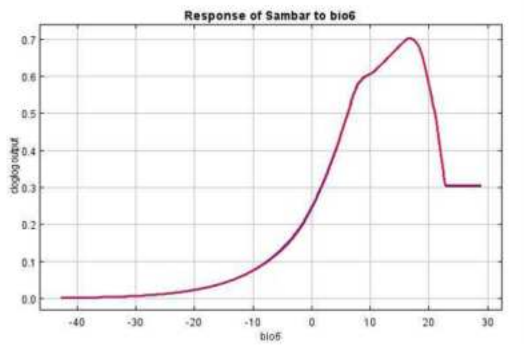

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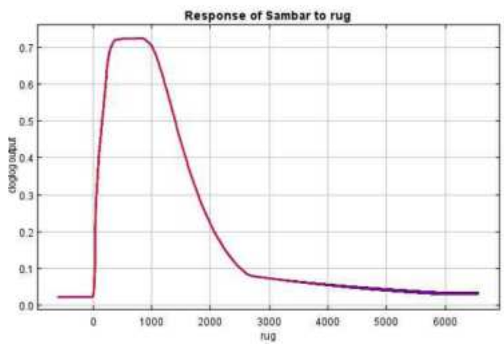

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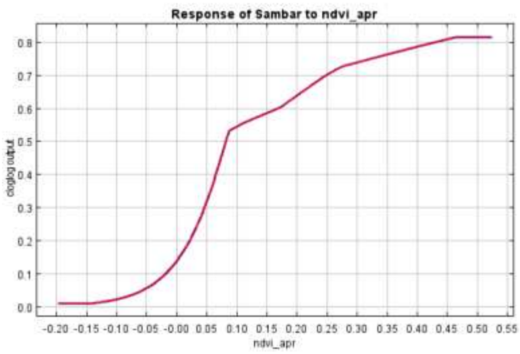


E)

Figure II. 10: Relationship of spatial covariates used in the best fit MaxEnt model explaining sambar habitat suitability across India

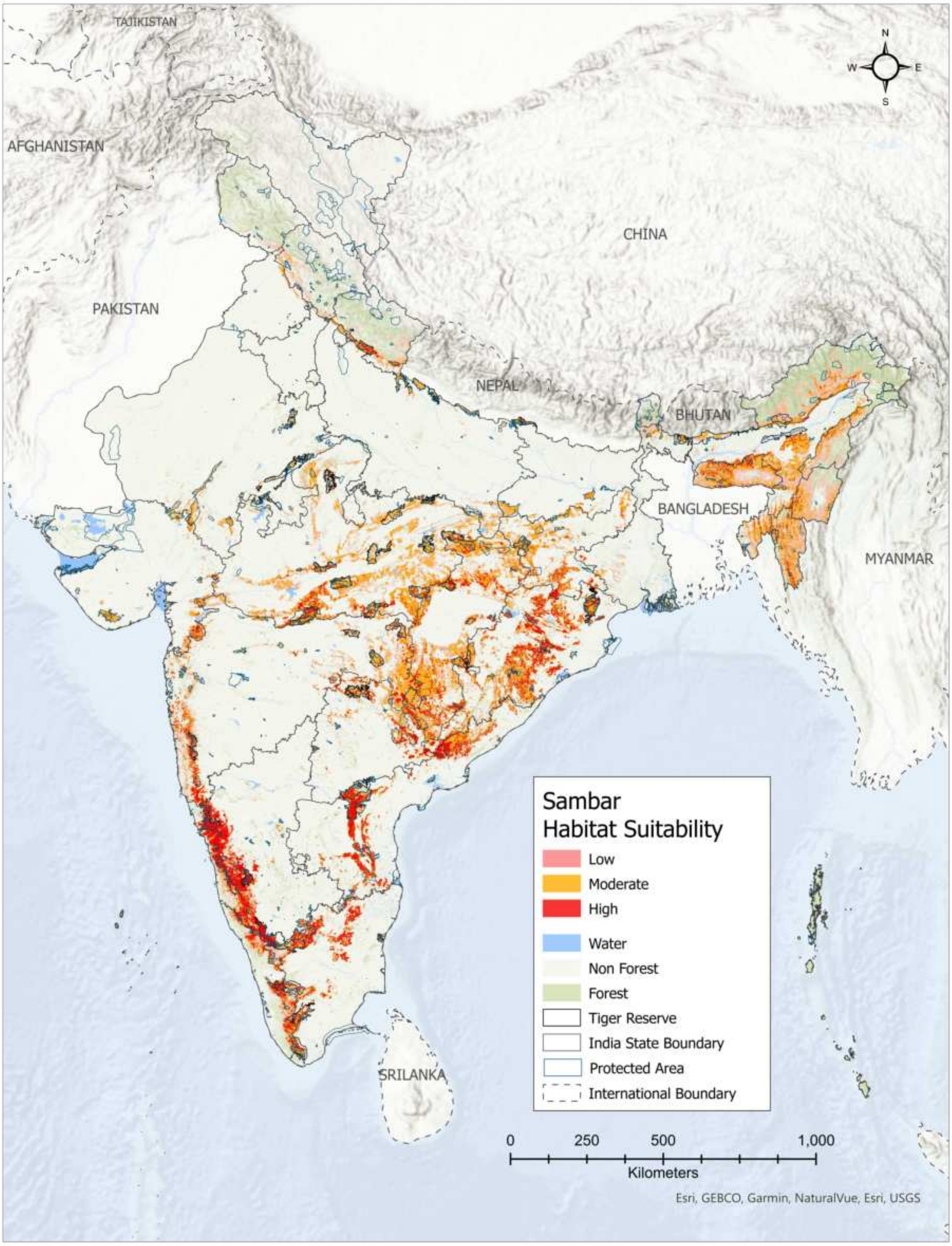


Figure II. 11: Modelled habitat suitability of sambar across the India using MaxEnt

II. 2. BOVIDAE (ANTELOPE, CATTLE, GOAT-LIKE)

BLACKBUCK (*Antilope cervicapra*)

Conservation status

Wildlife (Protection) Act, 1972: Schedule I

CITES: Appendix III

IUCN Red List: Least Concern (LC)

Introduction

Blackbuck, a member of the Bovidae family, is the only surviving species in the genus *Antilope* (Ranjitsinh, 1989), with fossil evidence tracing back to the Siwalik Hills of Pakistan (Tahir, 2021; Lydekker, 1878; Pilgrim, 1937; Pilgrim, 1939; Khan *et al*., 2006; Chauhan, 2008). Two subspecies of blackbuck are found in India.

- *Antilope cervicapra cervicapra* also known as south-eastern blackbuck, this subspecies is found in central, southern, and eastern India. It has a black neck, a black stripe that runs down its legs, and a white underbelly.
- *Antilope cervicapra rajputanae* also known as the north-western blackbuck, this subspecies is found in north-western India.

Species Description

Blackbuck exhibits marked sexual dimorphism, with males possessing spiral horns measuring up to 79 cm in length (Van der Geer, 2008; Mahato *et al*., 2010; Saluja *et al*., 2012; Sheikh and Molur, 2004). They are distinguished by streamlined bodies, and striking black and white pelage patterns. The coloration of males darkens with age, ranging from tawny to intense brown or black, while females and juveniles exhibit a yellow hue on their fronts and rears. Both sexes display white markings on the chin, undersides of legs, and chest, with eyes encircled by a distinctive white ring (Sheikh and Molur, 2004). Body length varies between 100-150 cm, with a tail length of 10-17 cm. Males weigh between 20-57 kg, while females weigh 19-33 kg (Roberts, 1997b; Sheikh & Molur, 2004).

During the rutting season, blackbuck males establish territories and exhibit lekking behavior, including loud grunts and head-to-head conflicts using their horns (Nowak, 1999). Lekking is resource-intensive and often results in injuries, favoring dominant males. The gestation period is six months, resulting in the birth of a single calf. Females resume mating about a month after giving birth. Newborns display light yellow fur and young males show a black patch on the head and neck, which darkens by the third year (Schmidly, 2004; Vats and Bhardwaj, 2009). Blackbucks live for 10 to 15 years (Mares, 1999; Schmidly, 2004).

Blackbuck is the fastest Antelope found in India, capable of achieving speeds of up to 50 mph (Nowak, 1999). The herd dynamics of these diurnal antelopes depend on food availability in their preferred habitat. Foraging time depends on herd size, with larger herds engaging in prolonged foraging (Isvaran 2007). During summer, they are seen foraging in smaller herds (Vats and Bhardwaj, 2009).

In India, they inhabit diverse habitats including grassy plains, forest areas, and agricultural lands across 15 states, with significant populations recorded in Rajasthan (Rahmani, 1991; Srinivasulu and Nagulu, 2002; Sharma *et al*., 2003; Saran and Meena, 2018). Additionally, Blackbuck has been introduced in semi-arid regions of the UAE and ranches in the USA indicating potential adaptability to non-native environments (Mallon and Kingswood, 2001; Meena *et al*., 2017). In Nepal, they are found in the Terai and adjacent foothills, particularly within the Blackbuck Conservation Area (BCA), characterized by semi-arid grassy environments (Wegge, 1997; Mallon and Kingswood, 2001; Bashistha *et al*., 2012).

Distribution

Blackbuck are native to India, Pakistan, Nepal, and Bangladesh, and non native reintroduced population in UAE, Argentina and the USA (Wright and Glaze, 1988; Mallon and Kingswood, 2001; Long, 2003).

Historically, blackbuck inhabited various regions across the Indian subcontinent south of the Himalayas, but their range has substantially decreased, leading to local extinctions in Bangladesh and Pakistan. Blackbuck populations have also been documented in specific locations in Pakistan, primarily within the northern regions of the Cholistan Desert, and are maintained under captive breeding programs in various wildlife parks (Roberts, 1977; Sheikh and Molur, 2004; Khattak *et al*., 2021).

Maxent Result

A total of 403 presence points of blackbuck were used to build up the species distribution model. Data and parameters of the MaxEnt model are provided in Table II. 11 & Table II. 12. Modelled distribution of blackbuck in the potential distributional range (model extent) is given in Figure II. 14.

According to MaxEnt estimates of the relative contribution of predictor variables (Table II.8), the distance from rangeland contributed the most (42.1%) to the blackbuck habitat model. The response curve for distance to rangeland, along with precipitation of the wettest month (21.4%), precipitation seasonality (8.6%), ruggedness (4.6%), treecover (3.9%), and NDVI post-monsoon (3.7%) predominantly prefer flat, arid and semi-arid areas. Response curve of human footprint Index (3.1%) along with rangeland suggest that blackbuck can tolerate moderate level of human disturbance but avoid highly disturbed areas. The temperature seasonality response curve indicates blackbuck presence in two distinct temperature ranges one in Rajasthan completely arid and other southern part of India semi arid and dry deciduous area as well as some parts of the terai landscape. The species was wide spread in India but due to habitat destruction through conversion to agricultural land, livestock pressure, and hunting it is present in different pockets across India.

Table II. 11: Parameters used in MaxEnt setting for modelling of blackbuck distribution in forested landscapes of India

Model setting	Values
Model features	Linear, Quadratic, Product and Hinge
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.60
Area under the ROC* Curve (AUC)	0.804

Table II. 12: Contribution percentage of covariates to the best model explaining blackbuck distribution

Covariates	Percent contribution	Permutation contribution
Distance from rangeland	42.1	28.3
Precipitation of Wettest Month (BIO13)	21.4	18.5
Temperature Seasonality (BIO4)	12.6	19.8
Precipitation Seasonality (BIO15)	8.6	12.3
Ruggedness	4.6	6.1
Treecover	3.9	4.3
NDVI post Monsoon	3.7	6.4
Human Footprint Index	3.1	4.3

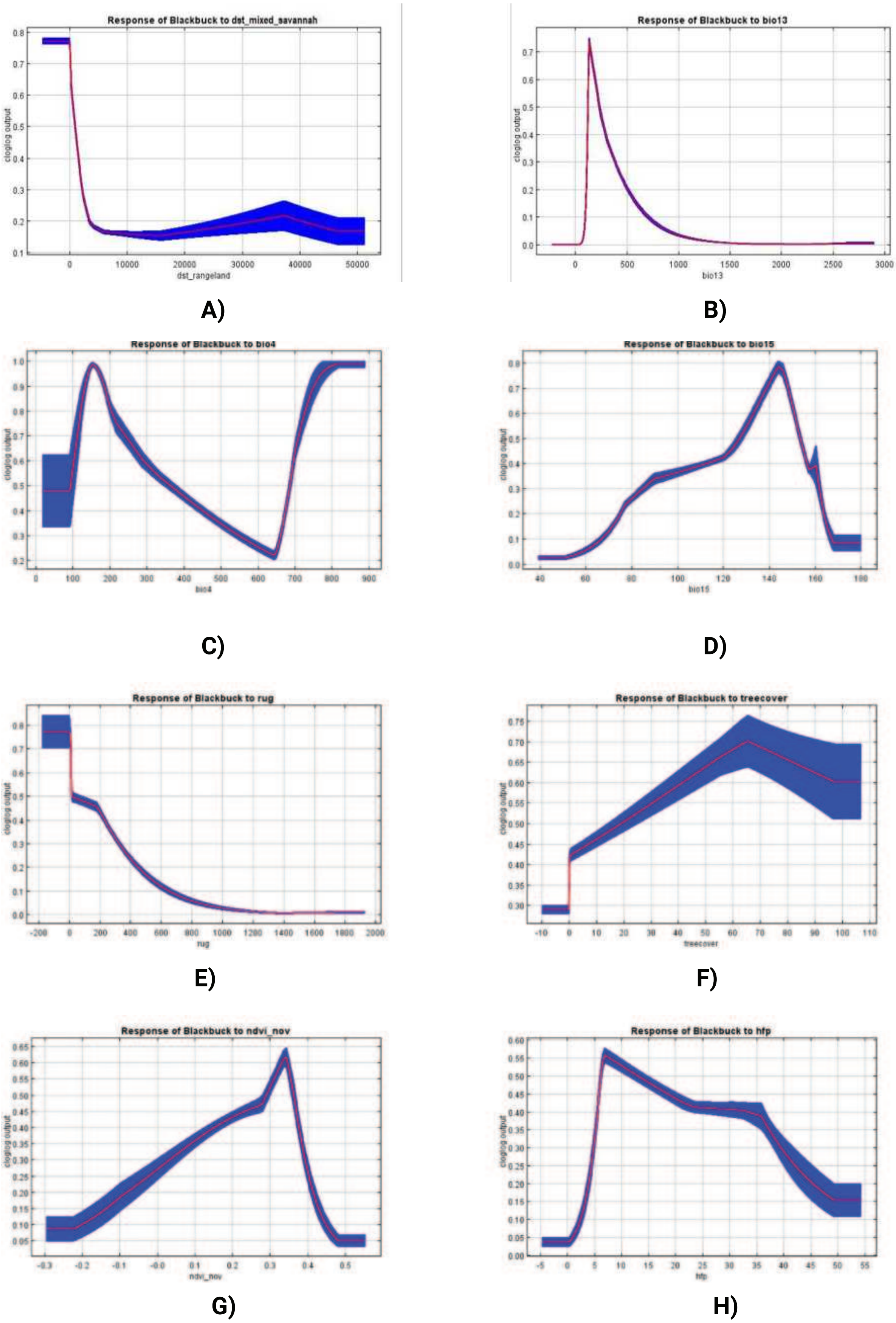


Figure II. 13: Relationship of spatial covariates used in the best fit MaxEnt model explaining blackbuck habitat suitability across India

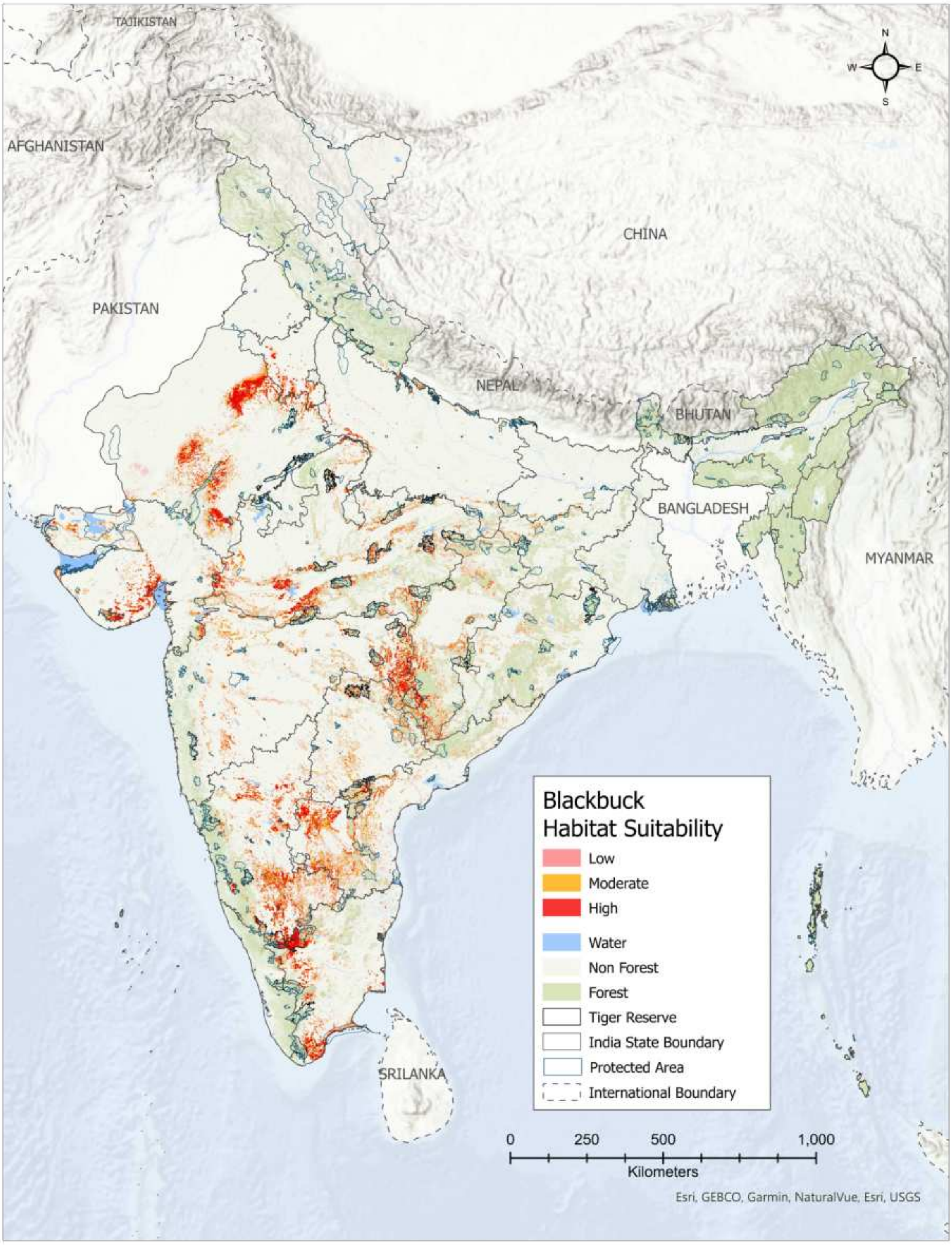


Figure II. 14: Modelled habitat suitability of blackbuck across the India using MaxEnt

CHINKARA (*Gazella bennettii*)

Conservation status

Wildlife (Protection) Act, 1972: Schedule I

IUCN Red List: Least Concern (LC)

Introduction

The Chinkara (*Gazella bennettii*), also known as the Indian Gazelle. It is the smallest Asiatic antelope. Among the six recognized subspecies of chinkara, three are present in India.

- *Gazella bennettii bennettii* (Sykes, 1831) (Deccan chinkara): Ranges across South India from the Ganges Valley to the Deccan Plateau
- *Gazella bennettii christii* (Blyth, 1842) (Gujarat chinkara): The smallest subspecies found in the Thar Desert and surrounding regions
- *Gazella bennettii salinarum* (Groves, 2003) (Salt range chinkara): The largest subspecies, located in Punjab, Haryana, and areas around Delhi.

Species Description

The chinkara is characterized by its tawny brown coat, white underparts, and distinctive dark brown tail flanked by white streaks (Prater, 1980). Both sexes possess unbranched horns, with males having thicker, slightly curved horns adorned with 15 to 20 rings, while females have smaller, straighter horns that may be ringless. Body size varies, with shoulder heights ranging from 60 to 80 cm, lengths from 90 to 120 cm, and weights typically between 20 to 25 kg.

Chinkara are primarily crepuscular, being most active at dawn and dusk, and they often feed at night. They typically form small groups of three to six individuals, although larger gatherings can occur during the breeding season. Breeding occurs throughout the year, with peaks in February-March and July-August (Dookia & Goyal, 2007). Females generally give birth to one young after a gestation period of 5 to 5.5 months, with a weaning period of around 60 days. While the lifespan of chinkara in the wild is not well-documented, they can live up to 12.3 years in captivity (Weigl, 2005).

Chinkara is extremely vigilant. In social defense, sub-adult individuals spot potential predators while foraging and communicate the threat to other herd members using a variety of displays (stamping on the ground and sharp hissing through the nose) or vocal communications (Arshad & Gill, 2010; Dookia, 2002).

Chinkara are better adapted to browsing than grazing (Behera *et al*., 2022) and selectively feed on a variety of nutrient and water-rich plant matter (Wildlife Institute of India and CZA, 2018). Specialization of diet, coupled with habitat selectivity, may be contributing to its relatively low density (Kumar, 2002). They are facultative drinkers and can withstand relatively long intervals between visits to water points by conserving metabolic water and taking advantage of water found in vegetation. (Mallon, 2008; Rahmani, 1990).

Depending on seasons and resource availability, home range sizes may vary between 2.2 to 2.4 km^2. (Jaipal, 2020). Home ranges are largest in summer and smallest during the monsoon. Dominant males maintain territories and aggressively defend them, especially during the mating season (Gittleman, 2013).

Distribution

Chinkara inhabits a variety of environments, including flat plains, grasslands, sand deserts, hilly areas, dry scrubs, and light forests. They are primarily distributed across central and western India and found in nine states: Haryana, Rajasthan, Uttar Pradesh, Bihar, Madhya Pradesh, Andhra Pradesh, Karnataka, Maharashtra, and Gujarat. Approximately 70 percent of the global population of chinkara resides in western Rajasthan (Arshad and Hussain Gill, 2010; Dookia, 2009).

Maxent Result

A total of 1106 presence points of chinkara were used to build up the species distribution model. Data and parameters of the MaxEnt model are provided in Table II. 13 & Table II. 14 and modelled distribution of chinkara in the potential distributional range (model extent) are given in Figure II. 16.

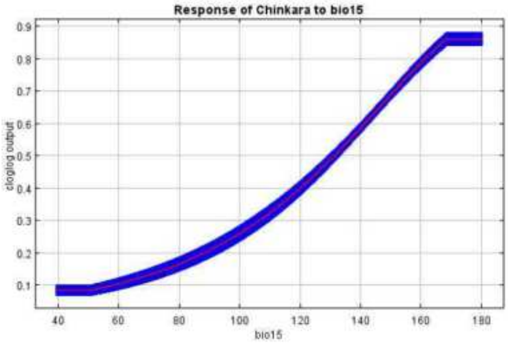
According to MaxEnt estimates of the relative contribution of predictor variables (Table II. 14), the precipitation seasonality (38.7%) has contributed the most to the chinkara habitat model. The response curve for distance to open forest (23.9%) has second most-highest contribution to the model, which indicates the chinkara does not prefer dense habitation and mainly prefer sparse vegetation. The contribution of annual precipitation (19.6%), deciduousness (8.3%), and minimum temperature of the coldest month (2.7%) along with precipitation seasonality and distance to open forest suggests that ungulates prefer open, warmer, and dry forests that have distinct wet and dry seasons.

Table II. 13: Parameters used in MaxEnt setting for modelling of chinkara distribution in forested landscapes of India

Model setting	Values
Model features	Linear Quadratic Product
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.45
Area under the ROC* Curve (AUC)	0.835

Table II. 14: Contribution percentage of covariates to the best model explaining chinkara distribution

Covariates	Percent contribution	Permutation contribution
Precipitation Seasonality (BIO15)	90.8	77.4
Distance from Open Forest	23.9	45.3
Annual Precipitation (BIO12)	19.6	12.1
Deciduousness	15.1	15.2
Min Temperature of Coldest Month (BIO6)	2.7	8.7



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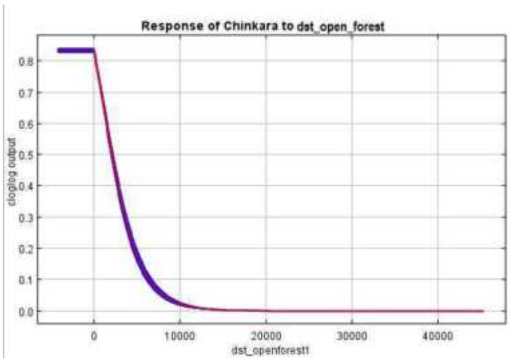

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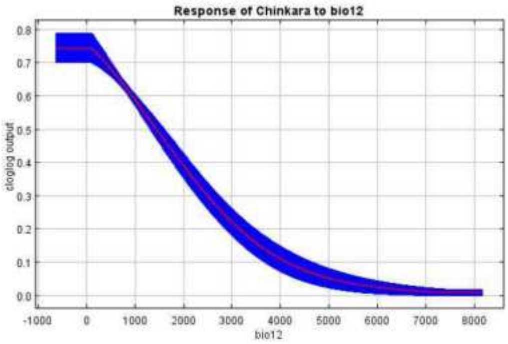

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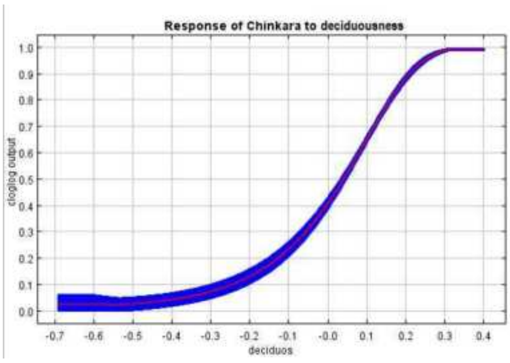

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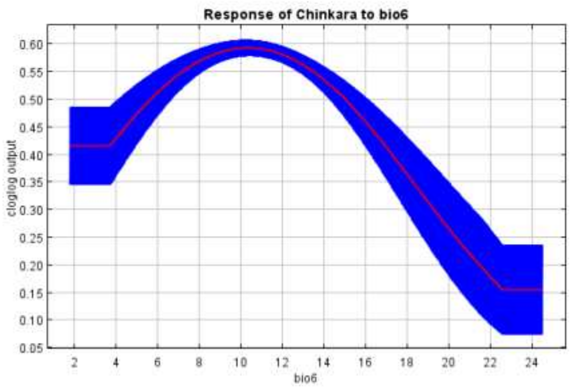

E)

Figure II. 15: Relationship of spatial covariates used in the best fit MaxEnt model explaining chinkara habitat suitability across India

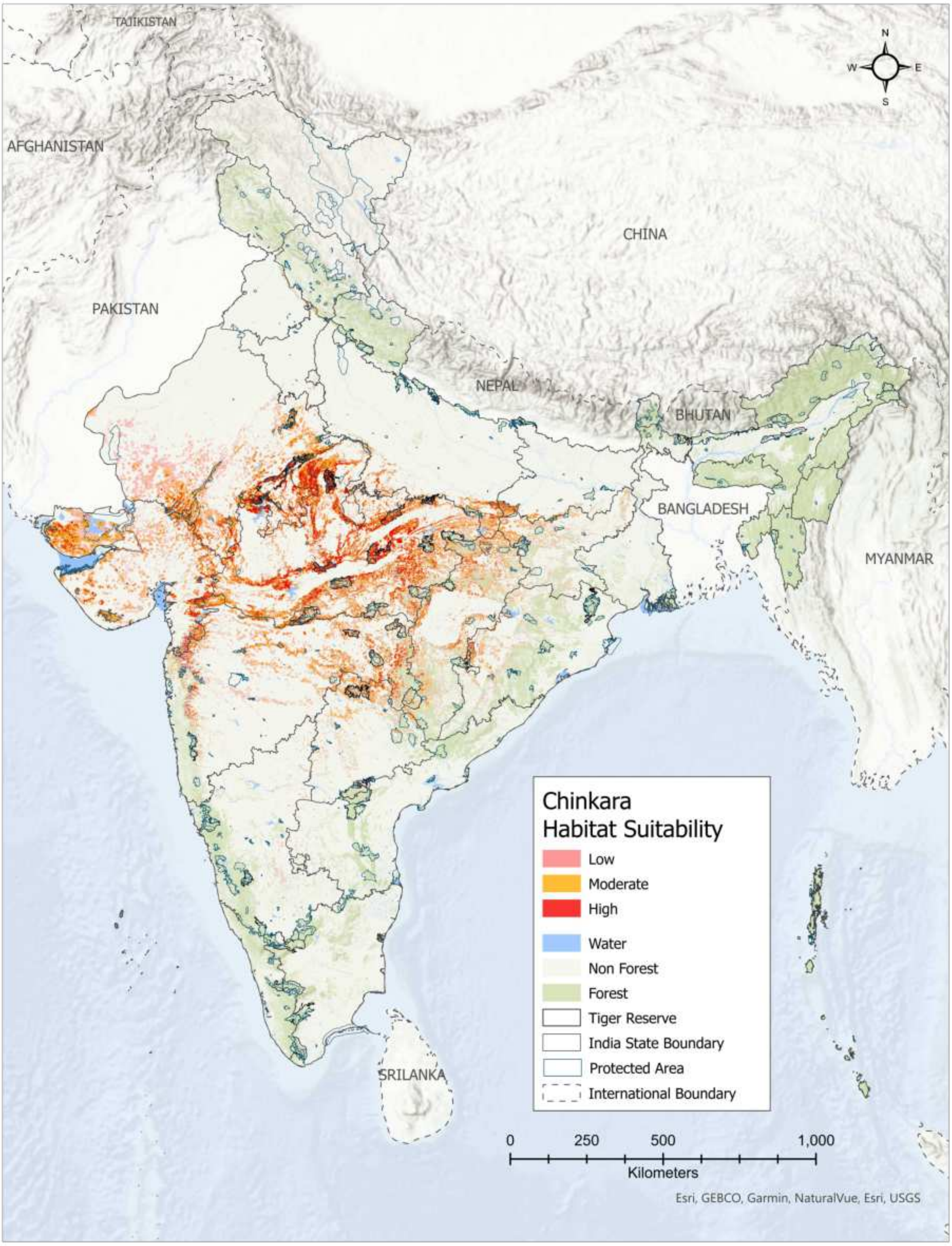

Figure II. 16: Modelled habitat suitability of chinkara across the India using MaxEnt


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CHOUSINGHA (*Tetracerus quadricornis*)

Conservation status

Wildlife (Protection) Act, 1972: Schedule I

CITES: Appendix III

IUCN Red List: Vulnerable (VU)

© Rohan Desai

Introduction

The four-horned antelope, also known as chousingha, is the sole member of the genus *Tetracerus*, and is placed under the family Bovidae. It belongs to the Boselaphini tribe, which consists of only two species, Nilgai and four horned antelope. Unlike other antelope groups, these species have horns with a front keel and lack the rings typically found on antelope horns. On the basis of body size, coloration, morphometric measurements and horn morphology, Groves (2003) suggests three subspecies of chousingha:

- *Tetracerus quadricornis quadricornis*: Found in central India, characterized by their large size and large horns.
- *T. q.iodes*: found in northern India and Nepal, similar in size to *T. q.quadricornis* but with smaller horns
- *T. q. subquadricornis*: found in southern India, characterized by the absence of anterior pairs of horns

Species Description

Chousingha is one of the smallest bovid found in India and is almost the same size as barking deer. The name "chousingha" refers to the four horns, which is the distinguishing characteristic of the species. The adult male typically sports a pair of spike-like anterior horns on the forehead and a pair of posterior horns located further back on the skull, while females lack horns altogether. The posterior horns are usually 8-10 cm long, while the front pair varies from 1-2.5 cm in length. Chousingha has a dull light brown to rufous brown coat, which is short and coarse. It has a lighter underbelly and white markings around the muzzle and eyes (Menon, 2014). The brown coat darkens after monsoon and fades after winter (Sharma *et al*., 2009). The forelegs have a distinct dark stipe in front. It weighs around 20–22 kg and stands around 55–65 cm at the shoulder (Menon, 2003). Its head to body length is 90 – 110 cm and has a short tail measuring about 10 – 15 cm. Both sexes have well developed pedal glands between the false hooves of their hind legs (Bahuguna and Mallik, 2010).

Due to its shy nature, preference for forested, undulating terrain (Prater, 1980) and solitary living, it is considered as one of the most elusive antelopes in India. Though chousingha is solitary by nature, sharma *et al*., (2009) reported that sometime it is seen in small groups, especially during mating season. Unlike blackbuck, it is dependent on water and inhabits areas in proximity to water sources. Localized defecation / urination behaviour and frequent visits to the middens (defecation sites) have been observed in chousingha which probably has some territorial significance (Sharma *et al*., 2009; Meghwal *et al*., 2018). Males defend their territory very aggressively especially during rutting season.

Chousingha is a selective browser, particularly a 'nibbler' and avoids low protein plant parts. It generally feeds on fruits, pods, flowers, seeds and occasionally on soft leaflets of shrubs, trees and creepers (Sharma *et al*., 2004; Kunwar *et al*., 2016). It favors open, dry deciduous forests in hilly terrains across the Indian subcontinent but avoids area with *Lantana camara* presence (Krishna *et al*., 2008; Meghwal *et al*., 2018).

The rutting season of chousingha is from July to September, and births occur from March to May after a gestation period of 7.5 to 8 months (Grizmek, 1990). Litter size is one to two fawns with an average weight of about 1 kg each (Nowak, 1999). Chousingha prefers areas with closed canopy and thick undergrowth for resting and nursing the young ones, as new born fawns are smaller than the size of a black napped hare and are very vulnerable to predation.

Distribution

The chousingha is endemic to India and predominantly found in central, southern, and western India, with a smaller population in Nepal. Approximately 95% of its current global population is present in India and the remaining 5% in a few pockets of Nepal (Rahmani, 2001; Shreshta, 2001). Its range spans from the Himalayan foothills in the north to the Deccan plateau in the south, except for the northeast and the Malabar coast. It uses tropical dry deciduous forest habitats, but the distribution is patchy (Krishna *et al*., 2009; Sharma *et al*., 2014). Major regions of its distribution include Central India, the Western Ghats, and parts of the Eastern Ghats, with significant populations in states like Madhya Pradesh, Maharashtra, Karnataka, Tamil Nadu, and Rajasthan.

Maxent Result

A total of 4913 presence points of chousingha were used to build up the species distribution model. Data and parameters of the MaxEnt model are provided in Table II. 15 & Table II. 16 and modelled distribution of chousingha in the potential distributional range (model extent) are given in Figure II. 18.

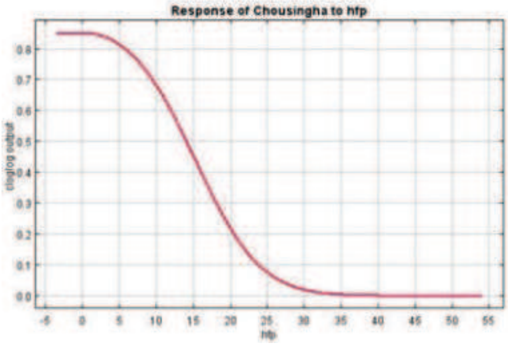
According to MaxEnt estimates of the relative contribution of predictor variables (Table II. 16), the human footprint index contributed the most (30%) to the chousingha habitat model, along with the distance from the forest (20.6%) and the distance from protected areas (PAs) (20.1%). Their response curves suggest that chousingha prefer wilderness and can tolerate low levels of human disturbance, but avoid highly disturbed areas. The response curves for the minimum temperature of the coldest month (21.6%), maximum temperature of the warmest month (3.2%), mean annual precipitation (2.5%), and elevation not more than 2000 meters (2%) indicate that they prefer open, dry deciduous mixed forests in undulating or hilly areas.

Table II. 15: Parameters used in MaxEnt setting for modelling of chousingha distribution in forested landscapes of India

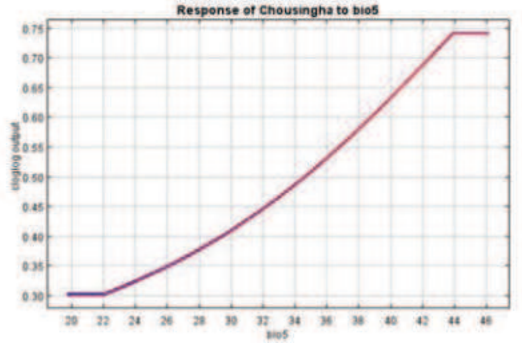
Model setting	Values
Model features	Linear and Quadratic
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.372
Area under the ROC* Curve (AUC)	0.813

Table II. 16: Contribution percentage of covariates to the best model explaining chousingha distribution

Covariates	Percent contribution	Permutation contribution
Human footprint index	30	7.4
Max Temperature of Warmest Month (BIO5)	21.6	13.3
Distance from forest	20.6	56.9
Distance from protected area	20.1	12.7
Min Temperature of Coldest Month (BIO6)	3.2	4.3
Annual Precipitation (BIO12)	2.5	0.4
Elevation	2	5.1



A)



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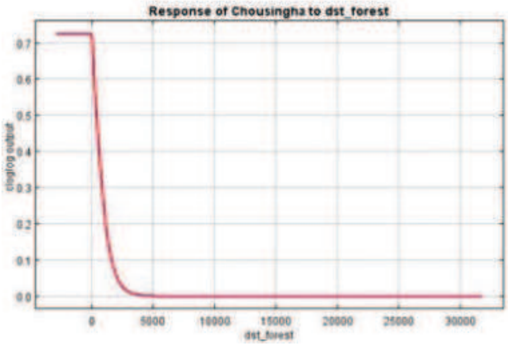

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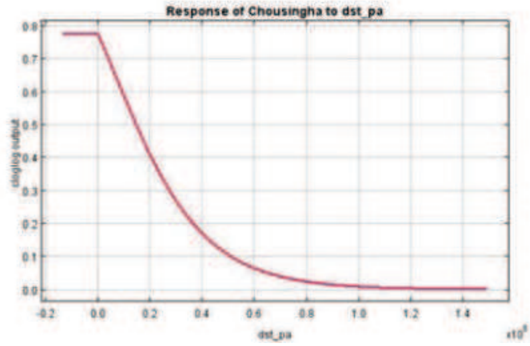

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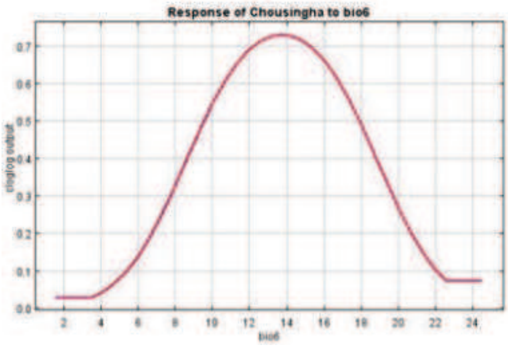

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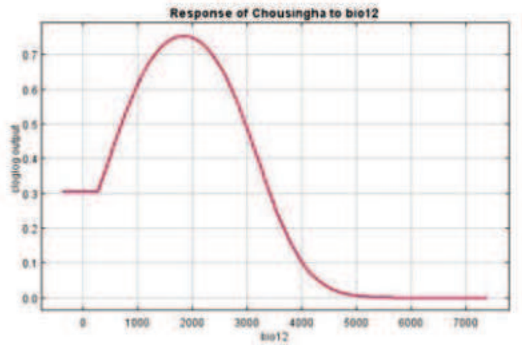
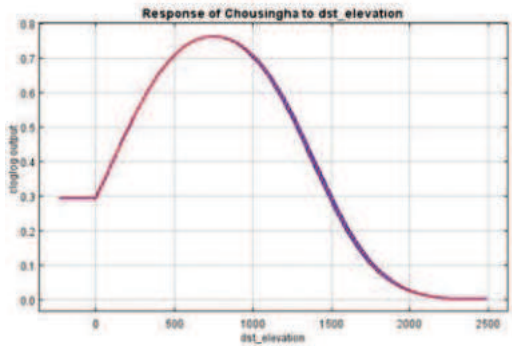


F)



G)

Figure II. 17: Relationship of spatial covariates used in the best fit MaxEnt model explaining chousingha habitat suitability across India

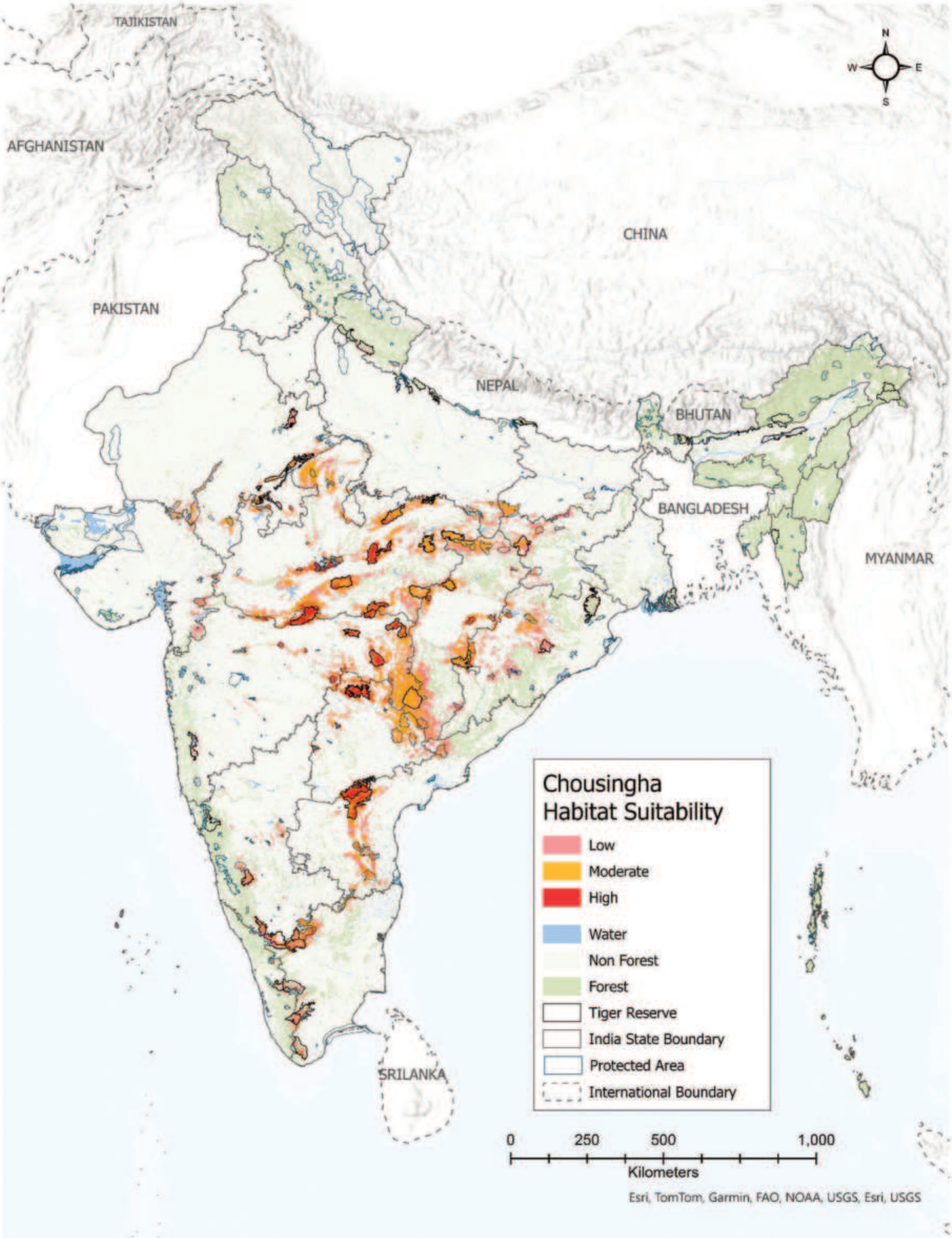


Figure II. 18: Modelled habitat suitability of chousingha across the India using MaxEnt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GORAL
(*Naemorhedus goral & Naemorhedus baileyi*)

Conservation status

Wildlife (Protection) Act, 1972: Schedule I

CITES: Appendix I

IUCN Red List: Near Threatened (NT) (*N. goral*)

IUCN Red List: Vulnerable (VU) (*N. baileyi*)

Introduction

The goral is a small, goat-like ungulate belonging to the family Bovidae and order Cetartiodactyla and genus *Naemorhedus*. According to Mori *et al*., (2019) and recognized by IUCN, two species of goral found in India with one of them having two subspecies.

- *Naemorhedus goral*: Commonly known as Himalayan goral. Its range extends across northern India, Nepal, Bhutan, and parts of China and Pakistan (Duckworth & MacKinnon, 2008). The species Himalayan goral has two subspecies
  - *N. goral goral* (Wilson and Reeder 2005): Also known as Himalayan brown goral. It is found in the central and eastern Himalayas from east of the Sutlej river to Arunachal Pradesh.
  - *N. goral bedfordi* (Wilson and Reeder 2005): Also known as Himalayan grey goral. It is found in western Himalayas (Sutlej river in Punjab, Himachal Pradesh and Jammu and Kashmir).
- *Naemorhedus baileyi*: The second goral species that is found in India, commonly known as Red goral. It is found in Eastern Arunachal Pradesh.

Species Description

The goral is characterized by its compact build, short legs, and dense fur, which is greyish-brown with a distinctive dark stripe along its back (Prater, 1971). The two subspecies of Himalayan goral are differentiated by their coat colour, as suggested by their names, while the red goral is distinguished by both coat colour and at molecular differences.

Male and female goral exhibit similar appearances, but males are slightly larger and possess more prominent horns. The average adult goral stands about 75–80 cm at the shoulder and weighs between 25–40 kg (Lovari and Apollonio, 1993). Both sexes have backward-curving, ridged horns that can grow up to 18 cm in length (Prater, 1971). Their dense coat provides insulation against the cold mountainous climate. The species exhibits excellent climbing abilities, owing to its strong limbs and specially adapted hooves that provide grip on rocky surfaces (Green, 1987).

Gorals inhabit rocky cliffs and steep slopes, often retreating to dense vegetation or rock crevices for shelter (Duckworth & MacKinnon, 2008). Their diet consists primarily of grasses, leaves, twigs, but at times may be supplemented with fallen fruits and seeds (Green, 1987). Gorals are diurnal and typically active during the early morning and late evening. Females are social animals, often found in small groups of 4–12 individuals, while males tend to be solitary (Duckworth and MacKinnon, 2008). Their territorial behaviour is most pronounced during the mating season, when males defend small territories of approximately 25 hectares (Lovari & Apollonio, 1993). The mating season typically occurs from November to January, followed by a gestation period of around 170–218 days. Females usually give birth to a single offspring, which matures at 2–3 years (Duckworth & MacKinnon, 2008). Gorals have a lifespan of up to 15 years in the wild (Prater, 1971).

Distribution

The Himalayan goral is distributed along the Himalayan Mountain range, spanning from Jammu and Kashmir in the west to Arunachal Pradesh in the east, occupying altitudes between 900 and 4,000 meters. The range of the two subspecies of Himalayan goral is divided by the Sutlej river. In India, it is found in several protected areas such as Dachigam and Kishtwar national parks in Jammu and Kashmir (Sathyakumar, 2002), the Great Himalayan national park and Shimla water catchment reserve in Himachal Pradesh (Gaston *et al*., 1981), Kedarnath wildlife sanctuary and Valley of Flowers national park in Uttarakhand (Green, 1987), as well as Khangchendzonga and Namdapha national parks in Sikkim and Arunachal Pradesh respectively (Sathyakumar, 2002). Their population varies significantly across its range, with higher observations recorded in regions with minimal human interference.

The red goral, found in Arunachal Pradesh at elevations between 2,000 and 4,500 meters, has a more restricted range and sparse populations influenced by steep terrain and low human disturbance. The species faces significant pressures from habitat loss (Duckworth & MacKinnon, 2008), hunting for its meat and hide (Rodgers & Panwar, 1988) and competition with livestock which reduces the availability of food for gorals (Green, 1987). Efforts to maintain and restore its natural habitat, along with sustainable management practices, and promoting community-based conservation programs to mitigate human-wildlife conflicts (Sathyakumar, 2002) are critical for the long-term survival of this species.

Maxent Result

A total of 173 presence points of goral were used to build up the species distribution model. Data and parameters of the MaxEnt model are provided in Table II. 17 & Table II. 18 and modelled distribution of goral in the potential distributional range (model extent, model constrain in and around PA) are given in Figure II. 20.

According to MaxEnt estimates of the relative contribution of predictor variables (Table II. 18), the distance from protected areas (PAs) contributed the most (43.1%) to the goral habitat model. The response curve for the distance to protected areas, along with the distance from the forest (12.7%), suggests that goral requires wilderness devoid of human disturbance. The response curves for elevation (16%), annual rainfall (13.9%), NDVI pre-monsoon (10%), and the minimum temperature of the coldest month (4.3%) indicate that goral predominantly prefers steep mountainous areas and forests near cliffs, primarily in rugged rocky terrain.

Table II. 17: Parameters used in MaxEnt setting for modelling of goral distribution in forested landscapes of India

Model setting	Values
Model features	Linear, Quadratic, Product and Hinge
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.1663
Area under the ROC* Curve (AUC)	0.905

Table II. 18: Contribution percentage of covariates to the best model explaining goral distribution

Covariates	Percent contribution	Permutation contribution
Distance from protected area	43.1	31
Elevation	16	34.3
Annual Precipitation (BIO12)	13.9	4.9
Distance from forest	12.7	3
NDVI pre Monsoon	10	5.2
Min Temperature of Coldest Month (BIO6)	4.3	21.6

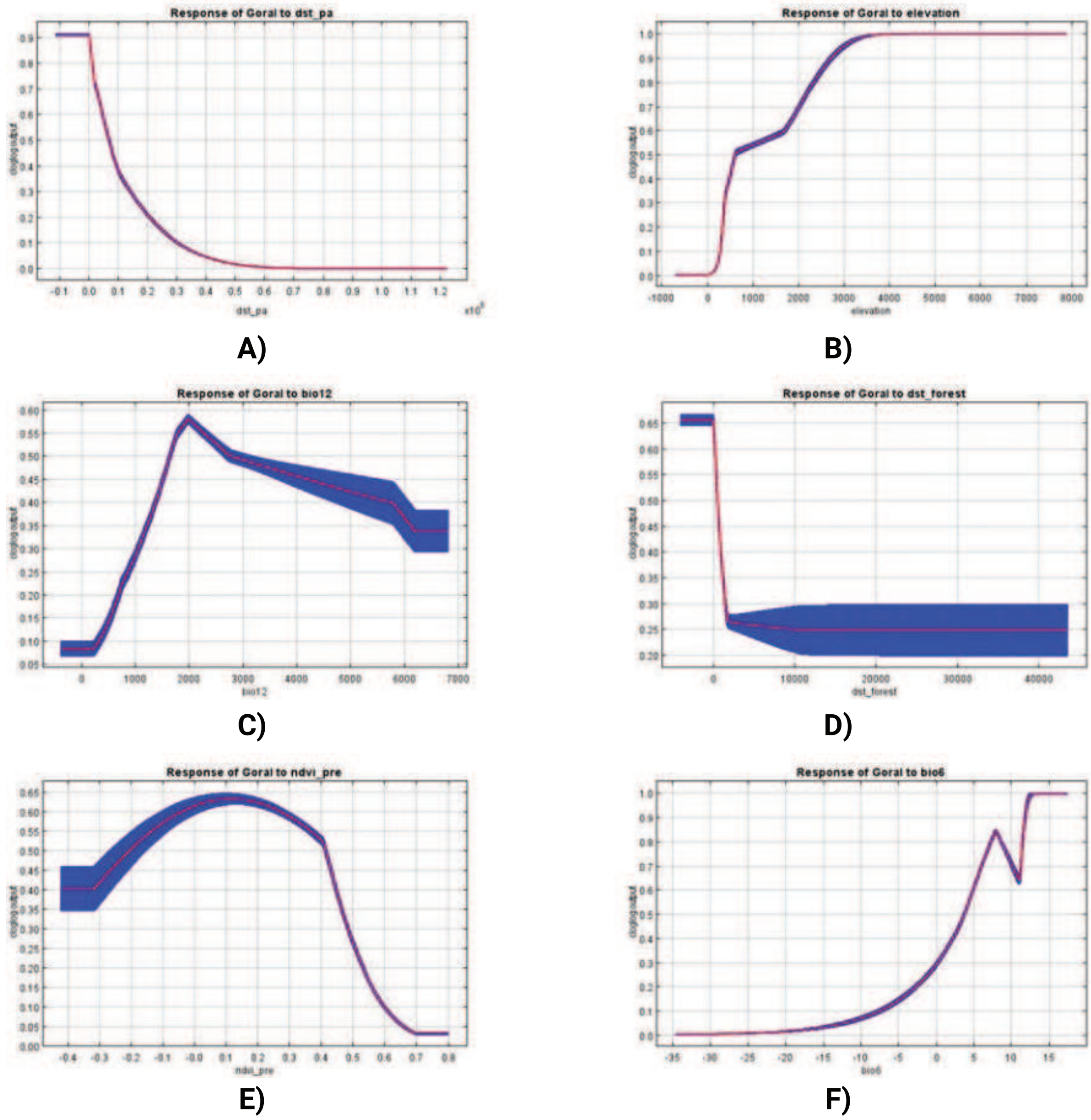

Figure II. 19: Relationship of spatial covariates used in the best fit MaxEnt model explaining goral habitat suitability across India

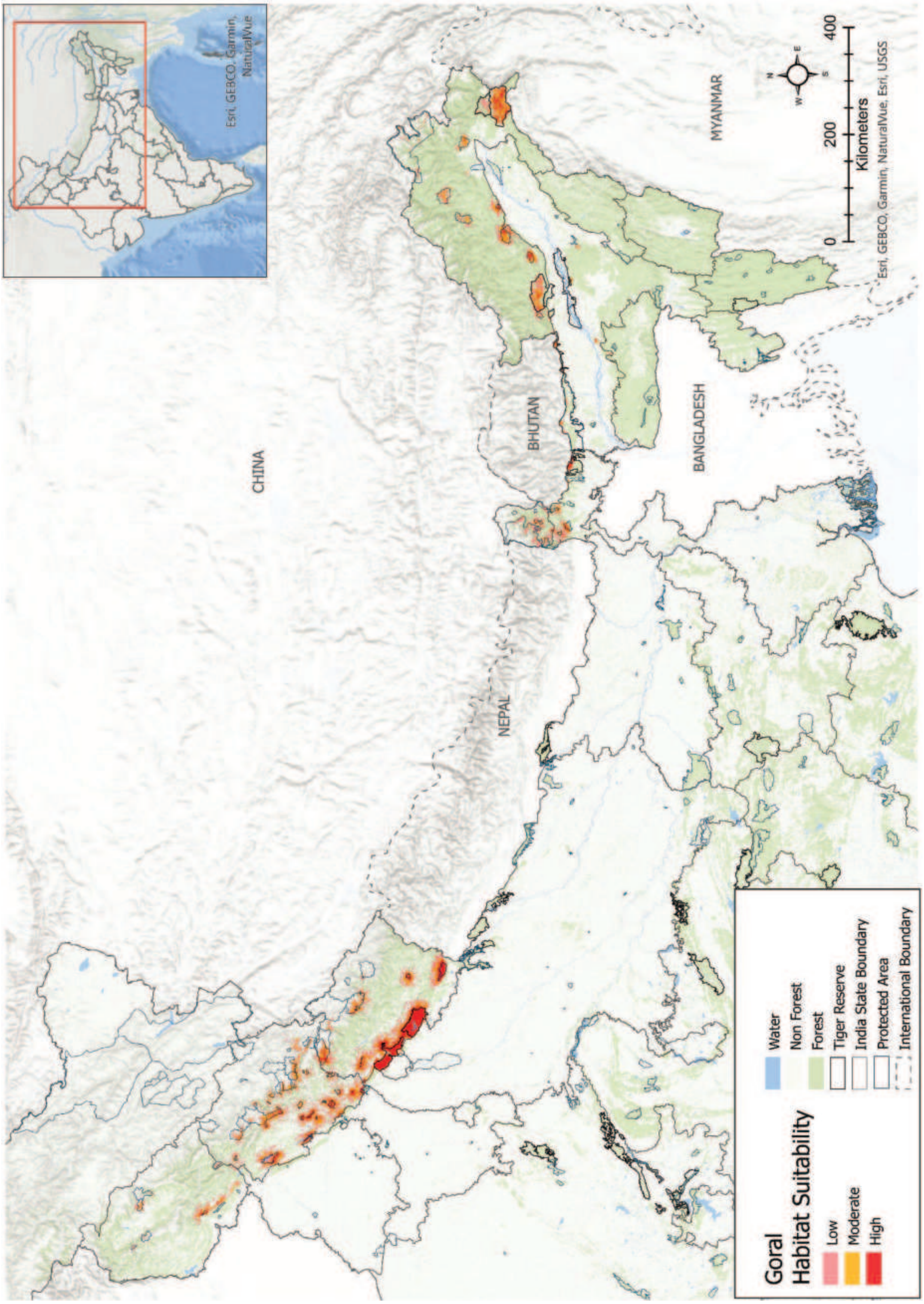

Figure II. 20: Modelled habitat suitability of goral across the India using MaxEnt

NILGAI (*Boselaphus tragocamelus*)

Conservation status

Wildlife (Protection) Act, 1972: Schedule II

IUCN Red List: Least Concern (LC)

Introduction

Nilgai is the largest species of Asian antelope and is widespread in the northern part of peninsular India, occupying a diversity of habitats (Ahrestani *et al*., 2011) which is an attribute to its evolution in open, dry forests of peninsular India during tertiary geological period (Rai, 2022). The species holds cultural significance in India, having been revered since the Vedic period, and is often associated with motherhood in Hinduism.

Species Description

Being the largest antelope species, males typically weigh between 109 – 288 kg and females weigh around 100 – 213 kg with shoulder height ranging from 120 – 150 cm. Adult males exhibit a striking coloration, appearing dark iron blue to grey. Female Nilgai and calves exhibit a light brown coloration. Both male and female individuals exhibit two white spots on each cheek, as well as white patches near the lips and a white area on the gular patch. Additionally, they display white markings on the inside of their tails and bellies. These animals also possess white bands above and below a black fetlock. Both genders develop a scruffy, short mane on the neck, and their long tails are tufted, extending down to the hocks. In males, a wispy beard is prominent (while rudimentary in females), and their short, smooth, conical black horns are ringed, with one or two rings at the base.

Their social unit is of 4 – 10 individuals in a herd, while bulls are solitary and territorial (Schaller, 1967). The nilgai social system includes the use of faecal deposits or repeated defecation at a localized site with territorial males defecating in the center of the dung pile, whereas subordinates defecate on the outer edge (Marneweck *et al*., 2018). Both sexes attain sexual maturity at about two years (Acharjyo and Misra, 1971). Breeding occurs year round with a typical litter size of 2 (Dover, 1932). A high reproductive rate combined with a lifespan exceeding 20 years (Dover, 1932) makes this species highly resilient and capable of rapid population growth.

Nilgai prefers areas with open canopy and avoids areas with high woody vegetation. Its prefer habitat represents shrub cover upto two-meter height, as it has very positive influence on its presence (Mathur, 1991). Nilgai prefers flat-gentle slopes, and compared to other wild ungulates. Nilgai is able to tolerate higher levels of disturbance from the human settlements (Mathur, 1991). Nilgai is opportunistic feeder, predominantly a browser but also a grazer and feeds on dry leaf foliage as well (Mathur, 1991). Moreover, its relatively less dependence on the availability of surface water allows it to utilize areas deficient in water (Mathur, 1991). Nilgai is more closely associated with croplands than any other ungulate (Dinerstein, 1980). They use forest fringe scrublands near farmland as shelter and utilise the farmlands in morning and evening (Chopra & Rai, 2009).

The relation of Nilgai with woody vegetation cover, open canopy mix forest or scrubland, slope, water availability and human disturbance probably explains the density trend of nilgai across India. Larger proportion of scrubland in and around TR's of Rajasthan is one of the reasons for relatively higher density of nilgai in the area.

Distribution

This species is distributed from the foothills of the Himalayan Mountains, including Nepal, southwards through central India to Mysore and into northeastern Pakistan (Corbet and Hill, 1992; Sankhala, 1964; Walker, 1964; Mirza and Khan, 1975). Nilgai is notable for its adaptability to various habitats, including lightly wooded forests, grasslands, scrub areas, and agricultural lands. Predominantly distributed on the periphery of forests, it avoids dense forests and often forages on agricultural lands (Bagchi *et al.,* 2003a, b; Singh 1995). The species has become locally overabundant and cause immense crop damage (Chauhan and Singh, 1990). Outside its native range, introduced populations of nilgai can be found in the United States (Texas), Mexico, South Africa, and Italy (Leslie, 2008). In Texas, where it was introduced in the early 20th century, nilgai populations have not only established themselves despite unrestricted, year-round hunting but have also expanded their range (Foley *et al.*, 2017).

Maxent Result

A total of 4788 presence points of nilgai were used to build up the species distribution model. Data and parameters of the MaxEnt model are provided in Table II. 19 & Table II. 20 and modelled distribution of nilgai in the potential distributional range (model extent) are given in Figure II. 22.

The response curve for the distance from cropland (54.2%) indicates that nilgai can live alongside human disturbances, and prefers forest fringes. Temperature, and elevation response curve indicate that nilgais can withstand quite high temperature. It prefers arid areas, scrub, grassy plains, dry deciduous open forests and agricultural areas.

Table II. 19: Parameters used in MaxEnt setting for modelling of nilgai distribution in forested landscapes of India

Model setting	Values
Model features	Linear, Quadratic, Product and Hinge
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.358
Area under the ROC* Curve (AUC)	0.786

Table II. 20: Contribution percentage of covariates to the best model explaining nilgai distribution

Covariates	Percent contribution	Permutation contribution
Distance from cropland	54.2	55
Annual Mean Temperature (BIO1)	25.3	18.4
Elevation	6.3	6.4
Min Temperature of Coldest Month (BIO6)	6.2	11.2
Distance from water	5.5	6.7
Precipitation of Driest Month (BIO14)	2.5	2.3

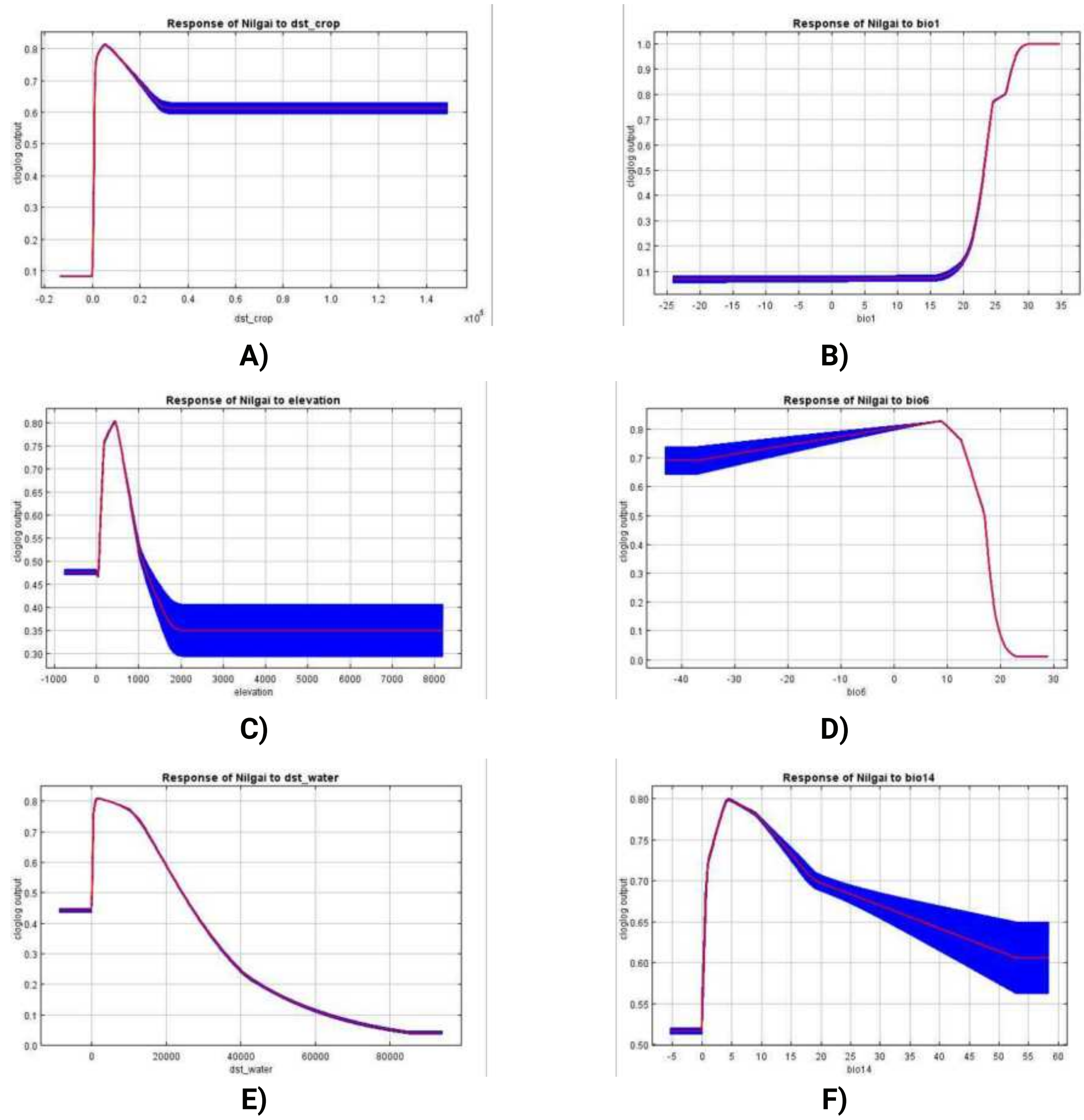

Figure II. 21: Relationship of spatial covariates used in the best fit MaxEnt model explaining nilgai habitat suitability across India

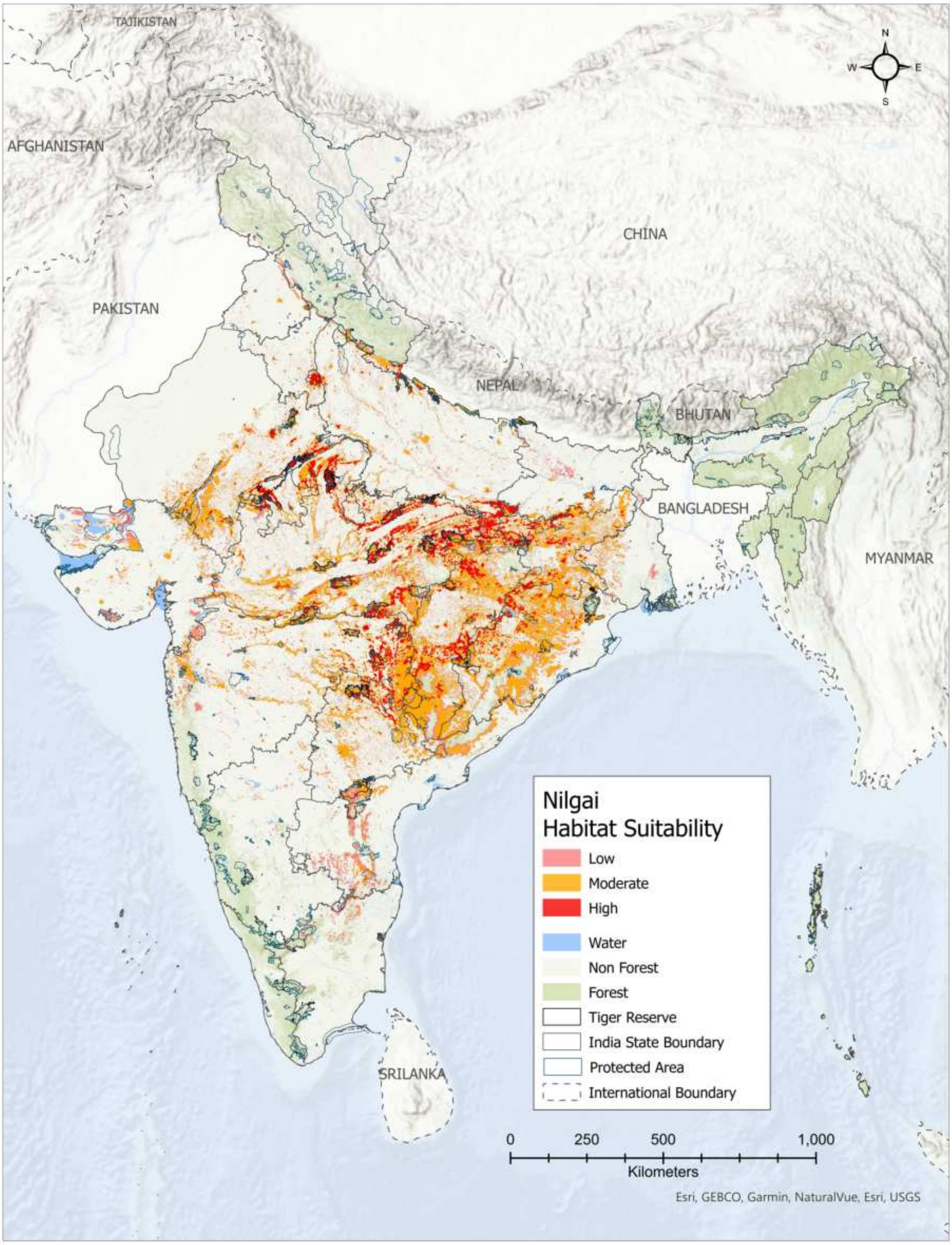

Figure II. 22: Modelled habitat suitability of nilgai across the India using MaxEnt


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HIMALAYAN SEROW (*Capricornis thar*)

Conservation status

Wildlife (Protection) Act, 1972: Schedule I

CITES: Appendix I

IUCN Red List: Vulnerable (VU)

Introduction

The Himalayan serow (*Capricornis thar*) is a species of goat-antelope that belongs to the family Bovidae and the genus *Capricornis*. It is closely related to other species of serows, such as the Chinese serow (*Capricornis milneedwardsii*) and the Formosan serow (*Capricornis swinhoei*).

Species Description

Himalayan serow is a medium-sized, stocky herbivore that exhibits some classic traits of mountain-dwelling animals. It is found in temperate to alpine regions and prefers areas with heavy shrub and ground cover (Schaller, 1977). The coat of Himalayan serow is dense and rough, adapted to withstand the harsh, cold conditions of its high-altitude habitat. It has dark grey to brown fur, with lighter underparts, and can sometimes appear reddish, particularly in younger individuals. The coat also serves as insulation against the cold. It has a large head, long mule like ears, thick neck and short limbs. Its legs are muscular and well-suited for climbing rugged terrain, and its hooves are sharp and hard, aiding its ability to navigate steep, rocky slopes. Both sexes have backward-curving horns, though the horns of males are typically larger and more pronounced. The horns have transverse rings that are indicative of age (Bahuguna and Mallik, 2010). These horns can reach lengths of 25 to 30 cm and are used primarily in defence and during territorial disputes. Adults typically weigh between 85 to 140 kg, with males generally being slightly larger than females (Menon, 2014). The body length ranges from 140 to 180 cm, and the shoulder height is about 100 to 110 cm (Prater, 1993). The tail is relatively short, measuring about 10 to 20 cm.

Himalayan serow is a solitary and elusive animal, often seen in small herds of 4-5 individuals. Intrasexual territoriality (defending territories against same-sex rivals) is seen in both genders (Ochiai and Susaki, 2002). It is an agile climber, able to navigate steep rock faces and dense vegetation with ease. The species is crepuscular and nocturnal, being most active at dawn and dusk when temperatures are cooler, and predation risk is lower (Wildlife Institute of India, 2016). During the day, it often seeks shelter in dense vegetation or rocky outcrops to avoid the heat and potential predators.

Diet of Himalayan serow consists mainly of grasses, shrubs, and leaves. It is particularly fond of bamboo shoots and other plant material found in its mountainous habitat. In winter, when food sources become scarcer, the serow is known to browse on lichens, moss, and woody plants. Its digestive system is adapted to extract nutrients from tough, fibrous plant material (Srivastava *et al*., 2021).

Himalayan serow exhibits a relatively low reproductive rate. The mating season typically occurs between November and December, with births occurring in late spring or early summer (April to May). After a gestation period of approximately 7 months, females give birth to 1–2 fawn per litter. The young are born in hidden locations, typically in dense vegetation, and are kept hidden for several weeks. At birth, the young weighs about 2 to 3 kg (4.4 to 6.6 lbs). As it grows, the young serow gradually transitions to a more varied diet, eating a wider range of plants. By the age of 6 months, the young ones become more independent. By the age of 2 years, females reach sexual maturity while males mature at 3 years. After 2–4 years, both sexes leave the natal area to establish their own territories (Sathyakumar, 1997). Himalayan Serows have a typical lifespan of 19-22 years (Tokida and Miura, 1988).

Distribution

The Himalayan serow is found in the rugged, forested mountain ranges of the Himalayas, including parts of Nepal, Bhutan, India and northern Myanmar. The species thrives in temperate to alpine regions, typically at elevations ranging from 1,500 to 4,000 meters (4,900 to 13,100 feet) above sea level (Aryal, 2008; Bhattacharya *et al*., 2012). They prefer steep, rocky slopes, dense underbrush, and mixed forests of oak, rhododendron, and conifer trees. The Himalayan serow is often associated with forests and shrublands but is also found in areas with more open terrain at higher altitudes, especially during the warmer months when they may move to slightly higher elevations for grazing (Wildlife Insitute of India, 2016).

Maxent Result

A total of 116 presence points of serow were used to build up the species distribution model. Data and parameters of the MaxEnt model are provided in Table II. 21 & Table II. 22 and modelled distribution of serow in the potential distributional range (model extent, model constrain in and around PA) are given in Figure II. 24.

According to MaxEnt estimates of the relative contribution of predictor variables (Table II. 22), the distance from protected areas (PAs) contributed the most (61.6%) to the serow habitat model. The response curve for the distance to PAs, along with the distance from the forest (16.9%) and the human footprint index (2.3%), suggests that serow require protected forested habitats devoid of human disturbance. The average annual rainfall (9.8%), maximum temperature of the warmest month (5.9%), ruggedness (1.8%), and elevation (1.7%) indicate that serow primarily prefer moist, warm, undulating evergreen forest habitats at high elevations.

Table II. 21: Parameters used in MaxEnt setting for modelling of serow distribution in forested landscapes of India

Model setting	Values
Model features	Linear and Quadratic
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.1463
Area under the ROC* Curve (AUC)	0.970

Table II. 22: Contribution percentage of covariates to the best model explaining serow distribution

Covariates	Percent contribution	Permutation contribution
Distance from protected area	61.6	55.5
Distance from forest	16.9	3.7
Annual Precipitation (BIO12)	9.8	12.8
Max Temperature of Warmest Month (BIO5)	5.9	14.3
Human footprint index	2.3	4.8
Ruggedness	1.8	2.1
Elevation	1.7	7

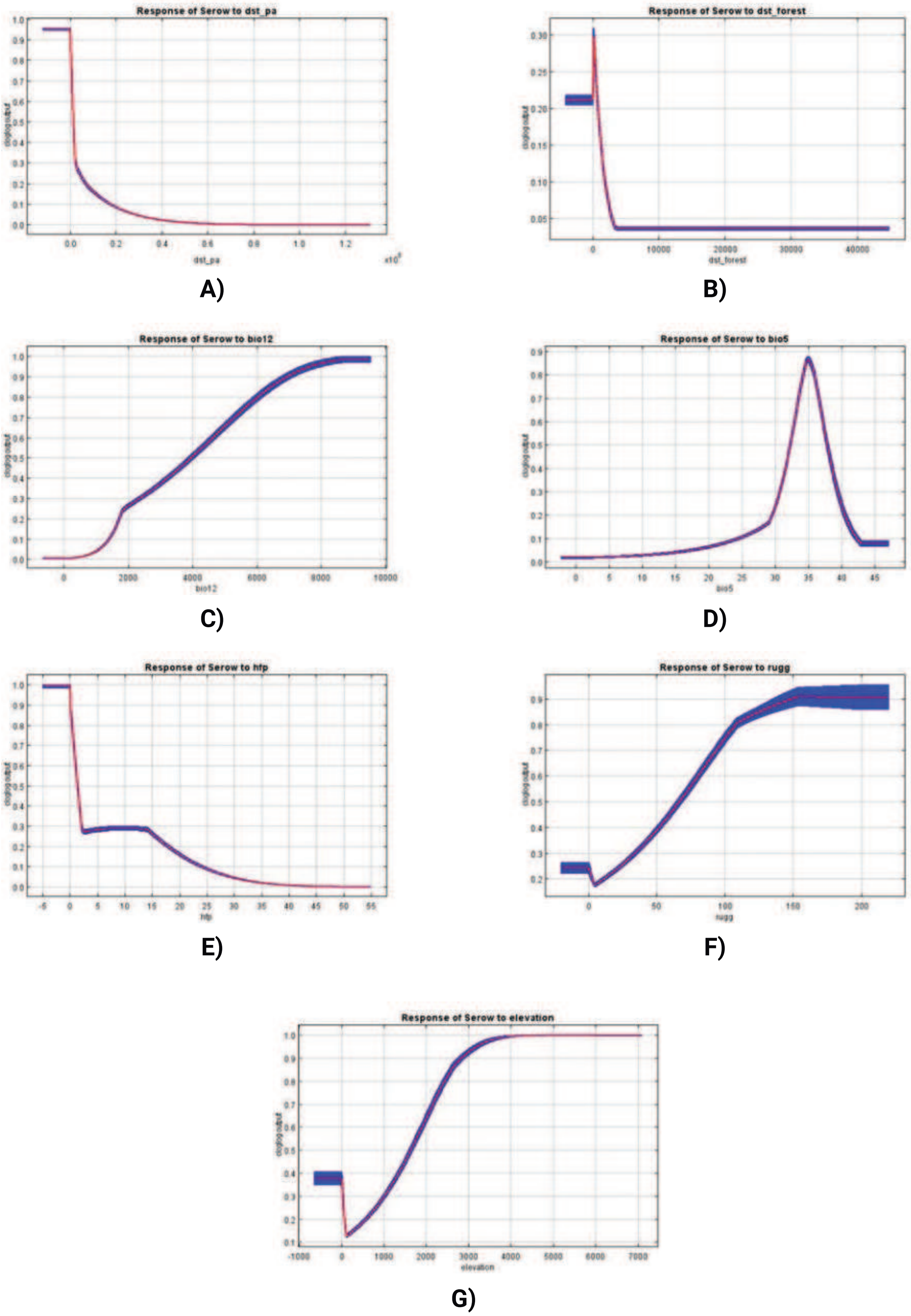


Figure II. 23: Relationship of spatial covariates used in the best fit MaxEnt model explaining himalayan serow habitat suitability across India

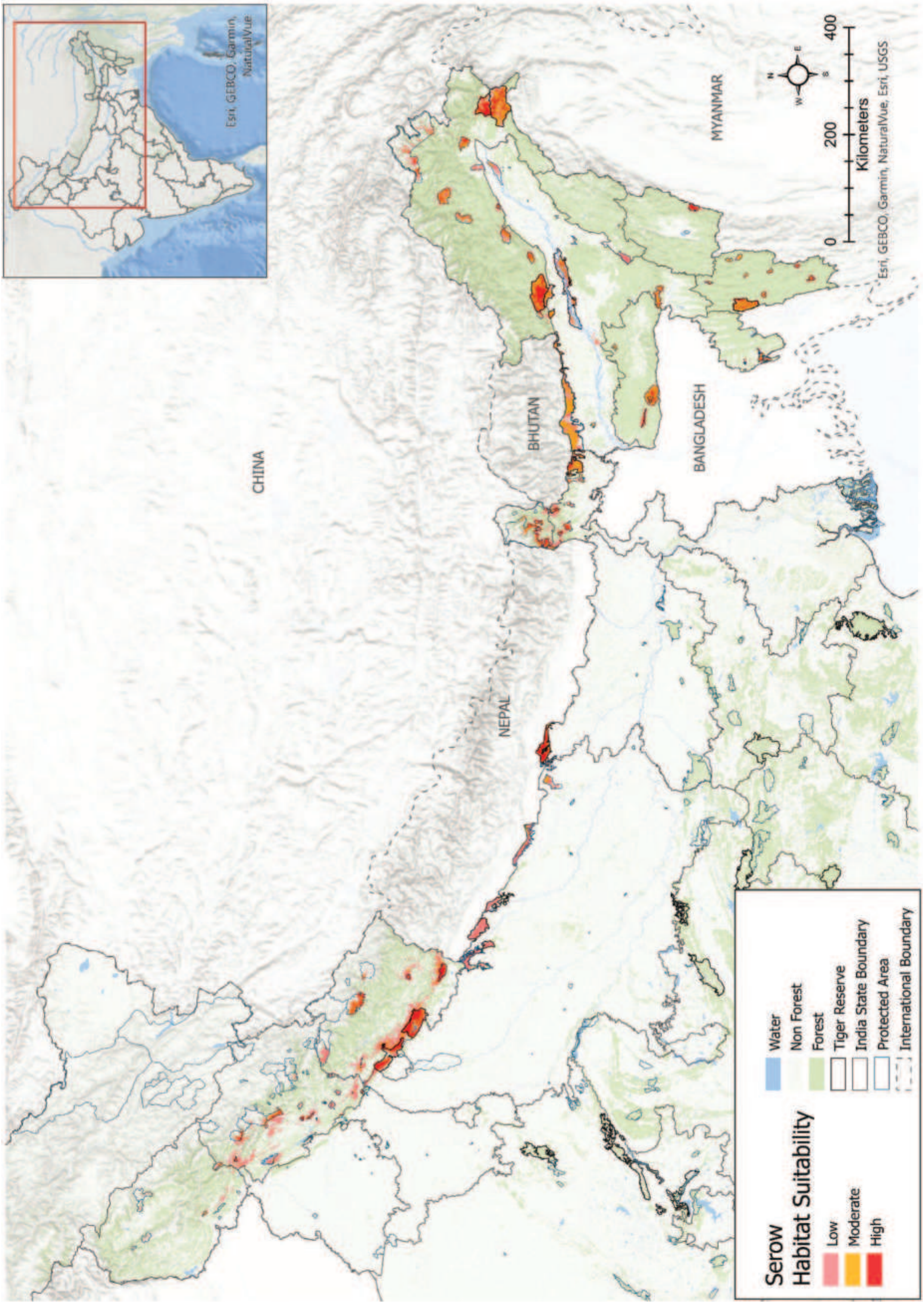


Figure II. 24: Modelled habitat suitability of himalayan serow across the India using MaxEnt

GAUR *(Bos gaurus)*

Conservation status

Wildlife (Protection) Act, 1972: Schedule I

CITES: Appendix I

IUCN Red List: Vulnerable (VU)

Introduction

The Gaur (*Bos gaurus*), also known as the Indian Bison, is the largest bovid found in the Oriental biogeographic region of the world. It is classified into three subspecies:

- *Bos gaurus gaurus found in India, Nepal, and Bhutan.*
- *B. g. readei is found in Myanmar, southern China, Laos, Vietnam, Cambodia, and northern Thailand.*
- *B. g. hubbacki found in southern Thailand and West Malaysia.*

Among these, *B. gaurus gaurus* is more closely related to *B. gaurus readei* than to *B. gaurus hubbacki*. The Mithun or Gayal, a domesticated form of the Gaur found in parts of India, China, and Myanmar, is considered a separate species, *Bos frontalis*, by the IUCN. Another subspecies, *B. g. sinhaleyus*, found in Sri Lanka, is locally extinct.

Species Description

The Gaur (*Bos gaurus*), also known as the Indian Bison, is the tallest and second heaviest bovid in Asia (Krishnan, 1972). This robust wild bovid has a head and body length ranging from 250 to 330 cm, with a tail measuring between 70 and 105 cm. A distinctive feature of the Gaur is its prominent convex ridge on the forehead, which creates a deep hollow in the upper part of its head. The shoulder height varies from 142 to 220 cm, with females averaging around 168 cm and males approximately 188 cm. The shoulder hump is present in both sexes; however, it is particularly pronounced in males. Gaurs possess strong limbs that are pale-coloured from the knees downward, and both sexes exhibit sexual dimorphism. Adult bulls can be identified by a muscular crest between their shoulders and a large dewlap hanging between their forelegs, while females have a smaller dewlap and are generally lighter in colour. Males are shiny black, whereas females and juveniles are brown (Krishnan, 1972; Schaller, 1967). In terms of size, Gaurs typically weigh between 650 and 1,000 kg, with males being about 25% larger than females. Both genders have horns that can reach lengths of 1.1 m, curving upwards from the sides of their heads, starting with a yellow base and darkening to black at the tips. The ratio of white to black on a Gaur's horns indicates its age, with males over eight years old often having horns that are more than 85% white and heavily corrugated near the base. The gestation period for Gaurs lasts about eight to nine months, typically resulting in a single calf, and they can live up to 24 years in captivity (Ahrestani *et al.*, 2011; Pasha *et al.*, 2004).

Gaur is a social animal with matrilineal society where females lead the herd. Males lead a solitary life or form bachelor herds with young bulls, they accompany the herd with females during rut (Schaller, 1967). Average herd size could be between 5 to 10 individuals but a composite of multiple herds containing 45 to 60 individuals has also been observed (Ahrestani & Karanth, 2014; Johnsingh, 1983). In undisturbed areas gaur is diurnal, but in areas of high human disturbance, it is reported to be nocturnal (Duckworth *et al.*, 2016; Johnsingh, 1983; Sankar *et al.*, 2013; Schaller, 1967).

Gaur from different age classes have different home range sizes. This was calculated using radio telemetry data. Estimated home ranges of gaur to be found 29.9 km^2 for a yearling male, 52.1 km^2 for a yearling female, and 137.3 km^2 for an adult male in Malaysia. Reintroduced gaurs in Bandhavgarh, have a rome range between 135 to 142 km^2 for males and 32 to 169 km^2 for females after the exploration of new areas.

Gaur prefers undisturbed forest tracts with water availability (Pasha *et al*., 2004; Schaller, 1967). Gaur is a bulk feeder that grazes more than browse. Grass makes up the majority of their diet (66%), followed by browse, herbs, and other foods (Chetri, 2006). Depending upon food availability they show seasonal migrations (Ahrestani & Karanth, 2014; Sankar *et al*., 2013).

Distribution

Gaur range is restricted to hilly terrain with evergreen, semi-evergreen, moist and dry deciduous forests (Ahrestani & Karanth, 2014). They are found in fragmented forests across Bhutan, Cambodia, China, India, Laos, Malaysia, Myanmar, Nepal, Thailand, and Vietnam, with 80% of their historic range lost due to anthropogenic pressure (Corbet & Hill, 1992; Duckworth *et al*., 2016). Within India, major Gaur populations can be found in protected areas located in the Western Ghats, Eastern Ghats, Central Indian highlands, and North-Eastern Himalayan foothills (transnational habitats contiguous with Bhutan and Nepal), with a few isolated populations in hill tracts south of the Brahmaputra River (Ashokkumar *et al*., 2011, Choudhary, 2002).

Maxent Result

For gaur species distribution model, we have used a total of 7511 presence locations to run the model. Data and parameters of the MaxEnt model are provided in Table II. 23 & Table II. 24 and modelled distribution of gaur in the potential distributional range (model extent) are given in Figure II. 26.

The relative contribution of predictor variables (Table II.23) from the MaxEnt estimates for gaur has given the maximum contribution of the Human footprint index (36.4%), which indicates high avoidance of human presence by the species. The second highest variable which has contributed to the model is distance to forested area (27.5%), which indicates the species' preference for dense forest area as their habitat. The maximum temperature of the warmest month has a contribution of 25.2%, subsequently, elevation, distance from water and NDVI of pre-monsoon have contributed 4.3%, 4.2% and 2.5 %, respectively.

Table II. 23: Parameters used in MaxEnt setting for modelling gaur distribution in forested Landscapes of India

Model setting	Values
Model features	Linear, Quadratic, Product and Hinge
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.454
Area under the ROC* Curve (AUC)	0.760

Table II. 24: Contribution percentage of every covariates to the best model explaining gaur distribution

Covariates	Percent contribution	Permutation contribution
Human Footprint Index	36.4	34
Distance from forest	27.5	43.9
Max Temperature of Warmest Month (BIO5)	25.2	1
Elevation	4.3	8.1
Distance from water	4.2	8.7
NDVI pre monsoon	2.5	4.3

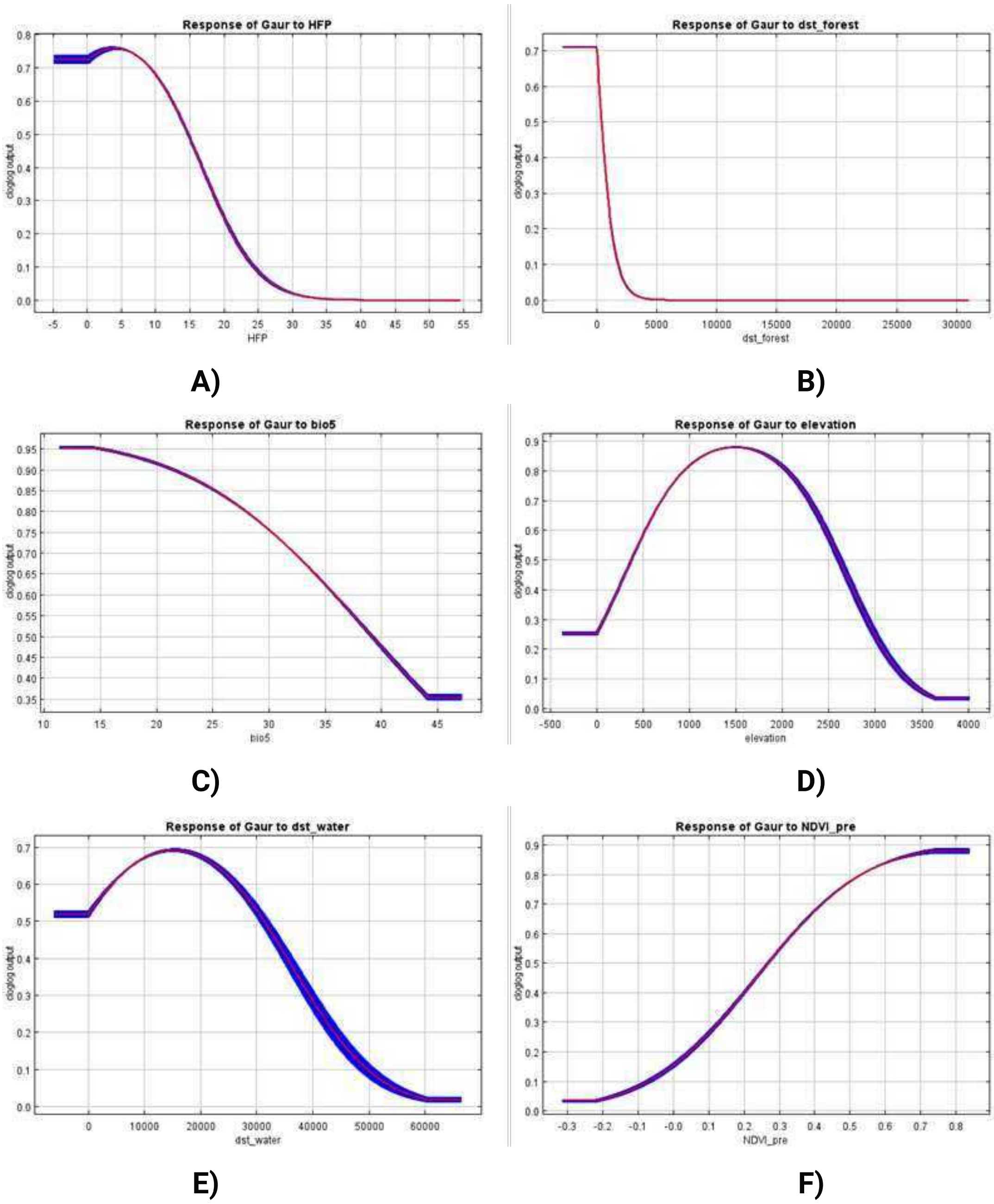


Figure II. 25: Relationship of spatial covariates used in the best-fit MaxEnt model explaining gaur habitat suitability across India

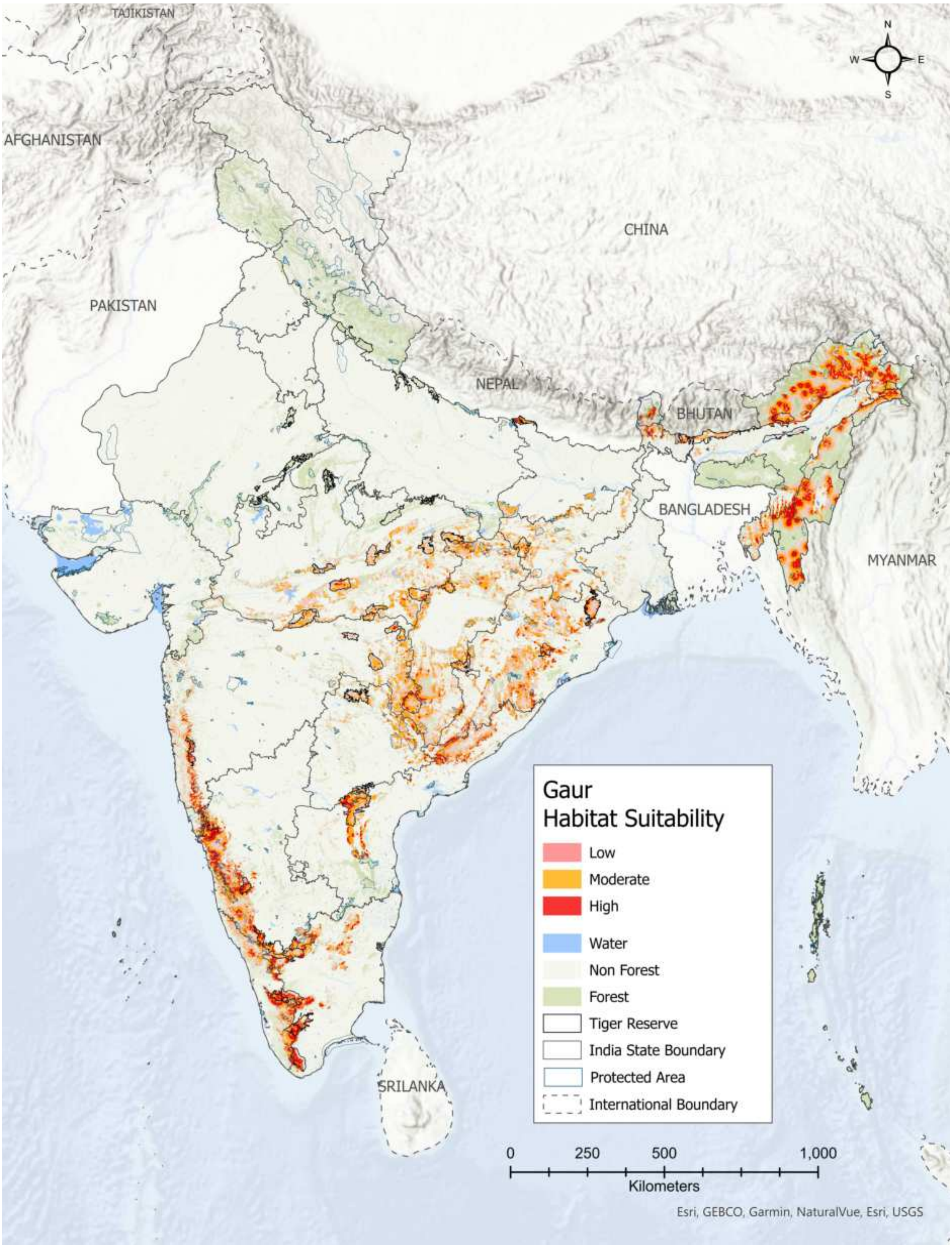


Figure II. 26: Modelled habitat suitability of gaur across the India using MaxEnt

II.3. SUIDAE (PIG)

WILD PIG (*Sus scrofa*)

Conservation status

Wildlife (Protection) Act, 1972: Schedule II

IUCN Red List: Least Concern (LC)

Introduction

The wild pig (*Sus scrofa*) is one of the world's most widely distributed ungulate species. It belongs to order Artiodactyla, family Suidae and is native to Eurasia. Taxonomically, the Indian group of wild pig consists of three different subspecies:

- *Sus scrofa cristatus* (Northern wild pig): Extends from the Himalayan foothills to east through north-east India and to River Godavari in the south.
- *Sus scrofa affinis* (Southern wild pig): Distributed in the south of River Godavari.
- *Sus scrofa davidi* (Western wild pig): Found in the arid parts of north-west India, including Gujarat, Rajasthan, Haryana and western Punjab.

The species has gone feral in the Andaman & Nicobar Islands and developed into 'long-snouted' and 'short-snouted' forms over the years (Menon, 2014).

Species Description

Wild pigs have an elongated snout ending in a hairless flat disc (rhinarial pad) with nostrils. They have a sparse greyish-brown coat and a stiff mane of bristles on their back, which appears like an erect crest during fierce fights. Piglets are lighter brown with longitudinal stripes for the first six months. The feet are narrow with four toes in each foot. The lateral toes are completely developed but do not touch the ground while walking (Chauhan, 2004). A full-grown male wild pig stands about 90 cm tall, weighs around 230 kg, and has dark markings on the legs. Upper and lower canines are well-developed in both sexes, with males having larger, more visible protruding canines (Mayer, 2009). Lower tusks can grow up to 30 cm in males. Sows are smaller, have shorter manes, more rounded backs, and slight lip curls (Mayer, 2009).

The three subspecies of wild pigs can be distinguished by morphological characters. Northern wild pig (*S. s. cristatus*) is rusty grey with a long mane reaching the rump and dark brindles in the fur. Southern wild pig (*S. s. affinis*) is browner and larger than northern wild pig. Western wild pig (*S. s. davidi*) is lighter grey in colour, smaller in size, has a shorter mane, longer head than the northern race and lacks dark markings on the legs.

Wild pigs are diurnal but most active in the early morning and late evenings. However, they have been observed to become nocturnal in areas of high human disturbance (Waithman, 2001; Pei, 2006). They are generally seen in herds (sounders) of 6–20 individuals. The basic social unit is matrilineal or bachelor groups, while old boars are usually solitary. The species is generally not territorial but exhibits home range behaviour. They have very strong olfactory senses, while eyesight and hearing are moderate. Wild pigs are outrageously bold, often engaging in fights with larger animals. Intra-sexual aggression among boars is common and increases with age. Competition for breeding opportunities and forage resources occurs year-round, but is most frequent during the peak of breeding (Barrette, 1986).

Vocalisation is frequent in wild pigs. They make contact calls with grunting noises. Some studies show that piglets imitate their mother's sounds, resulting in unique vocalizations for different litters (Bahuguna & Mallik, 2010). Combat calls are relatively high-pitched compared to the loud huffing noise made as alarm calls. Wild pigs wallow in mud pools to lower body temperature and protect against insects.

Sexual maturity attain at 6-10 months age (Wickline, 2014). Although breeding occurs year-round, peak reproductive activity positively correlates with resource availability (Chauhan, 2004). When pairing, wild pigs congregate in large circles with the master boar in the center (Chauhan, 2004). After a gestation period of 4 months, 4-13 piglets are born. The mother builds heaped nests of grass or twigs before giving birth. The average lifespan of a wild pig is 10–12 years (Singh *et al*., 2018).

Wild pigs are omnivorous, feeding on grass, roots, tubers, fruits, rodents, fish, crustaceans, mollusks, insects, and more. They have been observed feeding on venomous snakes, small ungulates, or kills of tigers and leopards. Wild pigs are infamous as 'crop pests' for raiding crop fields in groups, leading to frequent conflicts with humans.

Distribution

Wild pigs are classic generalist species that have successfully expanded their population globally (except Antarctica). Being resilient and fast-breeding, they can establish populations in new areas (Erkinaro *et al*., 1982; Ahmed, 1991). They inhabit a wide range of habitats, including semi-arid, scanty bushland, wetlands, grasslands, evergreen forests, and mixed deciduous forests. Historically, wild pigs were native to many countries but became "locally invasive" in some regions due to human population expansion. They utilize human-altered landscapes and often venture into agricultural land to forage (Fadeev, 1975; Erkinaro *et al*., 1982). The species *Sus scrofa* is found throughout the forested areas of India, Pakistan, southern Nepal, Sri Lanka, Myanmar, Thailand, and some areas of the Malay Peninsula and Europe. In India, they are found from the Himalayan foothills in the north to the southernmost regions of the Western Ghats and Eastern Ghats. They are found only in foothills and are absent in the high-altitude regions of the Himalayas. Previously, their distribution was limited in the deserts of western Rajasthan. However, the construction of additional canals in these arid regions has created favourable conditions for their population to increase.

Maxent Result

A total of 17307 presence points of wild pig were used to build up the species distribution model. Data and parameters of the MaxEnt model are provided in Table II.25 & Table II. 26 and modelled distribution of wild pig in the potential distributional range (model extent) are given in Figure II. 27.

The response curve for the human footprint index indicates that wild pigs can live alongside human disturbance, but their population decreases as disturbance increases . According to the temperature bioclimatic variables response curve, wild pigs can withstand quite high temperatures and elevations of 3,000-4,000 meters, as well as rugged terrain. The elevation response curve further supports this. NDVI measurements, both pre and post-monsoon, as well as the distance to water response curve, suggest that wild pigs prefer dense vegetation with moist soil and water availability.

Table II. 25: Parameters used in MaxEnt setting for modelling of wild pig distribution in forested landscapes of India

Model setting	Values
Model features	Linear, Quadratic and Product
Output formats	Cloglog
Threshold of 'Maximum test sensitivity plus specificity'	0.352
Area under the ROC* Curve (AUC)	0.649

Table II. 26: Contribution percentage of covariates to the best model explaining wild pig distribution

Covariates	Percent contribution	Permutation contribution
Human footprint index	53.8	30.9
Elevation	11.9	1.7
Max Temperature of Warmest Month (BIO5)	10	12.1
NDVI post monsoon	8.9	11.4
NDVI pre monsoon	8.7	3.6
Min Temperature of Coldest Month (BIO6)	3.8	26.2
Distance from water	2	1.4
Annual Mean Temperature (BIO1)	0.8	12.7

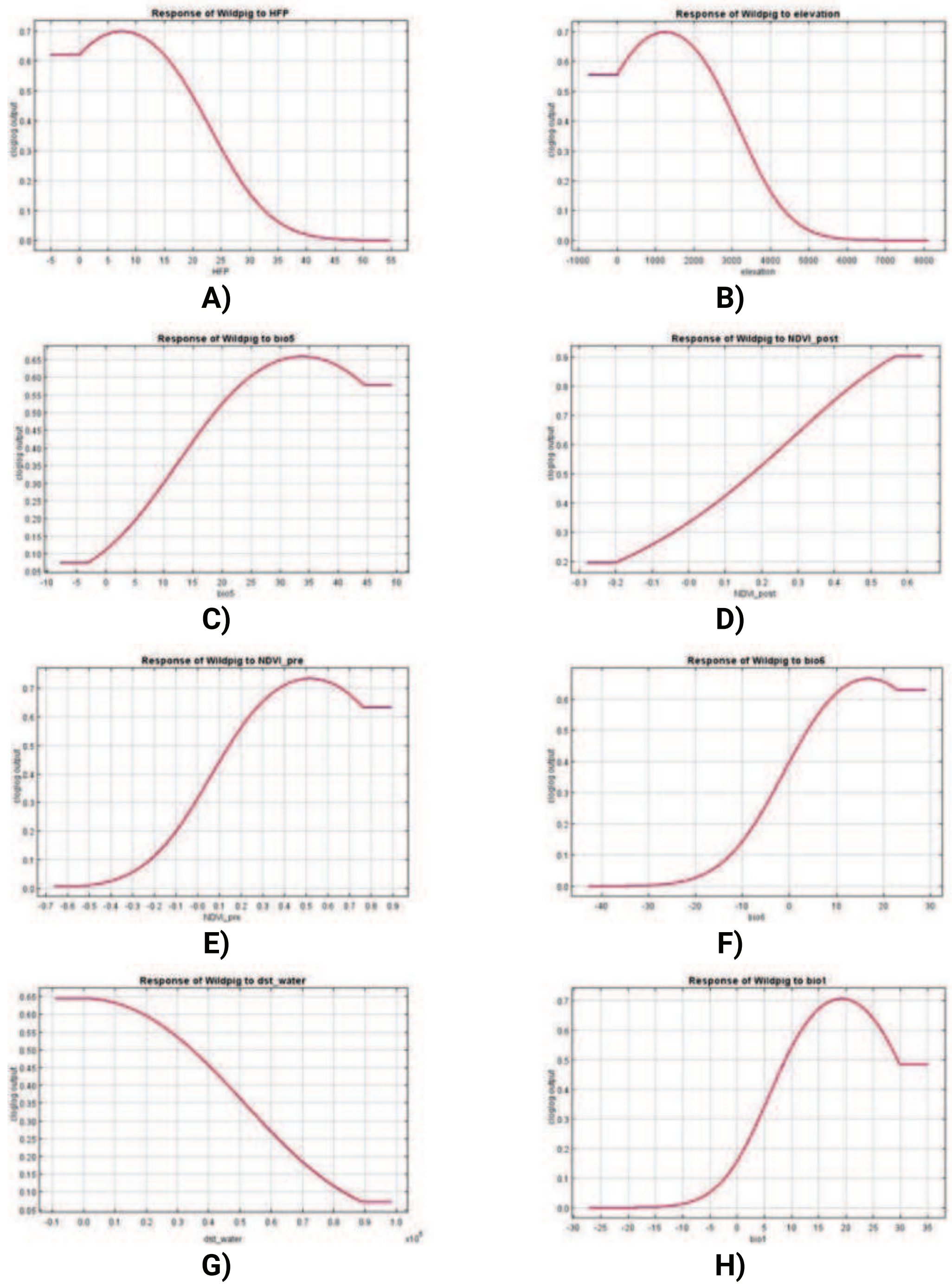


Figure II. 27: Relationship of spatial covariates used in the best fit MaxEnt model explaining wild pig habitat suitability across India

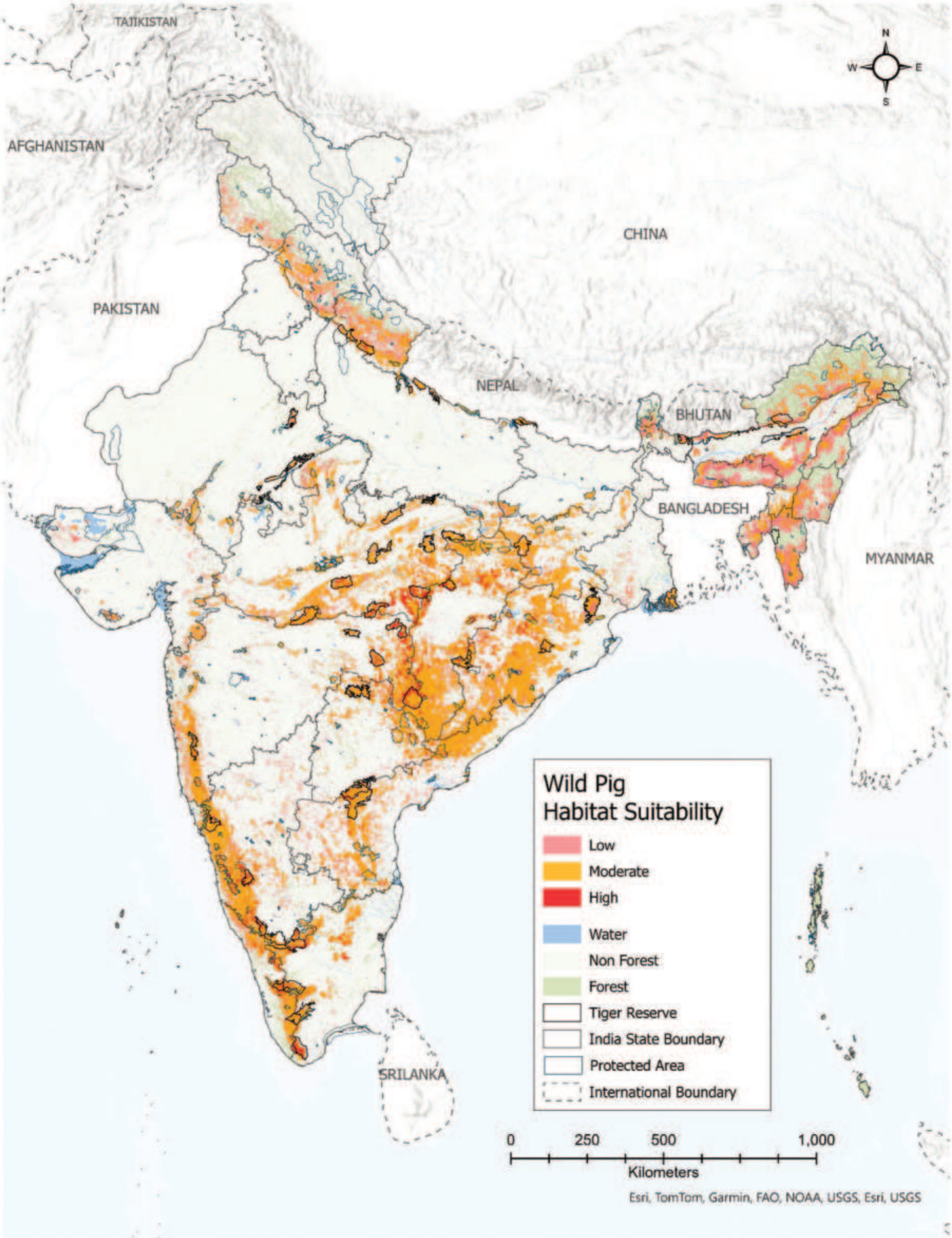


Figure II. 28: Modelled habitat suitability of wild pig across the India using MaxEnt

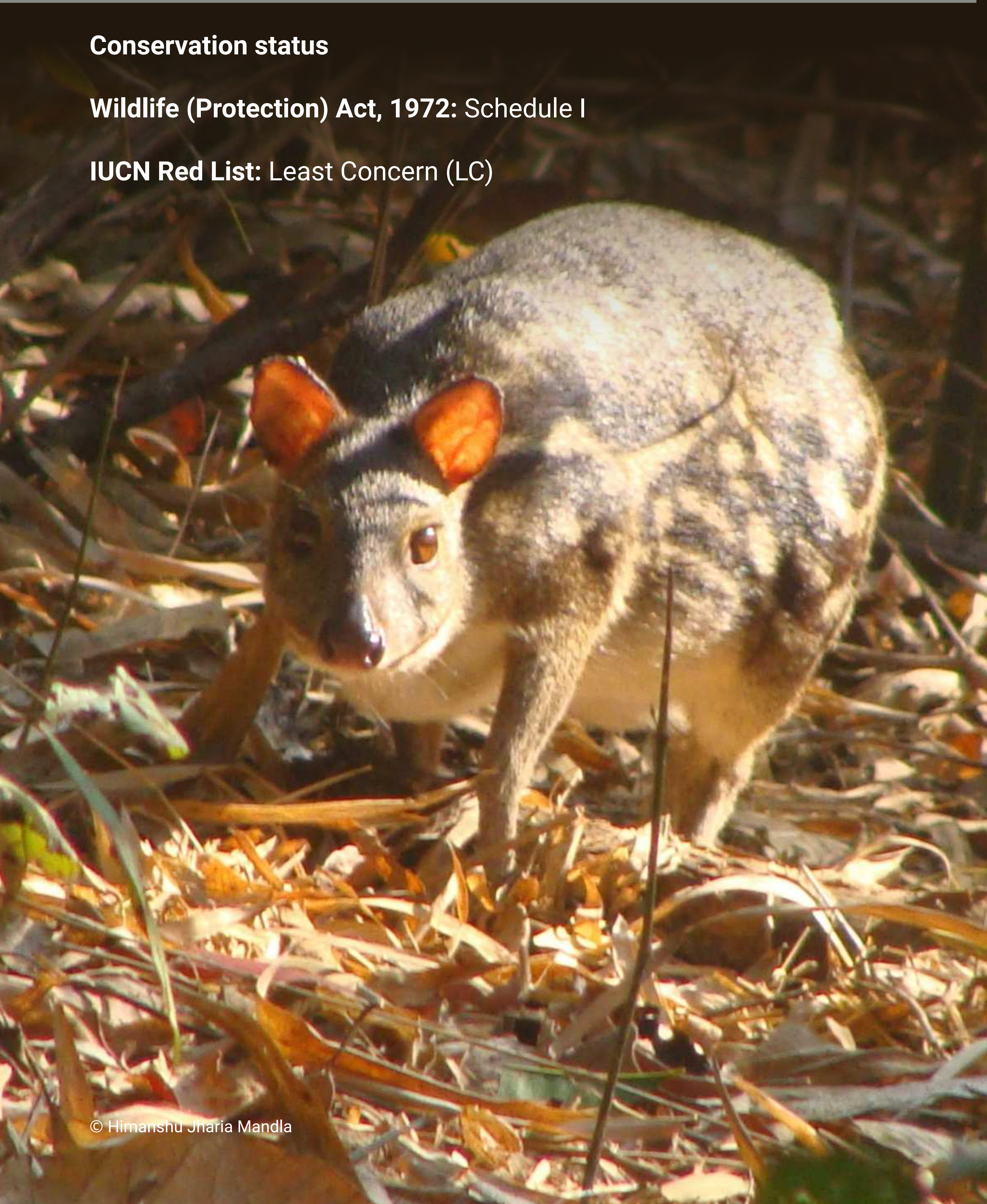
II.4. TRAGULIDAE (MOUSE DEER)

MOUSE DEER (*Moschiola indica*)

Conservation status

Wildlife (Protection) Act, 1972: Schedule I

IUCN Red List: Least Concern (LC)



Introduction

Mouse Deer also known as Indian chevrotain is an even toed ungulate (artiodactyl) and belong to the family Tragulidae, suborder Ruminantia. It is a unique ruminant with a three chambered stomach instead of a four chambered one, representing the link between ruminants and non-ruminants. Therefore, considered as primitive ruminants and also been called living fossils (Janis, 1984). Although, it is considered to be the smallest deer in India, Tragulids are not true deer / cervids.

The 10 extant species of mouse deer are placed in 3 genera – *Hyemoschus, Moschiola* and *Tragulus*. Genus *Moschiola* can be further divided into 3 closely related species (Groves and Meijaard, 2005) and only *Moschiola indica* (Indian chevrotain) found in India.

Species Description

Mouse deer has an olive-brown coat on the dorsal side with a pattern of white spots fusing into stripes along its flank and two pairs of distinct white stripes across the throat. The ventral side is creamish beige in colour. The crown and forehead is darker brown than the rest of its body. No clear sexual dimorphism can be seen other than slight differences in body sizes (Males are larger). Facial or foot glands are absent in the species and neither sex has antlers / horns. Upper canines can be seen in both sexes and like other ruminants, they lack upper incisors. The canines are large, curved, more prominent in males and smaller in females (Bahuguna and Mallik, 2010). Mouse deer measures 45 – 55 cm in length with a shoulder height of 25 – 30 cm and a very short tail (2 – 4 cm). An adult weigh around 2.5 – 3 kg. It has short and slender fore limbs which are dark grey in colour and distinctively high hindquarters, which gives it an arched back and a squat – like appearance (often mistaken for a hare). The hooves are small with 4 well developed toes. Its wedge shaped body allows swift movement through bushes and all the other characteristics acts as an effective camouflage when the animal is at rest.

Mouse deer prefers dense vegetation and generally exhibit crepuscular/ nocturnal habit. It spends most of the daytime concealed within dens built in tree hollows or rocky crevices. The species is very shy in nature and avoids open areas. It can occasionally be seen resting in leaf litter of the forest floor, where it often gets unnoticed due to its cryptic pelage. It is quite vigilant and scurries away at the slightest hint of alarm (Sankar and Goyal, 2004).

Adults are mostly solitary except during courtship. Male remains with the female during rutting season (June – July). Females attain sexual maturity at 5-5.5 month's age. After a gestation period of about 5 months, female gives birth to young ones (usually twins) that weighs around 470 g at birth. Although mouse deer breed throughout the year, peak birthing period is from September to February, the period following the monsoon season (Parvathy *et al*., 2014). They have a lifespan of 8-12 years in the wild.

Tragulids are an ancient group of frugivorous ungulates. Likewise, mouse deer is known to feed upon fallen fruits of species like *Terminalia bellerica*, *Gmelina arboria, Garuga pinnata*, *etc.* (Krishnan, 1972). It also forages for herbs and shrubs on the forest floor. This kind of feeding behaviour is very typical of a small –bodied ruminant – as a fruit based diet allows rapid fermentation and swift gut passage while meeting high energy requirements per unit body mass (Kay, 1987; Heydon and Bulloh, 1997).

Distribution:

Distributed across the peninsular India. Mouse deer inhabits Tropical deciduous moist evergreen and semi – evergreen forests of the peninsular Indian hills, plains and plateaus. The species also inhabits plantation forests (Ramesh *et al*., 2012). It is also found in montane forests, up to an elevation of 1850 m (Menon, 2017) It is commonly found in the forest's areas along the Western Ghats, Eastern Ghats (up to Orissa) and in some region of Central India (Schallar, 1967). Mouse deer prefer grass covered rocky and forest habitats in proximity to water sources like streams and rivers (Sankar and Goyal, 2004).

Maxent Result

To run the MaxEnt model of mouse deer we have used a total of 3092 presence locations. All the data and parameters of the model are provided in Table II. 27 & Table II. 28 and modelled distribution of mouse deer in the potential distributional range (model extent) are given in Figure II. 30.

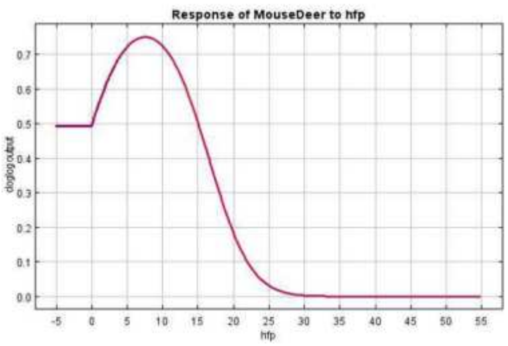
According to MaxEnt estimates of the relative contribution of predictor variables (Table II. 14), the human footprint index (35.9%) has contributed the most to the Mouse deer habitat model. The response curve for distance to dense forest (26.5%) has second most-highest contribution to the model, which indicates the Mouse deer prefer dense habitation and devoid of human disturbance. The response curve of NDVI pre monsoon (24.8%), precipitation seasonality (7.2%), and raggedness (5.7%) suggests that mouse deer can be found in tropical deciduous, moist evergreen and semi-evergreen forests but mainly prefer little rugged, dense, moist forests.

Table II. 27: Parameters used in MaxEnt setting for modelling mouse deer distribution in forested Landscapes of India

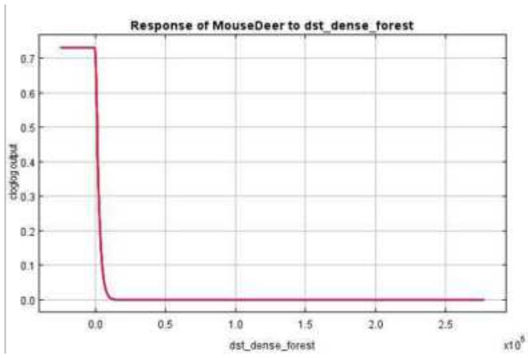
Model setting	Values
Model features	Linear Quadratic Product
Output formats	Cloglog
Threshold of 'Maximum test sensitivity and specificity Cloglog'	0.36
Area under the ROC* Curve (AUC)	0.853

Table II. 28: Contribution percentage of every covariate to the best model explaining mouse deer distribution

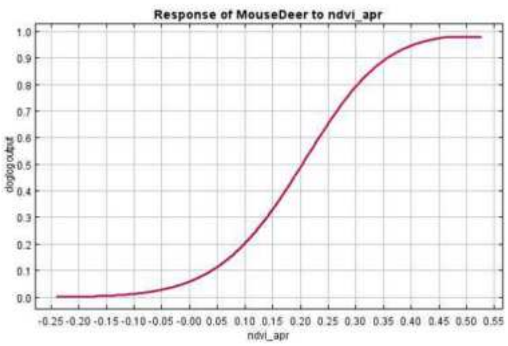
Covariates	Percent contribution	Permutation contribution
Human footprint index	35.9	23.4
Distance from Dense Forest	26.5	34.8
NDVI pre monsoon	24.8	12.9
Precipitation seasonality (bio15)	7.2	10.1
Ruggedness	5.7	18.8



A)

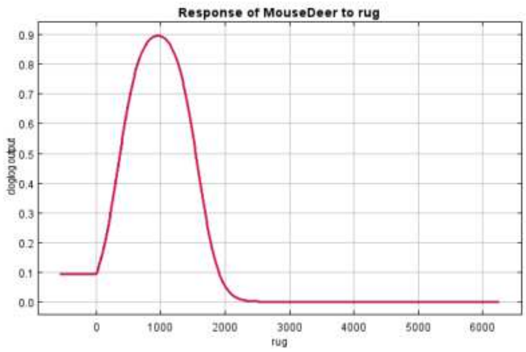


B)



C)

D)



E)

Figure II.29: Relationship of spatial covariates used in the best fit MaxEnt model explaining mouse deer habitat suitability across India

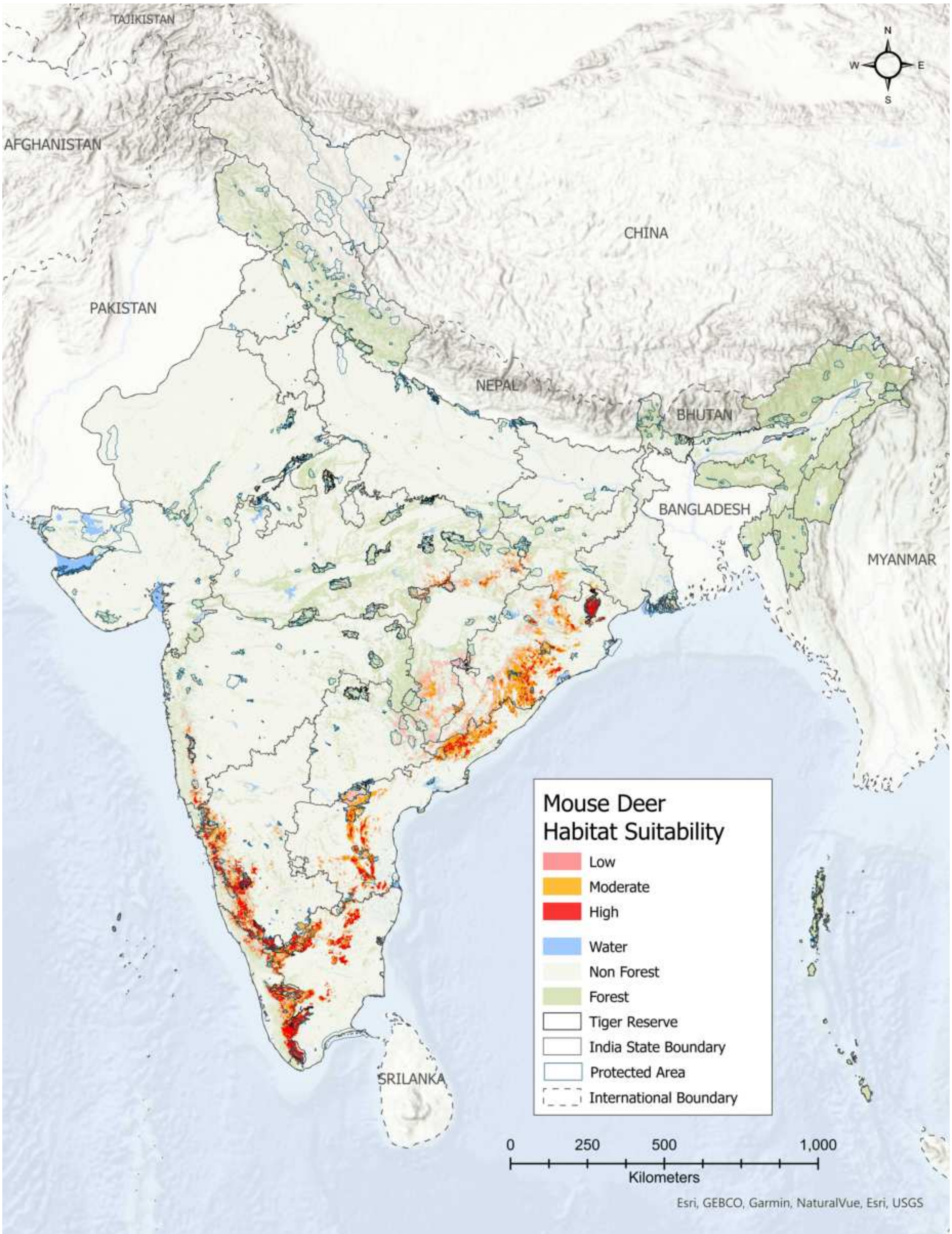


Figure II.30: Modelled habitat suitability of mouse deer across the India using MaxEnt

SECTION III

Shivalik Hills and Gangetic Plains Landscape

Sumandrita Banerjee, Shravana Goswami, Vaishnavi Gusain, Dhruv Jain, Shikha Bisht, Vishnupriya Kolipakam, Yadvendradev Jhala, Qamar Qureshi

The Shivalik Hills and Gangetic Plains (SHGP) landscape spans the Shivaliks, bhabar, and terai forest tracts across six Indian states—Himachal Pradesh, Uttarakhand, Uttar Pradesh, Bihar, West Bengal, and Assam. However, for assessment purposes, the landscape is limited to the eastern extent of Bihar. The lower-altitude hills of West Bengal and Assam are included in the Brahmaputra plains and North-eastern hills (Jhala *et al*., 2008).

The Shivaliks, known as the Churia Hills in Nepal, are young fold mountains (elevation 1,000–1,500 m) prone to erosion, with loose boulders and ephemeral streams. Erosion from the Shivaliks forms the boulder-strewn bhabar tract, where streams go underground, re-emerging in the waterlogged terai plains (Champion and Seth, 1968). The terai, characterized by a high water table, annual flooding, and shifting floodplains, is dominated by tall grasses and supports diverse ecosystems (Champion and Seth, 1968).

Western SHGP regions, including Rajaji and Corbett tiger reserves, are largely dominated by Shivaliks and parts of outer Himalayas; defined by seasonal and perennial streams, while the eastern SHGP, hosting Pilibhit, Dudhwa, and Valmiki tiger reserves, is composed primarily of sal; and miscellaneous forests of plain and terai grasslands (Champion and Seth, 1968) interspersed with human-use areas and sugarcane fields. This landscape, which blends elements from peninsular India and the Himalayas, sustains rich biodiversity, including iconic species like the barasingha (swamp deer), hog deer, rhinoceros, hispid hare, Bengal florican and tigers. Its transboundary connectivity with Nepal underscores its critical role in long-term tiger conservation.

Flora

The flora of the SHGP landscape combines elements from peninsular India and temperate regions of the western Himalayas. It is moist deciduous forests dominate, with sal (*Shorea robusta*) being the predominant species.

Bhabar and Terai: The bhabar tract supports sal forests, while the terai comprises woodland-grassland-wetland complexes dominated by graminoid species like *Saccharum narenga, Sclerostachya, Imperata, and Typha*. Species associated with the eastern Himalayas and Western Ghats, such as *Schefflera venulosa and Diospyros embryopteris*, are also present (Champion and Seth, 1968; Dabadhgao and Shankaran, 2010).

Endemic species: Notable endemic flora includes *Eremostachys superba* and *Catamixis baccharoides (*Modal *et al*., 2021*)*.

Fauna

The SHGP is a biodiversity hotspot, supporting diverse fauna ranging from cervids to rare and endangered species. The region is home to five species of deer: chital (*Axis axis*), sambar (*Rusa unicolor*), muntjac (*Muntiacus vaginalis*), hog deer (*Axis porcinus*), and barasingha (*Rucervus duvaucelii*). Additionally, three species of antelope thrive here: nilgai (*Boselaphus tragocamelus*), blackbuck (*Antilope cervicapra*), and chousingha (*Tetracerus quadricornis*). Other notable ungulate species include the Asian elephant (*Elephas maximus*), one-horned rhinoceros (*Rhinoceros unicornis*), gaur (*Bos gaurus*), wild pig (*Sus scrofa*), goral (*Naemorhedus goral*), and serow (*Capricornis thar*), which inhabit the slopes of the Shivalik hills.

Ungulate Distribution and Abundance in the landscape

The distribution and abundance of chital and sambar are mapped using landscape model from line transect data. Chital is most abundant and widely distributed in the landscape (Figure III. 1). It is present in high density in Uttarakhand followed by Uttar pradesh and Bihar. In Uttarakhand, density of chital is high in tiger reserves as well as outside tiger reserve. It has a continuous presence from Rajaji to Dudhwa. After Dudhwa chital density is low and restricted to protected areas only.

The largest population of sambar is in Uttarakhand largely in and around Rajaji and Corbett tiger reserves with moderate and low abundance in other protected areas and reserve forests (Figure III. 2). Uttar Pradesh and Bihar has a small sambar population that is restricted to protected areas only.

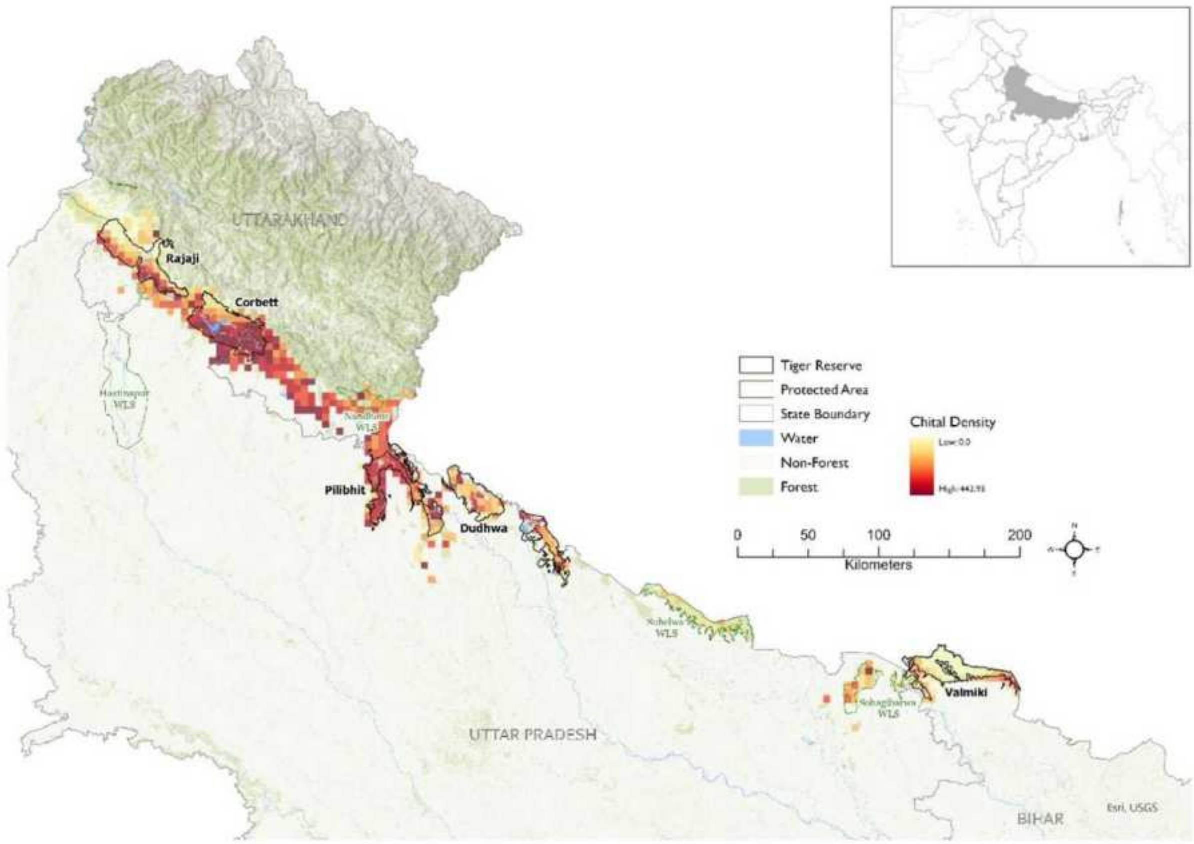


Figure III. 1: Distribution and density of chital (per 25 km²) in Shivalik hills and Gangetic plains landscape.

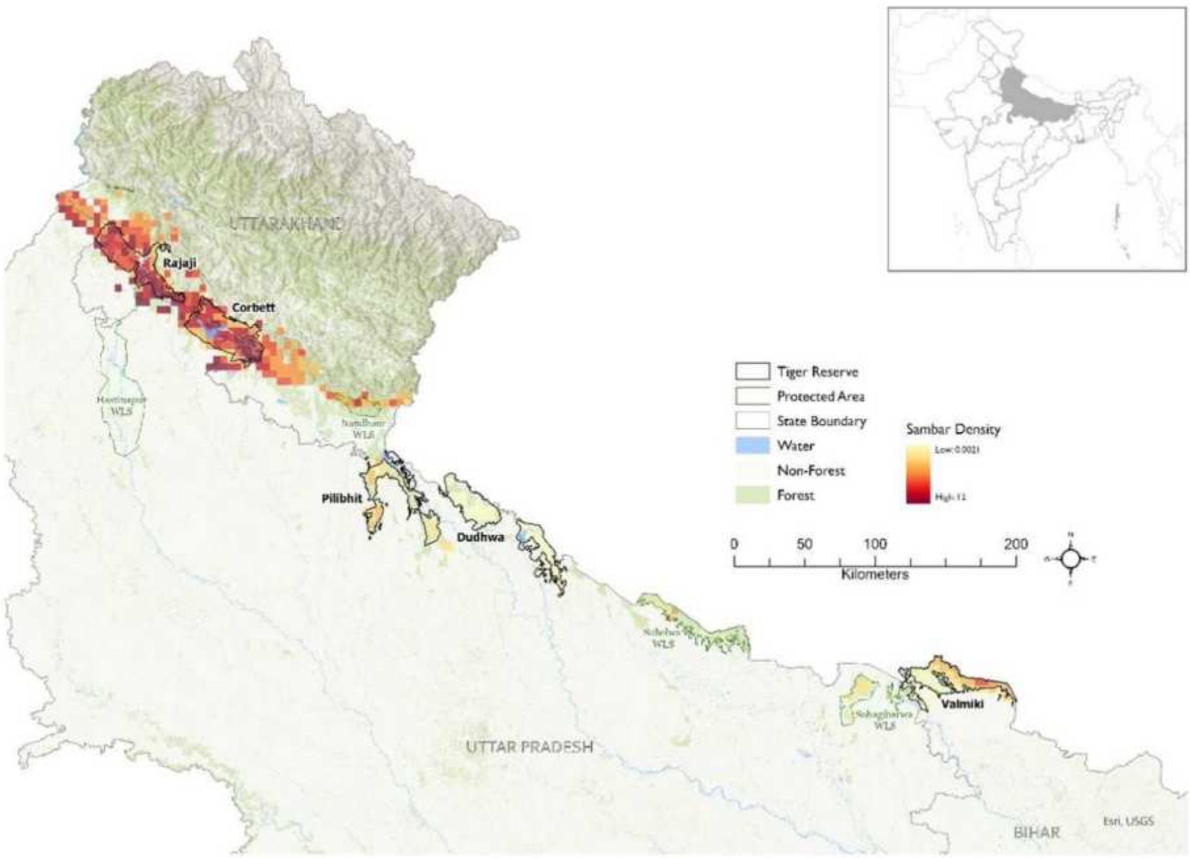


Figure III. 2: Distribution and density of sambar (per 25 km²) in Shivalik hills and Gangetic plains landscape.

The relative abundance maps of barking deer, hog deer, nilgai, wild pig and gaur in SHGP landscape is based on camera trap RAI. The barking deer and wild pig are widely distributed in this landscape (Figure III. 3, Figure III. 7), followed by nilgai (Figure III. 6), hog deer (Figure III. 5) and gaur is only reported from Valmiki tiger reserve of Bihar (Figure III. 4). Wild pig is widely distributed across this landscape within protected areas and around forested habitat. There is a huge issue of crop depredation by wild pig. Barking deer is well distributed and have good abundance in Uttarakhand, while in Uttar Pradesh and Bihar the population is small as the existing habitat is less suitable for barking deer. Hog deer population is found all along the rivers flood plains having grassy patches. It is abundant in Uttar Pradesh followed by Uttarakhand and Bihar. The population is not doing well due to poor grassland management, deterioration in grassland habitat, and poaching. Gaur is only found in Valmiki tiger reserve. This is the only northern population with contiguity to Chitwan population of Nepal.

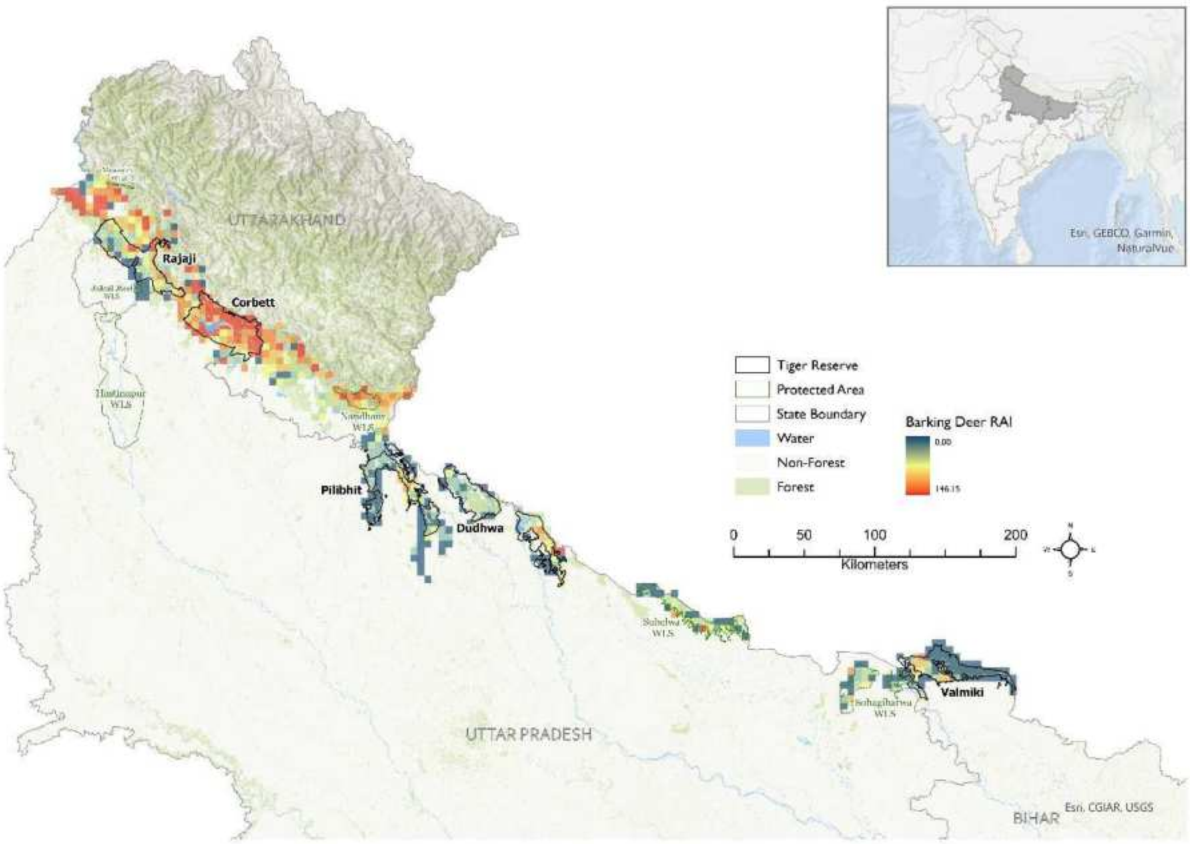


Figure III. 3: Spatial relative abundance of barking deer (per 25 km²) in Shivalik hills and Gangetic plains landscape.

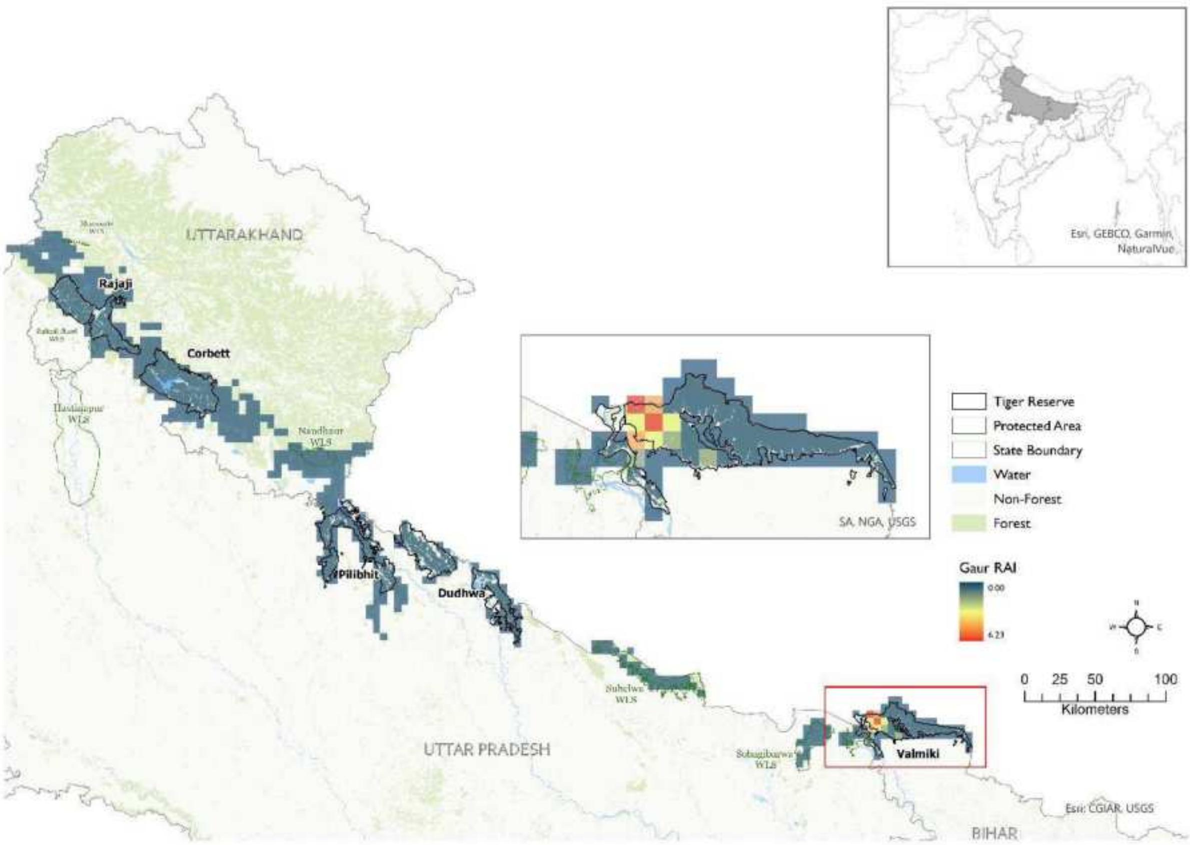


Figure III. 4: Spatial relative abundance of gaur (per 25 km²) in Shivalik hills and Gangetic plains landscape.

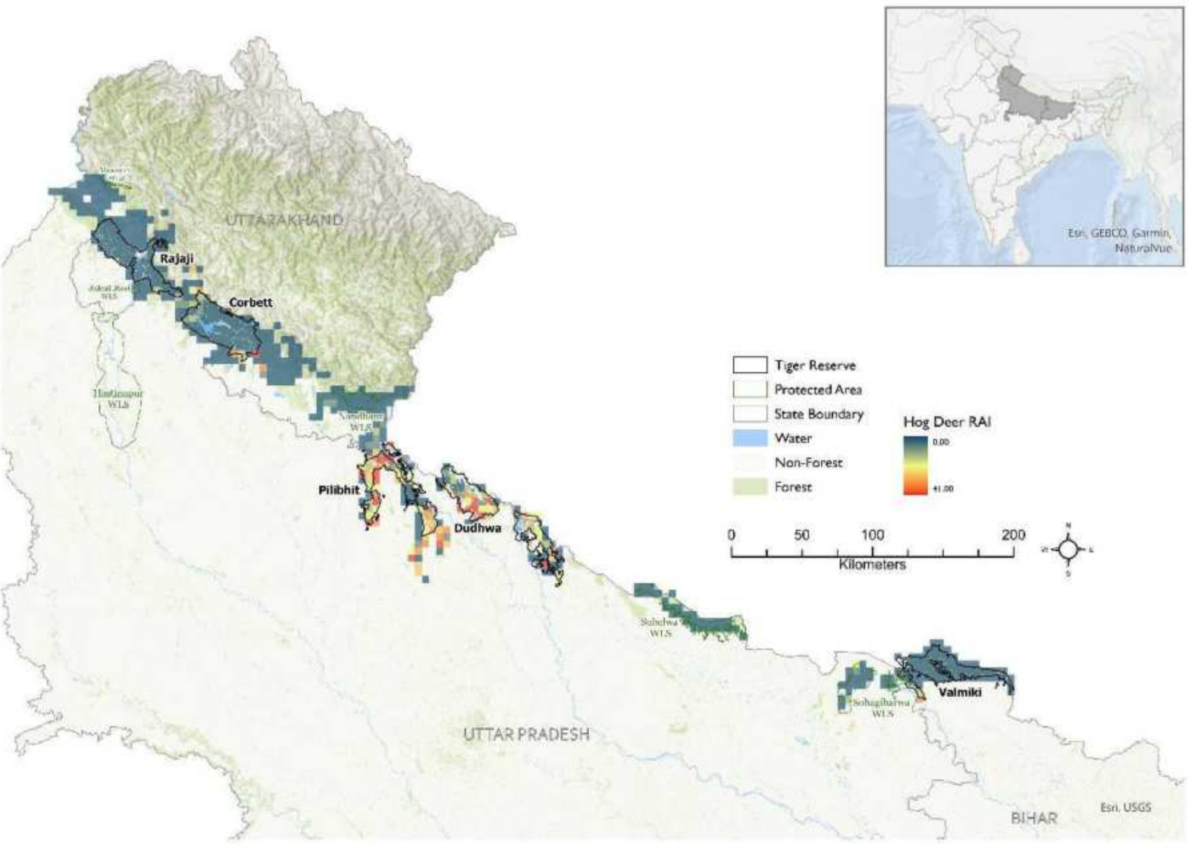


Figure III. 5: Spatial relative abundance of hog deer (per 25 km^2) in Shivalik hills and Gangetic plains landscape.

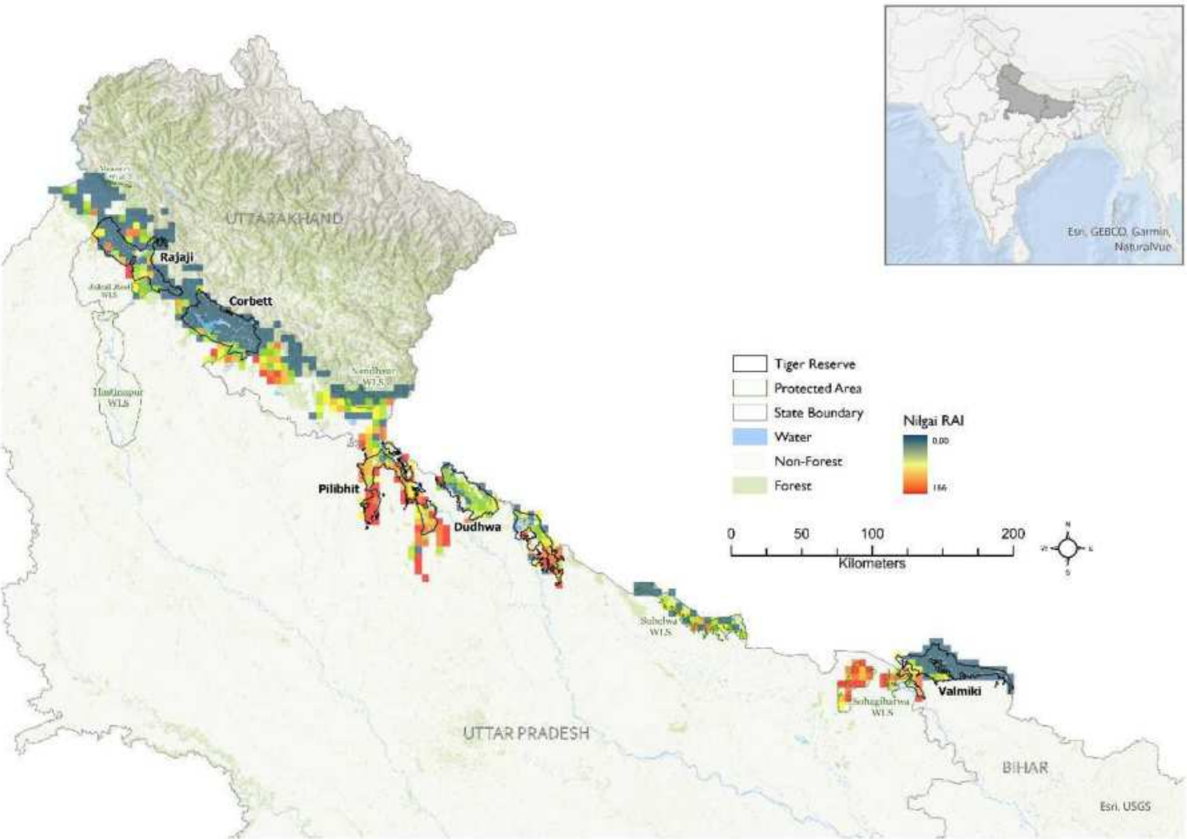


Figure III. 6: Spatial relative abundance of nilgai (per 25 km^2) in Shivalik hills and Gangetic plains landscape.

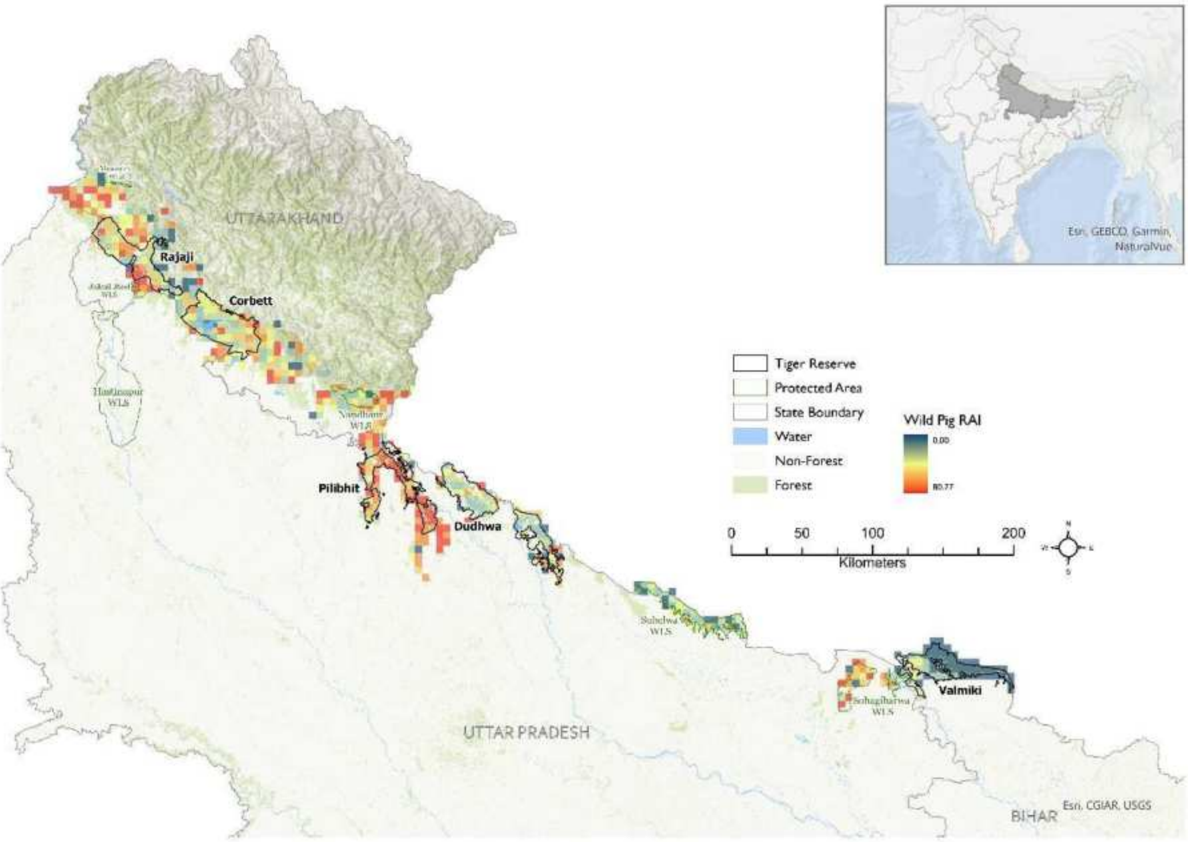


Figure III. 7: Spatial relative abundance of wild pig (per 25 km²) in Shivalik hills and Gangetic plains landscape.

UTTARAKHAND

Corbett Tiger Reserve

Corbett tiger reserve, located in the Nainital and Pauri Garhwal districts of Uttarakhand, is India's one of the first tiger reserves. Established in 1936 as Hailey National Park and later renamed in honour of the renowned hunter-turned-conservationist Jim Corbett, the reserve covers an area of 1,288 km². It is renowned for its rich biodiversity, including Bengal tigers, elephants, leopards, and over 600 bird species. Corbett has the highest tiger density in India (Qureshi *et al*., 2023). The reserve features diverse ecosystems, including dense Sal forests, swamps, riverine belts, and grasslands. The Ramganga River flows through the park, which along with its tributaries sustain grasslands. This biodiversity supports a remarkable range of plants and animals, providing vital habitats for elephants, hog deer, barking deer, sambar, and chital (Bisht *et al*., 2019).

Corbett has one of the highest prey densities in India. The densities of chital, sambar, barking deer, and wild pig were estimated using line transect data, while nilgai abundance was assessed through photo-capture data from camera traps. Chital is the most abundant prey species, present across all ranges of the reserve (Figure III. 8), with the highest densities recorded in the Bijrani, Dhela, Mandal, Sarpduli, and Jhirna ranges, and the lowest in Palain and Adnala ranges. Sambar is also widely distributed, with the highest densities in the Bijrani and Pakhrau ranges (Figure III. 9). All ranges, except Sonanadi, exhibit medium to high sambar densities. Barking deer are more concentrated near the eastern boundary, with the Dhela and Kalagarh ranges showing the highest densities (Figure III. 10). Wild pig density is high in the Mandal, Sarpduli, and Bijrani ranges, with densities declining toward the western parts of the reserve (Figure III. 11). Nilgai, which are rarely observed, were mapped using camera trap data. Their highest relative abundance was recorded in the Sonanadi range, with notable occurrences near the outer boundaries of the Kalagarh, Jhirna, and Dhela ranges (Figure III. 12).

Table III. 1: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Corbett tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Barking deer	91	0.121 (0.013)	0.52 (0.05)	1.56 (0.27)	1.95 (0.29)	3.04 (0.4)
Chital	298	0.397 (0.023)	0.27 (0.02)	9.74 (0.57)	6.03 (0.51)	56.72 (3.69)
Sambar	151	0.201 (0.016)	0.39 (0.03)	2.6 (0.11)	3.25 (0.36)	9.79 (0.89)
Wild pig	76	0.101 (0.011)	0.46 (0.04)	5.33 (0.41)	1.84 (0.27)	11.38 (1.08)

B)

Species	Chital	Sambar	Barking deer	Wild pig
Detection model	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)	Half-normal (Null)
s(x,y)	8.632	12.856	2.931	3.889
s(NDVI Post-Monsoon)	-	-	2.073	-
s(NDVI_diff)	2.671	1.787	-	1.856
s(Ruggedness)	1.956	2.366	-	2.935
s(Elevation)	5.88	-	-	-

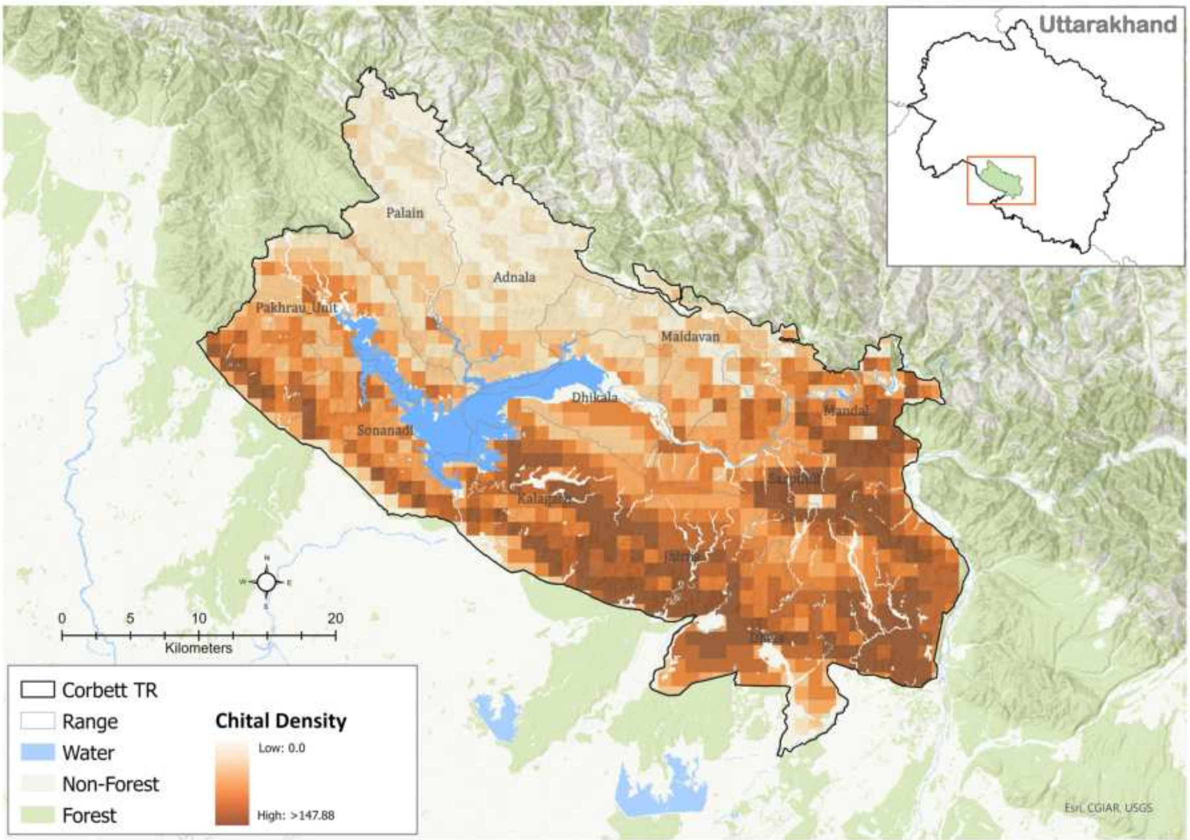


Figure III. 8: Density of chital (per km^2) in Corbett tiger reserve: Site-Level DSM

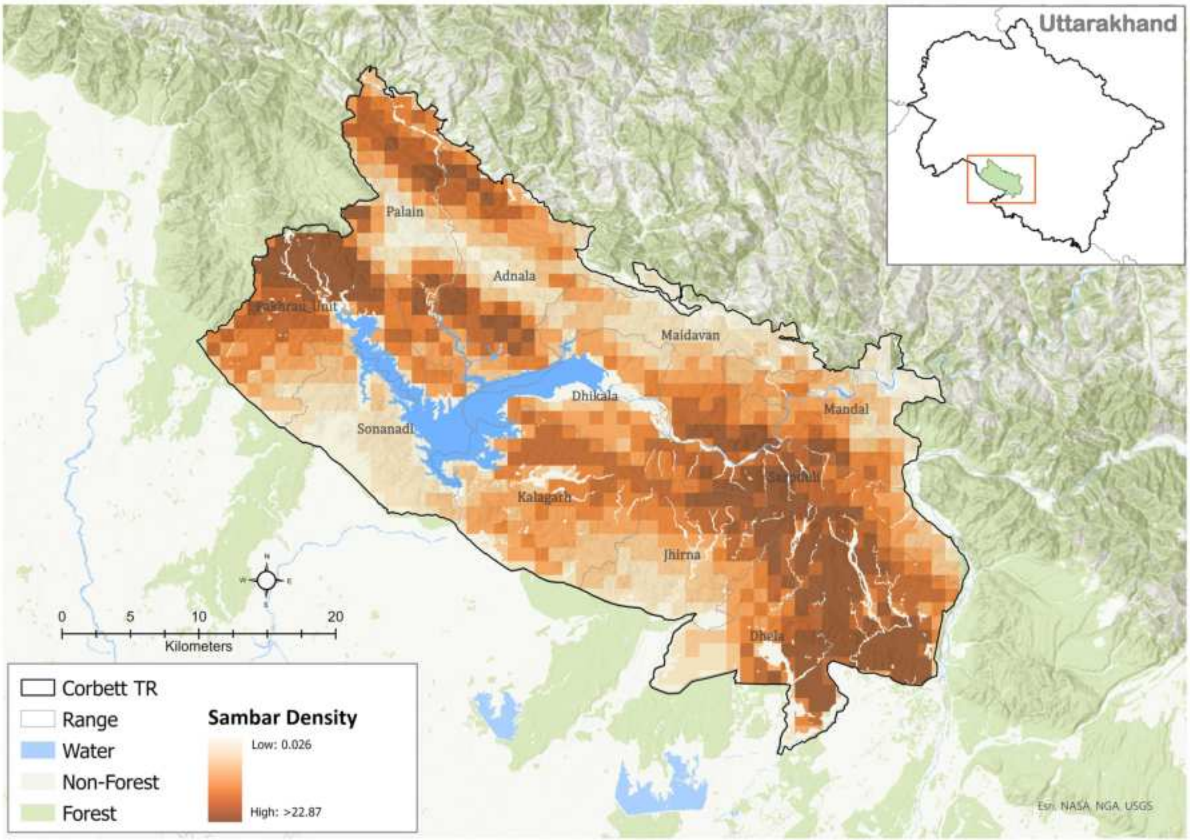


Figure III. 9: Density of sambar (per km²) in Corbett tiger reserve: Site-level DSM

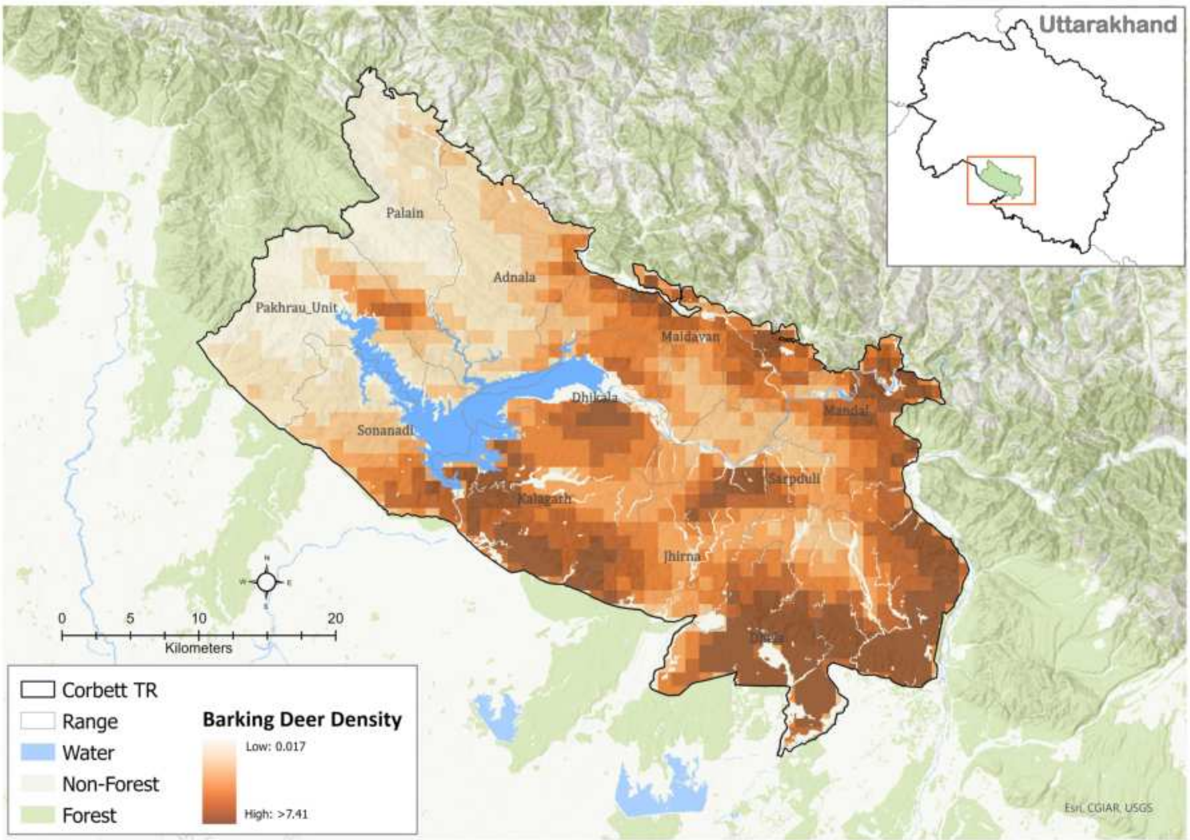


Figure III. 10: Density of barking deer (per km²) in Corbett tiger reserve: Site-level DSM

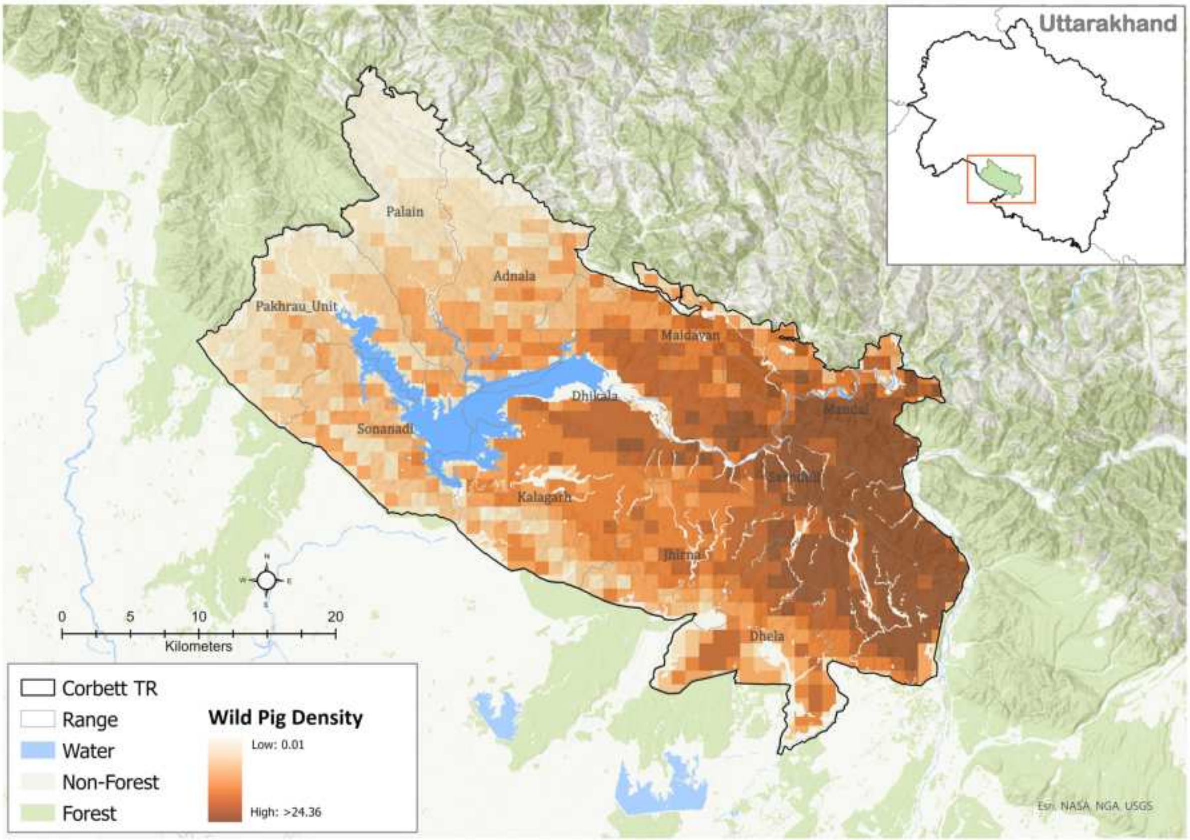


Figure III. 11: Density of wild pig (per km²) in Corbett tiger reserve: Site-level DSM

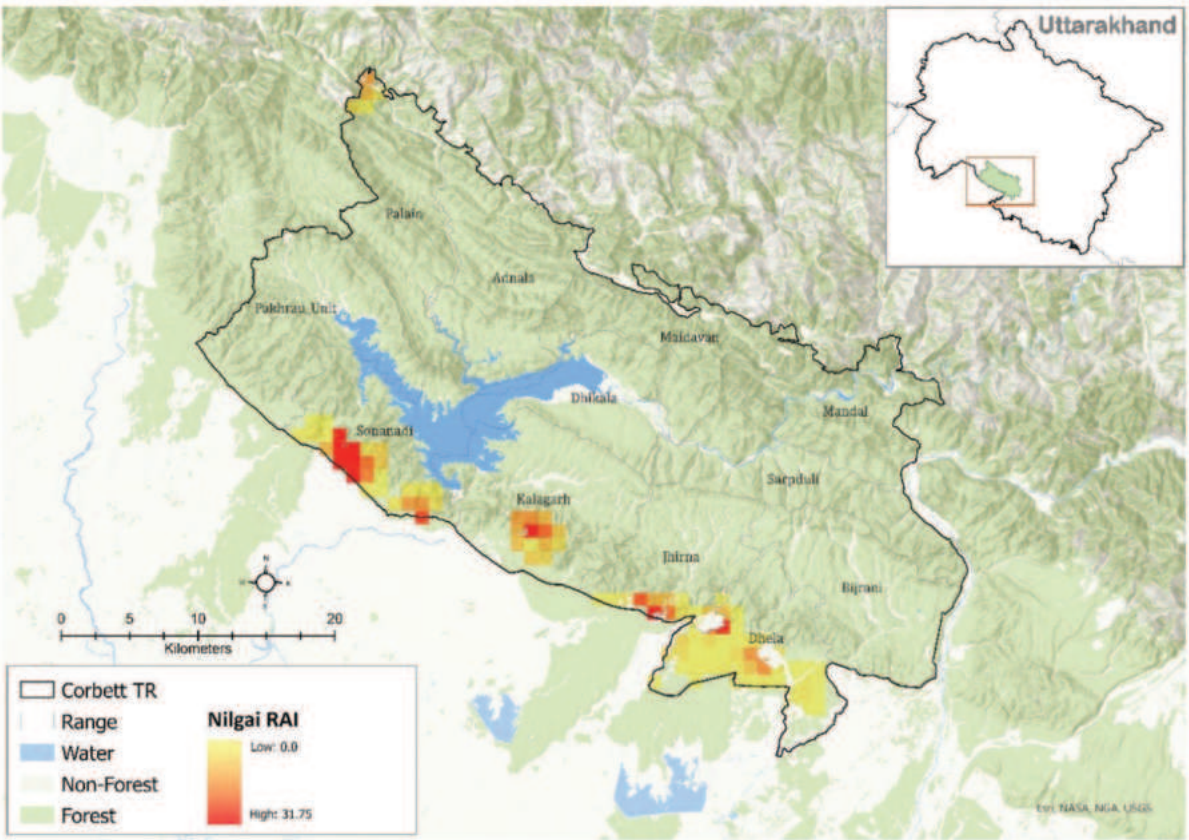


Figure III. 12: Spatial relative abundance of nilgai in Corbett tiger reserve.

Rajaji Tiger Reserve

Rajaji tiger reserve, located in the Himalayan foothills of Uttarakhand, spans approximately 1,075 km^2 and serves as a critical link in the Shivalik hills ecosystem. The reserve is ecologically significant for its diverse landscapes, ranging from tropical deciduous forests to temperate broadleaf forests and alpine forests at higher elevations, representing the vertical diversity of the Himalayan region (Nautiyal *et al*., 2023). The reserve is bisected by the Ganga river and its tributaries, which enhance the terrain with riparian habitats and wetlands that sustain a diverse range flora and fauna (Akash *et al*., 2019). Rajaji is home to the tiger, leopard, leopard cat, rusty spotted cat, elephant, Himalayan black bear, sloth bear, and striped hyena, along with a huge diversity of birds, amphibians, and reptiles.

Chital is the most abundant prey species in Rajaji (Table III. 2), predominantly distributed along the southern boundary of ranges east of the Ganga, where the terrain is less rugged (Figure III. 13). The highest densities are recorded in the Shyampur range, followed by southern parts of Laldang, Rawasan, and Kotdwar, with dense patches also found in Chilla, Haridwar, Beribara, Dholkhand, and Chillawali ranges. Sambar is widely distributed, with the highest densities in Rawasan and Laldang, followed by Shyampur, Chilla, and Kotdwar in Eastern Rajaji (Figure III. 14). In Western Rajaji, high sambar densities are observed in Ramgarh and Kansrao, as well as pockets of Dholkhand and Chillawali. Due to insufficient data, spatial densities for barking deer, nilgai, and wild pig were not estimated. However, camera trap data indicate high relative abundance of barking deer in Gohari, areas near Kansrao–Motichur, Laldang, and Rawasan (Figure III. 15), while nilgai are concentrated in small pockets of Haridwar, Chilla, Dholkhand, Beribara, and Rawasan (Figure III. 16).

Table III. 2: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Rajaji tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	82	0.001 (0.0001)	0.37 (0.02)	6.71 (0.62)	2.54 (0.34)	20.67 (2.11)
Sambar	78	0.18 (0.02)	0.21 (0.05)	2.1 (0.17)	4.36 (1.1)	12.06 (3.14)

B)

Species	Chital	Sambar
Detection model	Half-normal (Cosine)	Hazard rate (Null)
s(x,y)	3.497	2.738
s(Aridity)	3.931	3.534
s(Ruggedness)	-	2.451
s(Elevation)	2.978	-

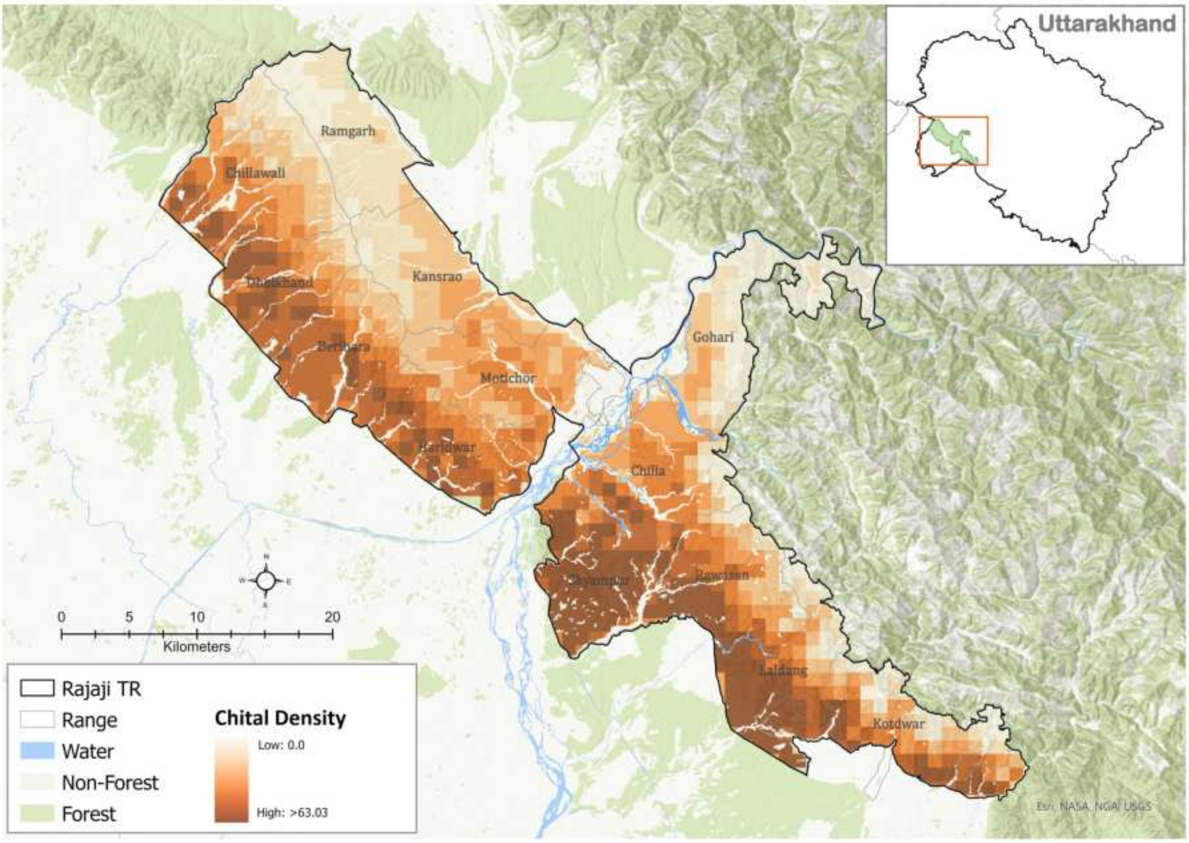


Figure III. 13: Density of chital (per km^2) in Rajaji tiger reserve: Site-level DSM

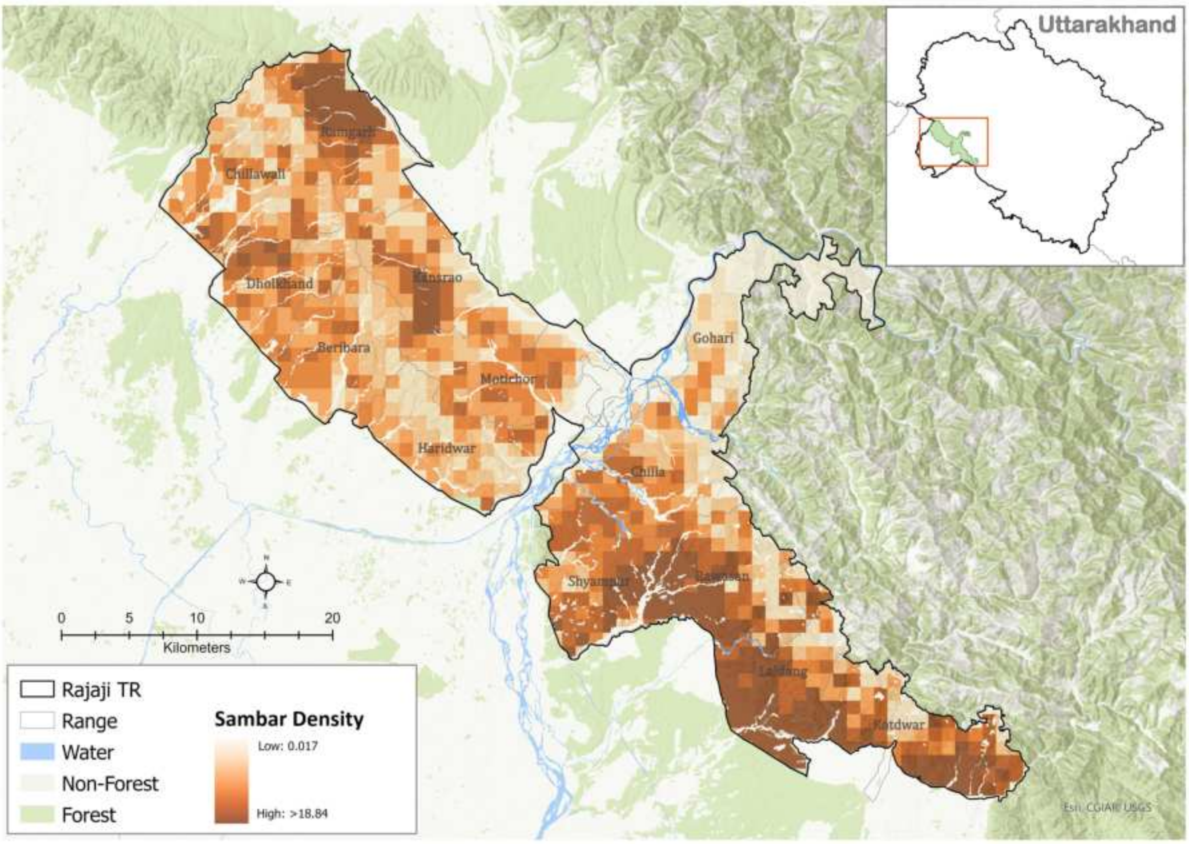


Figure III. 14: Density of sambar (per km^2) in Rajaji tiger reserve: Site-level DSM

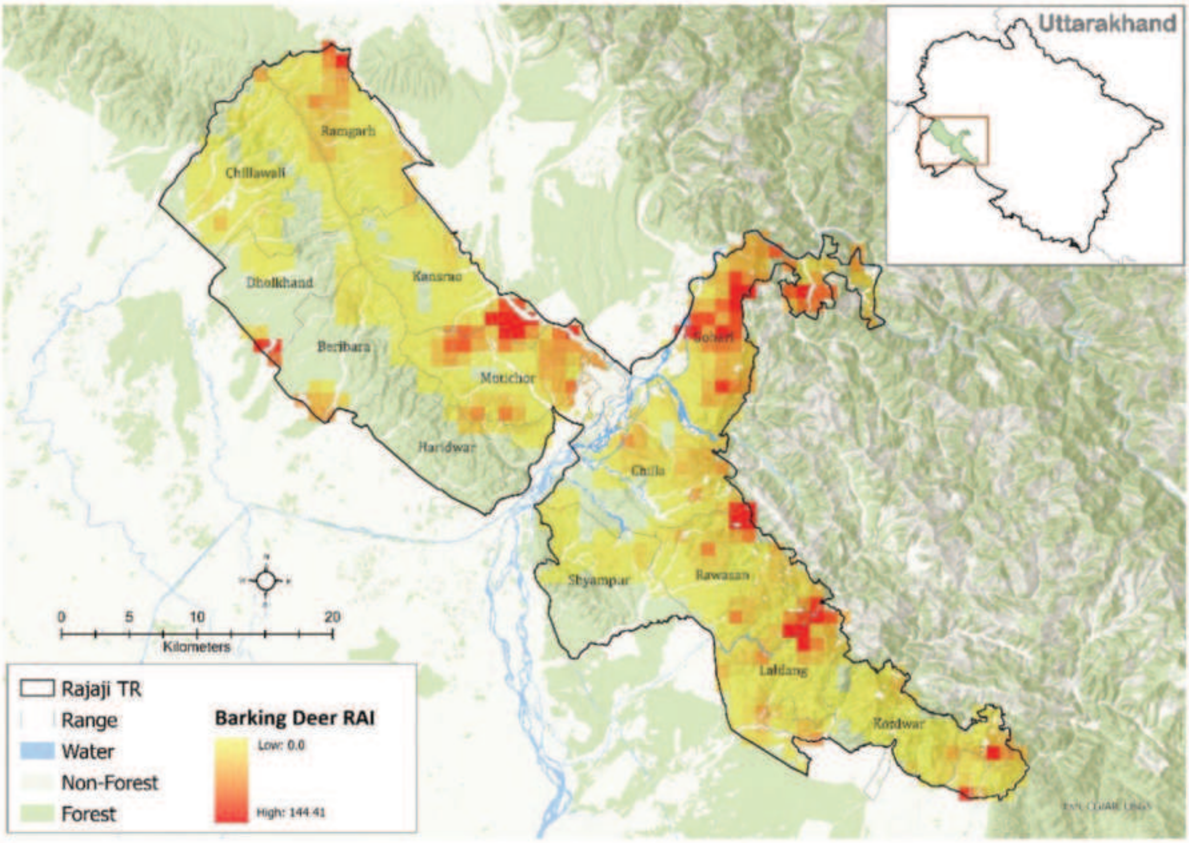


Figure III. 15: Spatial relative abundance of barking deer in Rajaji tiger reserve.

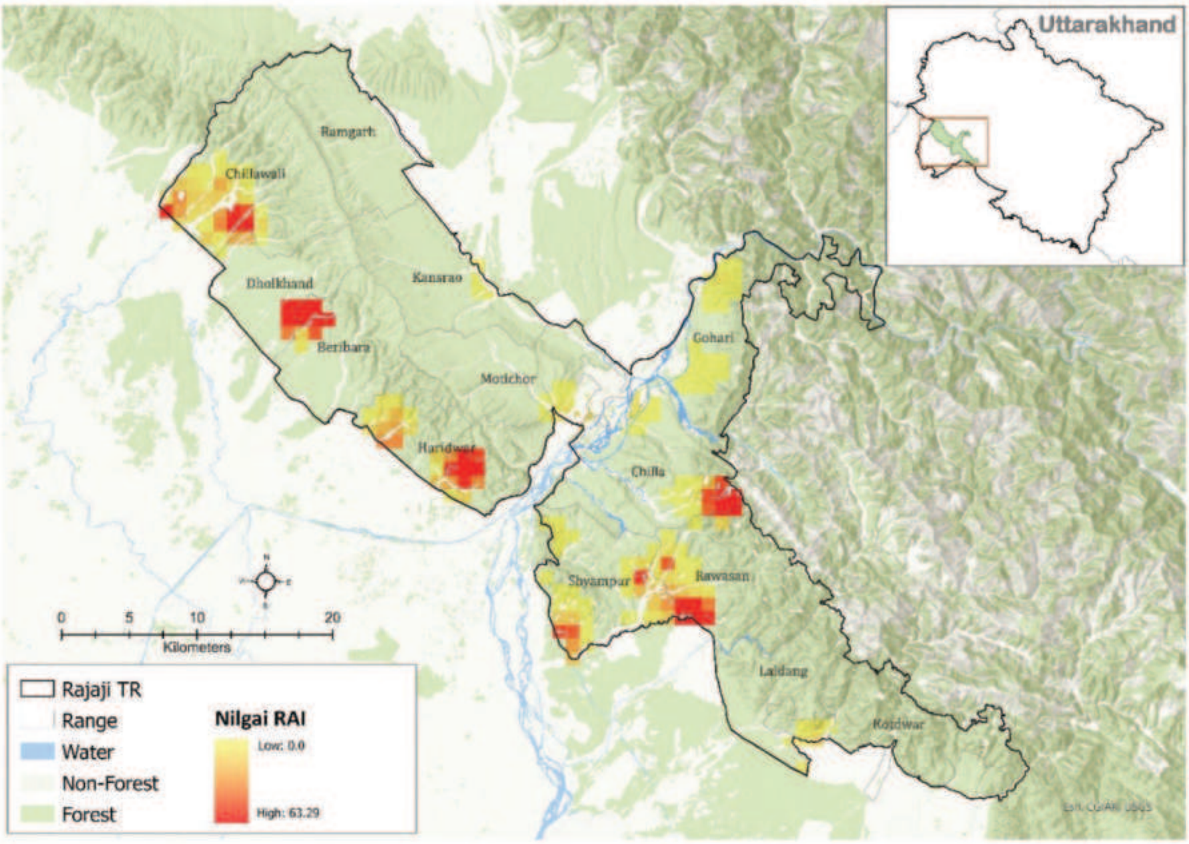


Figure III. 16: Spatial relative abundance of nilgai in Rajaji tiger reserve.

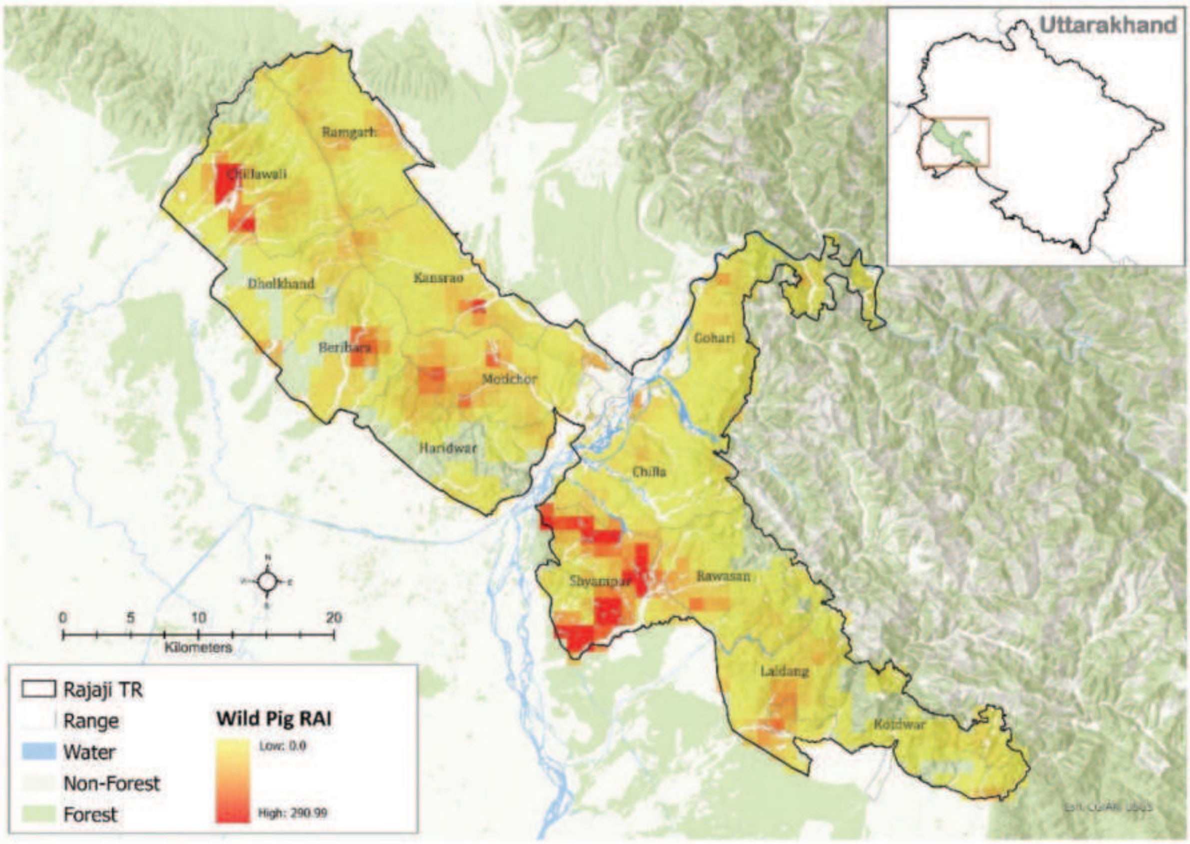


Figure III. 17: Spatial relative abundance of wild pig in Rajaji tiger reserve.

UTTAR PRADESH

Dudhwa Tiger Reserve

Dudhwa tiger reserve, located in the Terai region of Uttar Pradesh near the Indo-Nepal border, known for its unique and diverse ecosystems. Covering an area of 2,202 km^2, it encompasses Dudhwa National Park, Kishanpur Wildlife Sanctuary, and Katarniaghat Wildlife Sanctuary. The reserve is characterized by dense Sal forests, rich grasslands, wetlands, and swampy marshes (Mathur & Midha, 2008). It supports a rich variety of flora and fauna, including the Bengal tiger, Indian one-horned rhinoceros, barasingha (swamp deer), elephants, and gangetic dolphins.

Chital and sambar abundance in Dudhwa tiger reserve is predicted using landscape model as data from line transect is deficient. Landscape model predicts that chital is the most abundant prey species in Dudhwa TR, with high densities in the Kishanpur range and northern Katerniaghat. Its distribution in Dudhwa NP is patchy, with high abundance in pockets of South Sonaripur, Bankati, and Sathiyana ranges (Figure III. 18). Sambar density is very low, particularly in Dudhwa NP, and is largely restricted to Kishanpur WLS and the southern part of Katerniaghat WLS, (Murthia and Kakaraha ranges) (Figure III. 19). Management efforts should focus on relocating human settlements in core and buffer areas and controlling invasive plant species for prey management.

Barasingha, rhino, barking deer, nilgai, and wild pig spatial densities were not estimated due to data deficiency but were mapped using relative abundance from camera trap photo captures. Barasingha is scarce, mainly occurring in Kishanpur, northern Mailani, and patches in Belrayan, Sathiyana, and South Sonaripur (Figure III. 23). Rhino populations are concentrated in Katerniaghat, Sujauli, and South Sonaripur (Figure III. 21). Barking deer are most abundant in Katerniaghat WLS, particularly in Nishangara, Murthia, Kakaraha, and Dharmapur ranges, with smaller populations in Gauriphanta, South Sonaripur of Dudhwa NP and Mailani of Kishanpur WLS (Figure III. 20). Nilgai are prevalent in the outer areas of Kishanpur, Mailani, and Sathiyana, as well as southern Katerniaghat, including Murthia, Kakaraha, and Motipur (Figure III. 22). Wild pig are primarily abundant in Kishanpur, with additional patches in central Dudhwa NP and Murthia range in Katerniaghat WLS (Figure III. 24).

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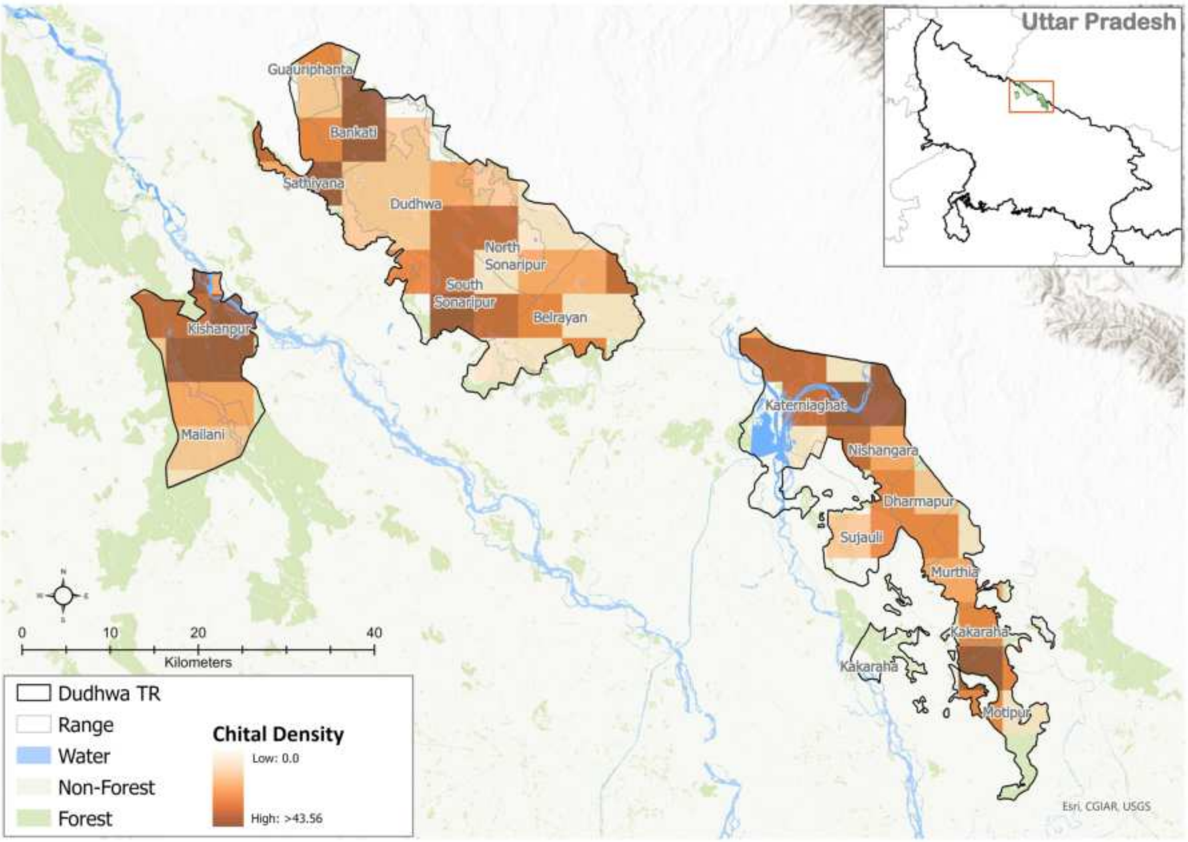

Figure III. 18: Density of chital (per 25 km²) in Dudhwa tiger reserve: Landscape-level DSM

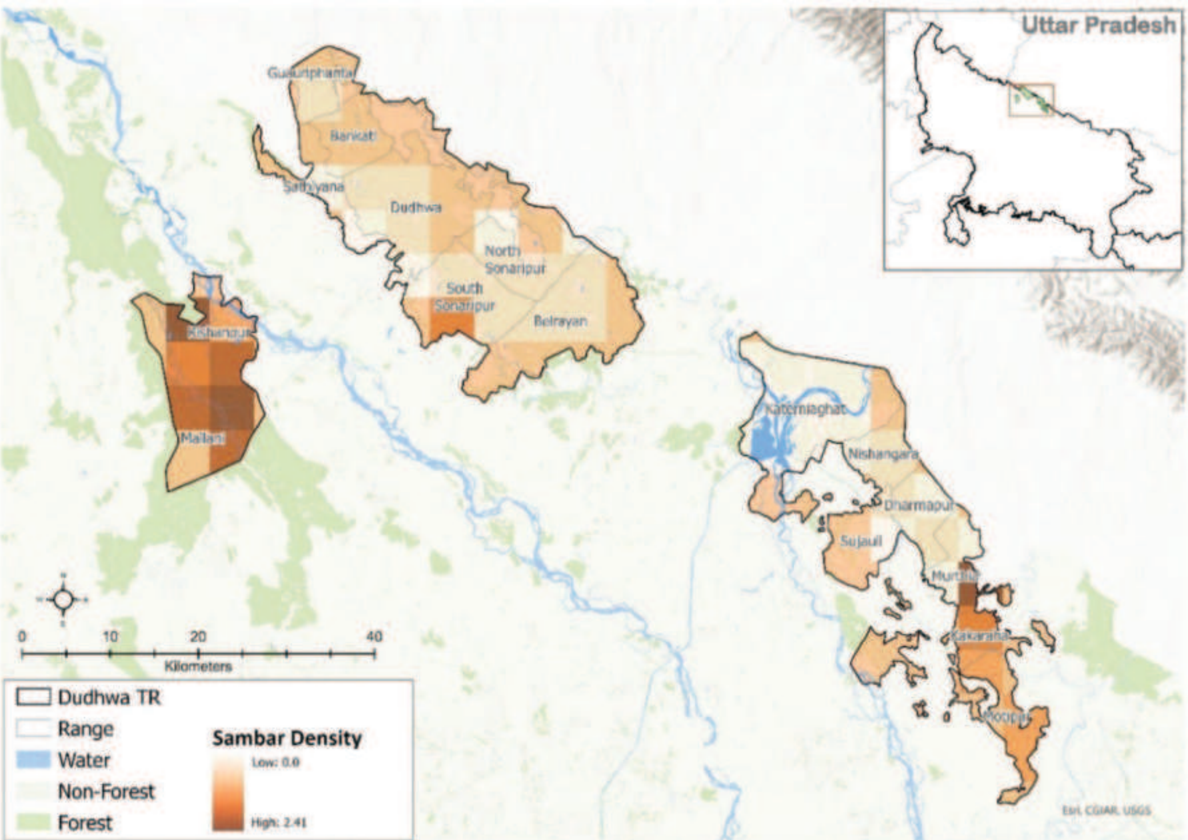

Figure III. 19: Density of sambar (per 25 km²) in Dudhwa tiger reserve: Landscape-level DSM

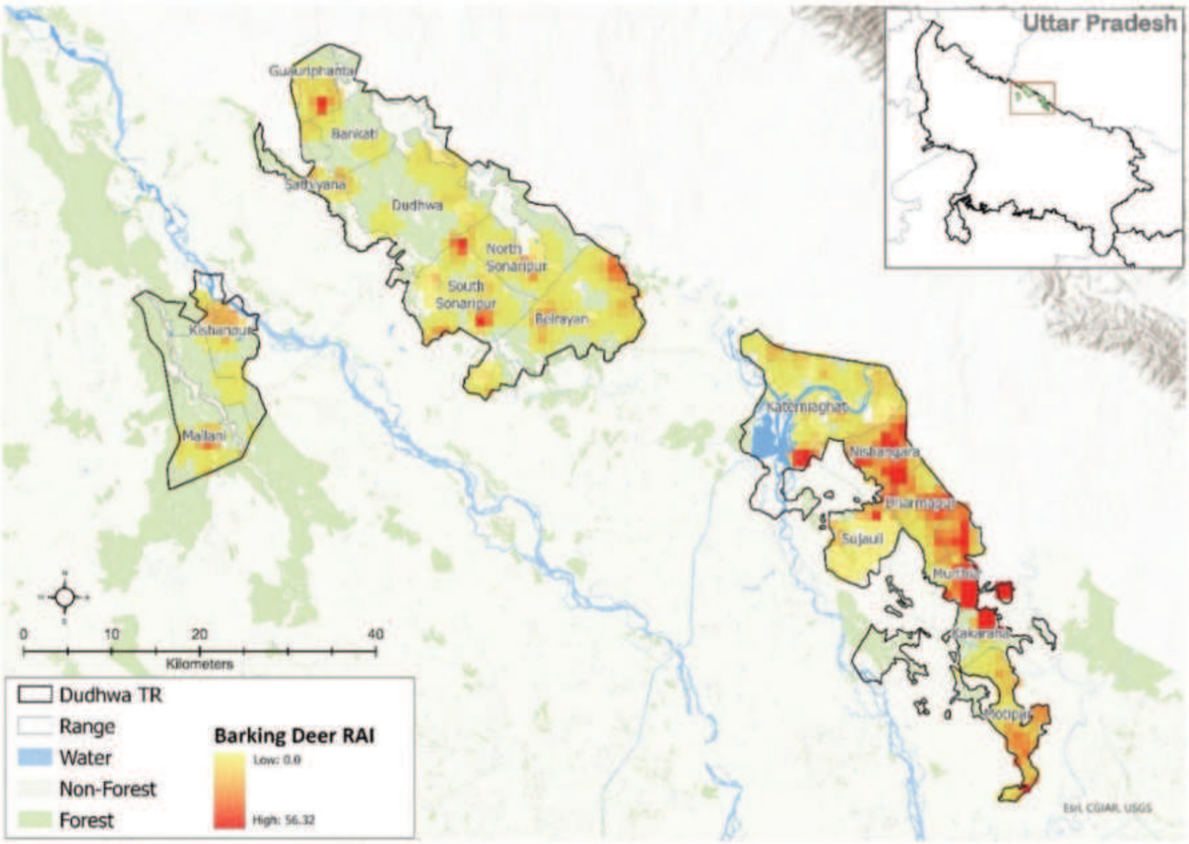

Figure III. 20: Spatial relative abundance of barking deer in Dudhwa tiger reserve.

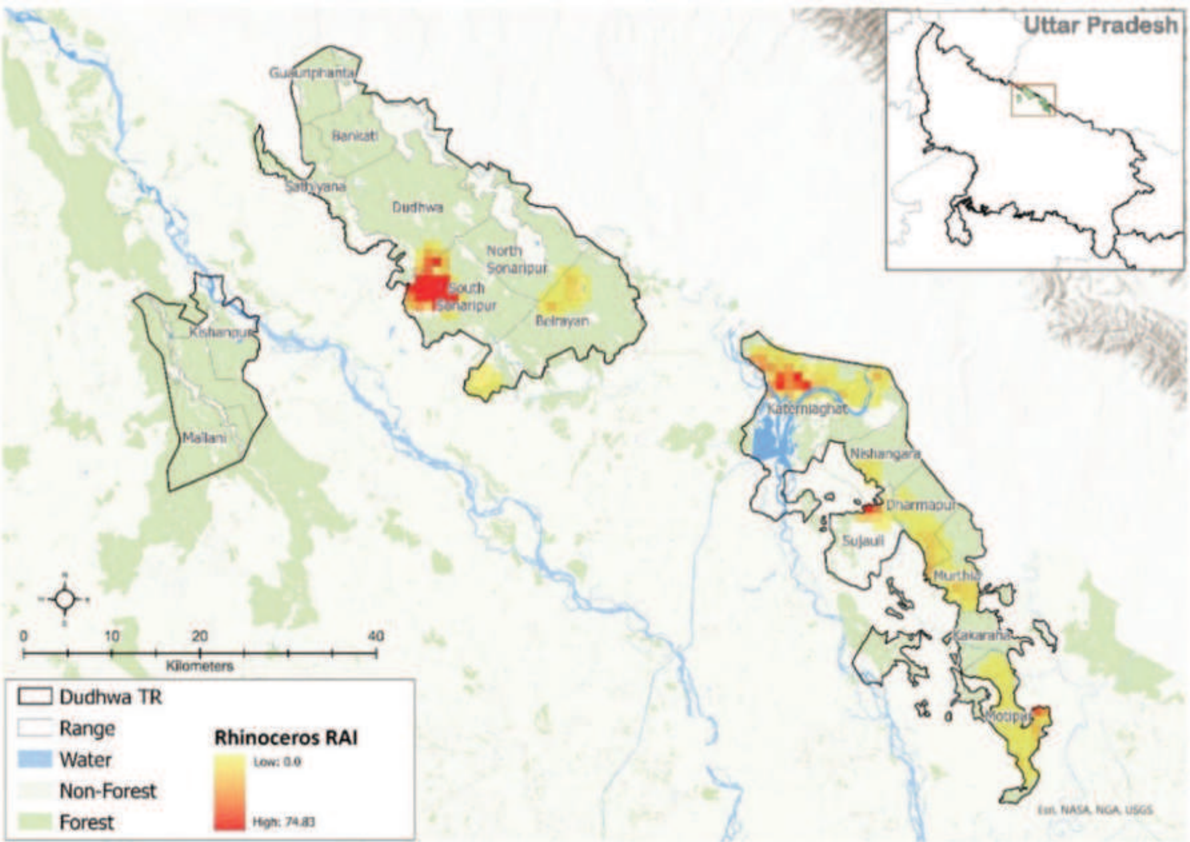

Figure III. 21: Spatial relative abundance of rhinoceros in Dudhwa tiger reserve.

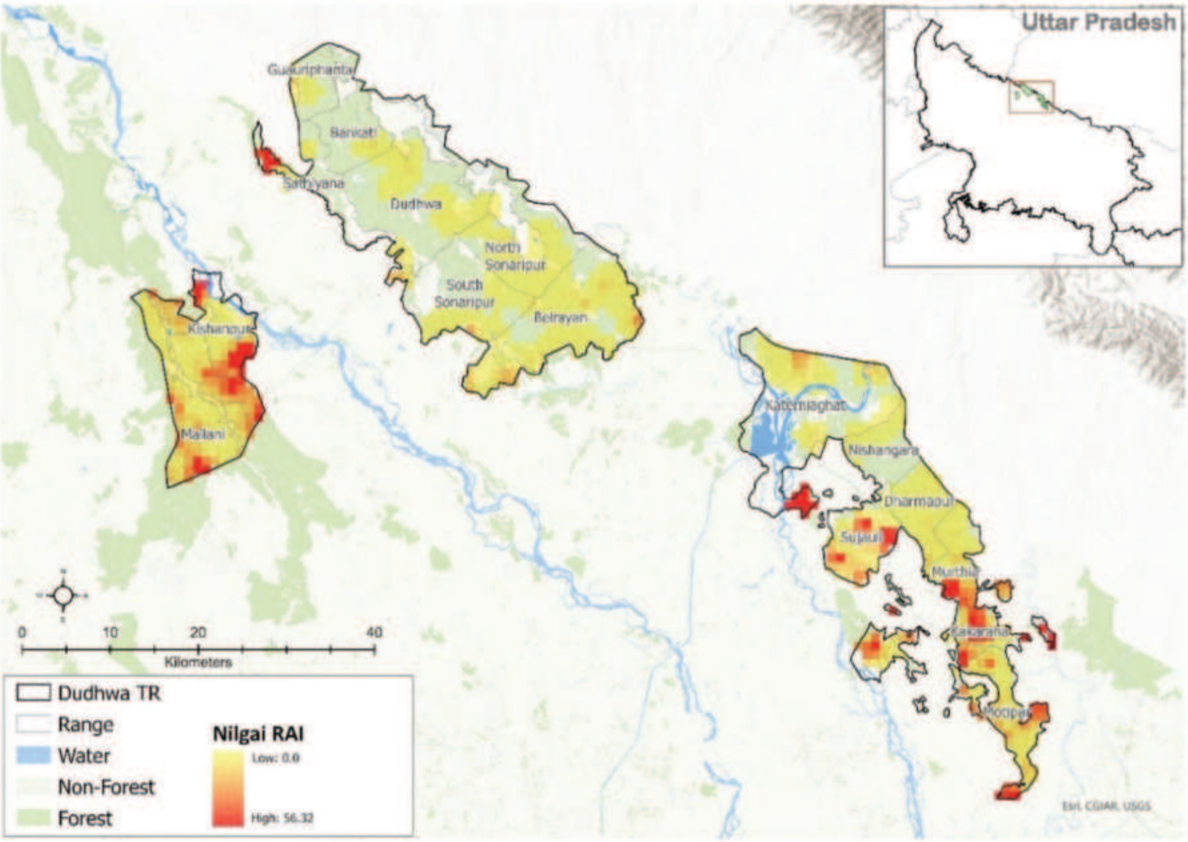

Figure III. 22: Spatial relative abundance of nilgai in Dudhwa tiger reserve.

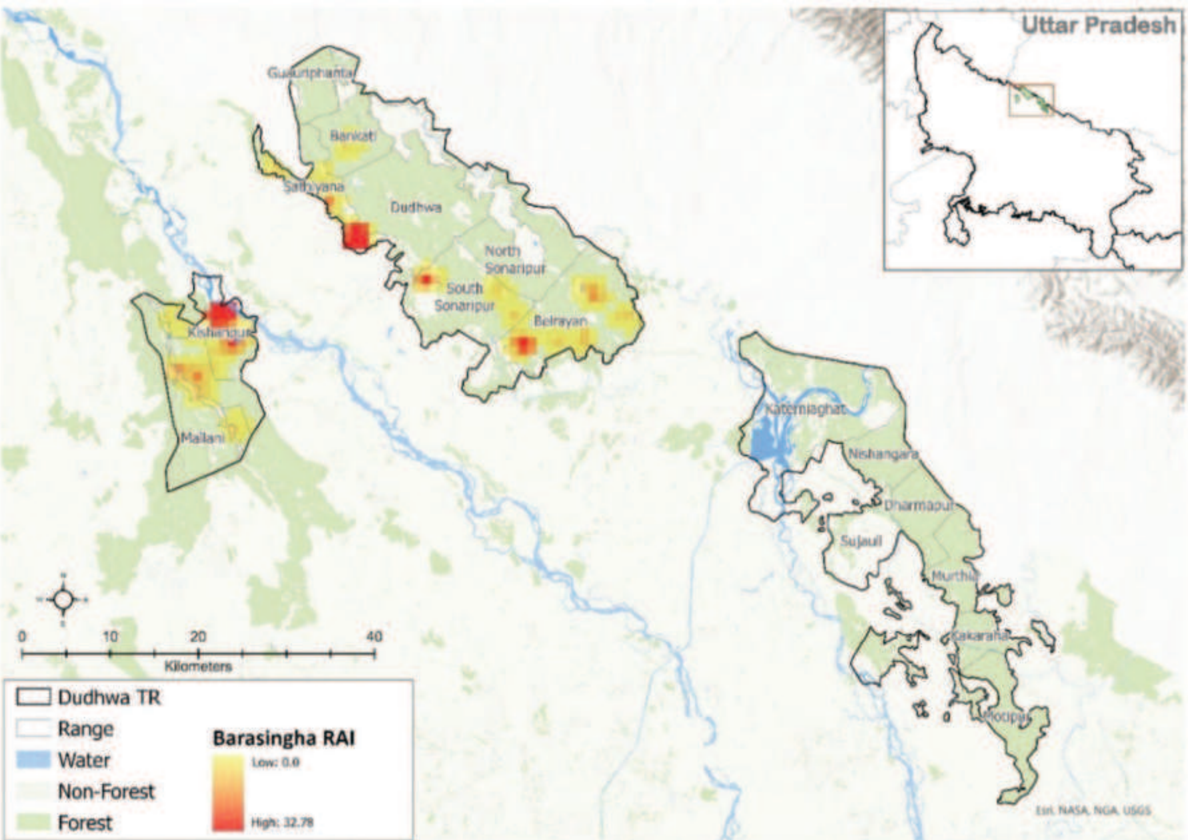

Figure III. 23: Spatial relative abundance of barasingha in Dudhwa tiger reserve.

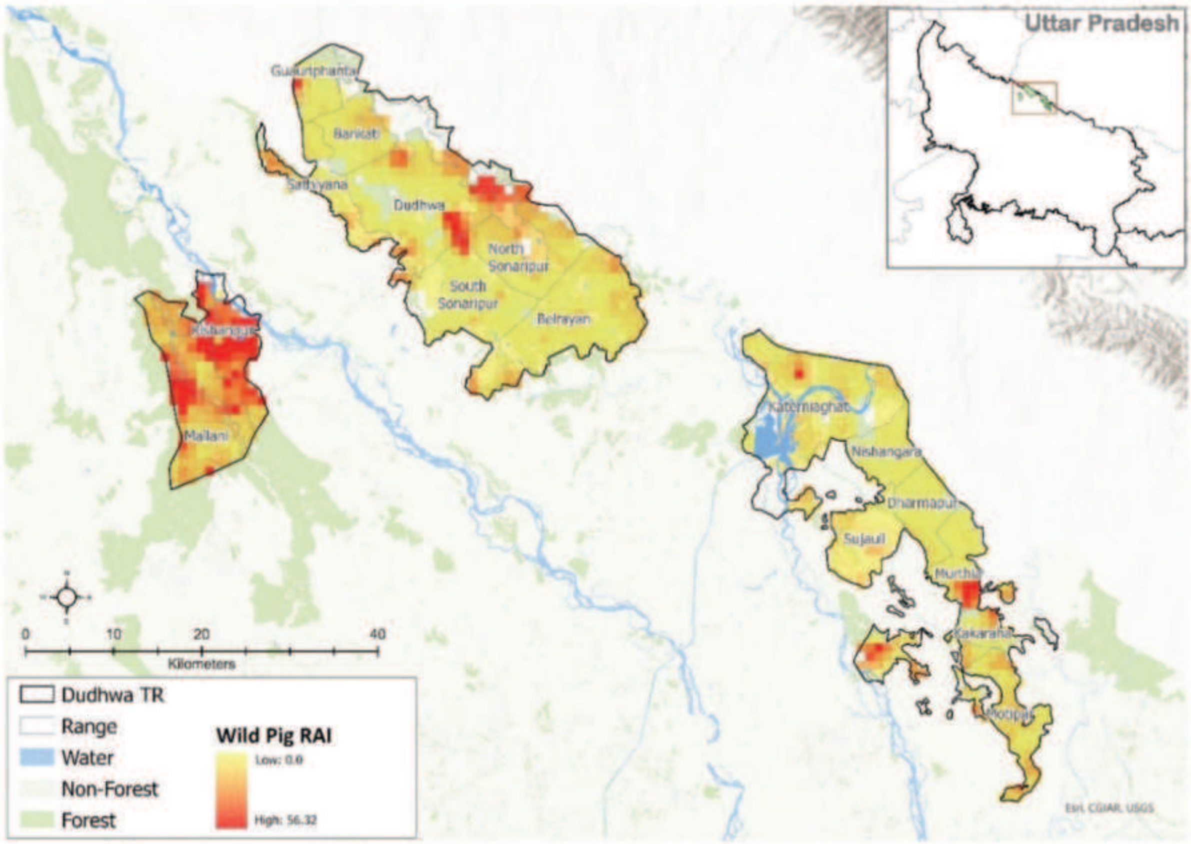

Figure III. 24: Spatial relative abundance of wild pig in Dudhwa tiger reserve.

Pilibhit Tiger Reserve

Pilibhit tiger reserve, spanning approximately 730 km² in the Pilibhit and Lakhimpur Kheri districts of Uttar Pradesh, is a critical part of the Terai landscape. It connects with Kishanpur WLS, and Suklaphanta Wildlife Reserve in Nepal, encompassing diverse ecosystems like terai grasslands, sal forests, riverine wetlands, and swamps shaped by the Sharda river. The reserve supports the Bengal tiger, greater one-horned rhinoceros, leopard, fishing cat, rusty-spotted cat, gharial, otters, and various ungulates, alongside migratory birds and herpetofauna.

Chital is the most abundant prey species, with the highest densities in Mala, Barahi, and Mahof ranges (Figure III. 25). Management priorities include restoring fragmented corridors by reducing human habitation, managing grasslands, and controlling grazing and resource extraction. Sambar density is low and abundance is predicted using landscape model. The encounter rate for sambar is 0.0038 (±0.0034). Sambar is mostly restricted to Deoria and parts of Mahof and Mala ranges (Figure III. 26). Enhancing understorey vegetation and reducing human disturbances will support population recovery.

Nilgai has moderate density, with concentrations along Deoria, southern Mala, and Haripur (Figure III. 27). Wild pigs are widely distributed, with high densities in Haripur, Mala, and the southern parts of Barahi (Figure III. 28). Barasingha, rhino, and barking deer spatial densities were not estimated but relative abundance was mapped using camera trap data for informed management decisions. Barasingha islimited to patches in Mahof and Mala ranges (Figure III. 31), rhinos are restricted to the northern Barahi range near Suklaphanta (Figure III. 30), and barking deer are sparsely distributed in Haripur and Barahi ranges (Figure III. 29).

Table III. 3: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Pilibhit tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	156	0.567 (0.047)	0.63 (0.09)	7.93 (0.58)	4.99 (0.83)	37.67 (5.54)
Nilgai	55	0.2 (0.026)	0.33 (0.07)	3.85 (0.5)	1.73 (0.42)	7.29 (1.55)
Wild pig	81	0.295 (0.033)	0.51 (0.05)	3.74 (0.28)	3.18 (0.47)	13.46 (1.55)

B)

Species	Chital	Wild pig	Nilgai
Detection model	Half-normal (Hermite polynomial)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	3.899	2.959	3.93
s(Aridity)	-	-	1.78
s(NDVI Pre-Monsoon)	-	1.509	-
s(NDVI difference)	5.637	-	-
s(Ruggedness)	-	1.951	-

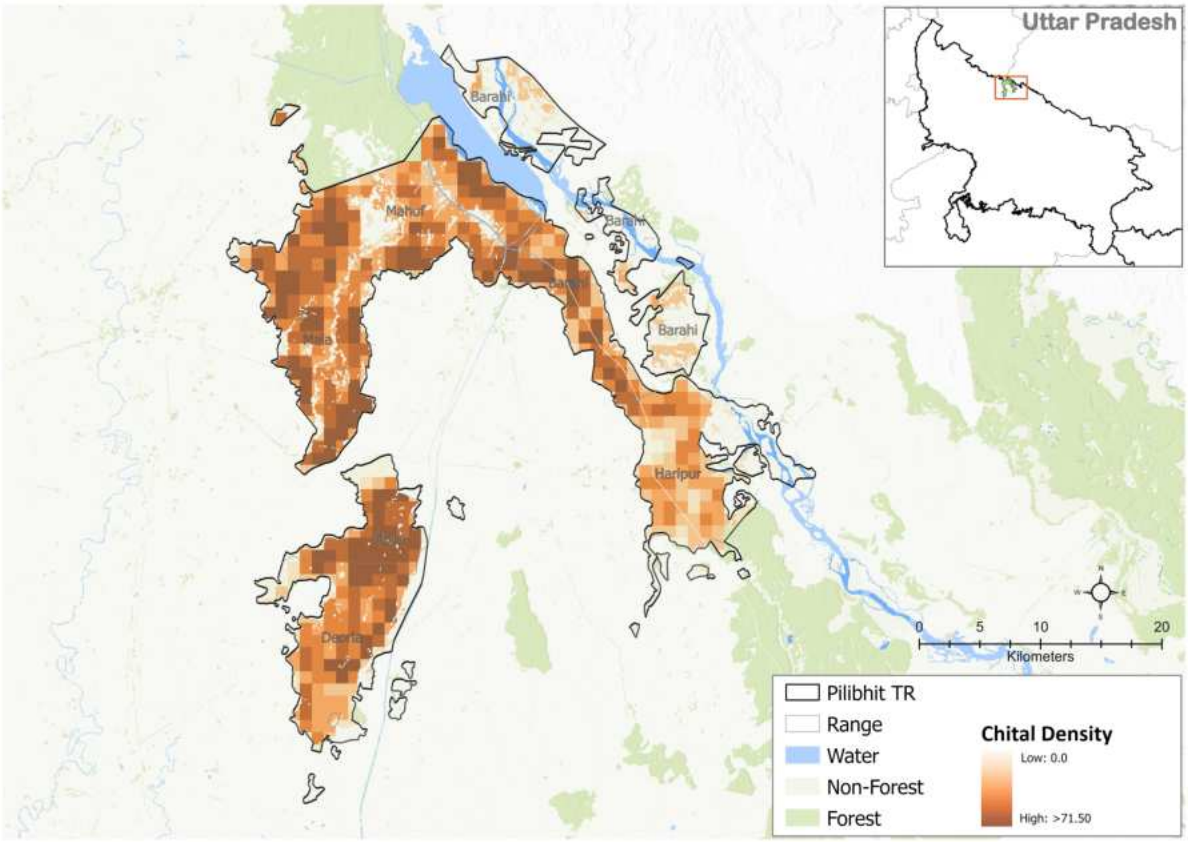

Figure III. 25: Density of chital (per km²) in Pilibhit tiger reserve: Site-level DSM

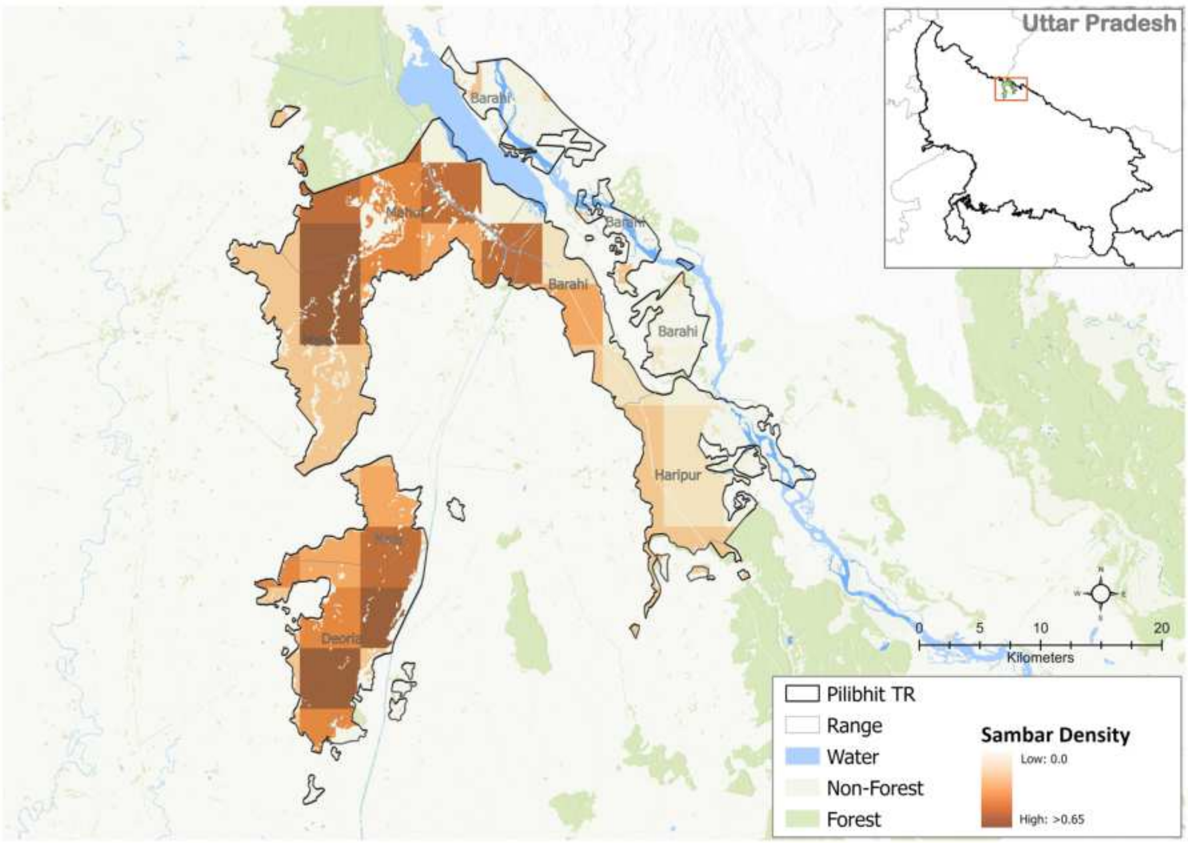

Figure III. 26: Density of sambar (per 25 km²) in Pilibhit tiger reserve: Landscape-level DSM

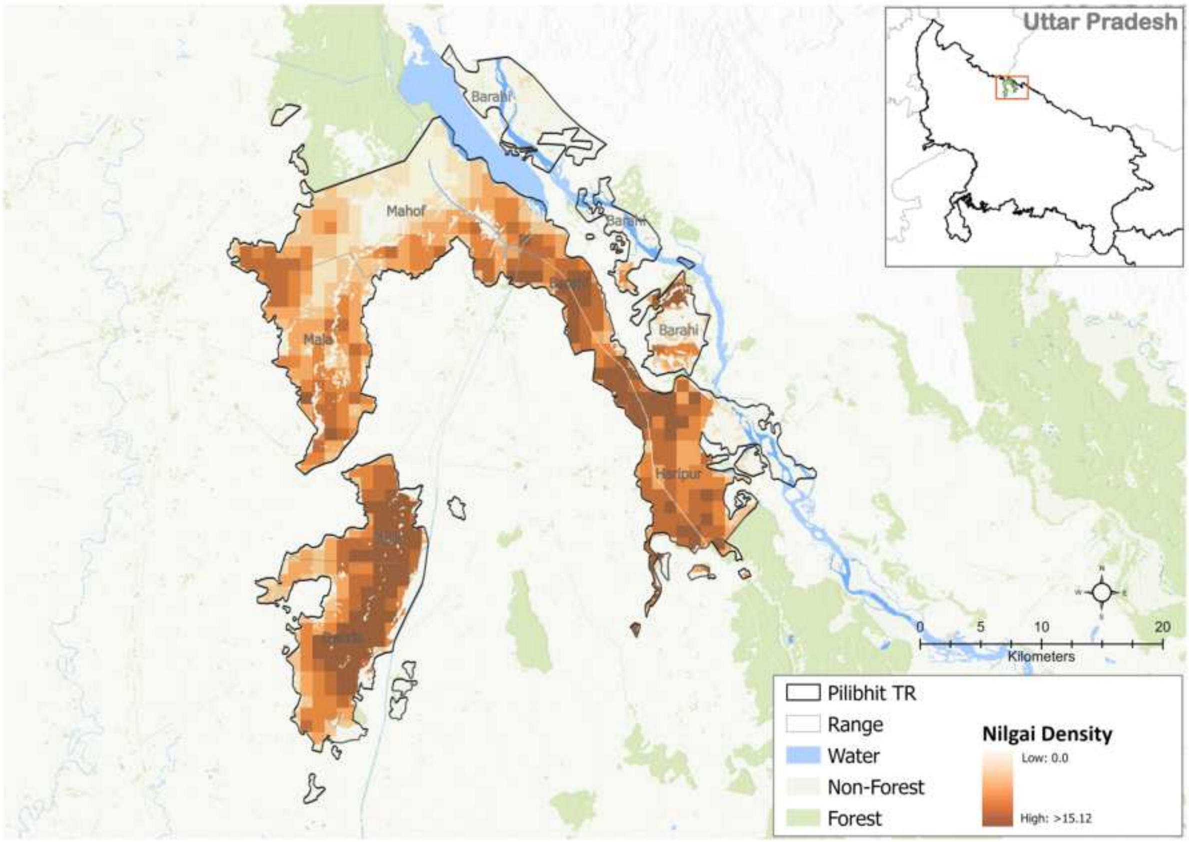

Figure III. 27: Density of nilgai (per km²) in Pilibhit tiger reserve: Site-level DSM

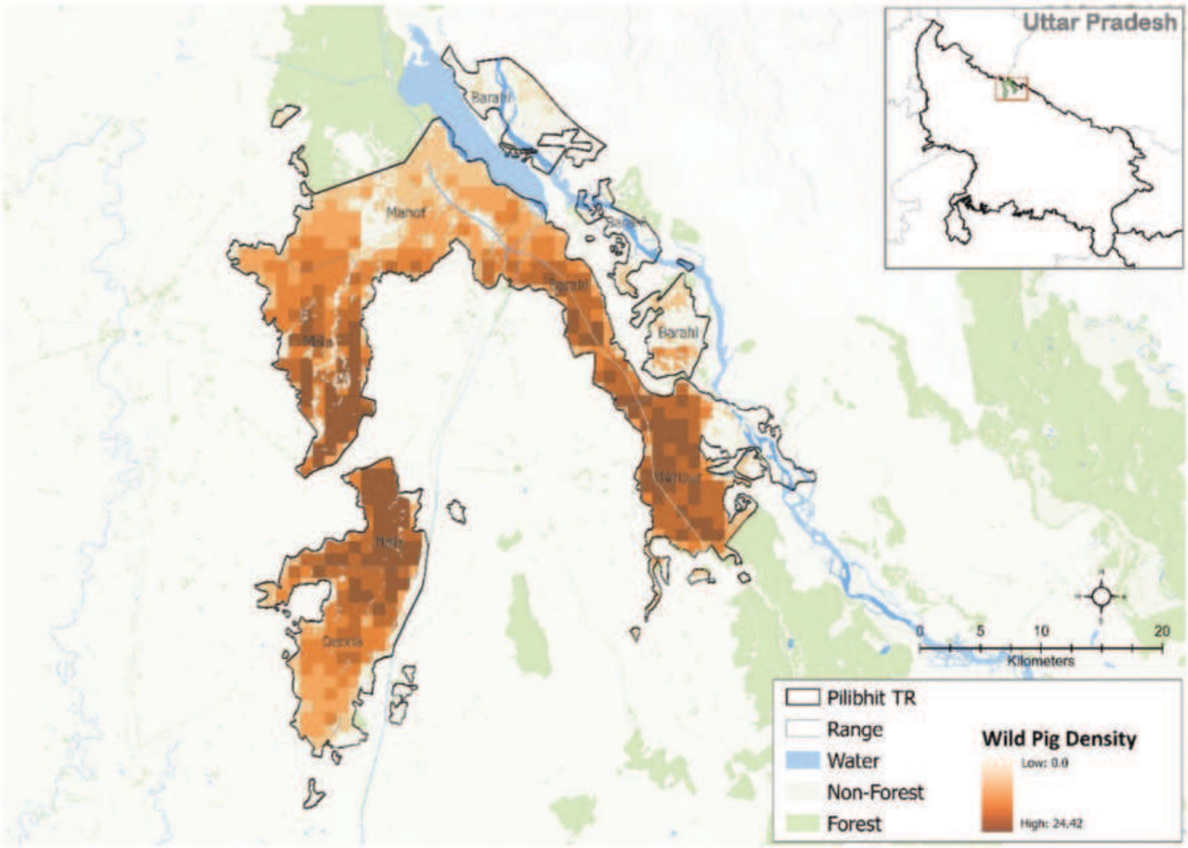

Figure III. 28: Density of wild pig (per km²) in Pilibhit Tiger Reserve: Site-level DSM

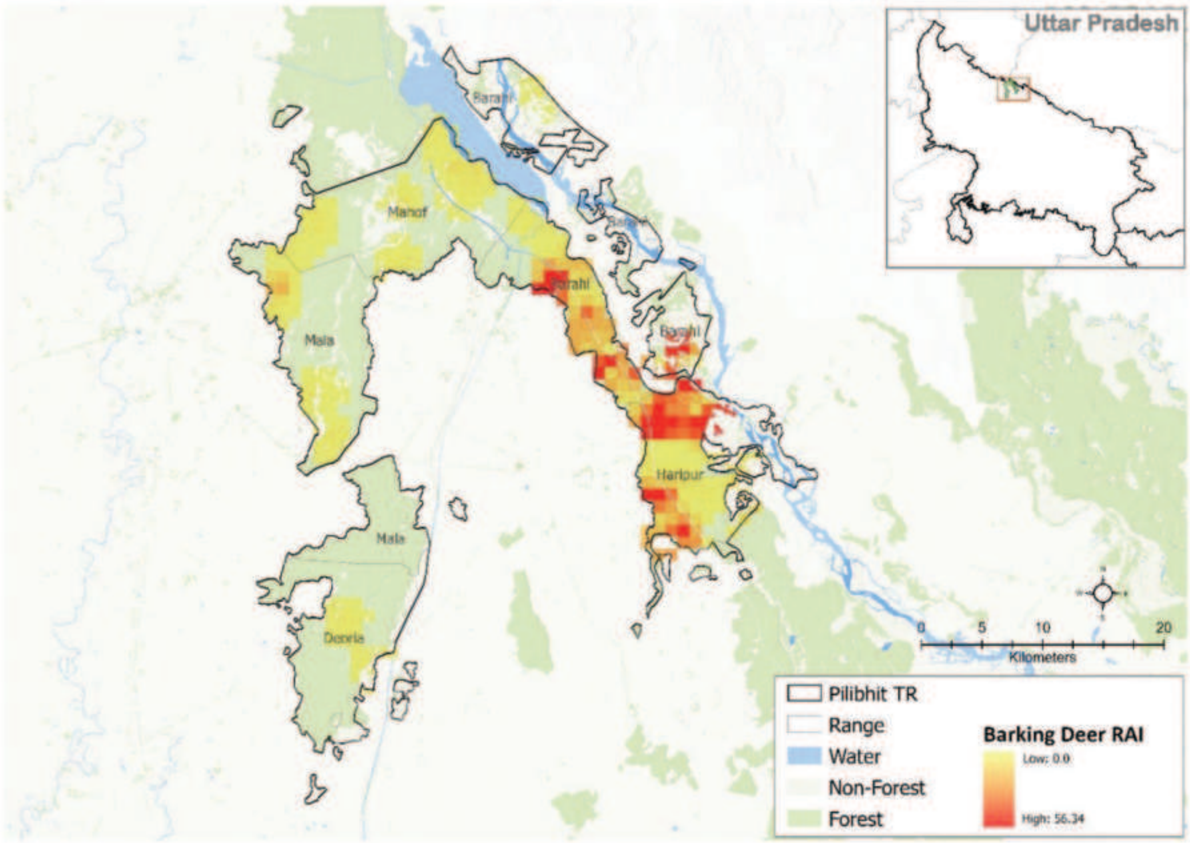

Figure III. 29: Spatial relative abundance of barking deer in Pilibhit tiger reserve.

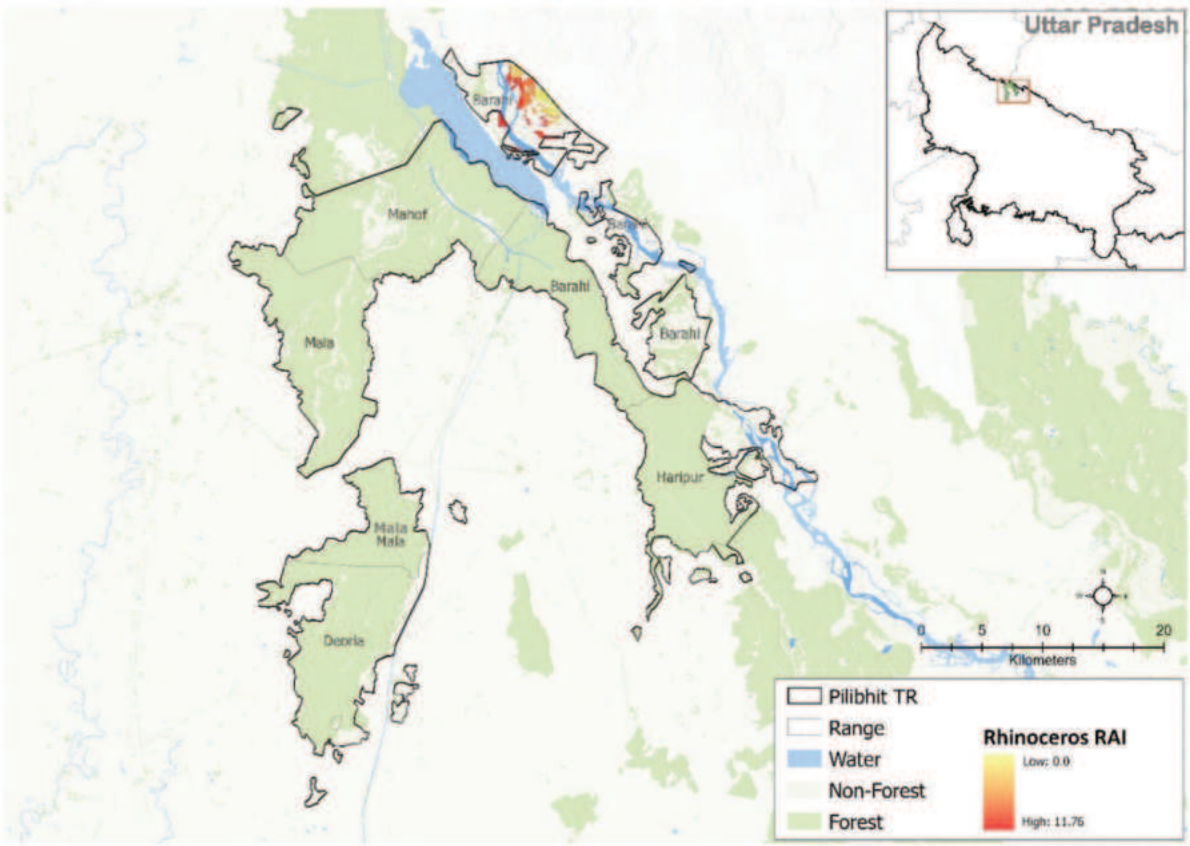

Figure III. 30: Spatial relative abundance of rhinoceros in Pilibhit tiger reserve.

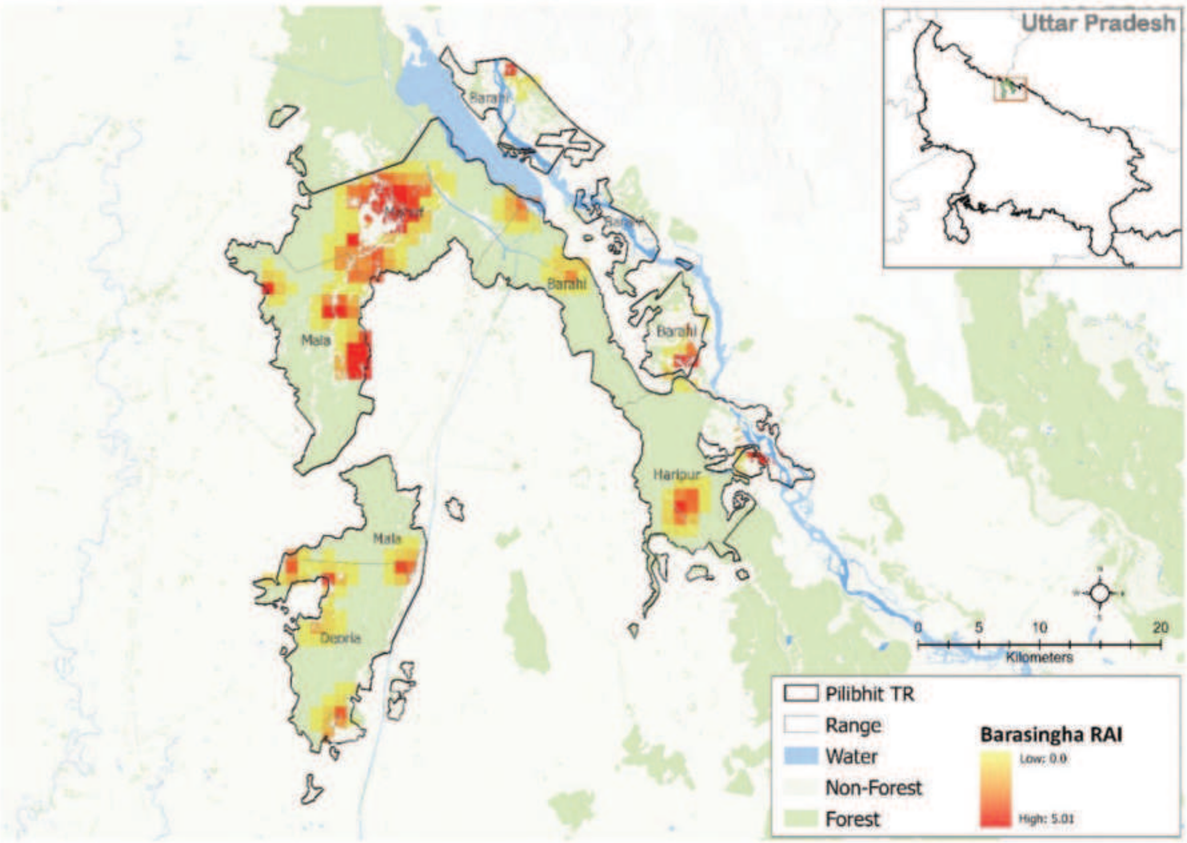

Figure III. 31: Spatial relative abundance of barasingha in Pilibhit tiger reserve.

BIHAR

Valmiki Tiger Reserve

Valmiki tiger reserve, spanning approximately 899 km² in the West Champaran district of Bihar, marks the easternmost extent of the Terai Arc landscape. Located at the Himalayan foothills, it borders Nepal's Chitwan National Park and comprises moist deciduous forests, sal woodlands, riverine grasslands, and fertile alluvial floodplains shaped by the Gandak river (Nautiyal *et al.*, 2023). The reserve is a crucial wildlife corridor for movement of wildlife across Indo-Nepal border for species like tiger, leopard, fishing cat, sloth bear, gaur, dhole, elephant, and Indian pangolin, along with various ungulates. Its landscape reflects evolutionary adaptations driven by a monsoonal climate and Himalayan uplift, with flora dominated by *Shorea robusta*, *Terminalia spp*., and bamboo species (Champion and Seth, 1968).

Prey species abundance has been mapped using line transect data except for gaur and hog deer. Chital is primarily distributed along the southern boundary, with the highest abundance in Manguraha and Madanpur ranges, while Harnatand has the lowest (Figure III. 32). The more rugged area of northern Valmiki has limited chital presence. Sambar is most abundant in the northern ranges, particularly Gobardhana, followed by Manguraha and Raghia (Figure III. 33). Barking deer densities are highest in Manguraha and Gobardhana, with minimal presence in Madanpur (Figure III. 34). Wild pigs are abundant in Raghia, Manguraha, and Harnatand, while Valmiki Nagar and Madanpur show the lowest densities (Figure III. 36). Nilgai are concentrated along the southern boundary, with no presence in the northern areas (Figure III. 35).

Gaur, unique to Valmiki within the Indian Shivalik landscape, was mapped using camera trap data. However, their abundance is very low and restricted to the Gonauli range (Figure III. 37). Relative abundance map shows that hog deer presence is also limited and is present only Madanpur range (Figure III. 38). The Valmiki nagar range has the lowest ungulate presence in Valmiki tiger reserve.

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Table III. 4: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Valmiki tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Barking deer	55	0.066 (0.009)	0.54 (0.04)	1.02 (0.02)	1.02 (0.16)	1.08 (0.17)
Chital	63	0.076 (0.01)	0.56 (0.06)	5.75 (0.47)	1.13 (0.19)	5.81 (0.73)
Nilgai	33	0.04 (0.007)	0.38 (0.07)	3.76 (0.34)	0.58 (0.15)	1.89 (0.38)
Sambar	86	0.104 (0.011)	0.33 (0.03)	1.27 (0.06)	1.56 (0.23)	2.42 (0.35)
Wild pig	58	0.07 (0.009)	0.43 (0.05)	2.67 (0.25)	1.35 (0.23)	3.36 (0.48)

B)

Species	Chital	Sambar	Barking deer	Wild pig	Nilgai
Detection model	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	3.929	2.001	2	2.843	3.86
s(Aridity)	-	-	1	2.418	3.41
s(NDVI Pre-Monsoon)	3.898	3.441	1.179	3.482	-
s(Ruggedness)	-	3.585	-	-	-
s(Elevation)	2.295	-	-	-	-

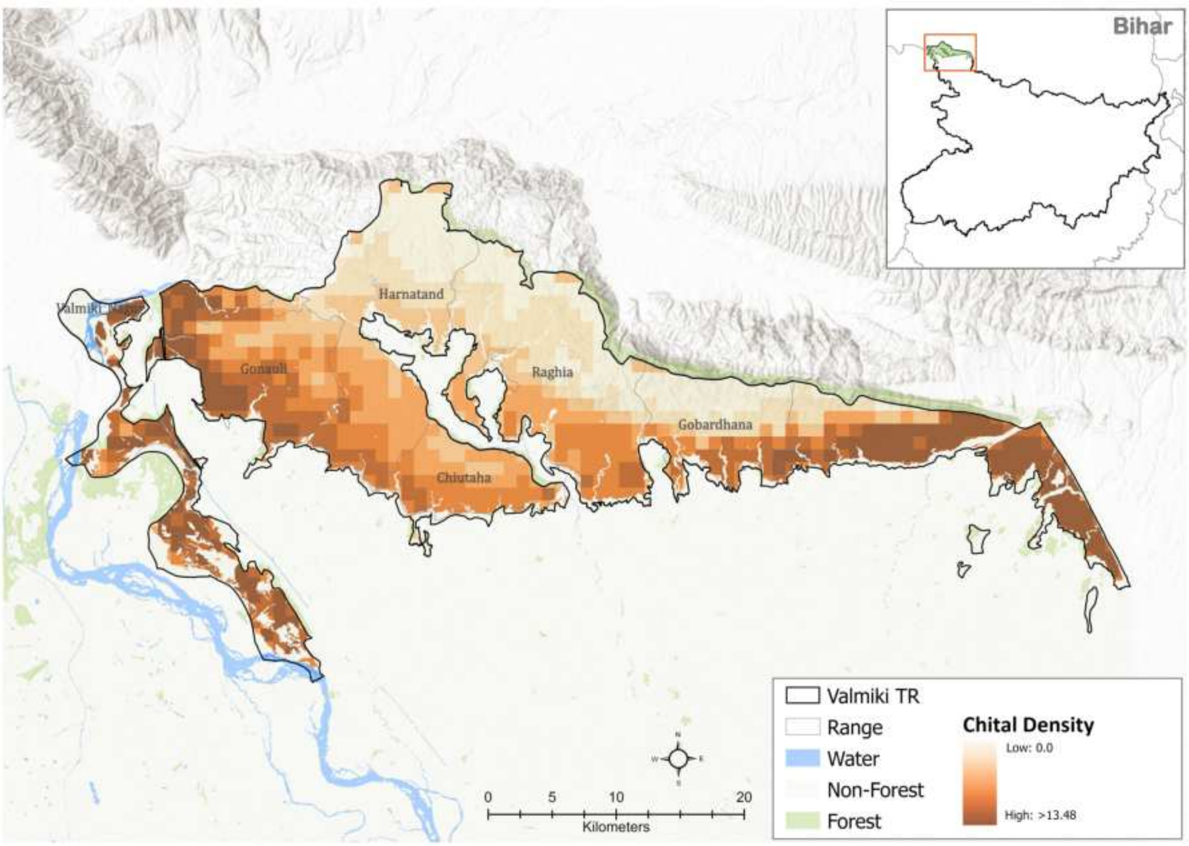

Figure III. 32: Density of chital (per km^2) in Valmiki tiger reserve: Site-level DSM

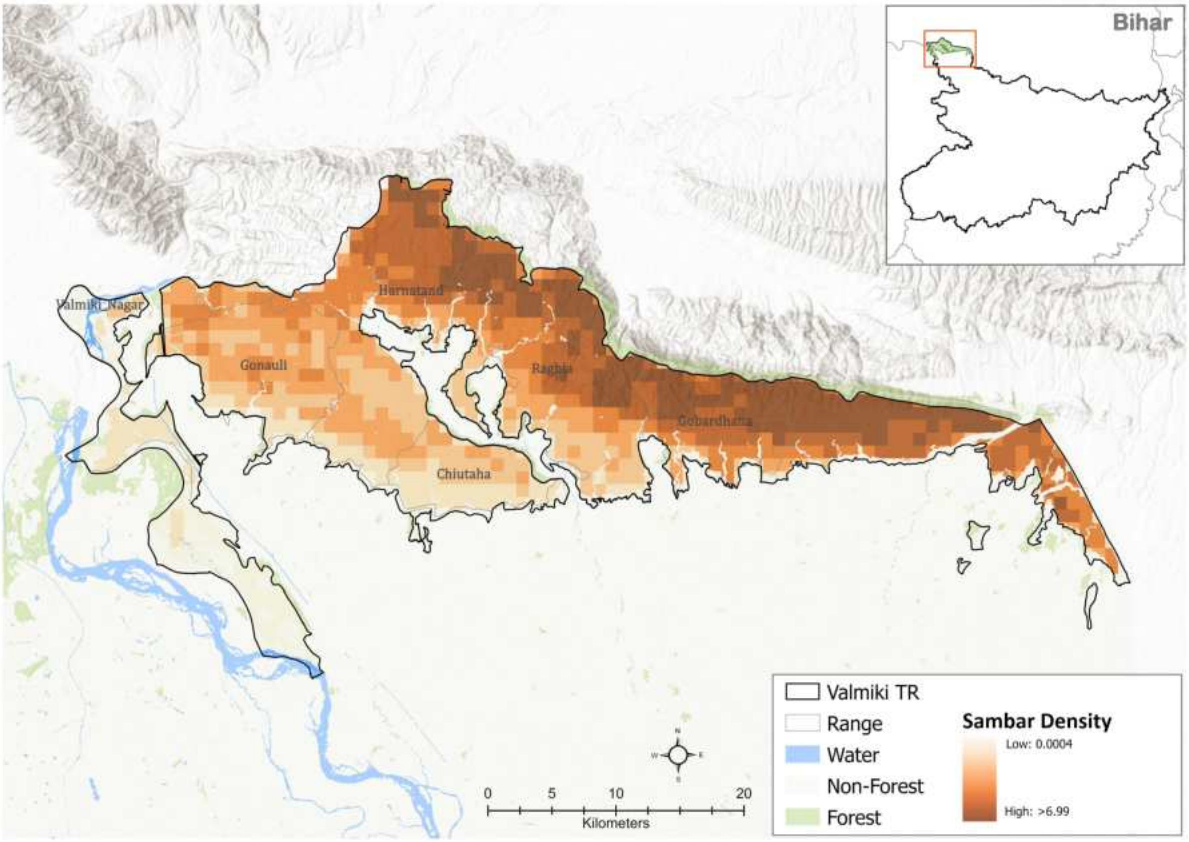

Figure III. 33: Density of sambar (per km^2) in Valmiki tiger reserve: Site-level DSM

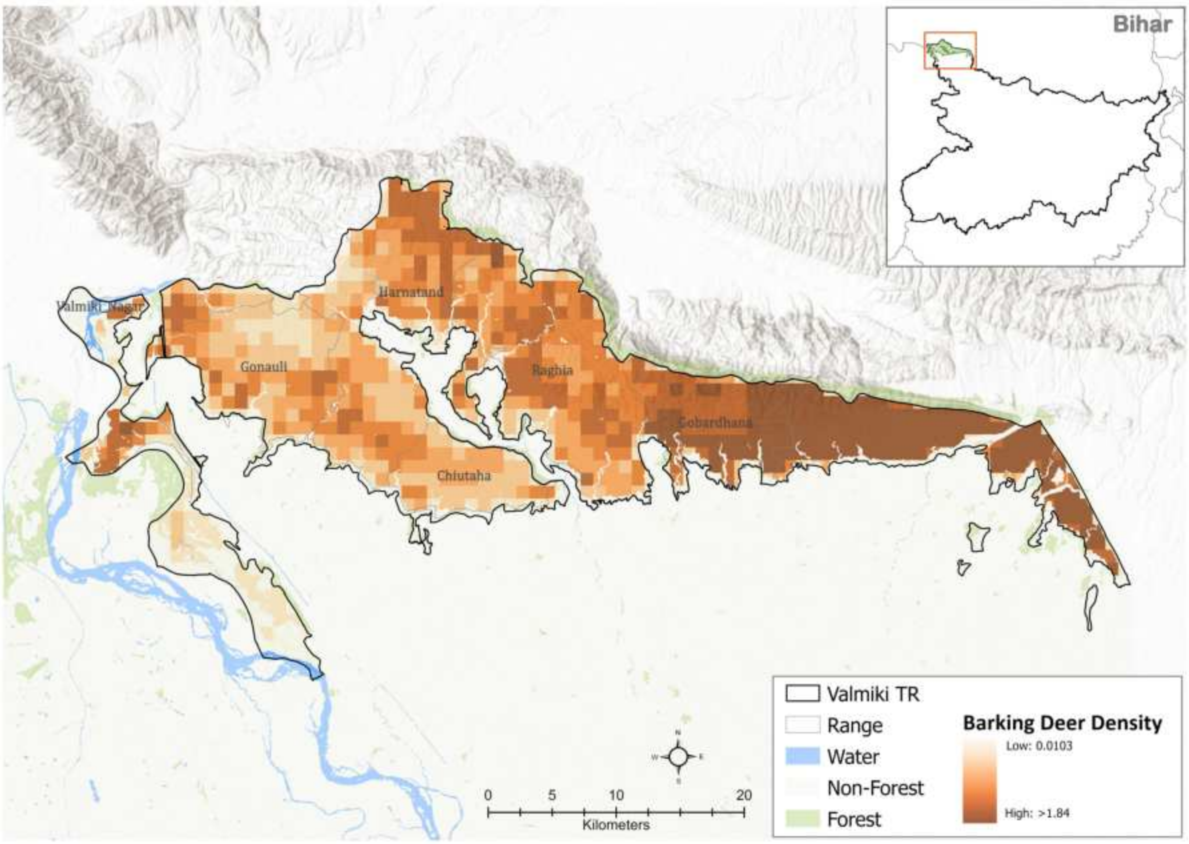

Figure III. 34: Density of barking deer (per km^2) in Valmiki tiger reserve: Site-level DSM

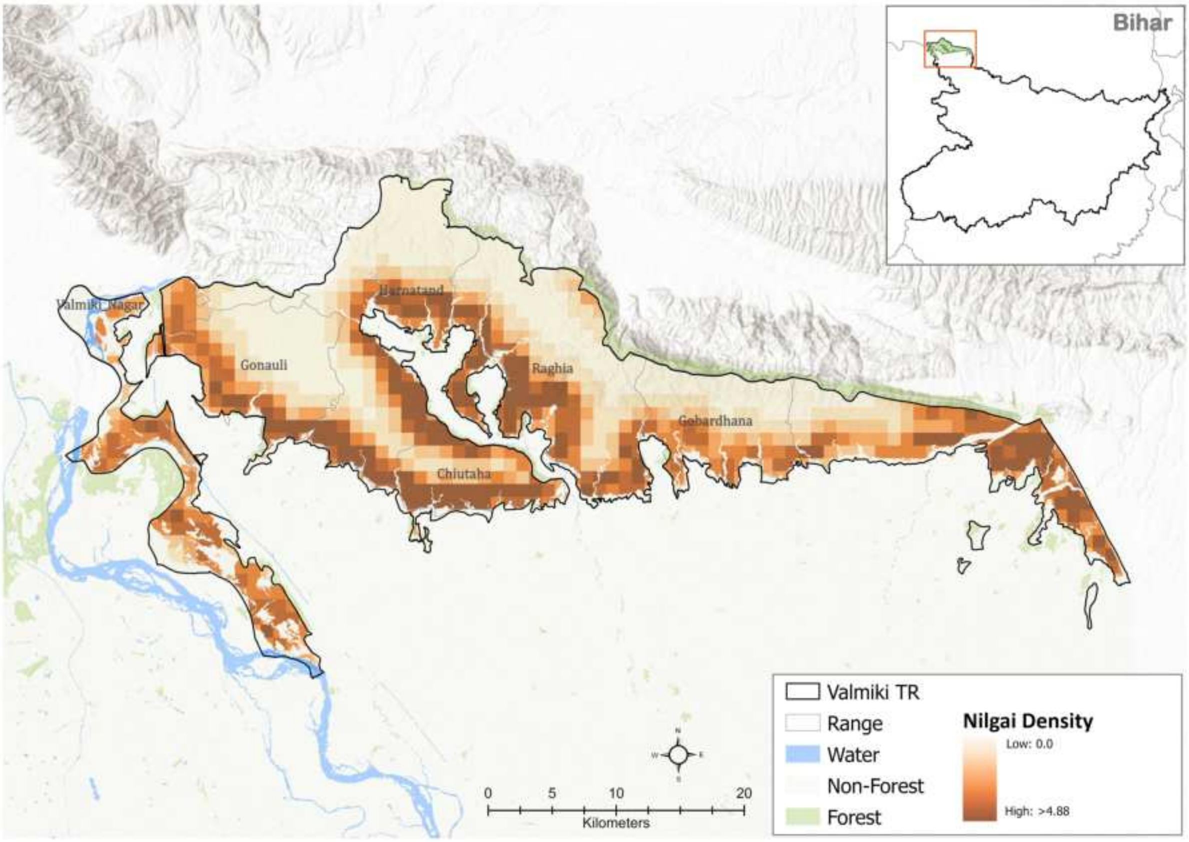

Figure III. 35: Density of nilgai (per km²) in Valmiki tiger reserve: Site-level DSM

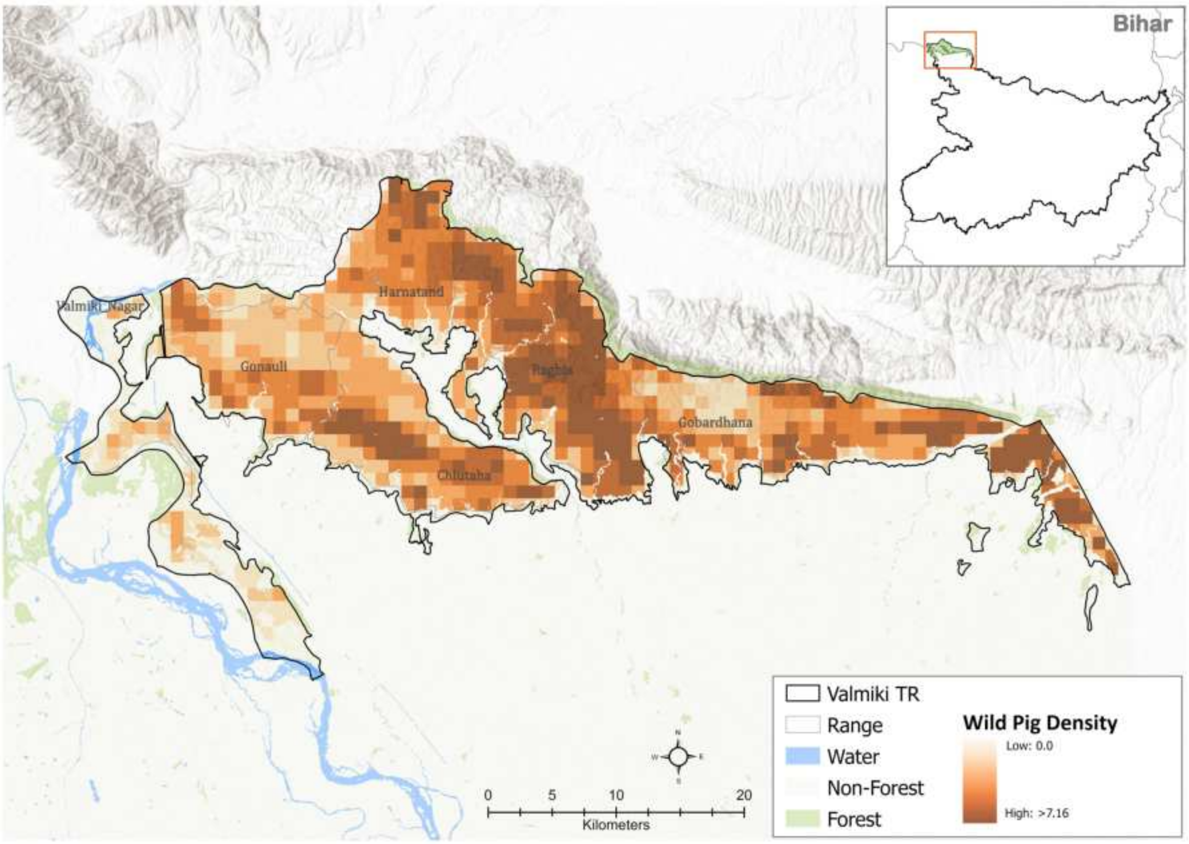

Figure III. 36: Density of wild pig (per km²) in Valmiki tiger reserve: Site-level DSM

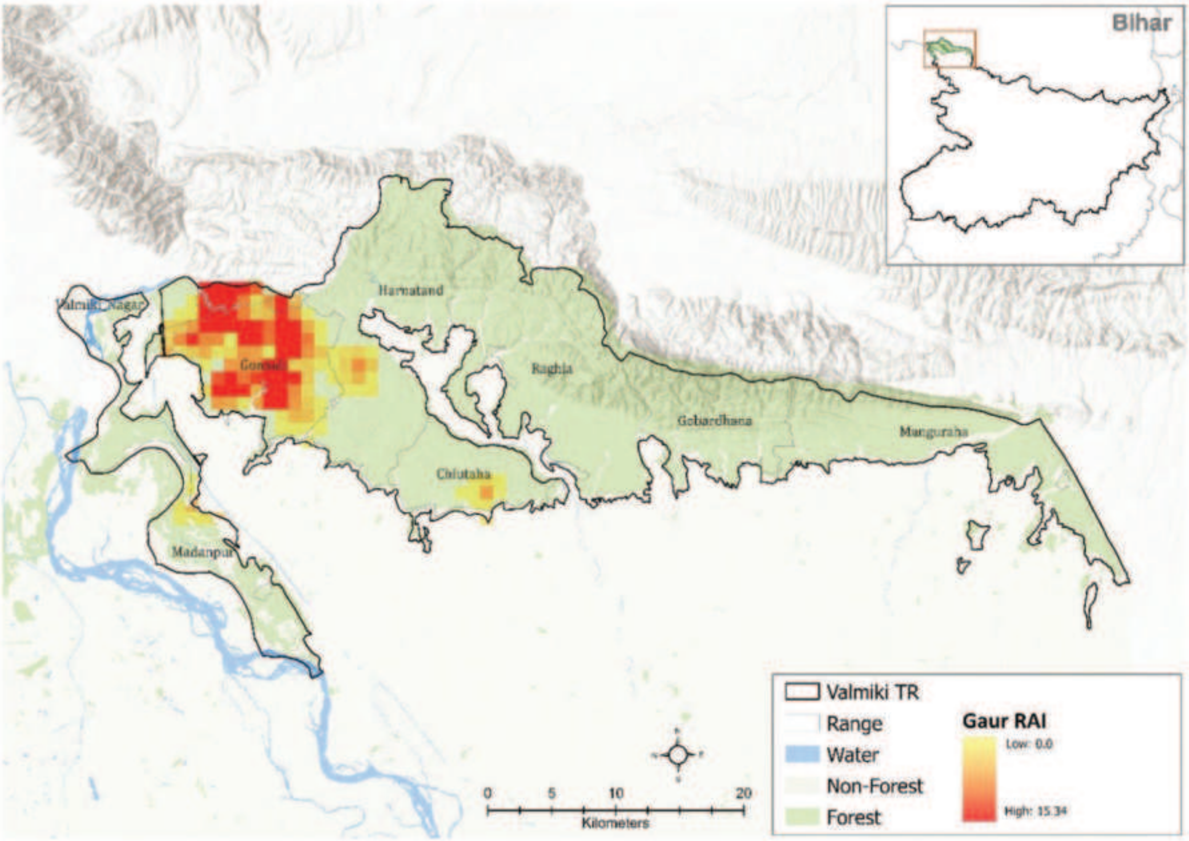

Figure III. 37: Spatial relative abundance of gaur in Valmiki tiger reserve.

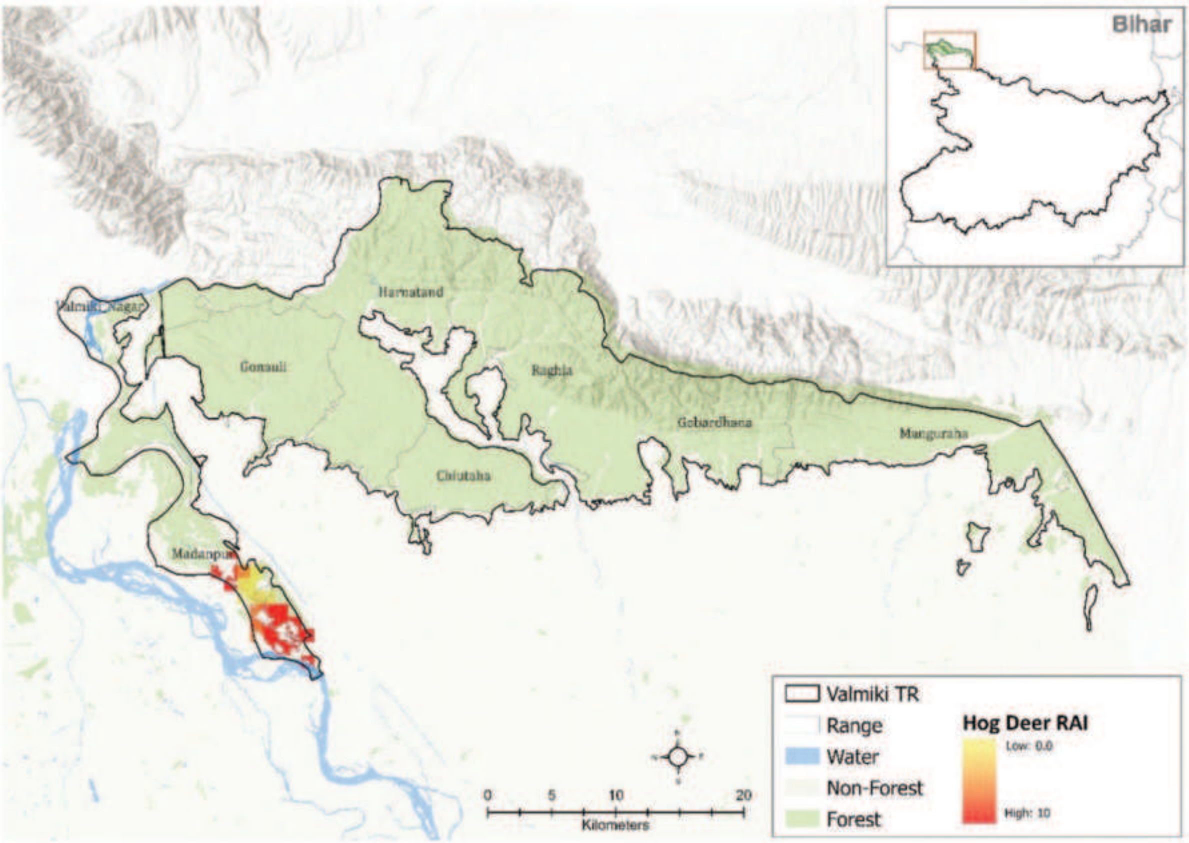

Figure III. 38: Spatial relative abundance of hog deer in Valmiki tiger reserve.

SECTION IV

Central India & Eastern Ghats Landscape

Omkar Nar, Shravana Goswami, Ujjwal Kumar, Vaishnavi Gusain, Dhruv Jain, Yadvendradev Jhala, Vishnupriya Kolipakam, Qamar Qureshi

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The Central India and Eastern Ghats (CIEG) landscape encompasses the semi-arid zone of Rajasthan and the Central India Plateau, which includes Maharashtra, Madhya Pradesh, Chhattisgarh, Jharkhand, and Odisha. It also extends into the Eastern Ghats in Telangana, Andhra Pradesh, and Odisha, while sections of the Northern Western Ghats (Sahyadri) in Maharashtra are included for continuity. Areas of the Eastern Ghats in Tamil Nadu and Karnataka are discussed separately in the Western Ghats landscape. The CIEG landscape is India's largest landmass and features diverse habitats ranging from moist to dry deciduous forests, valleys, and hilly terrains. The topography of the landscape is diverse with prominent hill ranges. It is surrounded by the Aravalli hills in the northwest, the Satpura range in the south, the Chota Nagpur plateau in the northeast, and the Eastern Ghats in the southeast. These ranges, with elevations ranging from 200 to 1300 meters, create a complex and biodiverse terrain.

Aravalli Range: The oldest mountain range in India, stretching over 700 km from Gujarat to Delhi, forms an extensive belt in Rajasthan.

Vindhya and Satpura Ranges: These ranges act as geographical dividers between the Indo-Gangetic plains and the peninsular region.

Chota Nagpur Plateau: Located in Jharkhand, Chhattisgarh, and northern Odisha, this plateau includes the Hazaribagh, Ranchi, and Koderma plateaus in a step-like formation.

Eastern Ghats: Running parallel to the eastern coast, the Ghats are fragmented by rivers like the Godavari and Krishna. Notable ranges include Nallamala, Erramala, Palakonda, and Seshachalam hills.

The landscape acts as a transitional zone, bridging the forests of the Indian peninsula with the Thar Desert, while maintaining ecological connectivity across regions. The forests of the landscape shaped by low rainfall and shallow soils, support significant biodiversity. The area houses five biosphere reserves: Similipal, Pachmarhi, Achanakmar-Amarkantak, Panna, and Seshachalam. However, these forests face immense pressure from mining, linear infrastructure development, grazing, non-timber forest product collection, and insurgency.

Flora

The region's forests are classified primarily as tropical dry deciduous, with some areas of tropical moist deciduous and tropical thorn forests.

Deciduous Forests: Teak (*Tectona grandis*) dominates the southern region, while sal (*Shorea robusta*) prevails in the north. Overlap occurs in parts of Chhattisgarh.

Chambal Ravines: These host thorn forests with species like *Acacia spp., Prosopis juliflora*, and *Anogeissus pendula*.

Eastern Ghats: Moist deciduous forests occur in high-soil-moisture areas, while dry mixed deciduous forests are widespread.

Unique flora like tree ferns (*Cyathea gigantea*) thrive in Pachmarhi's gorges, while species like Sterculia villosa and Gnetum ula enrich the tropical hill forests of Madhya Pradesh.

Fauna

This region shares similarities in mammalian diversity with the biodiversity hotspots of the Himalayas, Indo-Malayan region, and Western Ghats. Ungulates: The landscape supports six species of Bovidae: blackbuck (*Antilope cervicapra*), gaur (*Bos gaurus*), nilgai (*Boselaphus tragocamelus*), wild buffalo (*Bubalus arnee*), chinkara (*Gazella benetti*), and chowsingha (*Tetracerus quadricornis*), along with several other ungulates such as chital (*Axis axis*), hard ground barasingha (*Rucervus duvacelli branderi*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), mouse deer (*Moschiola indica*), wild pig (*Sus scrofa*), and Asiatic elephant (*Elephas maximus*).

Predators: Tigers dominate the region, which houses India's largest tiger population with high genetic diversity, including a unique lineage in Similipal Tiger Reserve.

Reintroductions: Conservation initiatives include reintroducing tigers in Panna, Sariska, and Nauradehi; gaur in Bandhavgarh and Sanjay-Dubri; and barasingha in Satpura and Bandhavgarh. Cheetah introductions in Kuno National Park mark another significant effort.

Ungulate Distribution and Abundance in the landscape

Chital is the most abundant ungulate species in central Indian landscape followed by sambar. Chital presents in high density in Madhya Pradesh, followed by Maharashtra (Figure IV. 1). Within Madhya Pradesh also, the eastern side has higher density than the western side. Although their presence is high in central India, their presence is mostly restricted to protected areas. Outside protected areas, chital present in high to moderate densities in Kanha-Pench corridor, around bandhavgarh tiger reserve and forest division between Nagzira-Navegaon tiger reserve and Tadoba Andheri tiger reserve. Sambar density is high in Kanha, Pench-Madhya Pradesh, Ranthambhore and Simlipal (Figure IV. 2). Sariska and Panna have moderate sambar density and all the other areas have low sambar density. Outside protected area sambar abundance in central Indian landscape is very low.

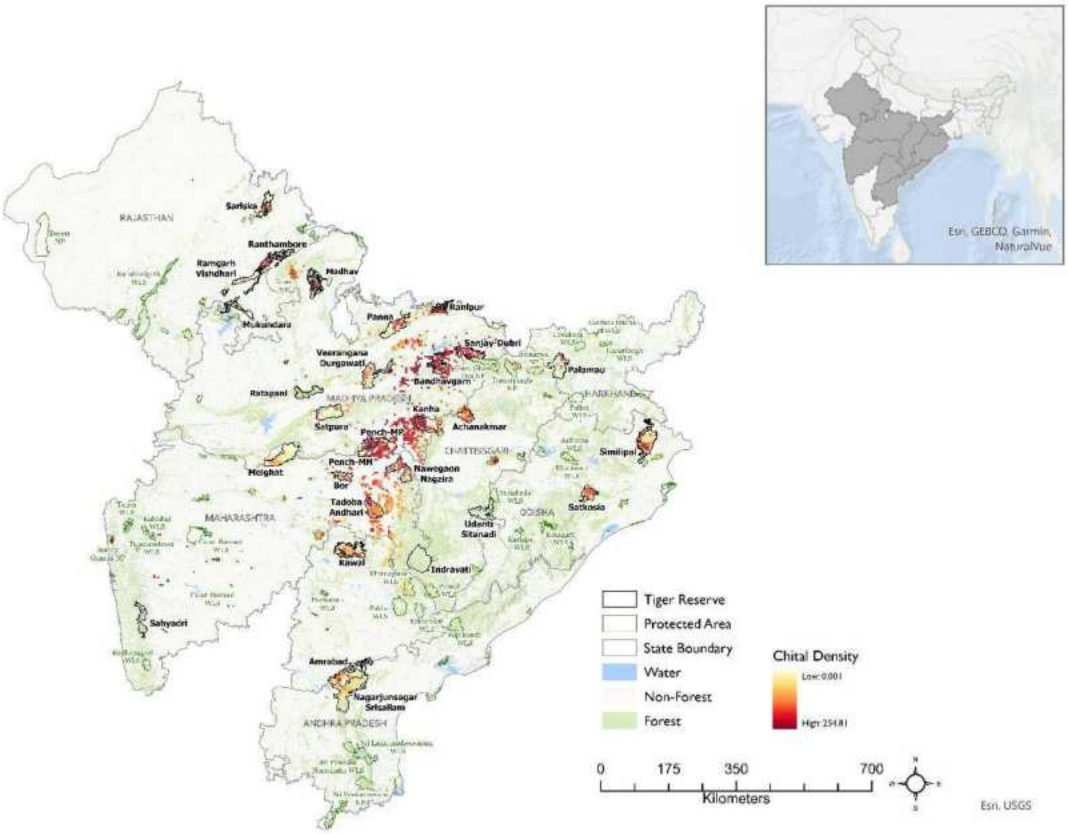

Figure IV. 1: Distribution and density of chital (per 25 km²) in Central India and Eastern Ghats landscape

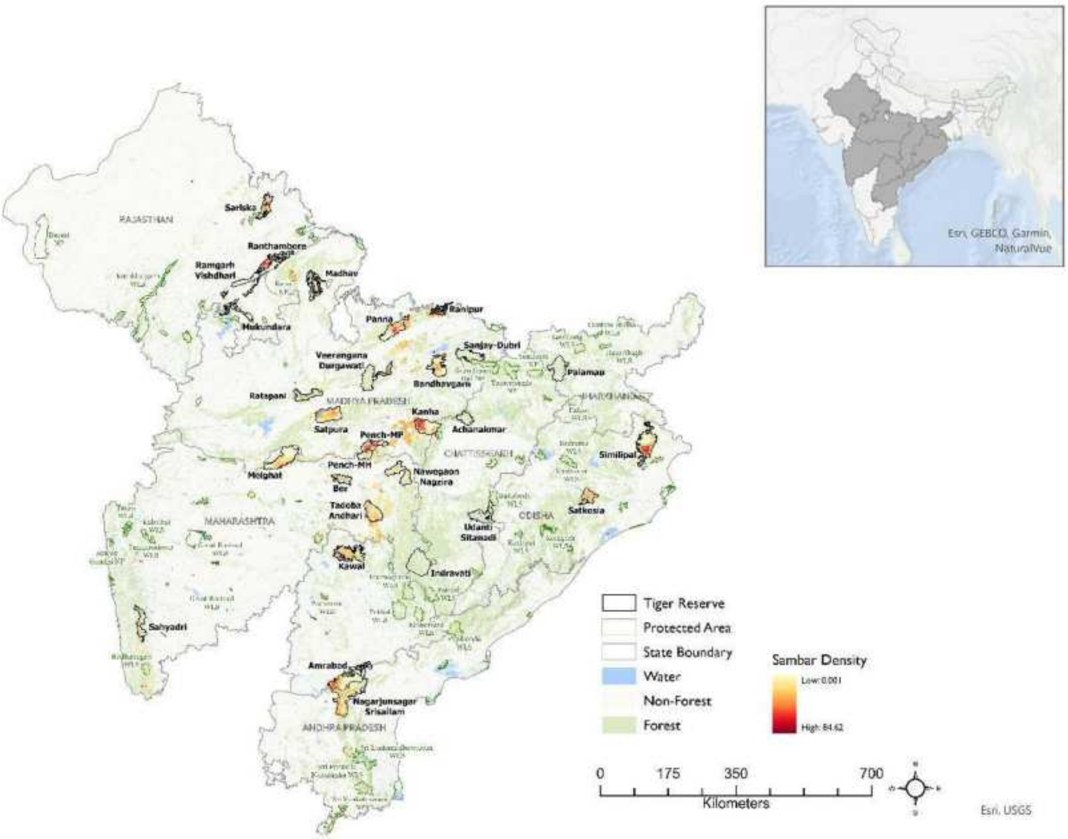

Figure IV. 2: Distribution and density of sambar (per 25 km²) in Central India and Eastern Ghats Landscape

The relative abundance of gaur, barking deer, nilgai, and wild pig in central India is based on camera trap. The gaur presence in central India is mostly limited to protected area only with exception Kanha-Pench corridor and forests around Tadoba Andheri tiger reserve (Figure IV. 4). Rajasthan and Andhra Pradesh have no gaur presence. Relative abundance of gaur is high in Maharashtra followed by Madhya Pradesh. Odisha, Jharkhand and Telengana have low gaur presence where as in Chattishgarh, only Achanakmar has gaur presence. Barking deer is highly abundant in Odisha followed by Madhya Pradesh (Figure IV. 3). The arid and semi-arid forests of Rajasthan and northern Madhya Pradesh do not have barking deer presence. The protected areas of Andhra Pradesh and Telengana also have very low abundance of barking deer presence. Barking deer abundance is mostly restricted to protected areas only with exception to areas around Kanha tiger reserve that comes under Kanha-Pench corridor, has higher abundance (Figure IV. 3). Nilgai is also abundant in this landscape. It is abundant inside as well outside tiger reserve. Odisha didn't have photo capture of nilgai during camera trap session. The area in and around Tadoba Andheri tiger reserve has high abundance of nilgai presence. All protected areas of Rajasthan and Kuno, Panna, and Veerangana Rani Durgawati have high abundance of nilgai inside protected area (Figure IV. 5). Wild pigs are abundant throughout the landscape. Jharkhand has very low abundance of all the ungulates in Central Indian landscape (Figure IV. 6).

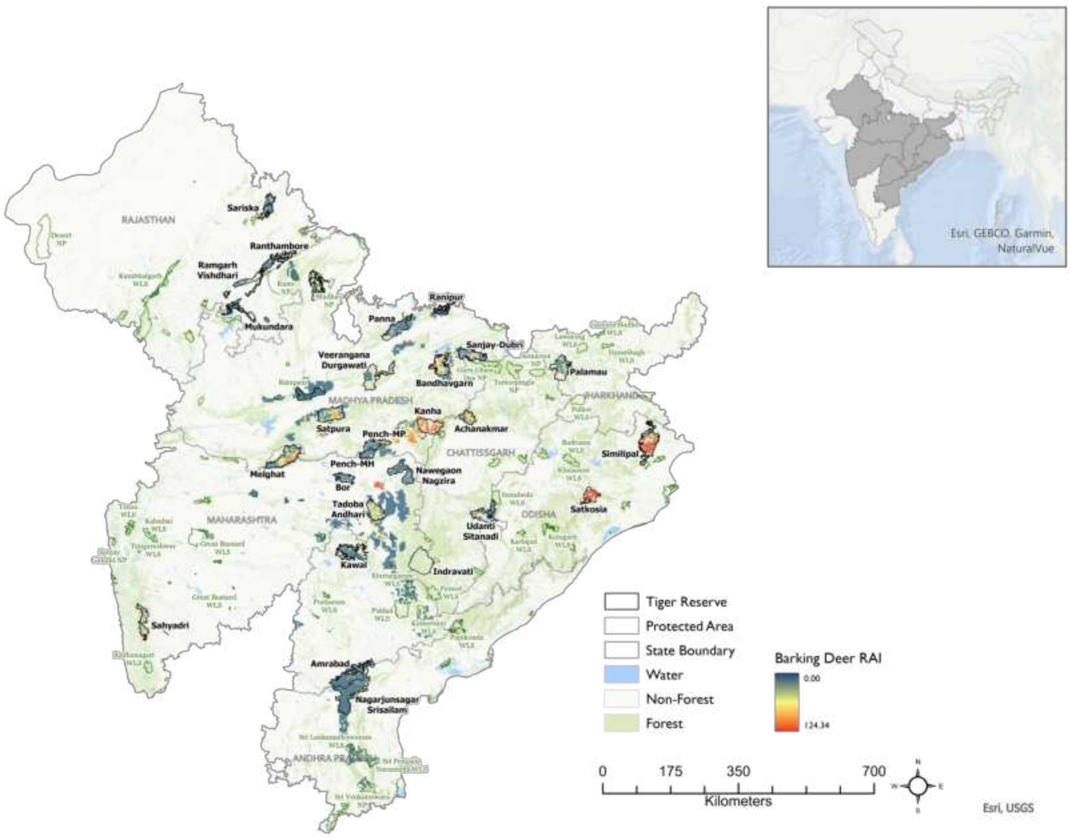

Figure IV. 3: Spatial relative abundance of barking deer (per 25 km^2) in Central India and Eastern Ghats landscape

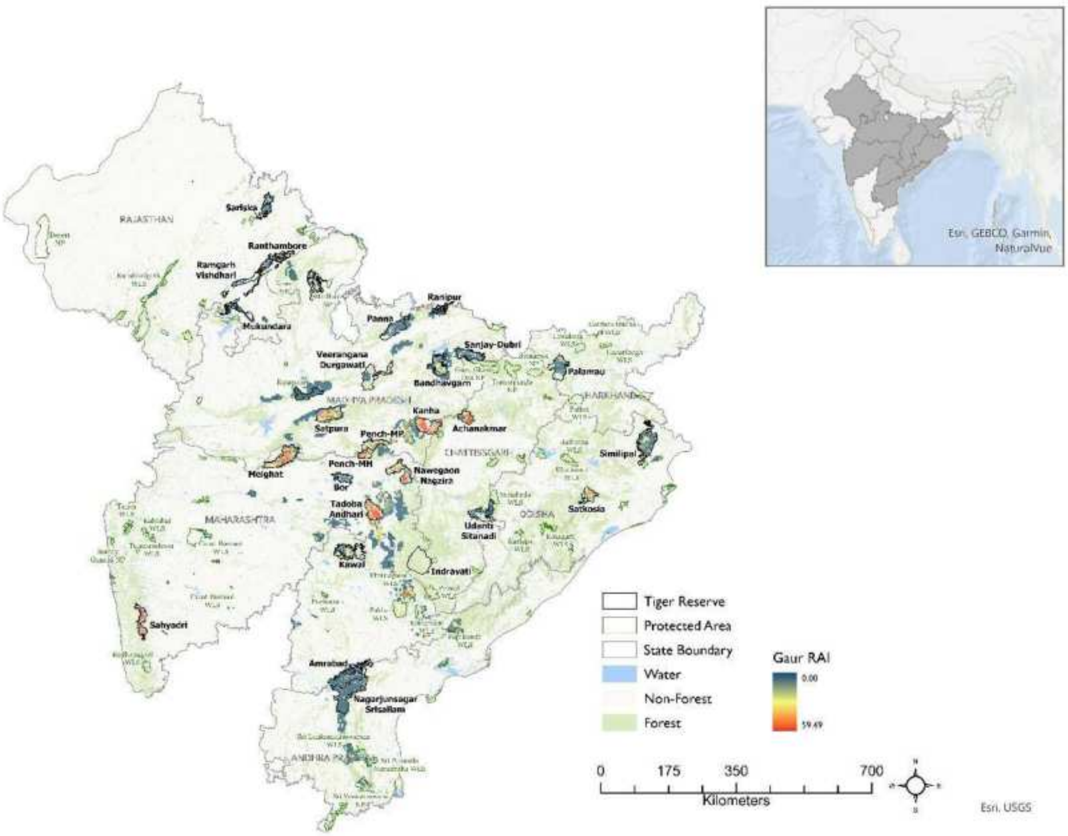

Figure IV. 4: Spatial relative abundance of gaur (per 25 km²) in Central India and Eastern Ghats landscape

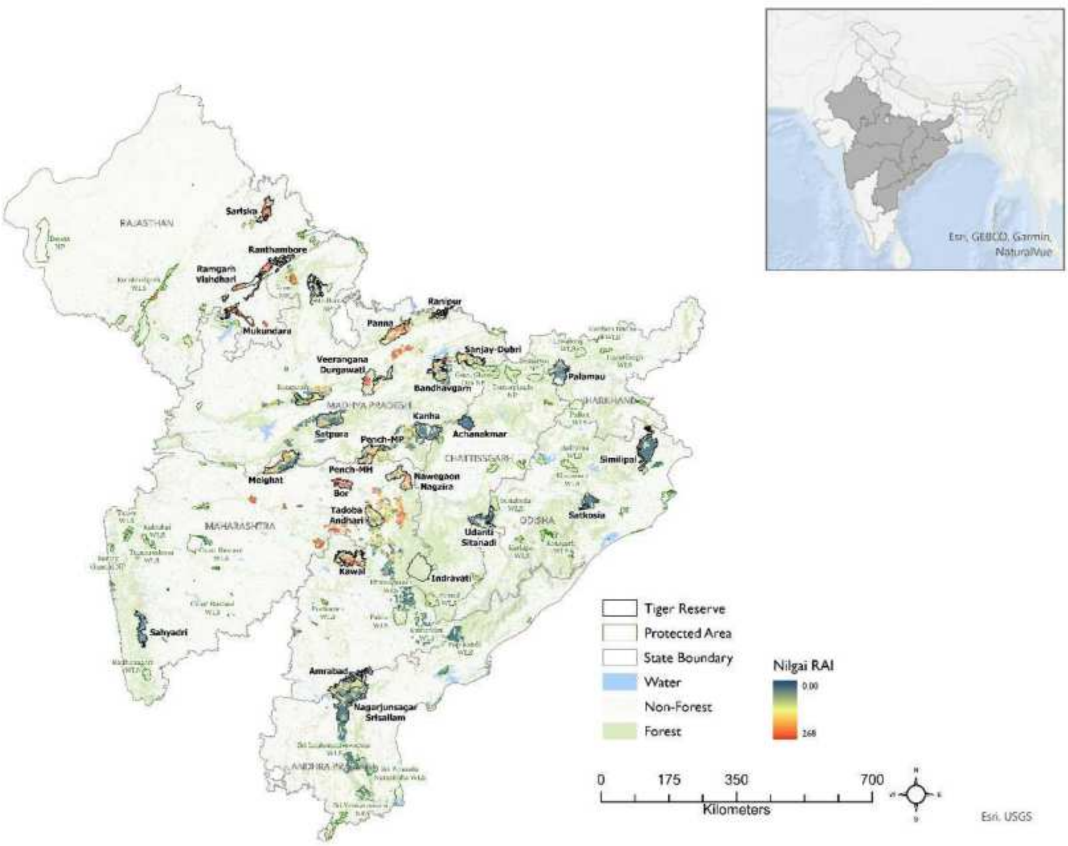

Figure IV. 5: Spatial relative abundance of nilgai (per 25 km²) in Central India and Eastern Ghats landscape

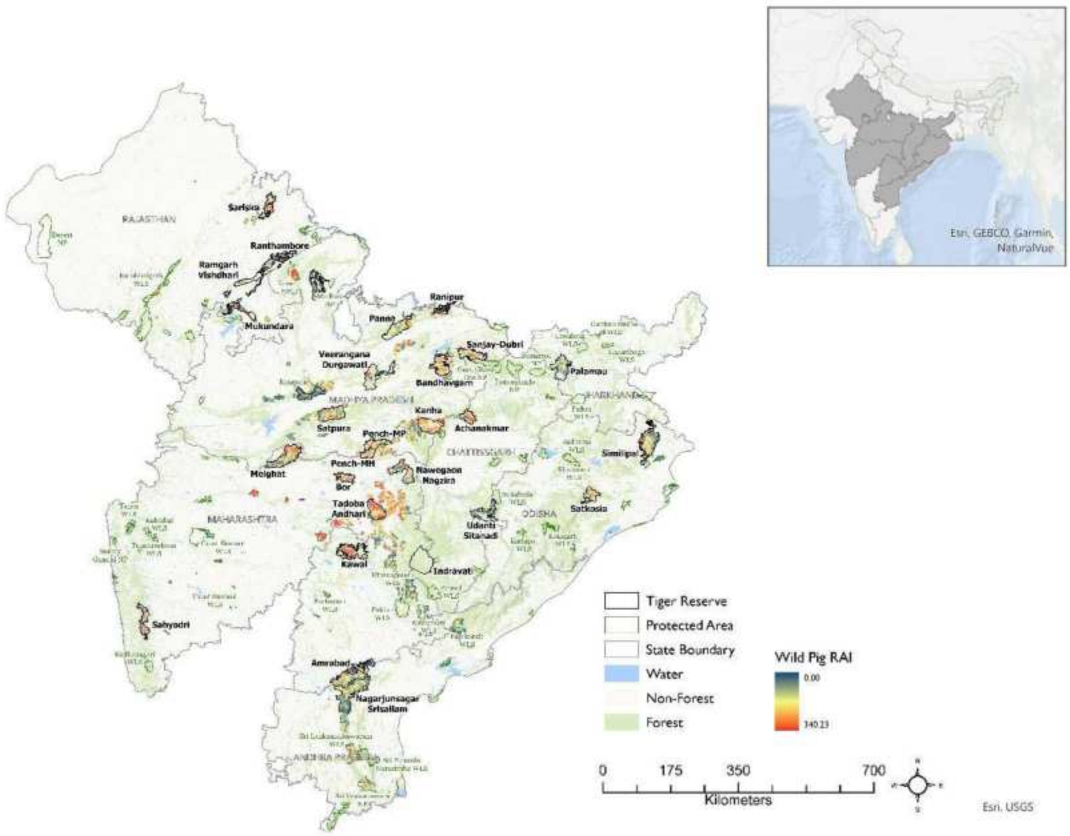

Figure IV. 6: Spatial relative abundance of wild pig (per 25 km^2) in Central India and Eastern Ghats landscape

ANDHRA PRADESH

Nagarjunasagar Srisailam Tiger Reserve

Nagarjunasagar-Srisailam tiger reserve (NSTR), located in the Nallamala Hills of Andhra Pradesh and Telangana, is the largest tiger reserve in India, spanning approximately 3,296 km². The reserve features rugged terrain with deep gorges, steep slopes, and plateaus, interspersed with southern tropical dry deciduous forests, scrublands, and riverine patches along the Krishna River (Reddy *et al*., 2004; Kumar *et al*., 2023). This diverse landscape supports a rich biodiversity, including the tiger, leopard, Indian wolf, and gaur, alongside a variety of prey species such as sambar, chital, nilgai chousingha, and chinkara. NSTR also harbours a rich array of bird species, such as the Indian peafowl and grey hornbill, and numerous reptiles and amphibians.

The abundance of major prey *i.e.* chital and sambar was estimated through landscape model. The encounter rate for chital is 0.06 and for sambar is 0.04 (Kumar *et al.*, 2023). Sambar is the most abundant prey species in NSTR, with the highest densities recorded along the southern ranges and localized patches in Yerragondapelam and Srisailam. In contrast, chital densities are low, primarily concentrated in the central ranges of Nagaluty, Srisailam, and Atmakur (Figure IV. 8). Conservation measures for prey population recovery should focus on controlling livestock grazing to reduce biotic pressure, augmenting chital populations, and restoring fragmented habitats and grassland to ensure sufficient forage availability to the ungulates.

Chousingha, nilgai, and wild pig spatial densities were not estimated due to insufficient data, the relative abundance through camera trap-based photo-captures were mapped for informed decision. Chousingha is well distributed throughout the tiger reserve with high abundance in the areas bordereing Vijayapuri South and Gangivaripalli ranges as well as in the rest of the ranges (Figure IV. 9). While nilgai have higher but localized abundance in central and southern ranges like Nandyal, Chelama, and Gundlakamma ranges in the south (Figure IV. 10). Wild pig abundance is relatively widespread, with highest records from Nagaluty and Atmakur followed by Srisailam (Figure IV. 11).

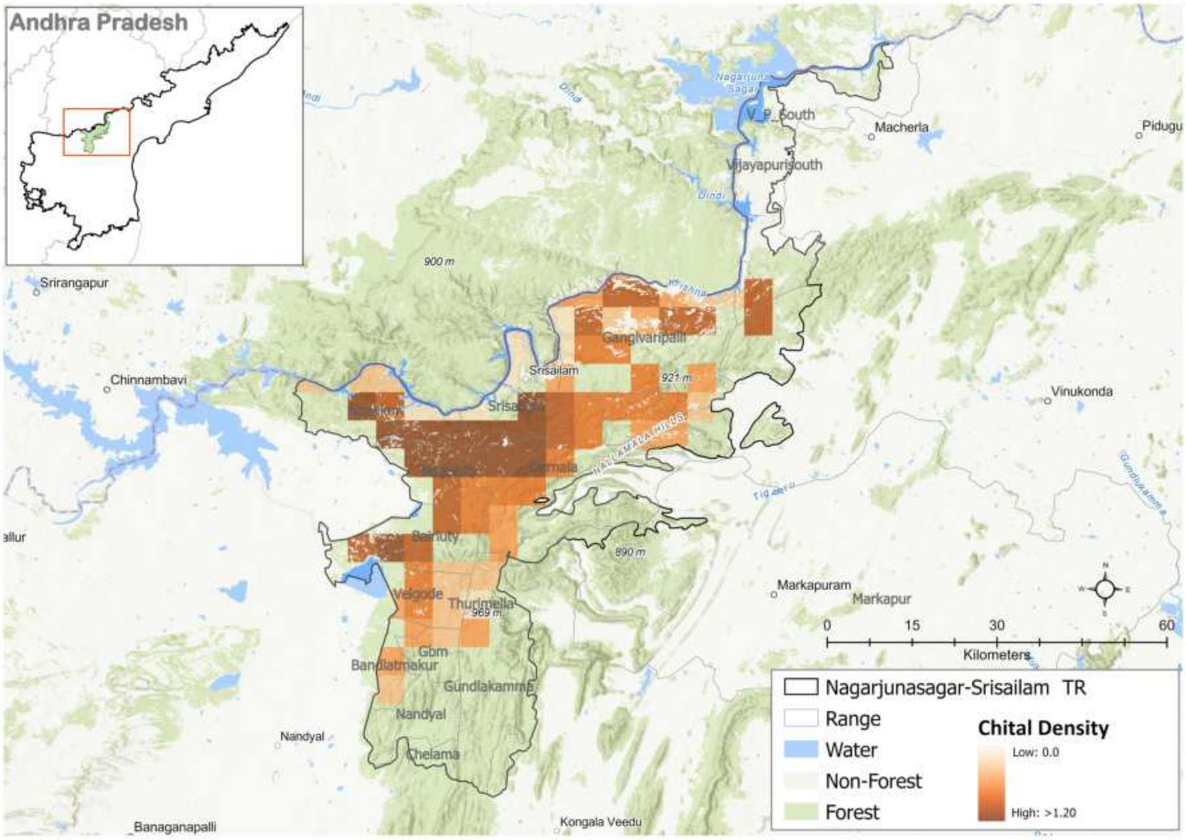

Figure IV. 7: Density of chital (per 25 km²) in NSTR: Landscape-level DSM

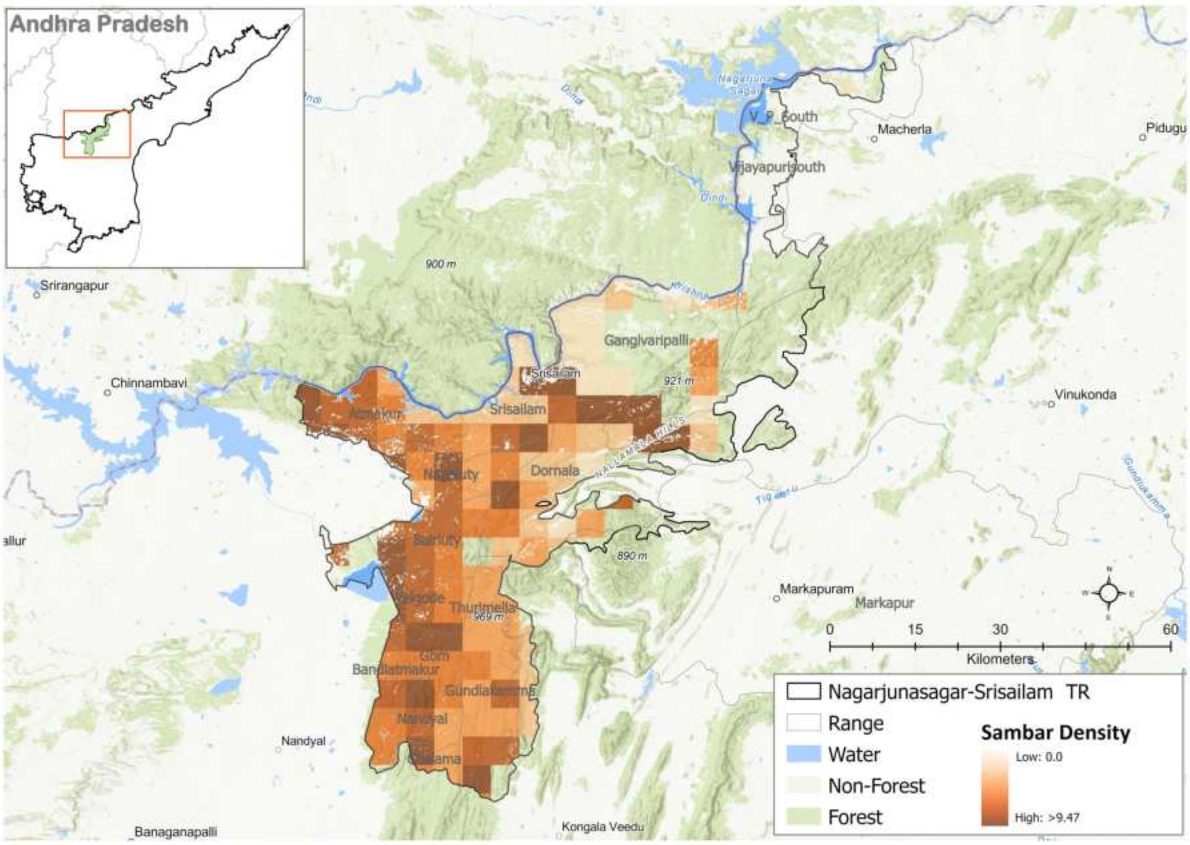

Figure IV. 8: Density of sambar (per 25 km²) in NSTR: Landscape-level DSM

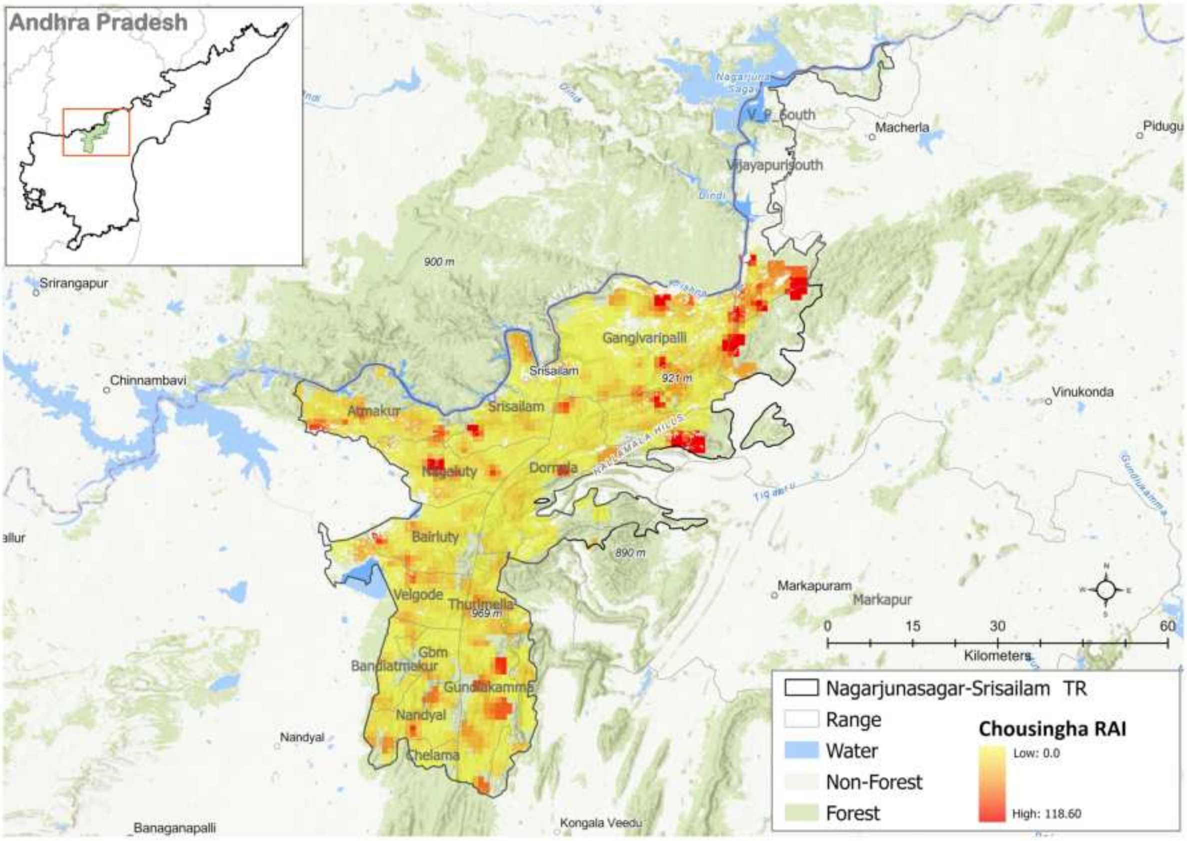

Figure IV. 9: Spatial relative abundance of chousingha in NSTR

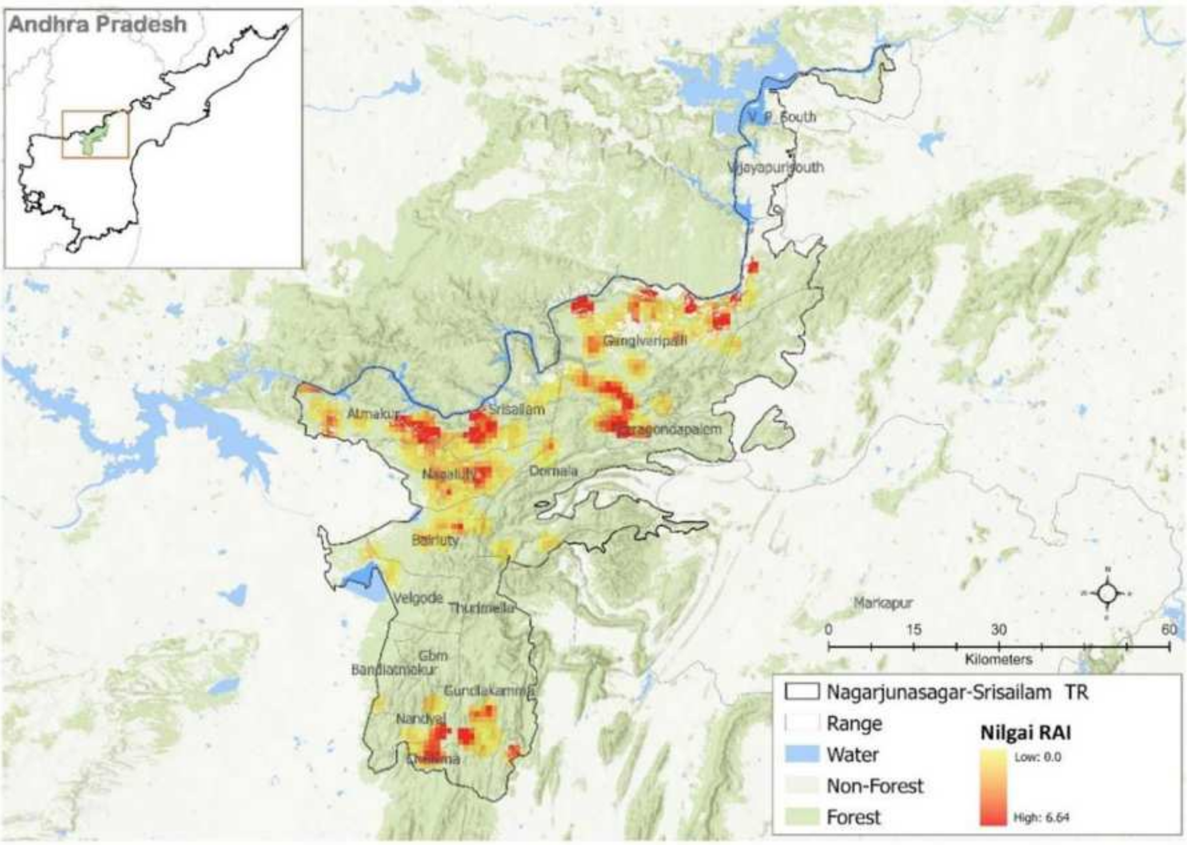

Figure IV. 10: Spatial relative abundance of nilgai in NSTR

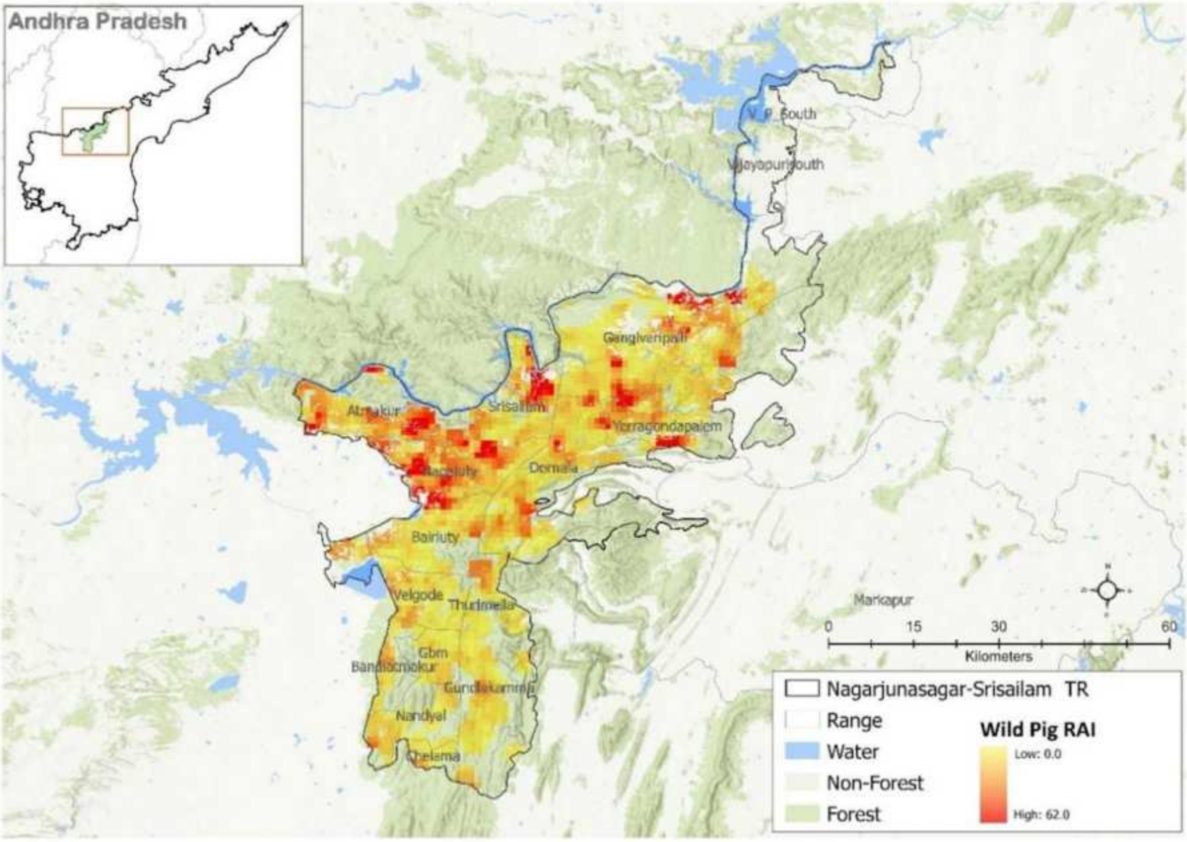

Figure IV. 11: Spatial relative abundance of wild pig in NSTR

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CHHATTISGARH

Achanakmar Tiger Reserve

Achanakmar tiger reserve located in the Mungeli district of Chhattisgarh, is a part of the Achanakmar-Amarkantak Biosphere Reserve, covering approximately 914 km^2. Situated in the Maikal Hills of the Satpura mountain range, the reserve is dominated by dense Sal and teak forests, interspersed with bamboo thickets and grasslands. Its terrain includes river valleys formed by Maniari River to hilly plateaus to supports rich biodiversity. The reserve's forests play a crucial role in regulating the regional climate and supporting the livelihoods of local communities. The tiger reserve is home to diverse fauna, including apex predators like tigers, leopards, dhole, jackal, and striped hyenas, as well as herbivores such as chital, sambar, nilgai, and barking deer. Other notable species include Indian wolves, sloth bears, and primates like langurs and macaques. Bird species such as the grey-headed fishing eagle and Indian vultures are found here, along with a host of reptiles and amphibians.

Chital is the most abundant prey species (Table IV. 1) with an encounter rate of 0.0217 (±0.0064). The highest spatial densities of chital are found in the Chhaparwa range, followed by the Lamni range (Figure IV. 12). These areas can serve as source populations for supplementing chital in other ranges. Management strategies should prioritize chital breeding through predator-proof fencing and the subsequent release of individuals into these areas to ensure long-term predator sustenance. Sambar was recorded at very low densities and were restricted to the Achanakmar range (Figure IV. 13). Targeted management interventions are required for the recovery of sambar populations. Voluntary village relocation should be encouraged to reduce biotic pressure on these habitats. Gaur was observed at moderate densities (Table IV. 1), with the highest abundance in the Achanakmar range, followed by Chhaparwa (Figure IV. 14).

Since spatial density estimates for barking deer and wild pigs were unavailable due to insufficient data, their relative abundance was mapped based on photo-captures from camera traps to aid in informed decision-making. Wild pigs were found to be abundant in the Achanakmar and Chhaparwa ranges (Figure IV. 16), while barking deer were most abundant in the Achanakmar, Chhaparwa, Surahi, and the outermost regions of the Lamni range (Figure IV. 15).

Table IV. 1: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Achanakmar tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	81	0.135 (0.016)	0.46 (0.04)	7.09 (0.58)	1.05 (0.15)	7.78 (0.82)
Gaur	48	0.08 (0.012)	0.45 (0.05)	6.9 (0.89)	0.74 (0.14)	3.77 (0.48)

B)

Species	Chital	Gaur
Detection model	Half-normal (Null)	Hazard rate (Null)
s(x,y)	8.841	8.905
s(Aridity)	3.843	3.123
s(NDVI Post-Monsoon)	-	1.975
s(NDVI difference)	3.801	-
s(Elevation)	7.817	-

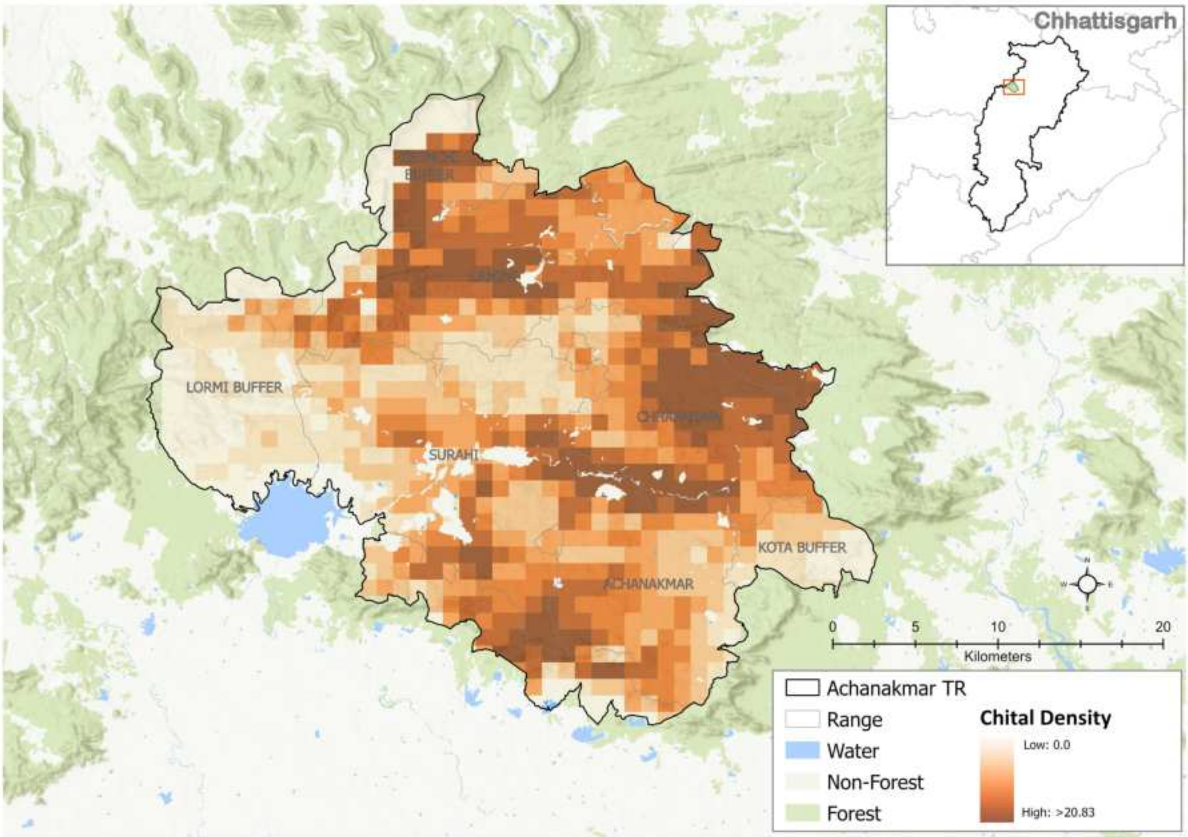

Figure IV. 12: Density of chital (per km²) in Achanakmar tiger reserve: Site-level DSM

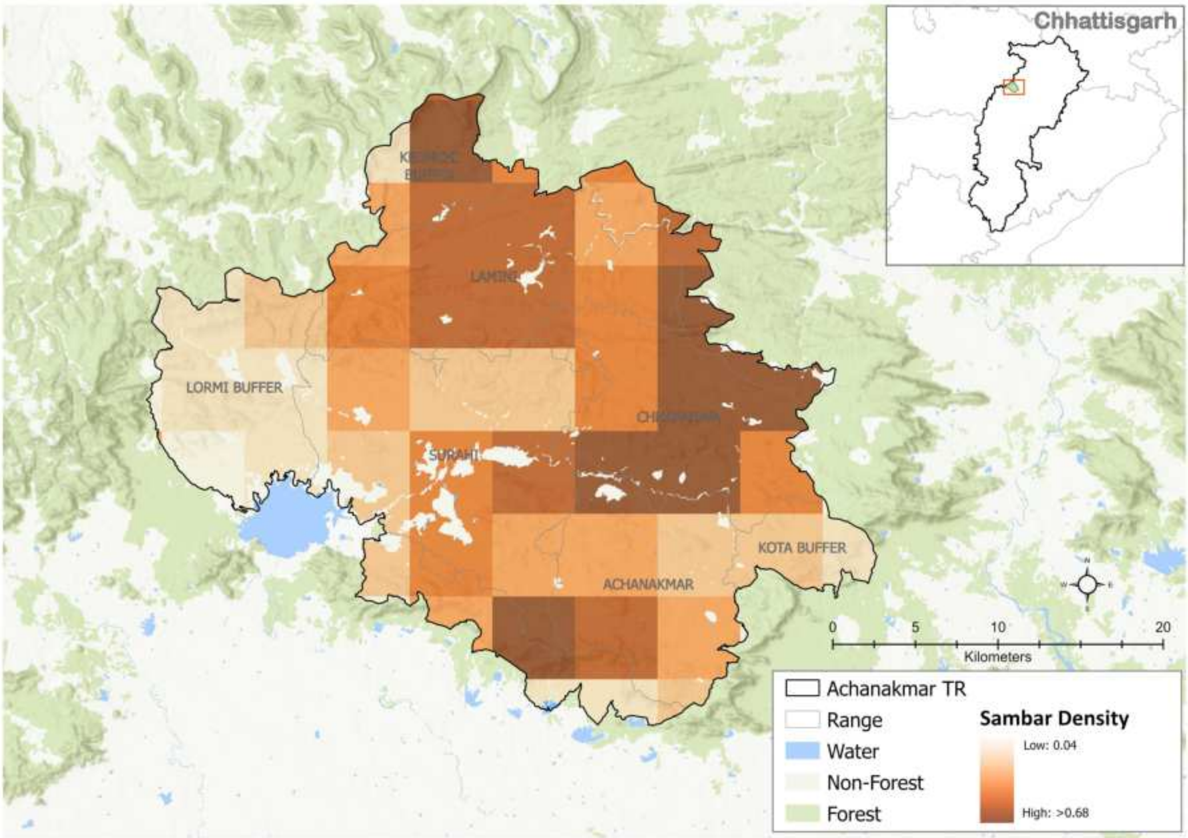

Figure IV. 13: Density of sambar (per 25 km²) in Achanakmar tiger reserve: Landscape-level DSM

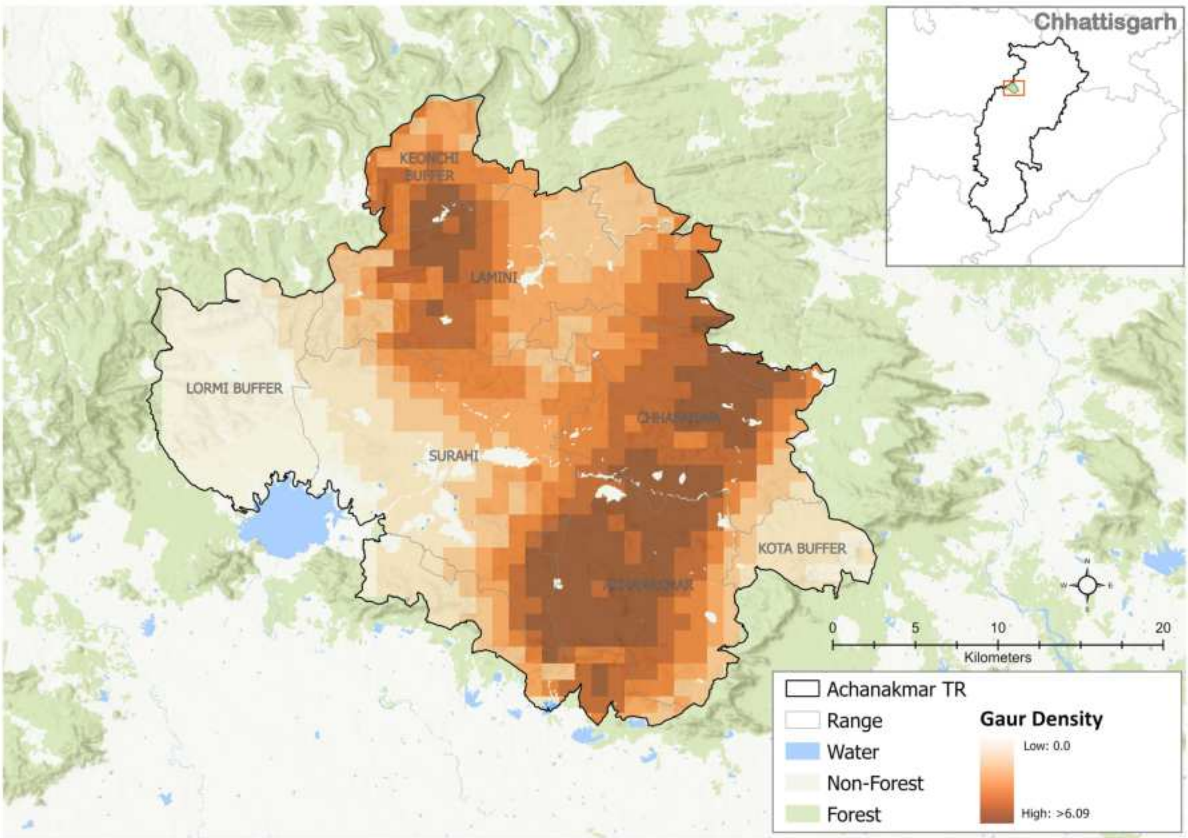

Figure IV. 14: Density of gaur (per km²) in Achanakmar tiger reserve: Site-level DSM

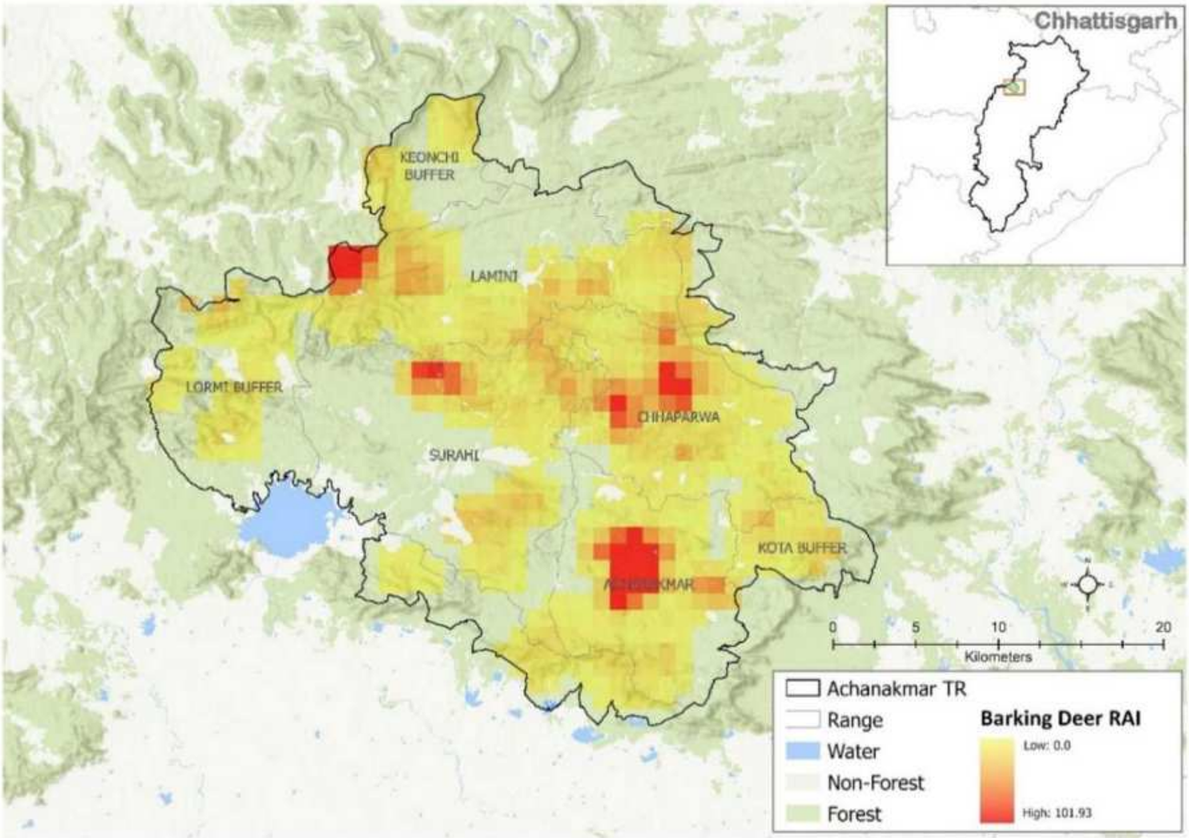

Figure IV. 15: Spatial relative abundance of barking deer in Achanakmar tiger reserve

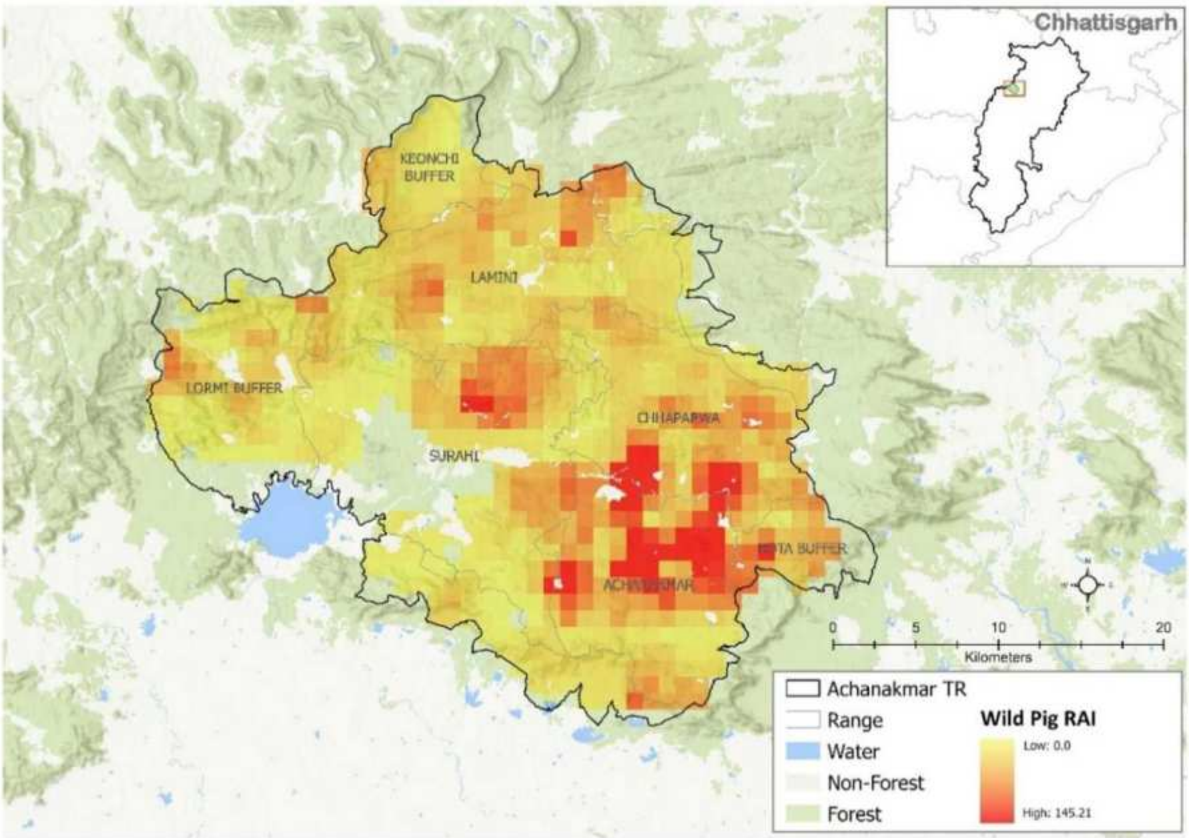

Figure IV. 16: Spatial relative abundance of wild pig in Achanakmar tiger reserve

Indravati Tiger Reserve

Indravati tiger reserve, situated in the Bijapur district of Chhattisgarh, is a cornerstone of the Dandakaranya forest landscape, covering approximately 2,799 km^2. Named after the Indravati River, the reserve features a mosaic of tropical moist and dry deciduous forests, extensive bamboo brakes, and savanna-like grasslands, representing a transitional ecosystem between central Indian forests and the Eastern Ghats. Indravati along with neighbouring Gadchiroli division of Maharashtra, harbours one of the last viable populations of the endangered wild water buffalo (*Bubalus arnee*) in central India. Despite severe challenges like Left-wing extremism that hinders conservation activities and leaves vast areas unmonitored, the reserve remains a crucial habitat for the tiger, gaur, and many ungulates, ensuring the vital predator-prey dynamics.

Due to limited sampling, the inference on prey density in Indravati tiger reserve could not be made. Only chital density is predicted using landscape model which shows very sparse presence of chital in the tiger reserve. Only Madded Buffer has higher abundance (Figure IV. 17). A comprehensive survey covering all areas of the reserve is necessary to obtain a robust and accurate estimate. To restore animal population in the tiger reserve, the area should be free from armed conflict by left wing extremists and control on poaching through bush meat hunting.

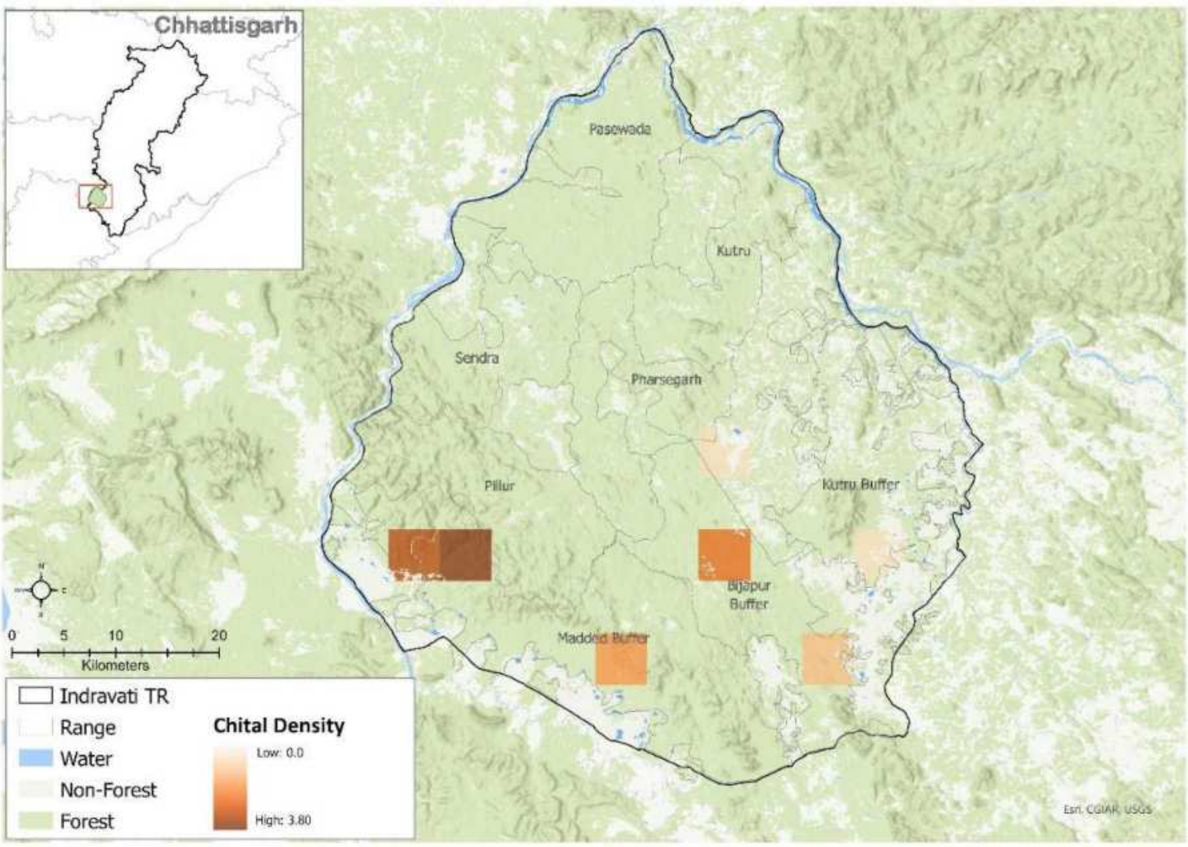

Figure IV. 17: Density of chital (per 25 km^2) in Indravati tiger reserve: Landscape-level DSM

Udanti Sitanadi Tiger Reserve

Udanti-Sitanadi Tiger Reserve, located in the Gariaband district of Chhattisgarh, covers approximately 1,842 km^2 and is a critical part of the Chhattisgarh plains ecosystem. The reserve is characterized by a diverse range of tropical dry deciduous forests, sal and teak woodlands, riverine grasslands, and swampy wetlands, shaped by the flow of the Sitanadi River and its tributaries. Despite the challenges like left wing extremism, habitat degradation, and human encroachment, Udanti-Sitanadi supports a variety of species, including the Bengal tiger, leopard, sloth bear, Indian wolf, and wild boar (Basak *et al*., 2024).

Ungulate observations along the line transects of USTR's are minimal, and the data is insufficient for analysis. Therefore, Chital and Sambar abundance is predicted using landscape models, while Barking Deer, Gaur, Nilgai, and Wild Pig abundance is mapped using camera trap photo captures. Chital occurs in low density. Its presence is restricted to a small area bordering Mainpur, and Kulhadighat as well as in North Udanti (Figure IV. 18). Sambar density is extremely low and restricted to North Udanti range (Figure IV. 19). Gaur presence has been recorded only in the North Udanti range and its abundance here, appears to be relatively low (Figure IV. 21). Barking deer is abundant in western part of the tiger reserve, particularly in Sitanadi, and Risgaon (Figure IV. 20). Nilgai is abundant in Risgaon range only (Figure IV. 22) while wild pig exhibits a wider distribution. Wild pig is present almost everywhere in the tiger reserve with high abundance in Kulhadighat (Figure IV. 23). A habitat restoration, prey recovery and supplementation plan is needed for Udanti-Sitanadi Tiger Reserve.

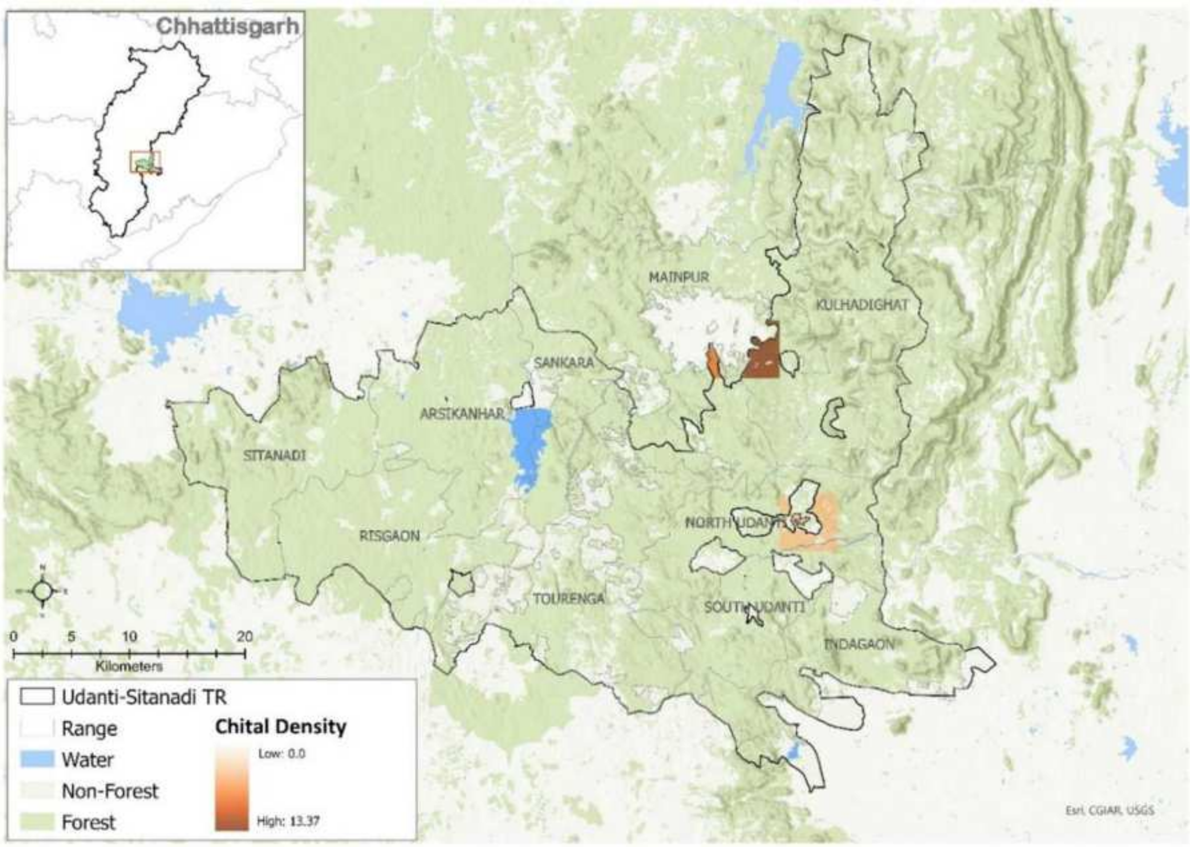

Figure IV. 18: Density of chital (per 25 km^2) in Udanti-Sitanadi tiger reserve: Landscape-level DSM

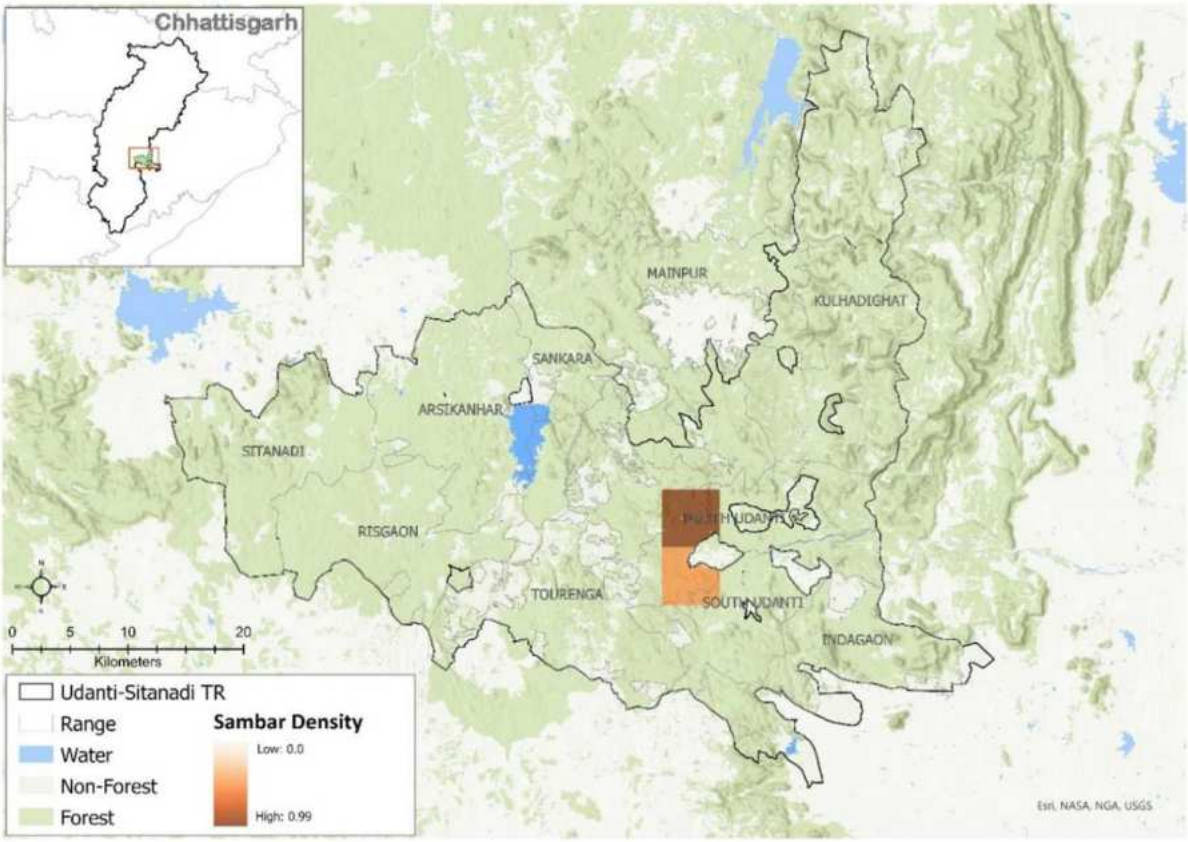

Figure IV. 19: Density of sambar (per 25 km^2) in Udanti-Sitanadi tiger reserve: Landscape-level DSM

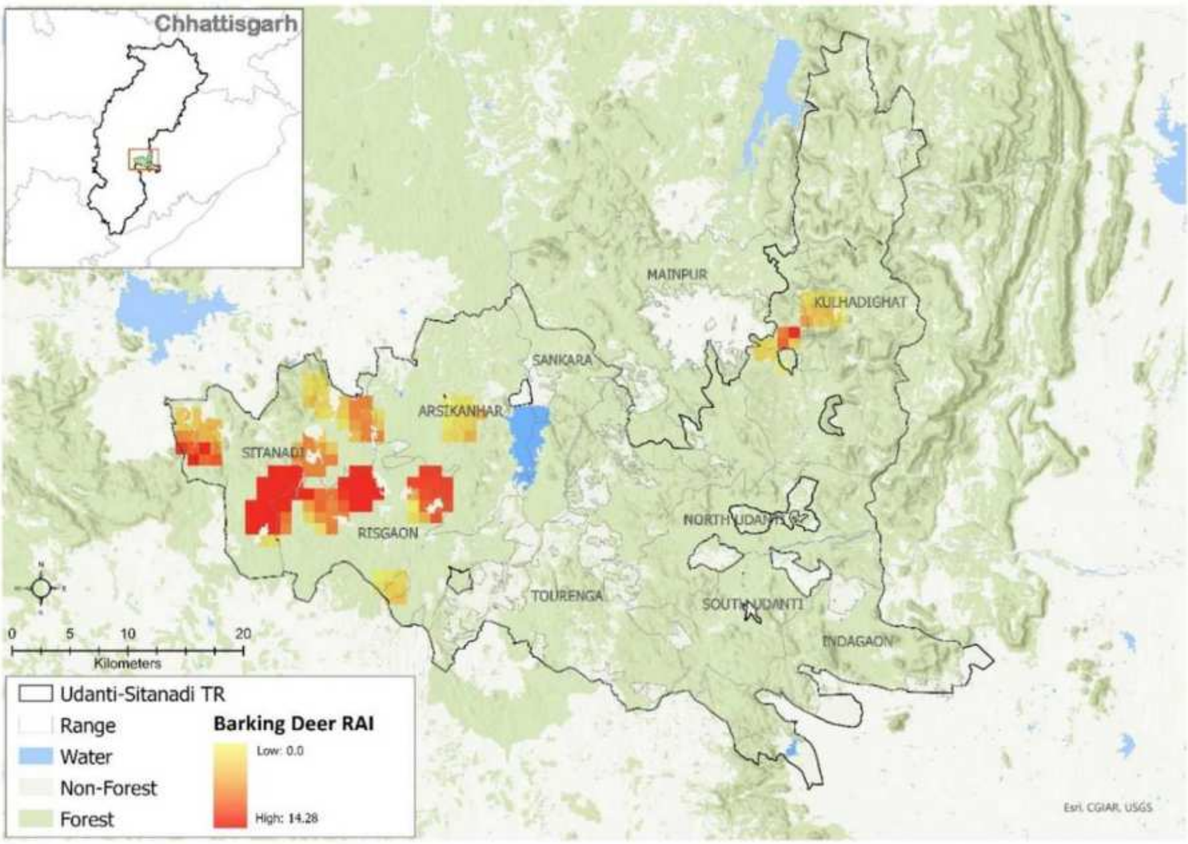

Figure IV. 20: Spatial relative abundance of barking deer in Udanti-Sitanadi tiger reserve.

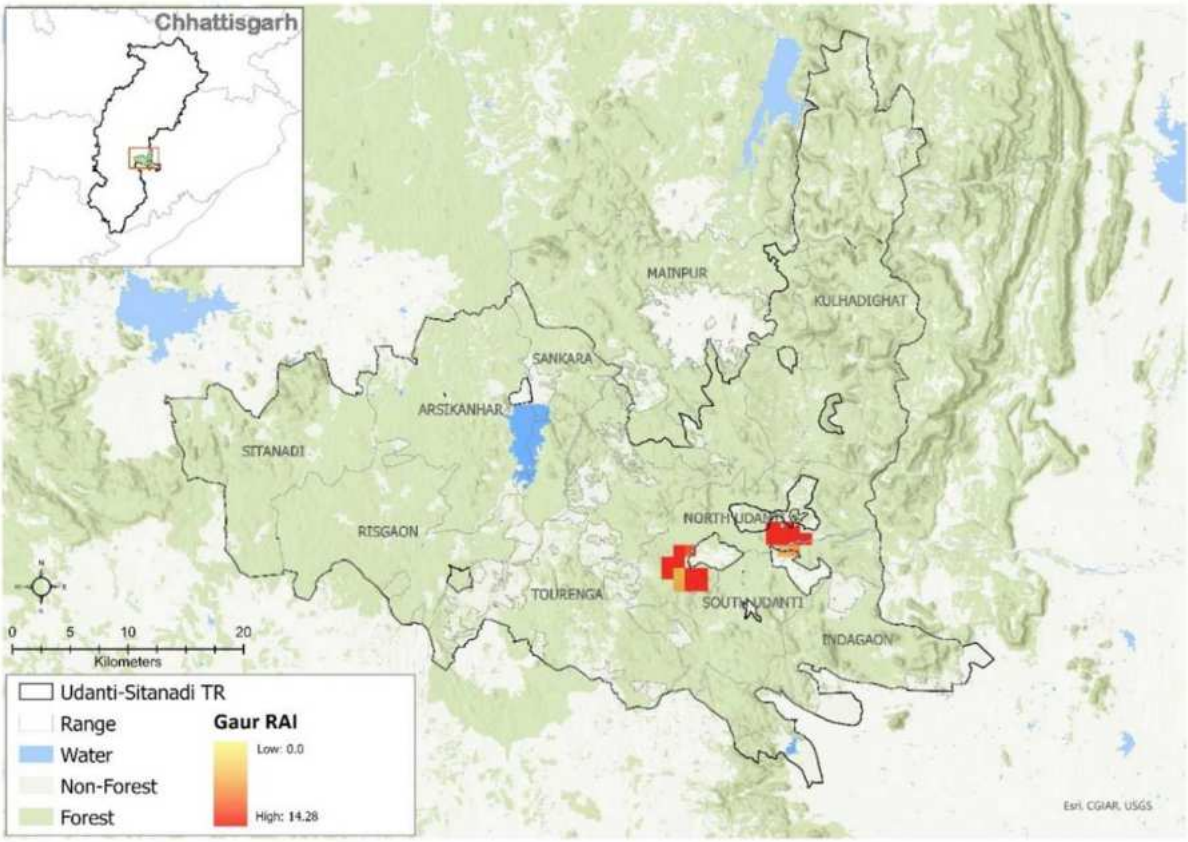

Figure IV. 21: Spatial relative abundance of gaur in Udanti-Sitanadi tiger reserve.

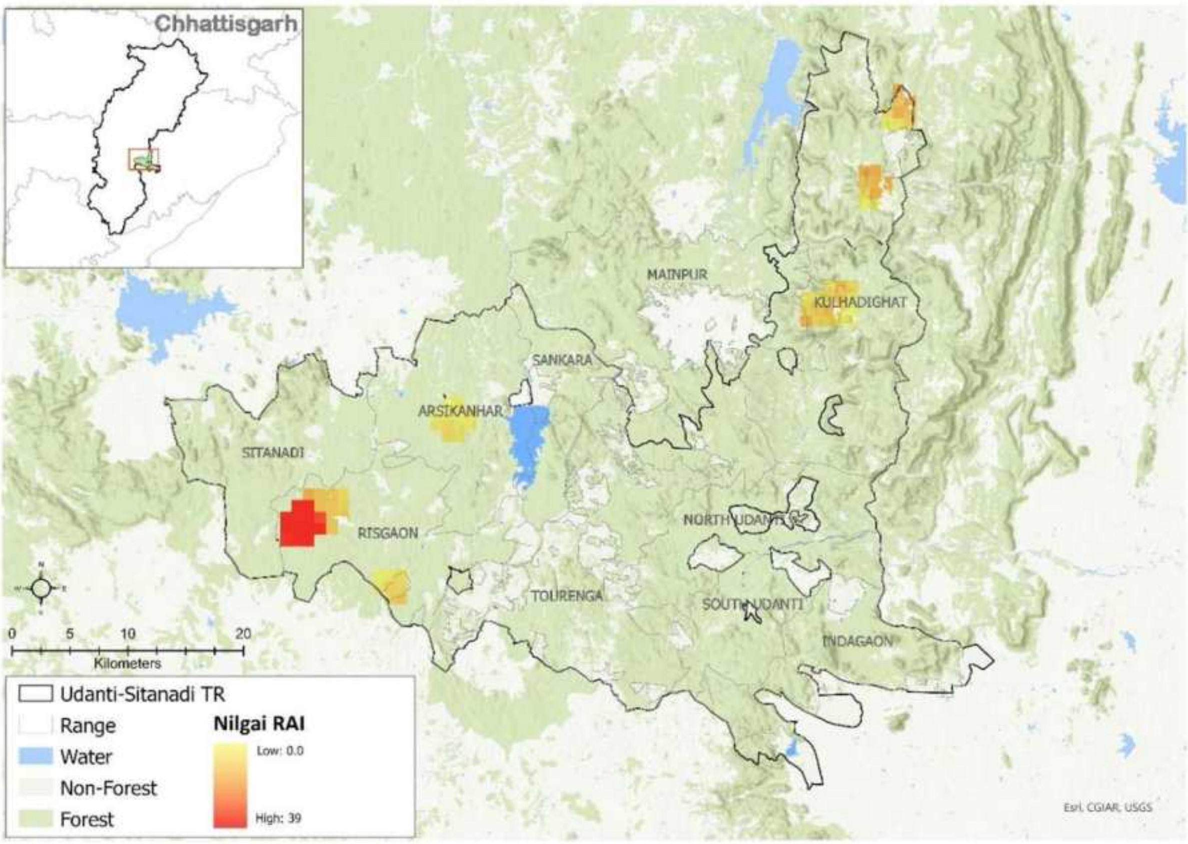

Figure IV. 22: Spatial relative abundance of nilgai in Udanti-Sitanadi tiger reserve.

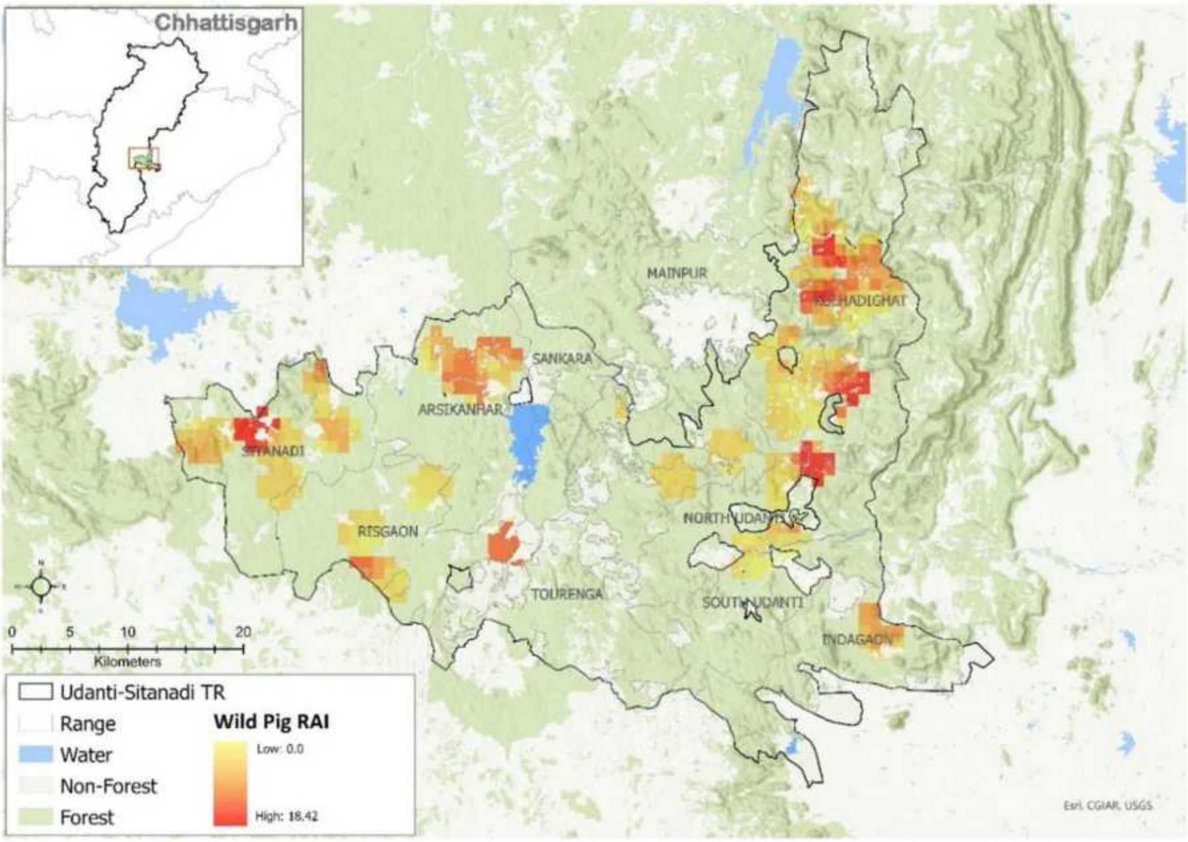

Figure IV. 23: Spatial relative abundance of wild pig in Udanti-Sitanadi tiger reserve.

JHARKHAND

Palamau Tiger Reserve

Palamau tiger reserve, situated in Latehar and Garhwa district on the Chhota-nagpur plateau in Jharkhand, spans 1,129 km². It holds historical significance as one of the first nine tiger reserves established under project tiger. The major forest types in the area include dry mixed forest, dry sal forest, moist sal forest, high-level plateau sal forest, and moist mixed forest. Despite challenges like left-wing extremism, Palamau is critical for maintaining connectivity within the Central Indian corridor, linking it to Bandhavgarh tiger reserve via the Semarsot-Timor Pingla-Guru Ghasidas-Sanjay tiger reserves and to the Gautam Buddha wildlife sanctuary and Koderma wildlife sanctuary through the Lawalong wildlife sanctuary. This strategic positioning highlights Palamau's potential as a source population for future tiger recovery and the broader revitalization of the tiger population in the state.

Since line transect data of Palamau is deficient for analysis, hence, chital density is predicted using landscape model whereas relative abundance of gaur, barking deer, nilgai, and wild pig are mapped using photo capture in camera trap. The encounter rate for chital is 0.0782 (±0.0215). The most abundant spatial densities of chital is in Betla range followed by East Chhipadohar (Figure IV. 24). For recovery of chital population voluntary village relocation should be encouraged alongside grassland restoration. Chital augmentation should be done to recover the population which will also help in establishing a resident tiger population in the area.

Historically, gaur occupied the entire area of Palamau, especially in the hilly region of south division. But at present gaur presence is restricted to Betla and East Chhipadohar (Figure IV. 26). Management efforts should be directed towards reducing anthropogenic pressure and explore potential reintroduction of gaur population in regions that it once occupied. Barking deer is mostly distributed in the the South division particularly in Baresanr, Garu West, Garu East, and in the areas bordering Mahuadanr and Baresanr (Figure IV. 25). Despite the species being fairly abundant, it continues to face threats due to poaching. Although wild pig is distributed throughout the tiger reserve, it is most abundant in few pockets of Chhipadohar East & West, Garu West and Baresanr (Figure IV. 28). Nilgai was photo captured in all ranges except Mahuadanr and Garu East and its abundance is moderate (Figure IV. 27).

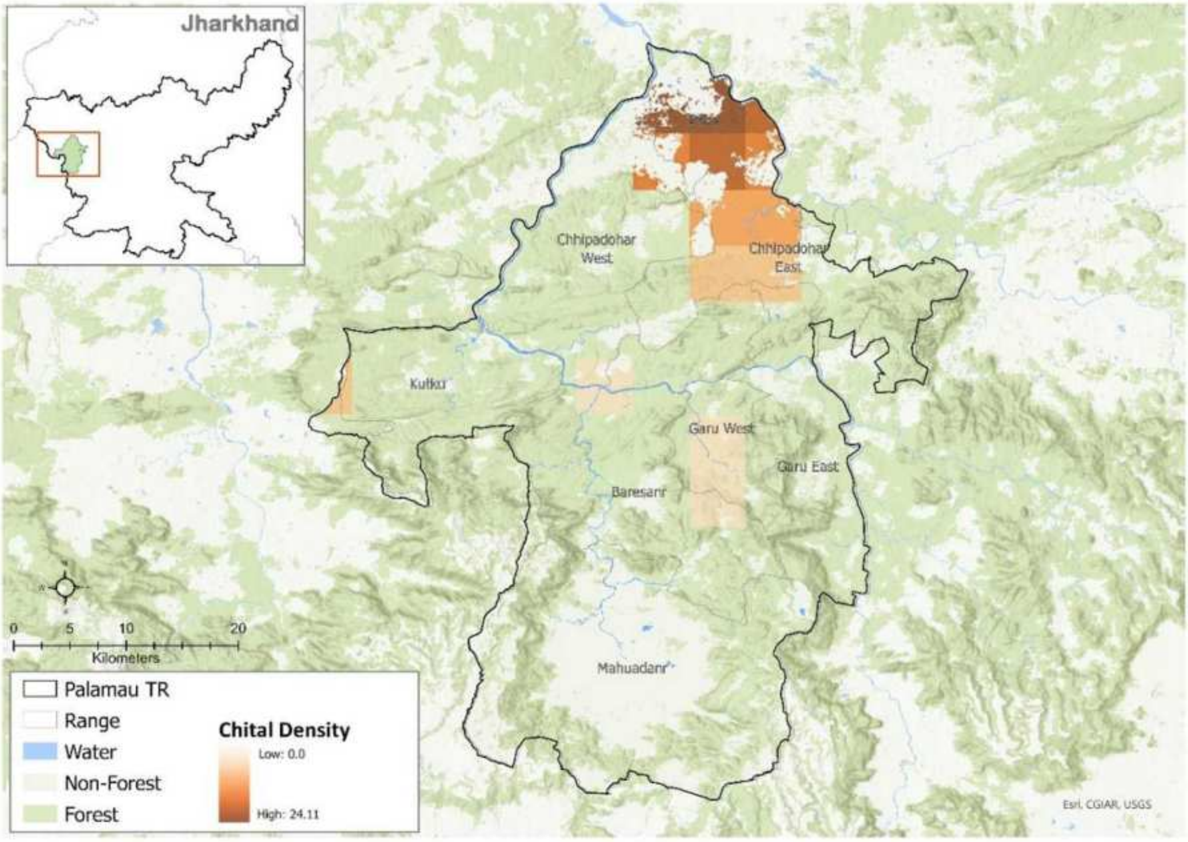

Figure IV. 24: Density of chital (per 25 km²) in Palamau tiger reserve: Landscape-level DSM

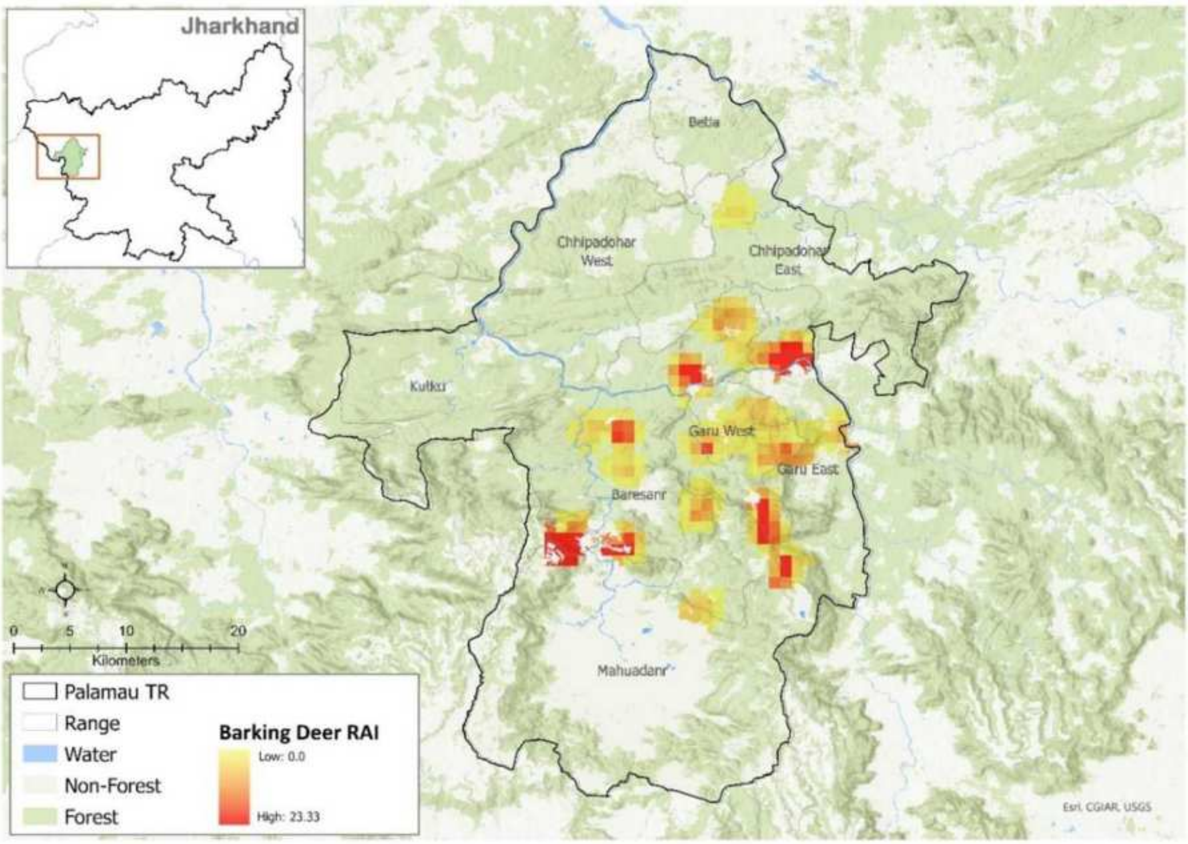

Figure IV. 25: Spatial relative abundance of baking deer in Palamau tiger reserve.

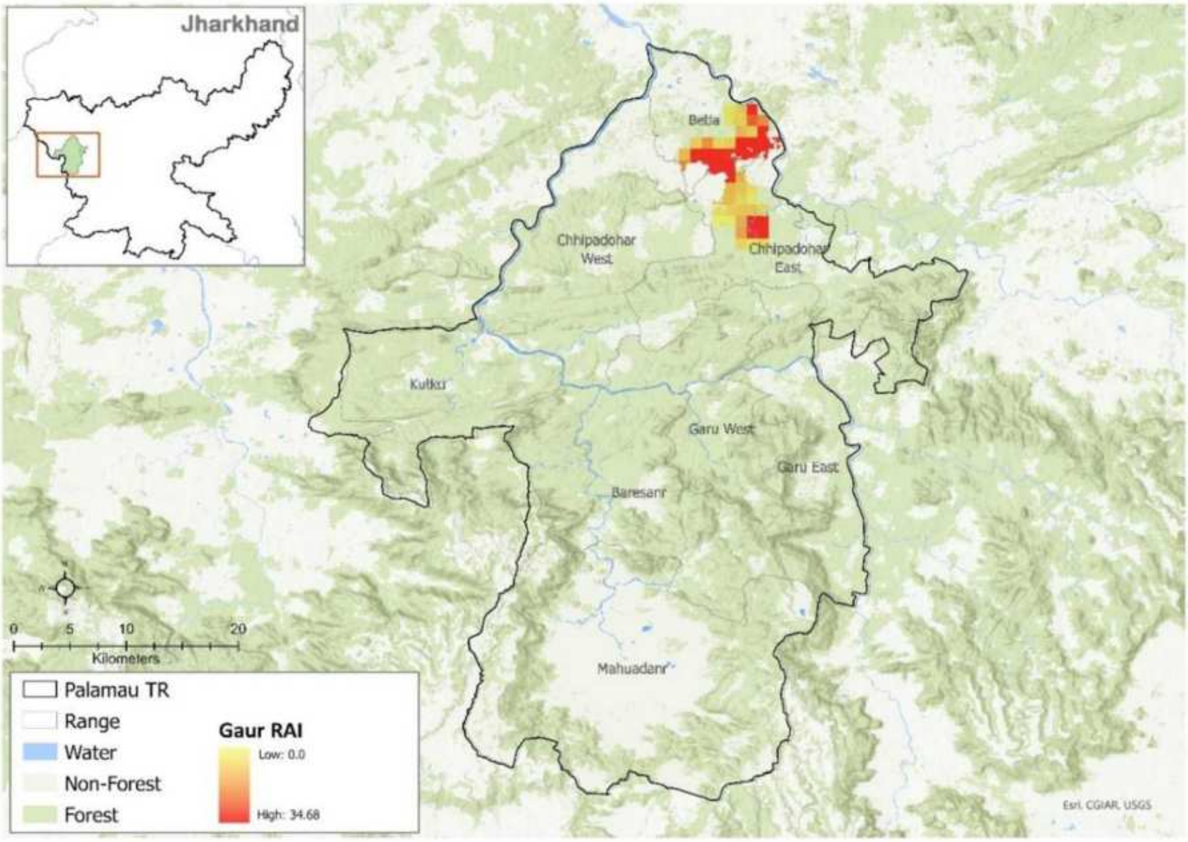

Figure IV. 26: Spatial relative abundance of gaur in Palamau tiger reserve.

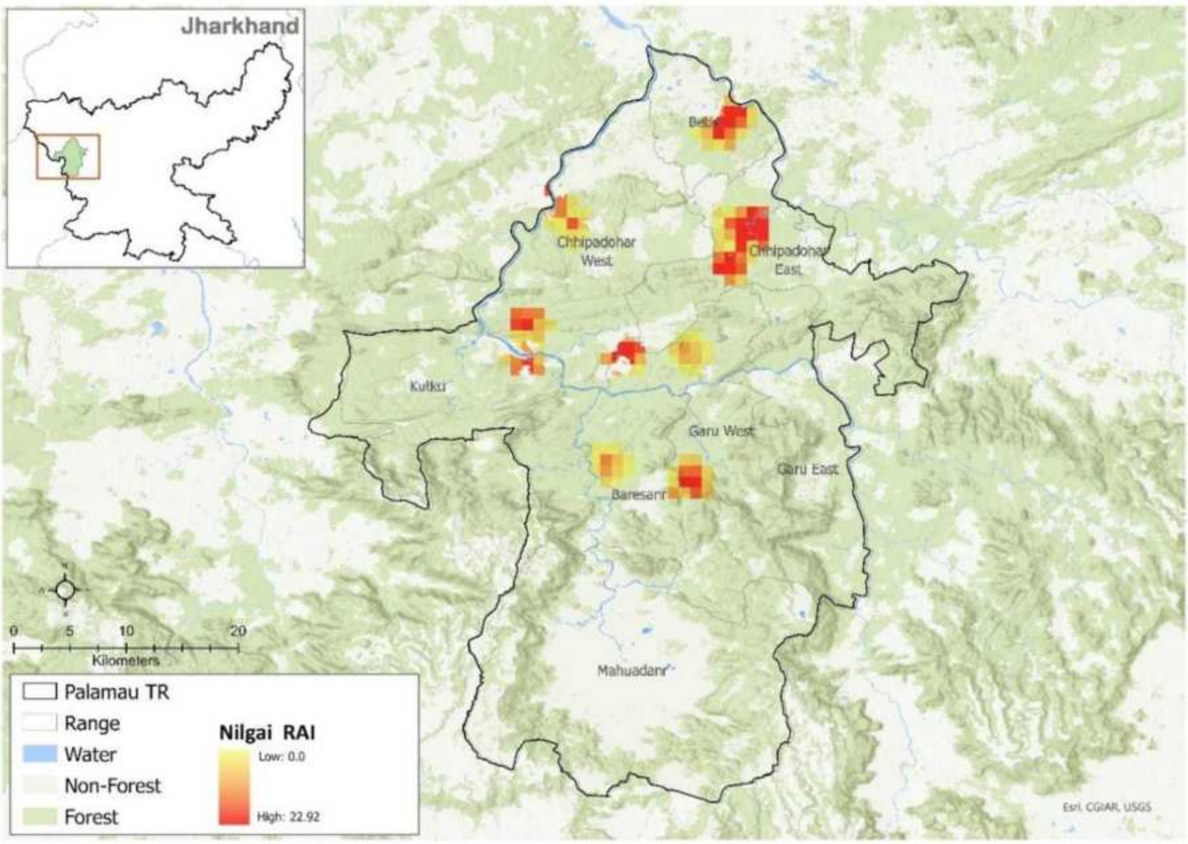

Figure IV. 27: Spatial relative abundance of nilgai in Palamau tiger reserve.

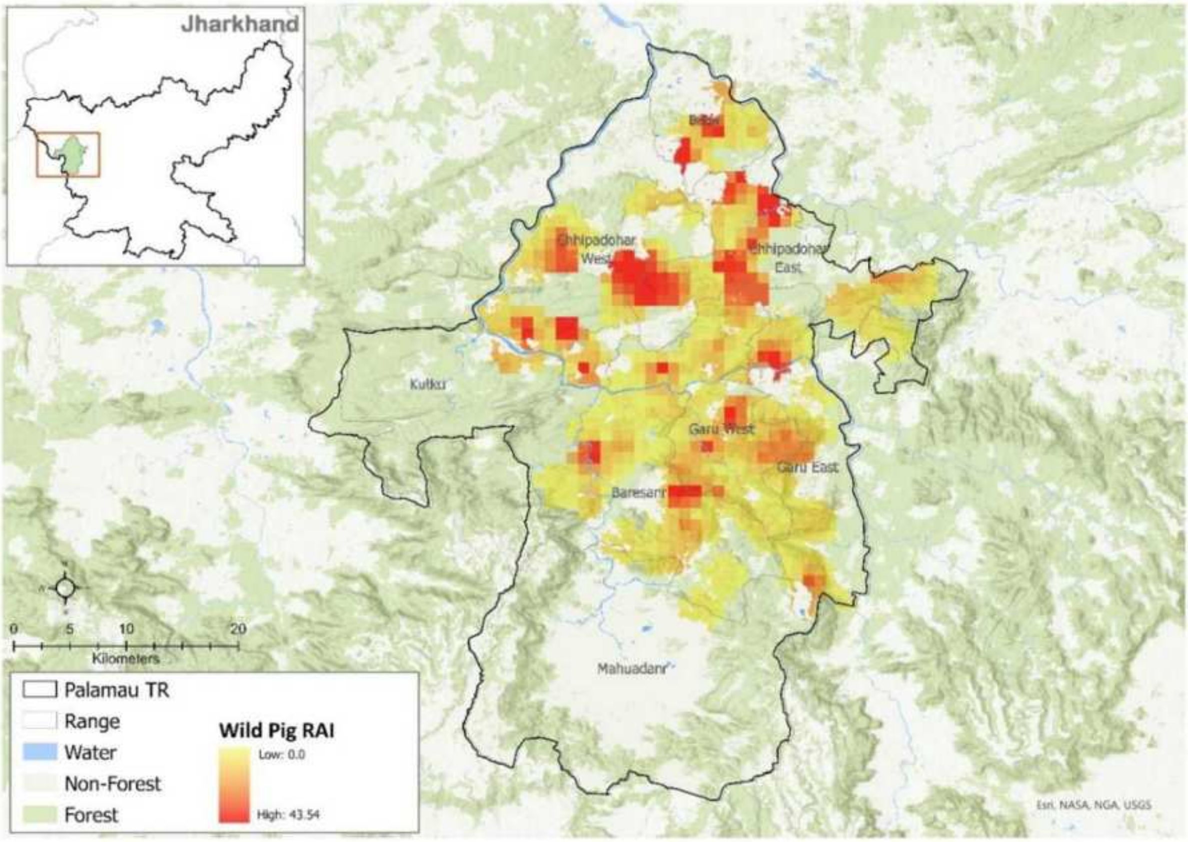

Figure IV. 28: Spatial relative abundance of wild pig in Palamau tiger reserve.

MADHYA PRADESH

Bandhavgarh Tiger Reserve

Bandhavgarh tiger reserve, lies on the north-eastern border of Madhya Pradesh, tracing the northern slopes of the eastern Satpura Mountain range (Jhala *et al*., 2015, 2020; Qureshi *et al*., 2023). Initially designated a National Park in 1968, it has undergone expansions to encompass a total area of 1536.94 km^2, with the Bandhavgarh National Park and Panapata Wildlife Sanctuary forming the core area (716.903 km^2). An additional buffer area of approximately 820.035 km^2 was assigned to complement the reserve. Bandhavgarh Tiger Reserve is situated in the biogeographic province known as the Deccan Peninsula within the central Indian highlands (Rodgers *et al*., 2002). Bandhavgarh features rugged terrain with small hillocks scattered amidst grassy swamps in the foothills (Manjrekar *et al*., 2017; Gopal, 1991). The vegetation primarily consists of moist peninsular low-level Sal, northern dry mixed deciduous forest, dry deciduous scrub, dry grassland, and west Gangetic moist mixed deciduous forest (Champion and Seth, 1968).

Bandhavgarh is one of the high prey abundance area in Central India Landscape. Chital, sambar, wild pig, and nilgai spatial density is mapped using line transect data whereas gaur and barking deer abundance is mapped using photo captured data from camera trap. Chital is the most abundant prey species in Bandhavgarh. Spatial density of Chital is highest in Tala range (Figure IV. 29). The adjoining areas of Tala also have higher density compared to other areas. Chitals of Tala range can act as a source population for supplementation to other ranges. Sambar is most abundant in Tala followed by Magadhi (Figure IV. 30). It is more abundant in core ranges compared to buffer ranges of Bandhavgarh tiger reserve. Spatial density of wild pig is highest in Khitauli followed by Pataur and Tala (Figure IV. 32). Sambar and wild pigs are present in all ranges of Bandhavgargh, although their spatial density vary in different area. Nilagai is present towards outer boundary areas of the tiger reserve (Figure IV. 31). Highest density is reported from Panpatra buffer and Dhamokhar buffer.

Barking deer is very sparsely distributed in Bandhavgarh. Abundance is mapped using photo capture of camera trap data for management purposes. Maximum captures are from Khitauli (Figure IV. 33). Other areas have very low capture of barking deer *i.e.* Tala and Magadhi range. Gaur is reintroduced to Bandhavgarh. The reintroduced population is now grown and they are spread to different ranges. Maximum captures are from Tala and Magdhi range and few captures are from Khitauli range (Figure IV. 34).

Table IV. 2: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Bandhavgarh tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	472	0.625 (0.032)	0.45 (0.02)	8.35 (0.54)	5.35 (0.35)	46.26 (2.05)
Nilgai	63	0.082 (0.011)	0.44 (0.04)	3.15 (0.29)	0.52 (0.09)	1.63 (0.2)
Sambar	90	0.119 (0.013)	0.47 (0.05)	2.67 (0.19)	1.27 (0.19)	3.37 (0.41)
Wild pig	59	0.078 (0.01)	0.38 (0.05)	6.75 (0.79)	0.6 (0.11)	3.89 (0.51)

B)

Species	Chital	Sambar	Wild pig	Nilgai
Detection model	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	8.982	8.481	7.94	8.28
s(Aridity)	-	-	-	3.55
s(NDVI Pre-Monsoon)	-	3.307	1.966	-
s(NDVI difference)	1.969	-	-	-
s(Ruggedness)	1.975	-	-	2.48

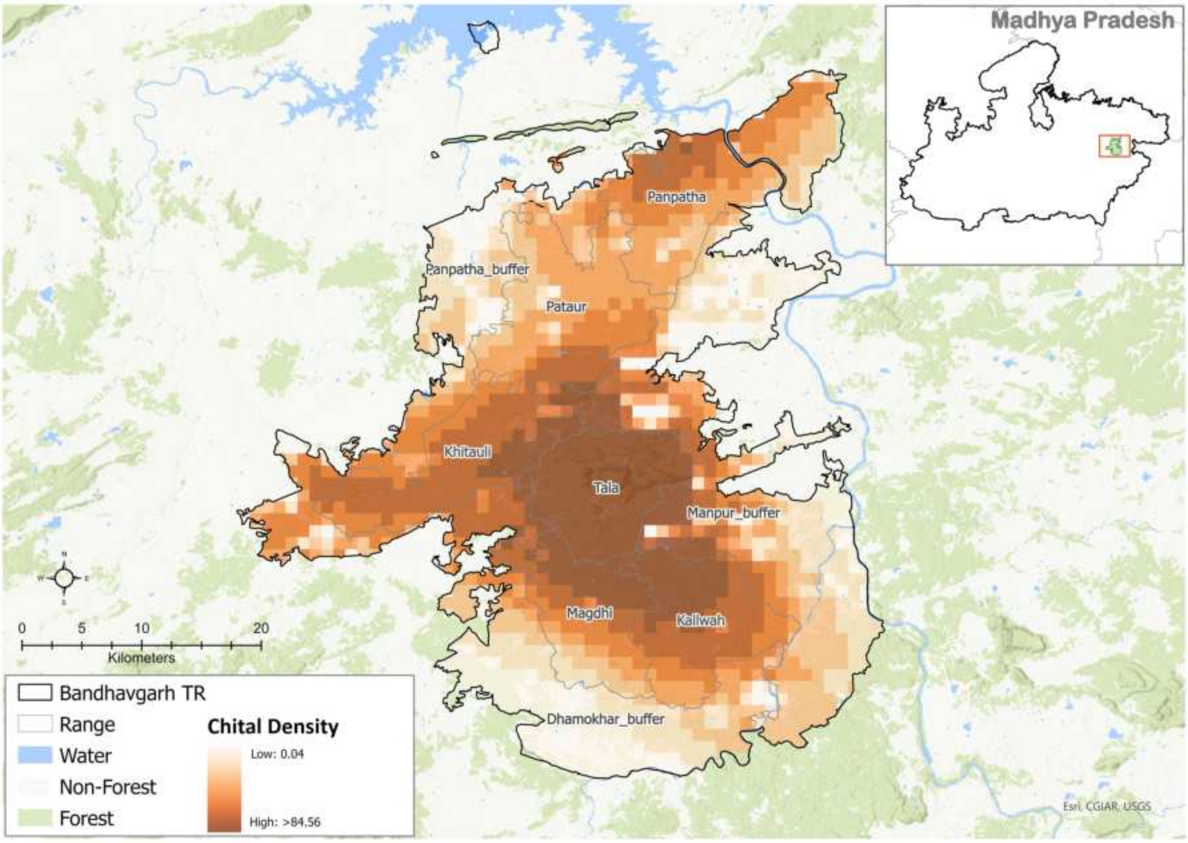

Figure IV. 29: Density of chital (per km^2) in Bandhavgarh tiger reserve: Site-level DSM

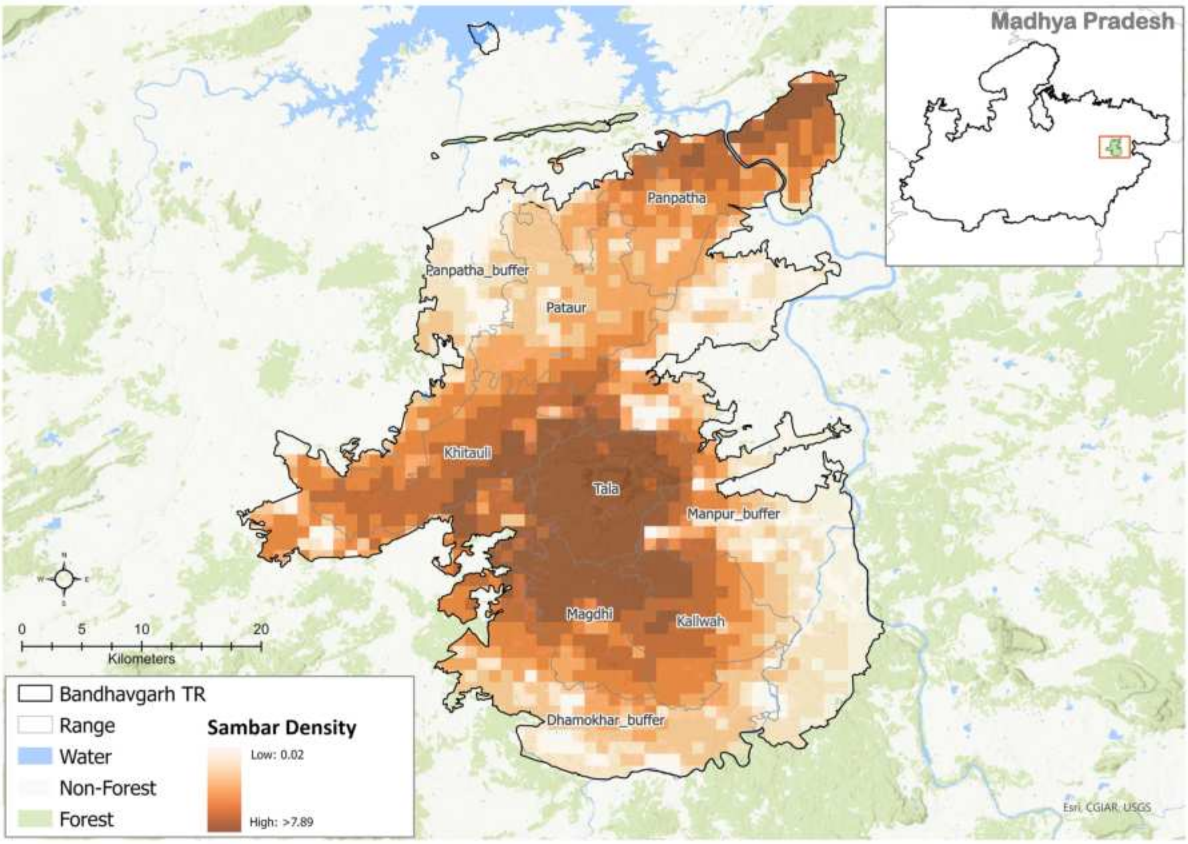

Figure IV. 30: Density of sambar (per km^2) in Bandhavgarh tiger reserve: Site-level DSM

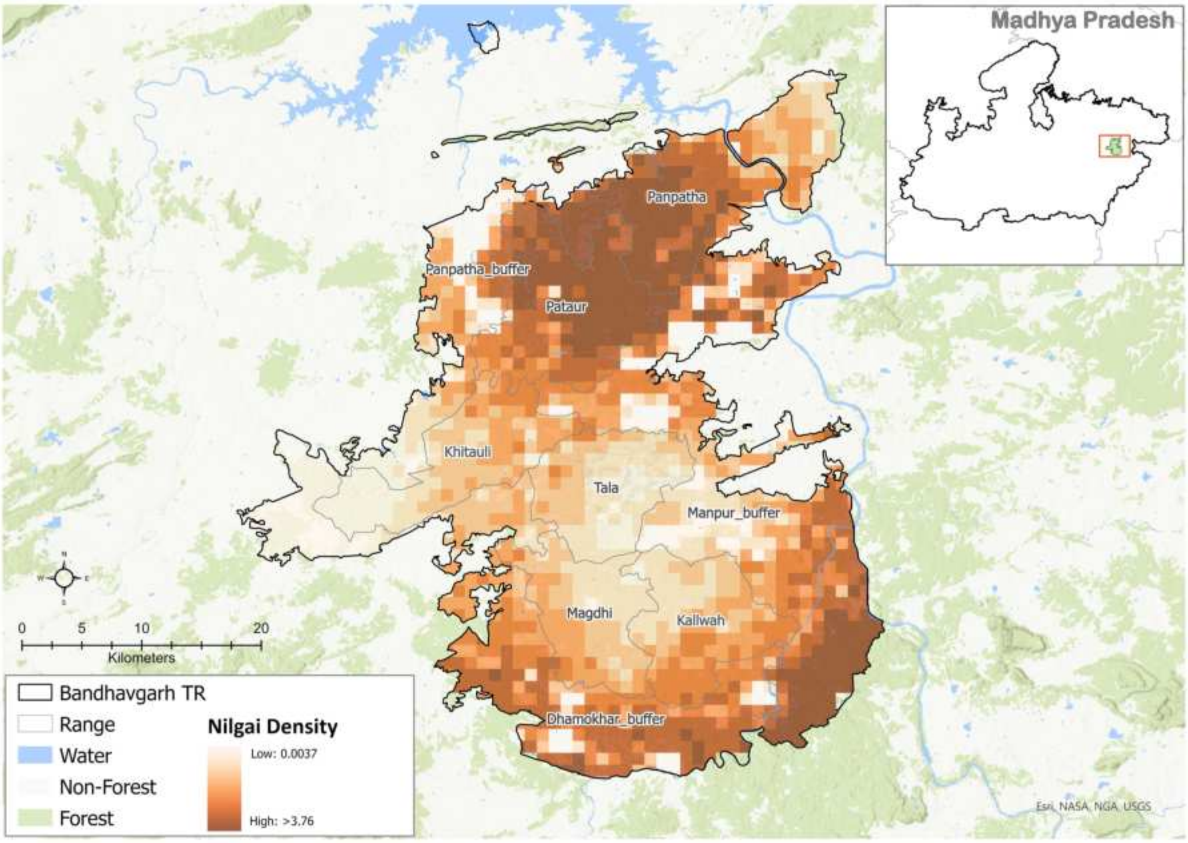

Figure IV. 31: Density of nilgai (per km^2) in Bandhavgarh tiger reserve: Site-level DSM

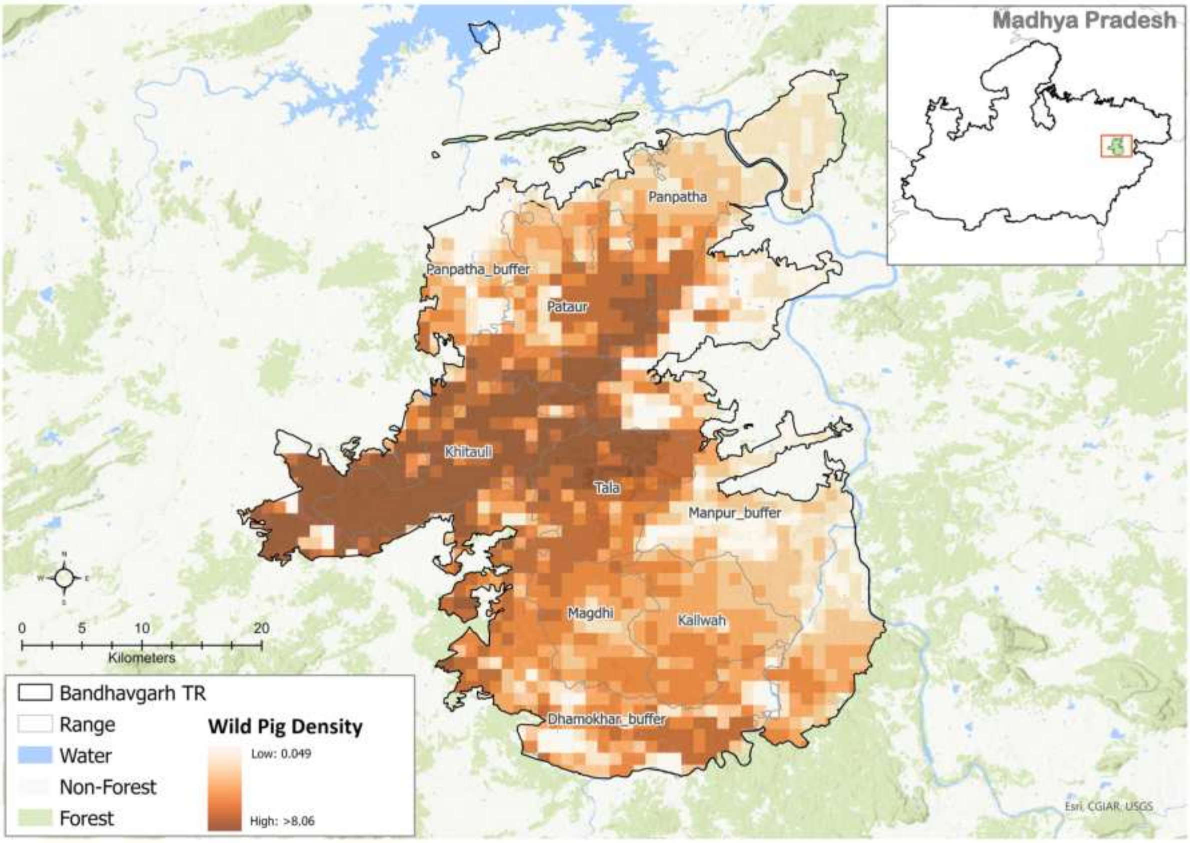

Figure IV. 32: Density of wild pig (per km^2) in Bandhavgarh tiger reserve: Site-level DSM

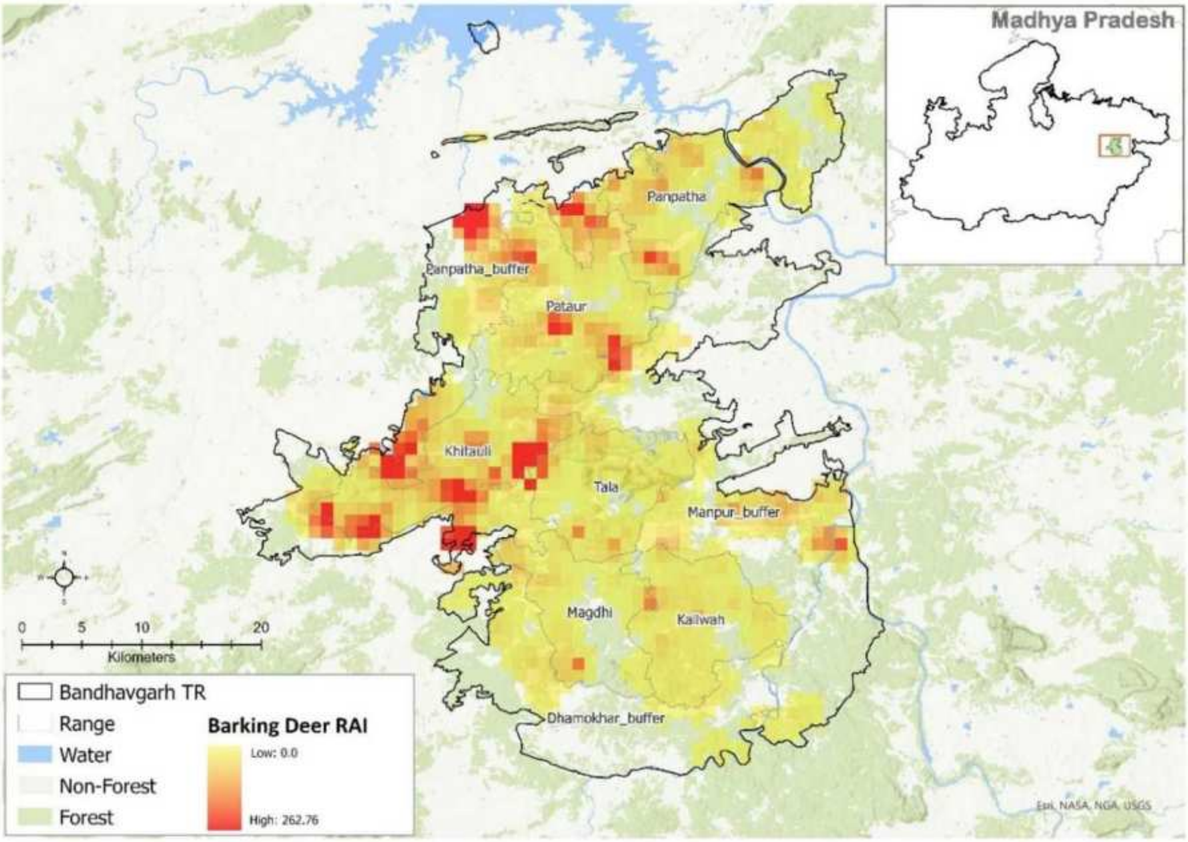

Figure IV. 33: Spatial relative abundance of baking deer in Bandhavgarh tiger reserve.

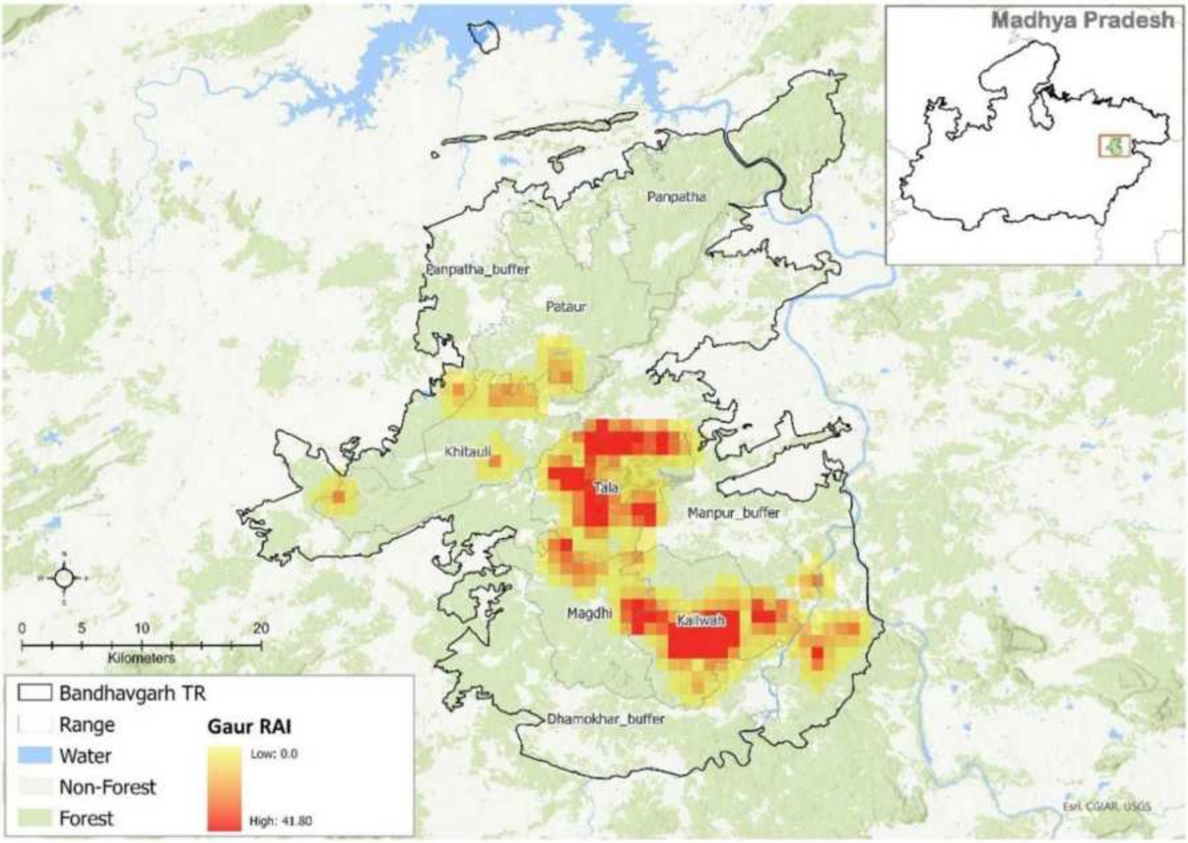

Figure IV. 34: Spatial relative abundance of gaur in Bandhavgarh tiger reserve.

Kanha Tiger Reserve

Kanha tiger reserve, located in the Mandla and Balaghat districts of Madhya Pradesh, spanning an area of approximately 2,052 km^2. Situated in the Maikal Hills of the Satpura range, the landscape includes flat hilltops, varying degree of slops, and valleys with lots of seasonal and perennial streams. This diversity of the area offers an ideal niche for flora and fauna. Major habitat types of Kanha includes sal-dominated forests, miscellaneous forest, bamboo thickets and grasslands (Awasthi *et al*., 2016). Kanha is a stronghold for the Bengal tiger and is renowned for its conservation success with the hard-ground barasingha (swamp deer), a subspecies that was brought back from the brink of extinction (Gopal and Shukla, 2001). Kanha is well connected to many nearby tiger reserves like Achanakmar, Pench, Bandhavgarh, and Satpura by corridors where animal movement was recorded.

Kanha has one of the highest prey abundances in the Central Indian Landscape. Chital, sambar, gaur, barking deer, and wild pig are highly abundant in Kanha. Density of these species was mapped using line transect data. Nilgai, however, is primarily found in the buffer zones and border areas of the core ranges of Kanha, resulting in low sightings during transects. Therefore, nilgai abundance was mapped using photo-capture data from camera traps. Chital is the most abundant prey species in Kanha and is distributed throughout the tiger reserve (Figure IV. 35). The highest spatial density is recorded in the Sarhi range, followed by the Kanha, Mukki, and Kisli ranges. The eastern part of the tiger reserve has very low chital density, requiring targeted management interventions. Sambar is most abundant in the Sarhi range, followed by the Kisli and Mukki ranges (Figure IV. 36). The western side of the park has a higher density of sambar compared to the eastern side. Gaur is an abundant prey species in the core ranges of Kanha (Figure IV. 38). All core ranges—Kanha, Kisli, Sarhi, Mukki, Supkhar, and Bhaisanghat—have medium to high gaur density, while the buffer ranges have low to no gaur presence.

Barking deer are abundant in the Sarhi, Kanha, Sijhora, Garhi, Bhaisanghat, Supkhar, and Motinala ranges. In contrast, they have very low density or/are nearly absent in the Khatiya and Khapa ranges (Figure IV. 37). Wild pigs are present throughout the tiger reserve (Figure IV. 39). Wild pig density is high in the Sarhi, Kisli, Motinala, Supkhar, and Bhaisanghat ranges, while the Khapa and Sijhora ranges have very low wild pig abundance (Figure IV. 39). Nilgai are mostly photo-captured in the Khatiya range and near the border areas of the Sarhi and Sijhora ranges (Figure IV. 40). The eastern side of the Kanha tiger reserve needs management efforts for prey recovery as this area has low abundance of major prey species found in Kanha.

Table IV. 3: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Bandhavgarh tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Barking	207	0.173 (0.012)	0.29 (0.02)	1.18 (0.03)	3.15 (0.28)	3.75 (0.33)
Chital	421	0.3 (0.018)	0.29 (0.01)	9.29 (0.45)	3.52 (0.26)	40.29 (1.85)
Gaur	134	0.074 (0.008)	0.36 (0.03)	4.94 (0.51)	0.95 (0.13)	6.42 (0.58)
Sambar	284	0.183 (0.013)	0.36 (0.02)	2.81 (0.11)	2.56 (0.23)	8.21 (0.54)
Wild pig	161	0.134 (0.01)	0.29 (0.02)	6.07 (0.34)	1.9 (0.2)	11.19 (0.88)

B)

Species	Chital	Sambar	Gaur	Wild pig
Detection model	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	37.717	30.543	31.516	8.631
s(Aridity)	1	-	-	-
s(NDVI Pre-Monsoon)	-	2.67	1.002	1.895
s(NDVI Post-Monsoon)	-	-	1.954	-
s(NDVI difference)	-	1.473	-	-
s(Ruggedness)	3.114	-	-	-
s(Elevation)	-	-	1.001	-

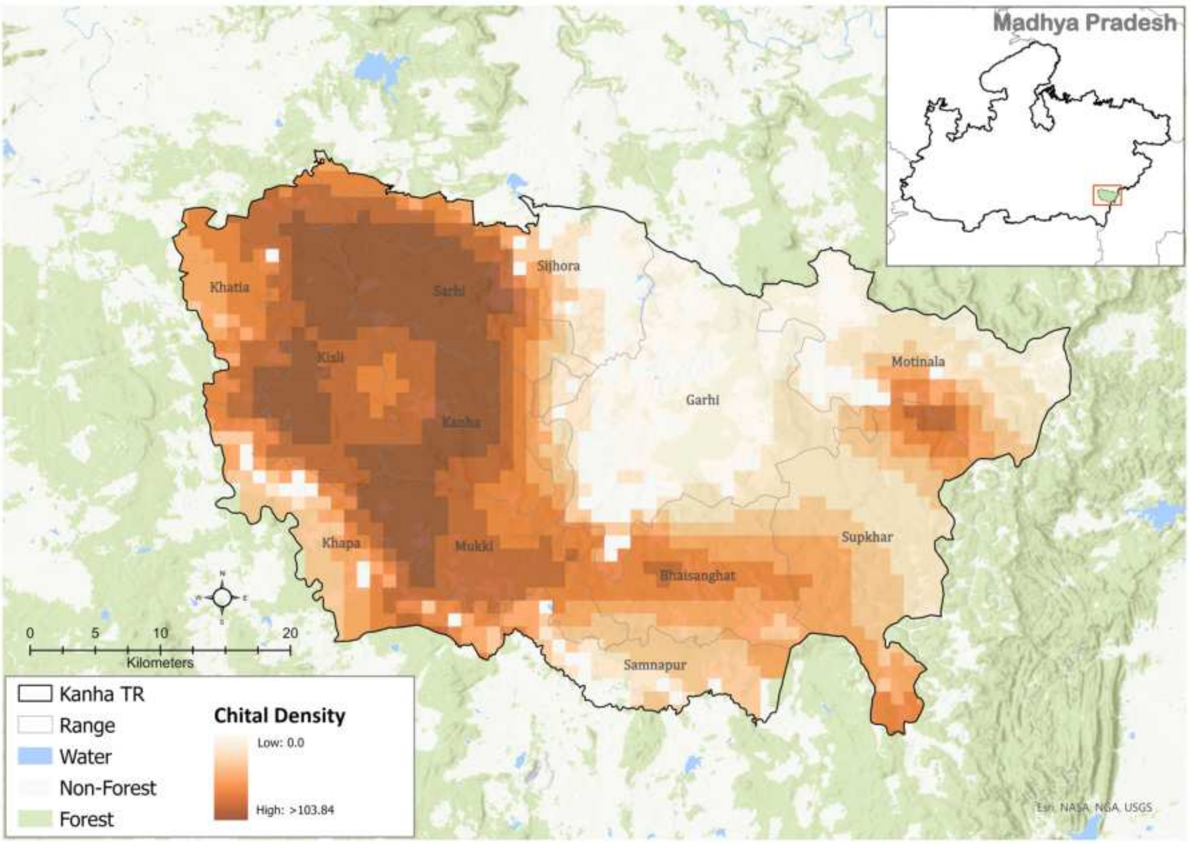

Figure IV. 35: Density of chital (per km²) in Kanha tiger reserve: Site-level DSM

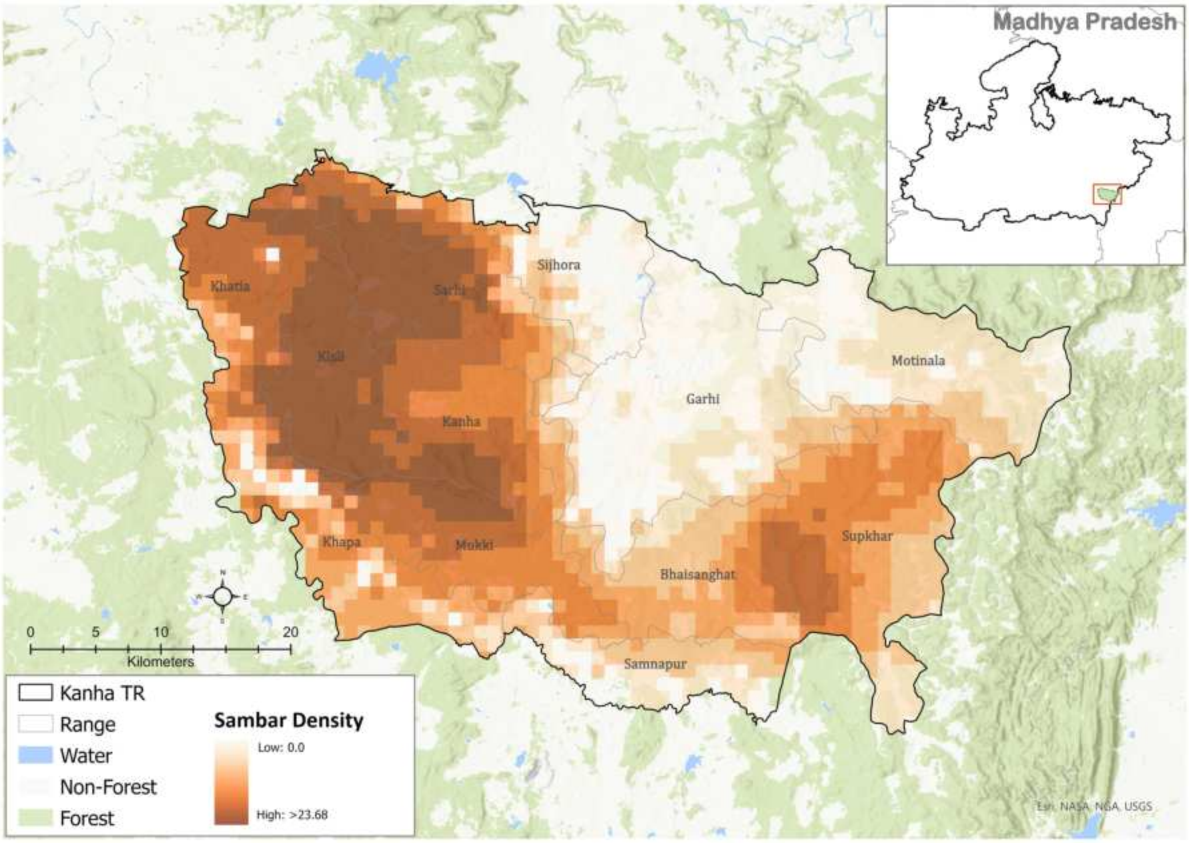

Figure IV. 36: Density of sambar (per km²) in Kanha tiger reserve: Site-level DSM

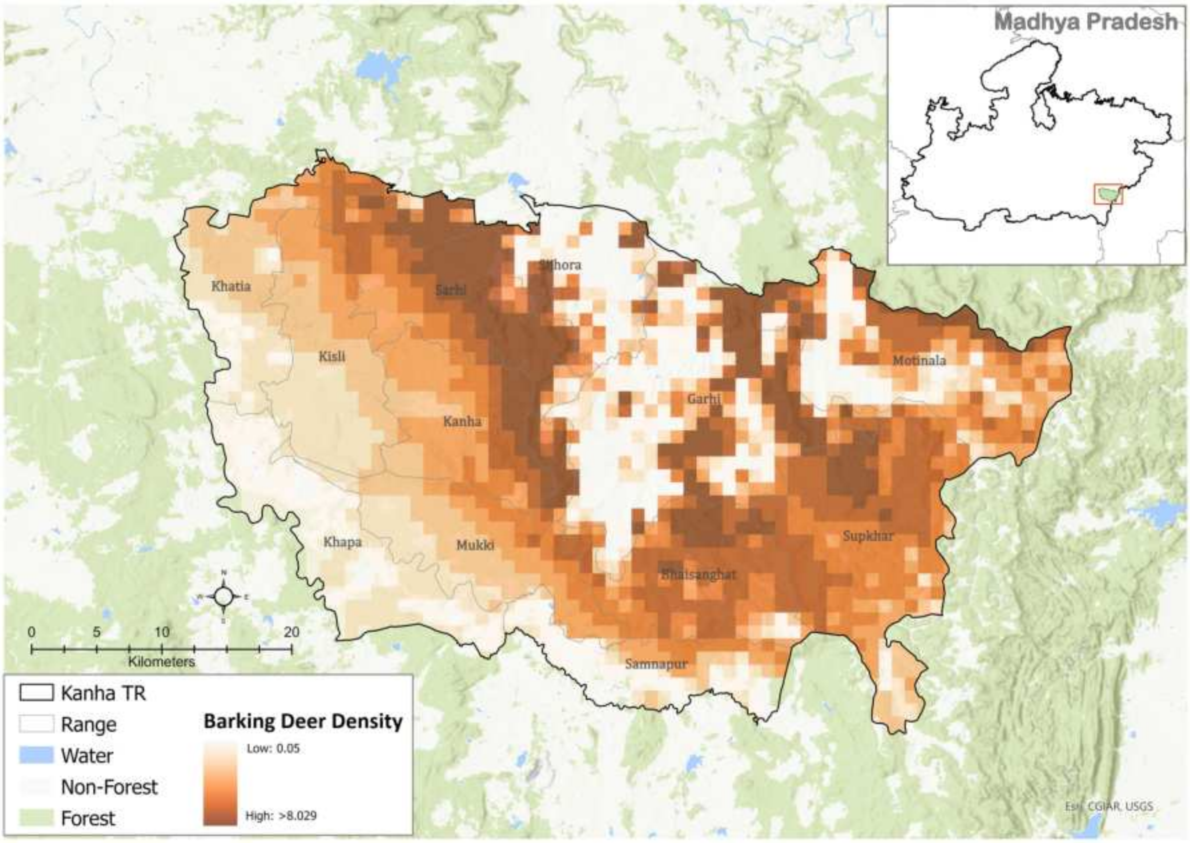

Figure IV. 37: Density of barking deer (per km²) in Kanha tiger reserve: Site-level DSM

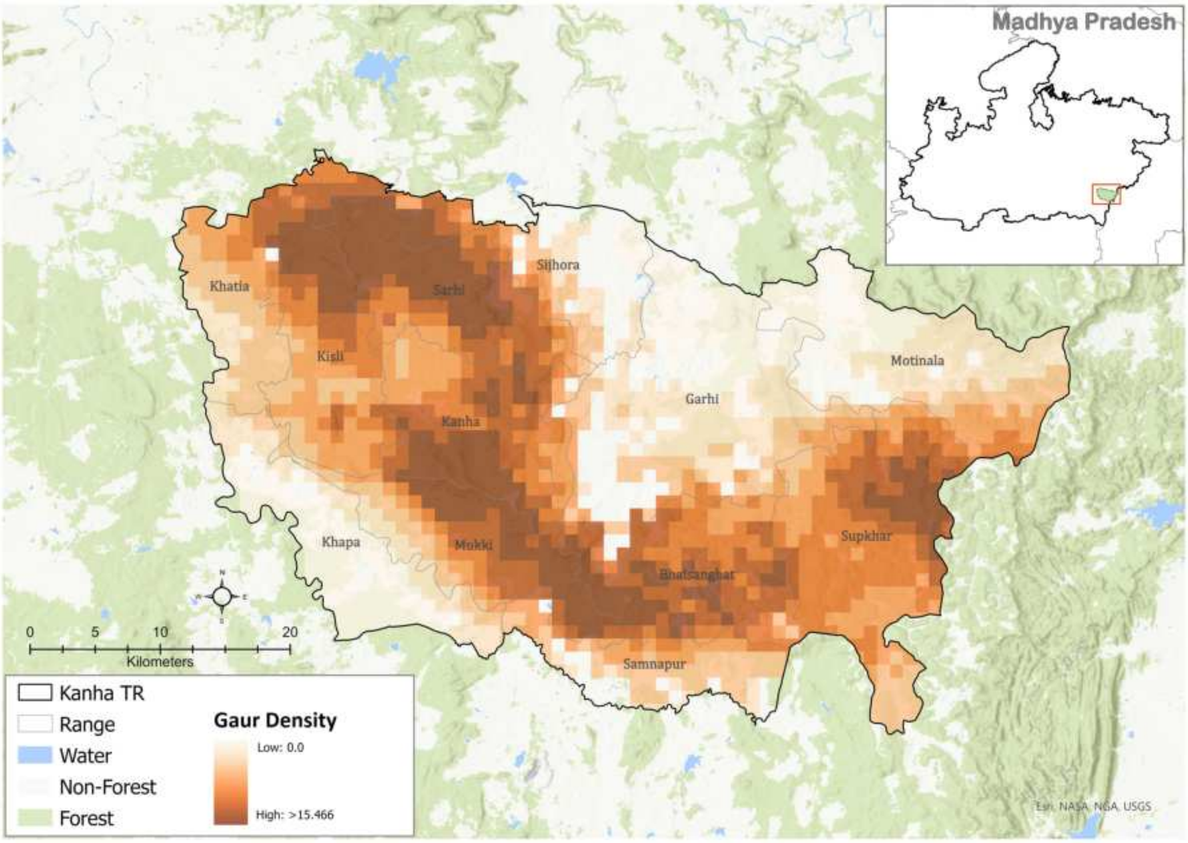

Figure IV. 38: Density of gaur (per km²) in Kanha tiger reserve: Site-level DSM

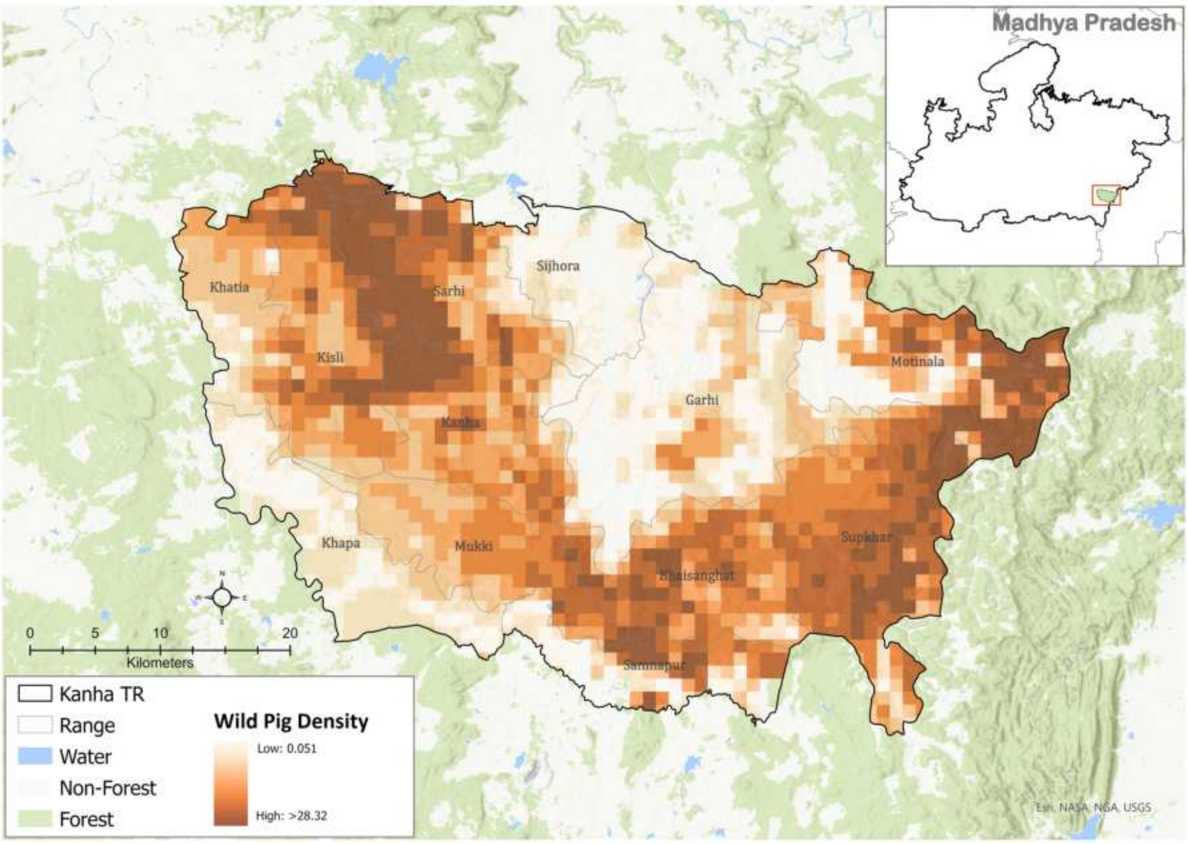

Figure IV. 39: Density of wild pig (per km²) in Kanha tiger reserve: Site-level DSM

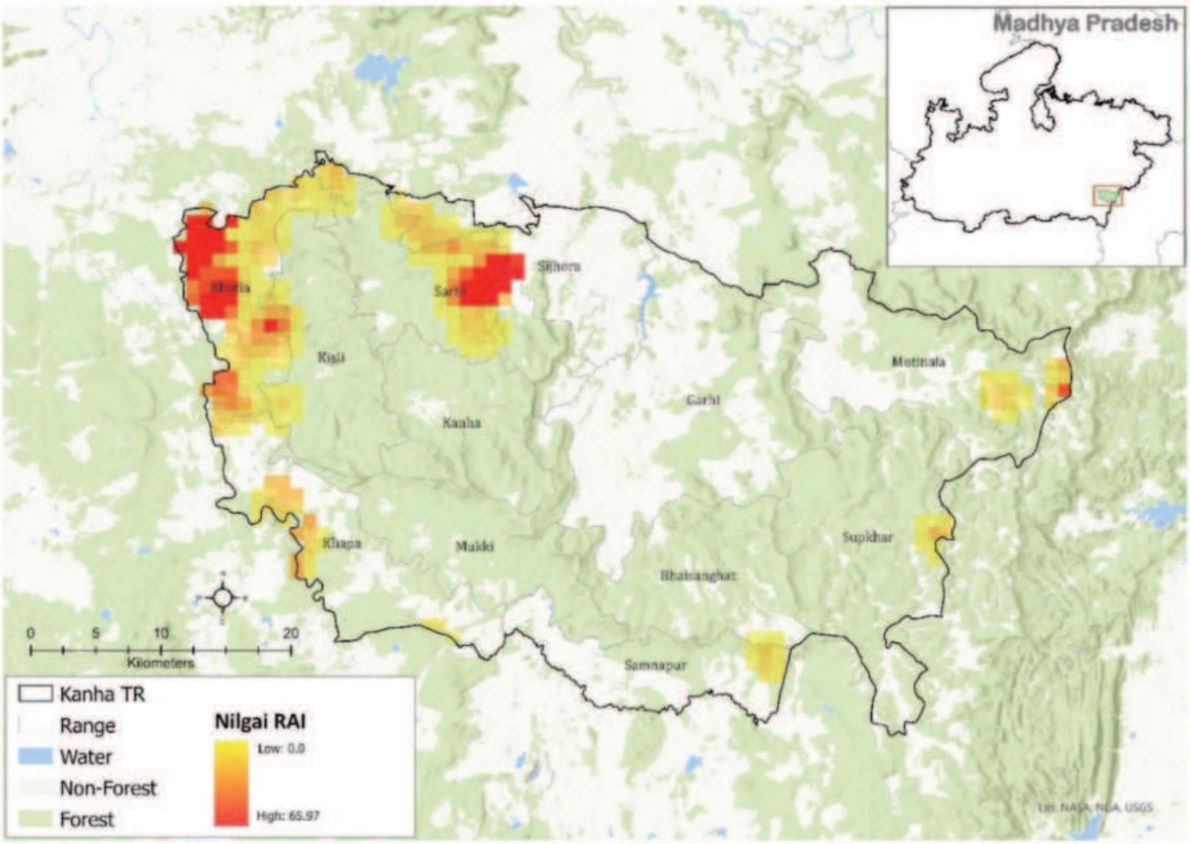

Figure IV. 40: Spatial relative abundance of nilgai in Kanha tiger reserve.

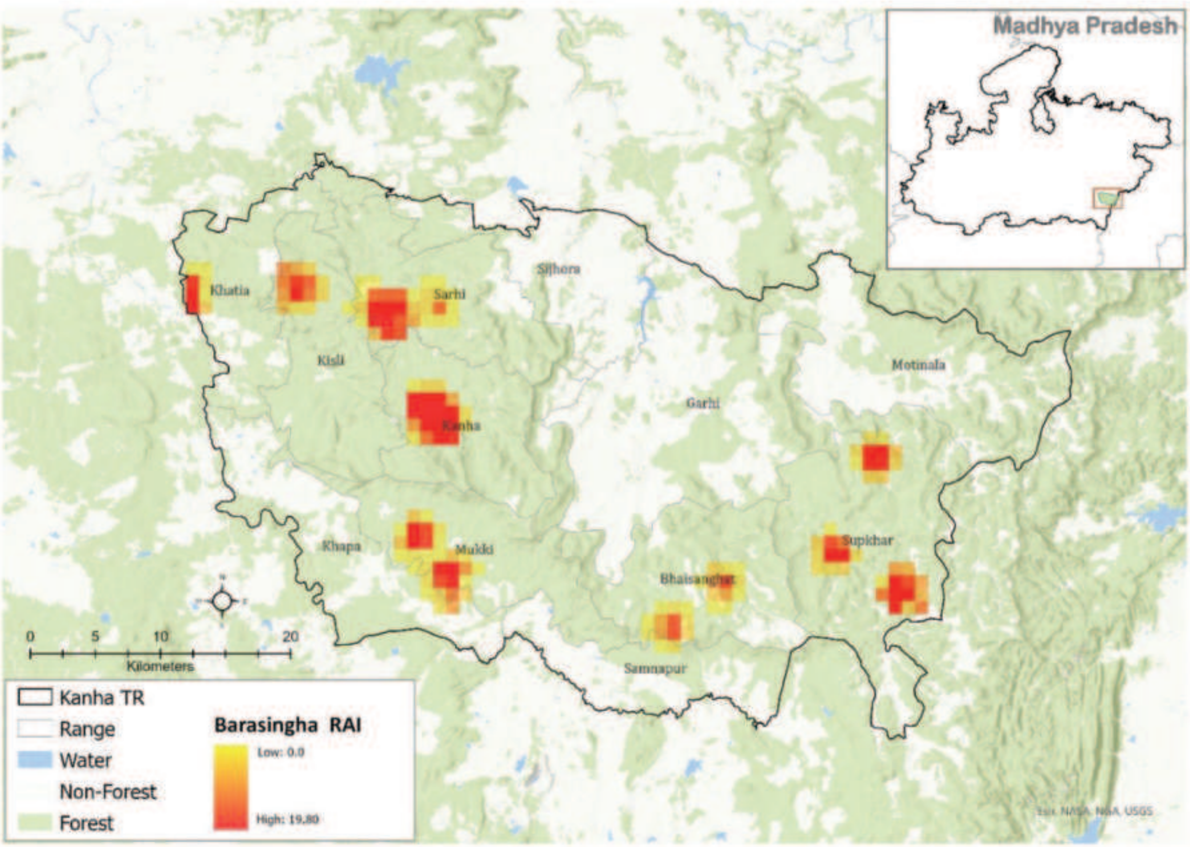

Figure IV. 41: Spatial relative abundance of barasingha in Kanha tiger reserve.

Panna Tiger Reserve

Panna tiger reserve, located in the Chhatarpur and Panna districts of Madhya Pradesh, spans approximately 1,598 km^2 and is a vital part of the Vindhyan Range. The reserve's landscape is shaped by ancient plateaus, deep gorges, and cascading waterfalls, dominated by tropical dry deciduous forests (Champion & Seth, 1968), interspersed with grasslands and riverine habitats. The Ken River, a perennial water source, cuts through the reserve, creating rich riparian zones that sustain a diverse variety of flora and fauna (Gopal *et al.*, 2010). Panna is a crucial habitat for tiger, leopard, sloth bear, dhole, Indian wolf, hyaena alongside herbivores such as chital, sambar, chousingha, chinkara, nilgai, sambar, and a rich birdlife, including the endangered vultures. Panna is also renowned for its successful tiger reintroduction program, which restored a once-extinct tiger population, showcasing its ecological resilience (Dutta and Krishnamurthy, 2024).

Chital is the major prey species in Panna and is highly abundant in all ranges of Panna Tiger Reserve, except for the Kishangarh Buffer and Chandranagar Range (Figure IV. 42). Hence, the abundance of chital was mapped using line transect data. Among all the ranges, the Madla range has the highest chital density in Panna. Sambar is also abundant in the core ranges of Panna Tiger Reserve (Figure IV. 43). The highest density of sambar is reported from the Kishangarh Core and Gaharighat ranges. In contrast, the Marhiado Buffer and Kishangarh Buffer ranges have the lowest sambar density. Nilgai are predominantly abundant in the buffer ranges of Panna Tiger Reserve (Figure IV. 44), with the highest density recorded in the Panna Buffer and followed by the Kishangarh Buffer and Marhiado Buffer. Wild pig abundance was mapped using photo-capture data from camera traps, as observations of wild pigs during transects were very low, resulting in insufficient data for analysis. Wild pigs are sparsely distributed across all ranges except Marhiado (Figure IV. 45), with the highest abundance recorded in the Amanganj range.

Table IV. 4: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Panna tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	89	0.151 (0.017)	0.53 (0.04)	4.73 (0.36)	1.57 (0.22)	6.19 (0.88)
Nilgai	73	0.124 (0.015)	0.34 (0.05)	2.85 (0.3)	1.28 (0.23)	4.02 (0.81)
Sambar	89	0.151 (0.016)	0.25 (0.03)	2.72 (0.2)	2.02 (0.34)	4.92 (0.74)

B)

Species	Chital	Sambar	Nilgai
Detection model	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	23.169	10.751	17.7
s(NDVI Pre-Monsoon)	-	2.455	1.89
s(NDVI difference)	8.722	-	1.88
s(Ruggedness)	8.097	1.957	-

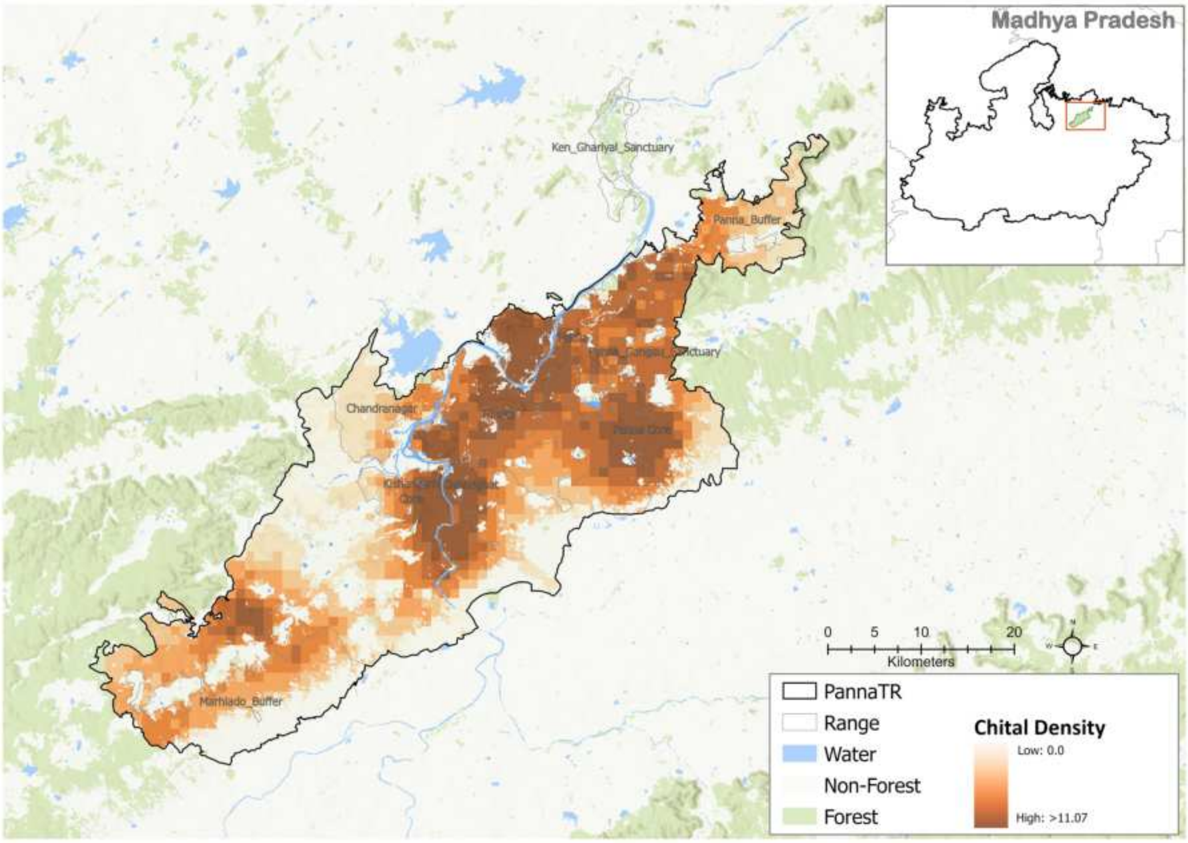

Figure IV. 42: Density of chital (per km²) in Panna tiger reserve: Site-level DSM

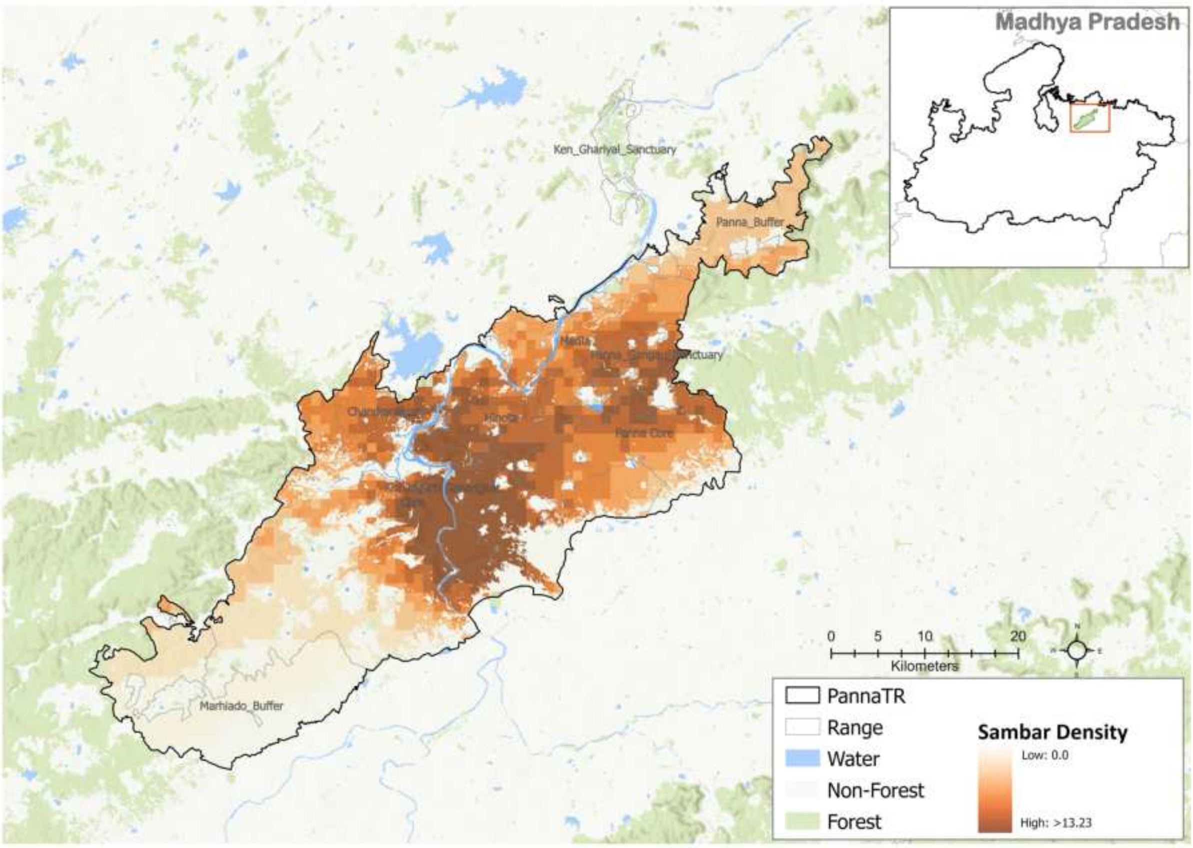

Figure IV. 43: Density of sambar (per km²) in Panna tiger reserve: Site-level DSM

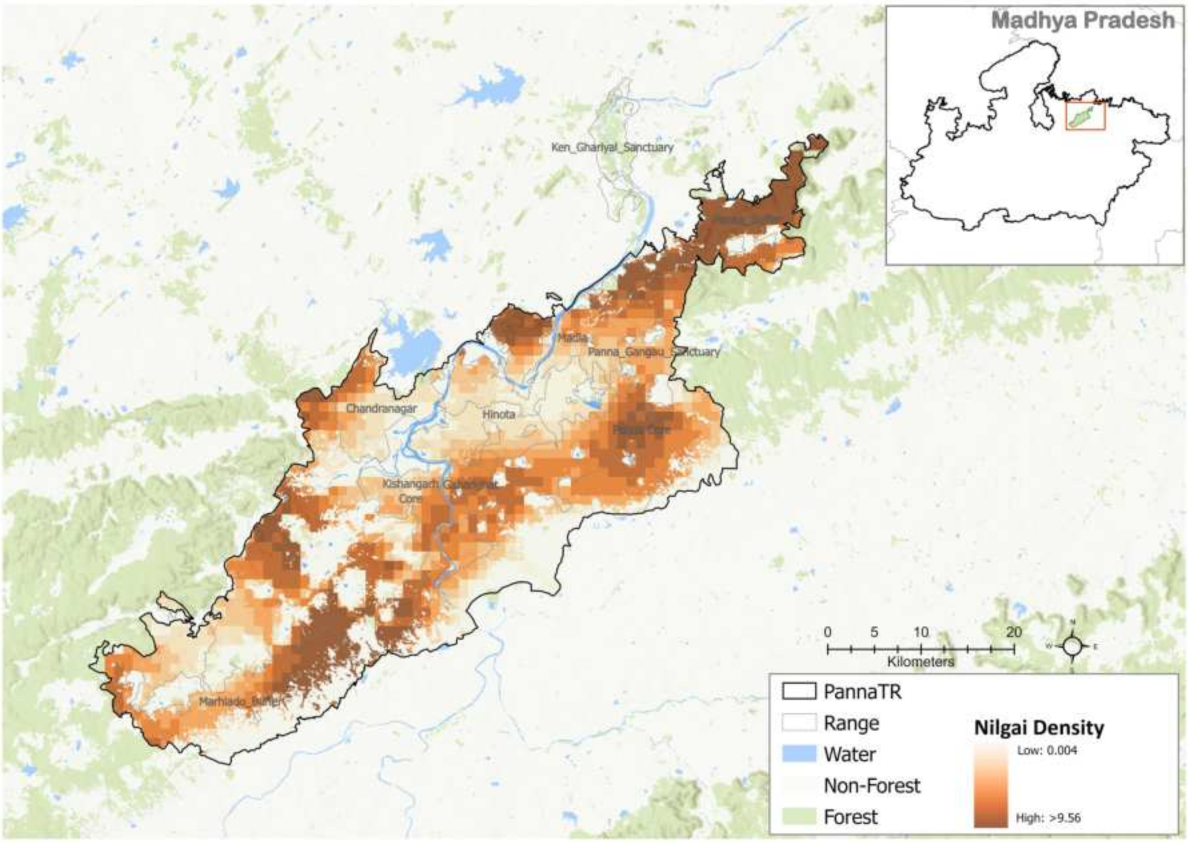

Figure IV. 44: Density of nilgai (per km^2) in Panna tiger reserve: Site-level DSM

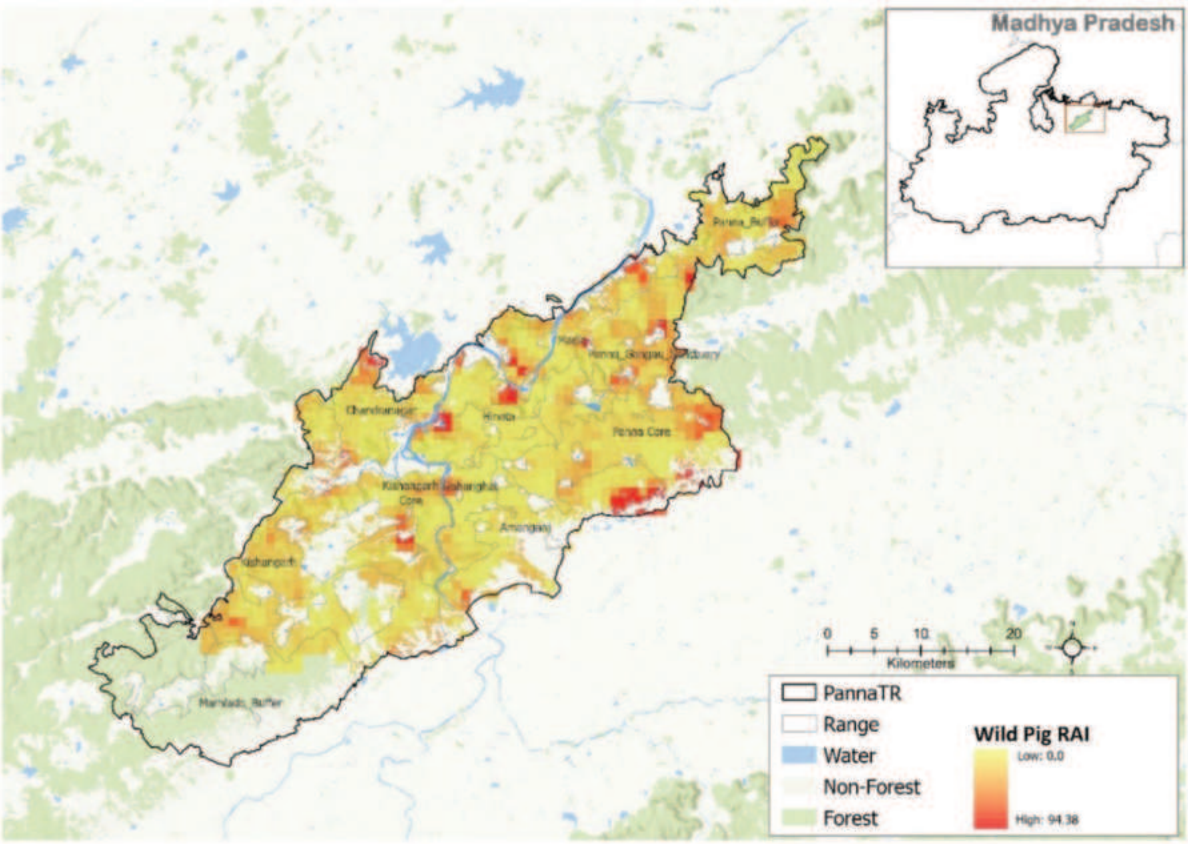

Figure IV. 45: Spatial relative abundance of wild pig in Panna tiger reserve.

Pench Tiger Reserve – Madhya Pradesh

Pench (MP) Tiger Reserve, spanning approximately 1,179 km^2, is located in the Seoni and Chhindwara districts of Madhya Pradesh. It is the northern portion of the larger Pench landscape. The reserve is dominated by tropical dry and moist deciduous forests (Champion and Seth, 1968), primarily composed of teak, saja, mahua, and bamboo, interspersed with open meadows and riverine belts. The Pench River, flowing centrally through the reserve, sustains its rich biodiversity, creating a riparian habitat that support a variety of aquatic and terrestrial species (Sankar *et al*., 2001). The reserve provides an excellent habitat to tiger, leopard, dhole and numerous herbivores like gaur, chital, sambar, nilgai, barking deer and wild pig alongside over 325 bird species. Pench is well connected to Kanha and Satpura through functional wildlife corridors.

Pench MP has the highest ungulate abundance in Central India. Species like chital, sambar, gaur, nilgai, and wild pig are highly abundant, and their populations are mapped using line transect data. Barking deer data is limited in line transects, so it is mapped using photo captures from camera trapping. Chital is the primary prey species and the most abundant ungulate in Pench MP. Karmajhiri and Gumtara ranges have the highest density of Chital, while the Ari and Rukhad ranges have the lowest (Figure IV. 46). The chital population in Karmajhiri can potentially act as a source population for prey management.

Kurai has the highest sambar density (Figure IV. 47), followed by Karmajhiri. Khawasa has the lowest density. Gaur is most abundant in Kurai and Gumtara ranges, followed by Karmajhiri and Ari ranges (Figure IV. 48), while Rukhad has very low gaur density.

Nilgai is abundant in the Gumtara, Khawasa, and Kurai ranges (Figure IV. 49), and wild pig is most abundant in the Karmajhiri, Gumtara, and Kurai ranges (Figure IV. 50). Barking deer is rarely present in Pench. It has been captured in only a few locations in the camera trap (Figure IV. 51), with Ari showing relatively higher presence compared to other areas of Pench MP. Rukhad and Ari ranges have the lowest ungulate abundance in Pench MP, and these areas require management intervention for herbivore population recovery.

Table IV. 5: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Pench tiger reserve (Madhya Pradesh).

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	409	0.641 (0.034)	0.33 (0.01)	8.25 (0.36)	6.47 (0.44)	53.97 (2.55)
Gaur	38	0.06 (0.01)	0.47 (0.06)	4.87 (0.62)	0.71 (0.15)	3.4 (0.59)
Nilgai	186	0.292 (0.021)	0.52 (0.04)	4.93 (0.37)	3.14 (0.35)	15.2 (1.41)
Sambar	183	0.287 (0.021)	0.56 (0.04)	2.86 (0.12)	3.18 (0.31)	9.18 (0.73)
Wild pig	89	0.139 (0.015)	0.5 (0.07)	7.4 (0.67)	1.69 (0.29)	12.47 (1.74)

B)

Species	Chital	Sambar	Gaur	Wild pig	Nilgai
Detection model	Hazard rate (Null)	Hazard rate (Null)	Half-normal (Null)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	18.432	8.816	10.633	8.043	13.7
s(Aridity)	1.484	-	2.836	-	1.9
s(NDVI Pre-Monsoon)	-	-	-	1.894	2.78
s(NDVI Post-Monsoon)	-	-	1.946	-	-
s(NDVI difference)	-	1.651	-	-	-
s(Elevation)	3.508	4.366	-	-	-

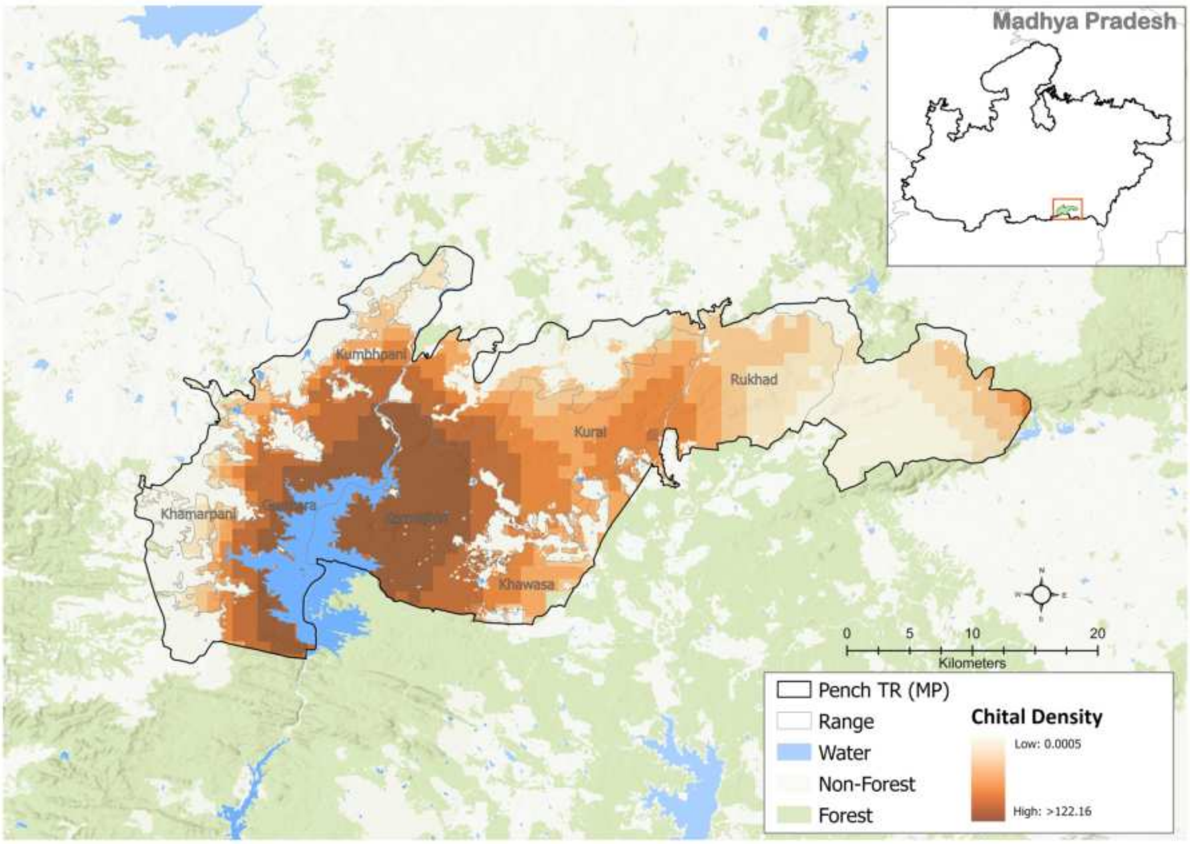

Figure IV. 46: Density of chital (per km^2) in Pench tiger reserve: Site-level DSM

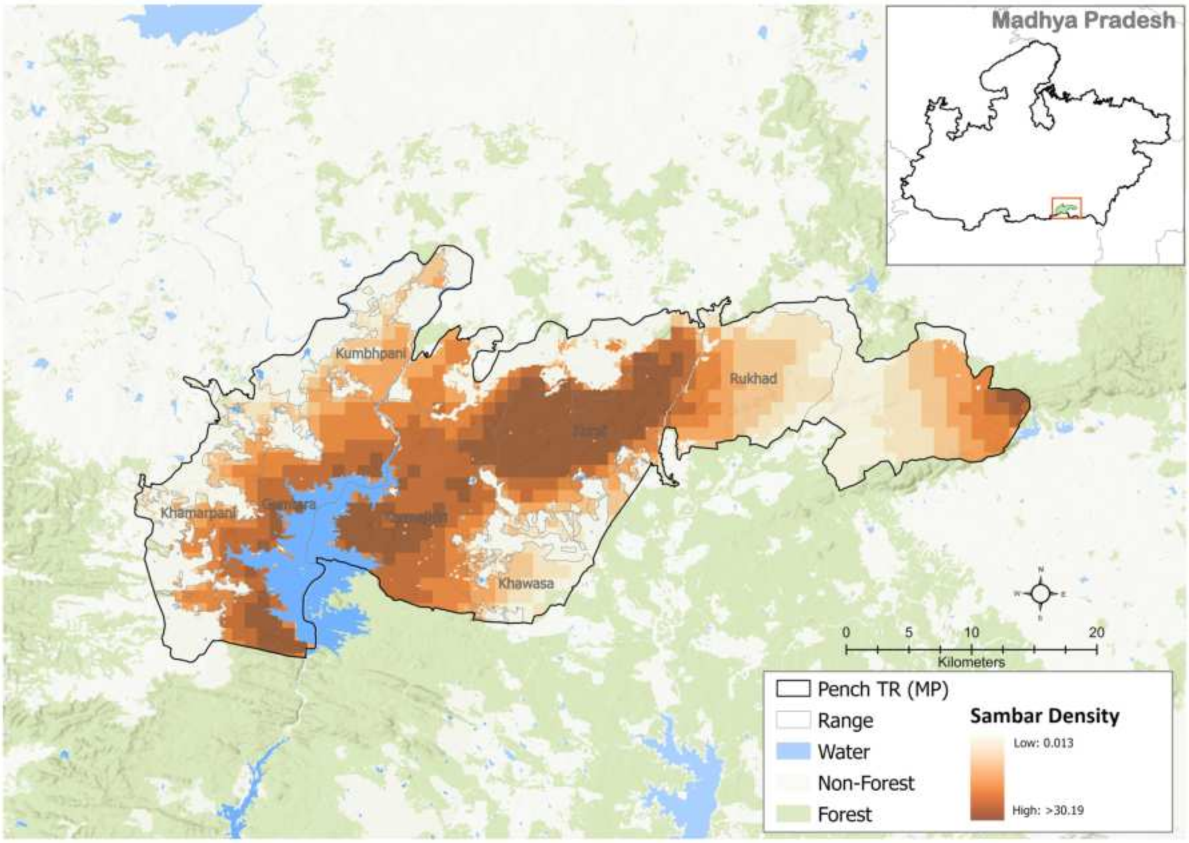

Figure IV. 47: Density of sambar (per km²) in Pench tiger reserve: Site-level DSM

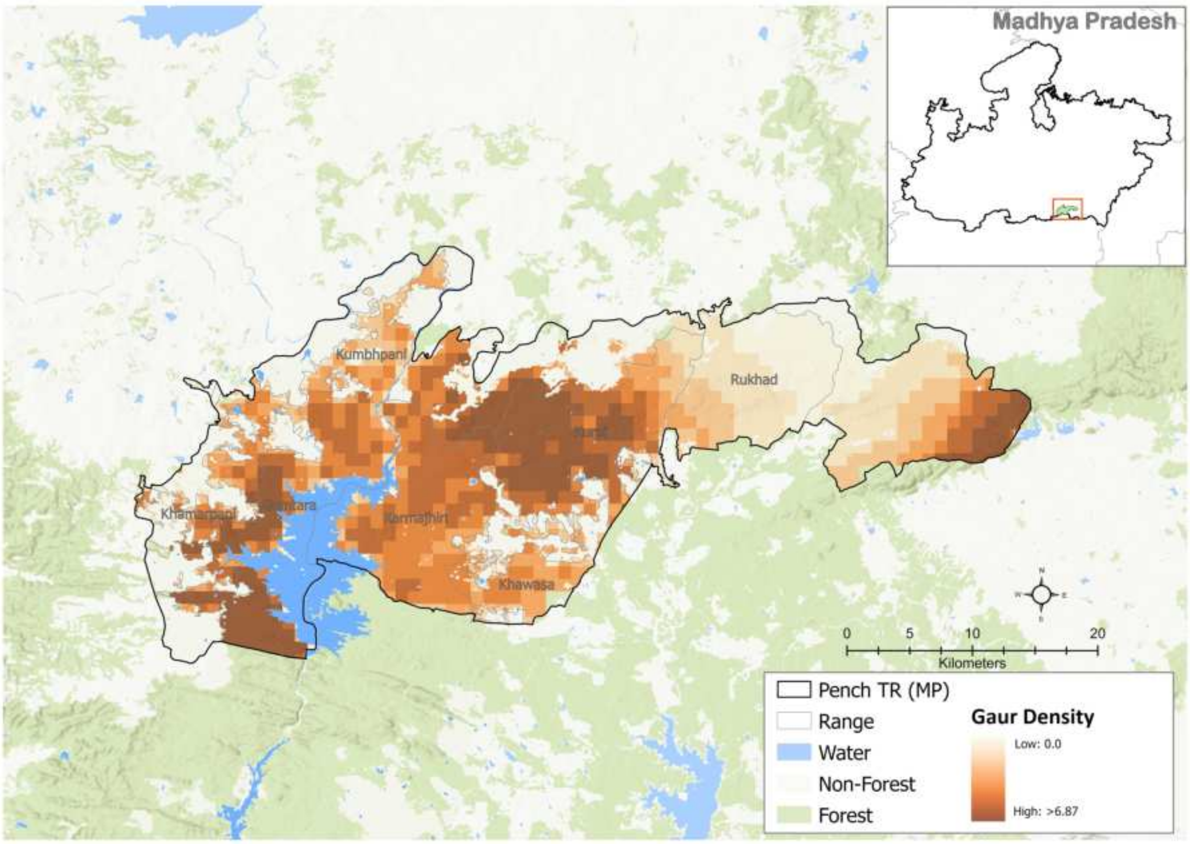

Figure IV. 48: Density of gaur (per km²) in Pench tiger reserve: Site-level DSM

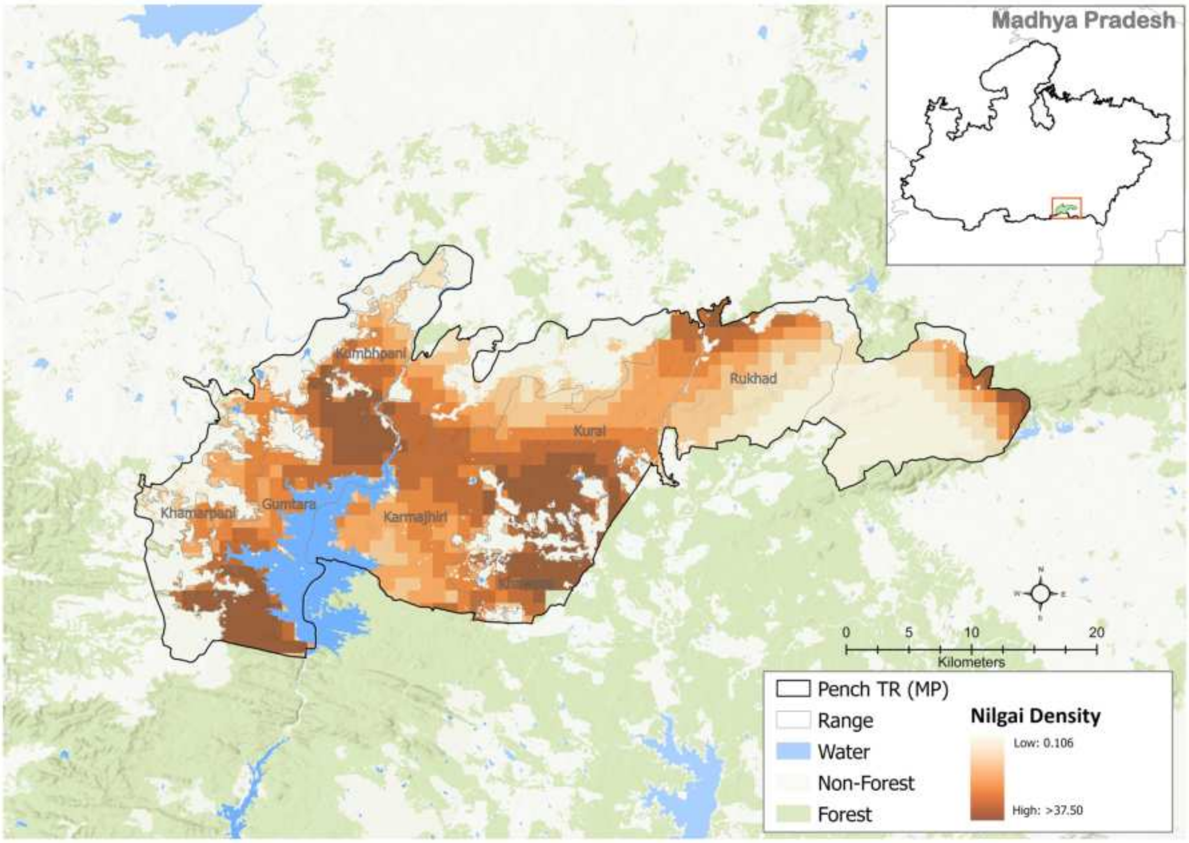

Figure IV. 49: Density of nilgai (per km^2) in Pench tiger reserve: Site-level DSM

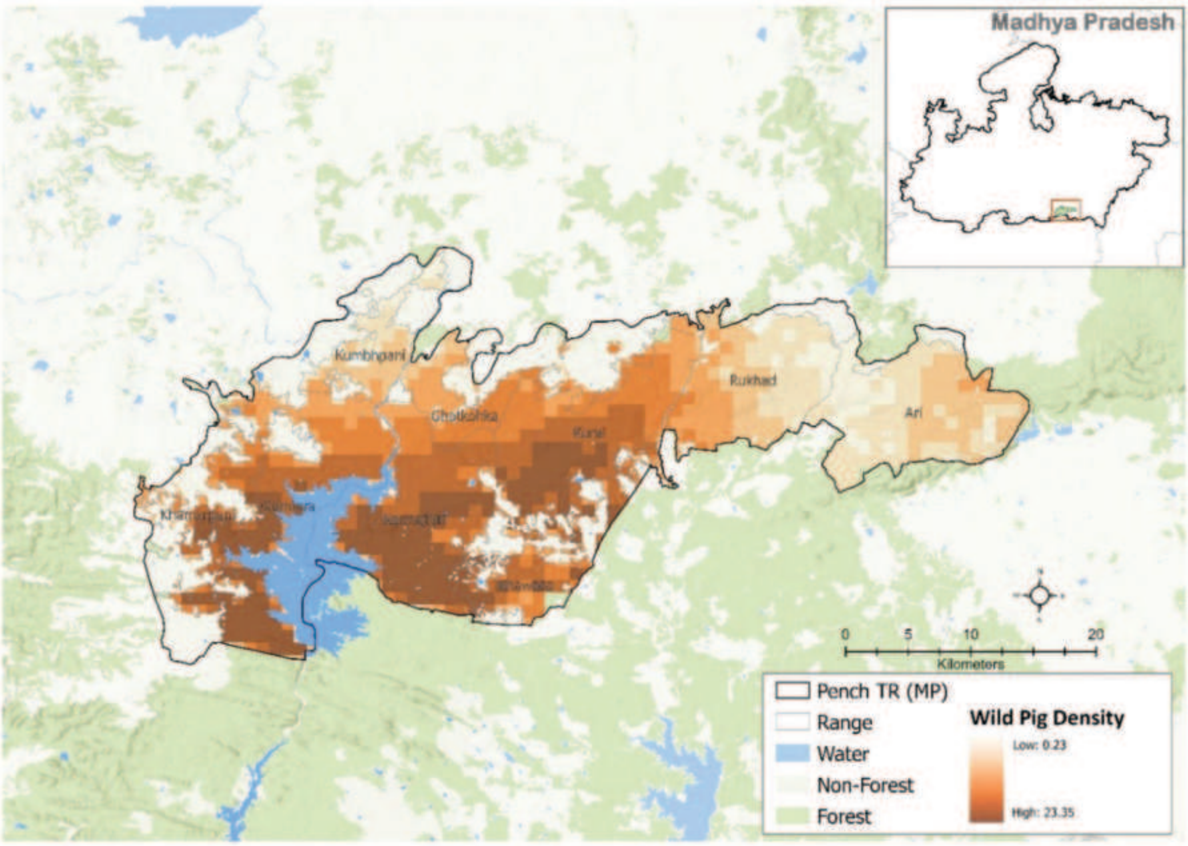

Figure IV. 50: Density of wild pig (per km^2) in Pench tiger reserve: Site-level DSM

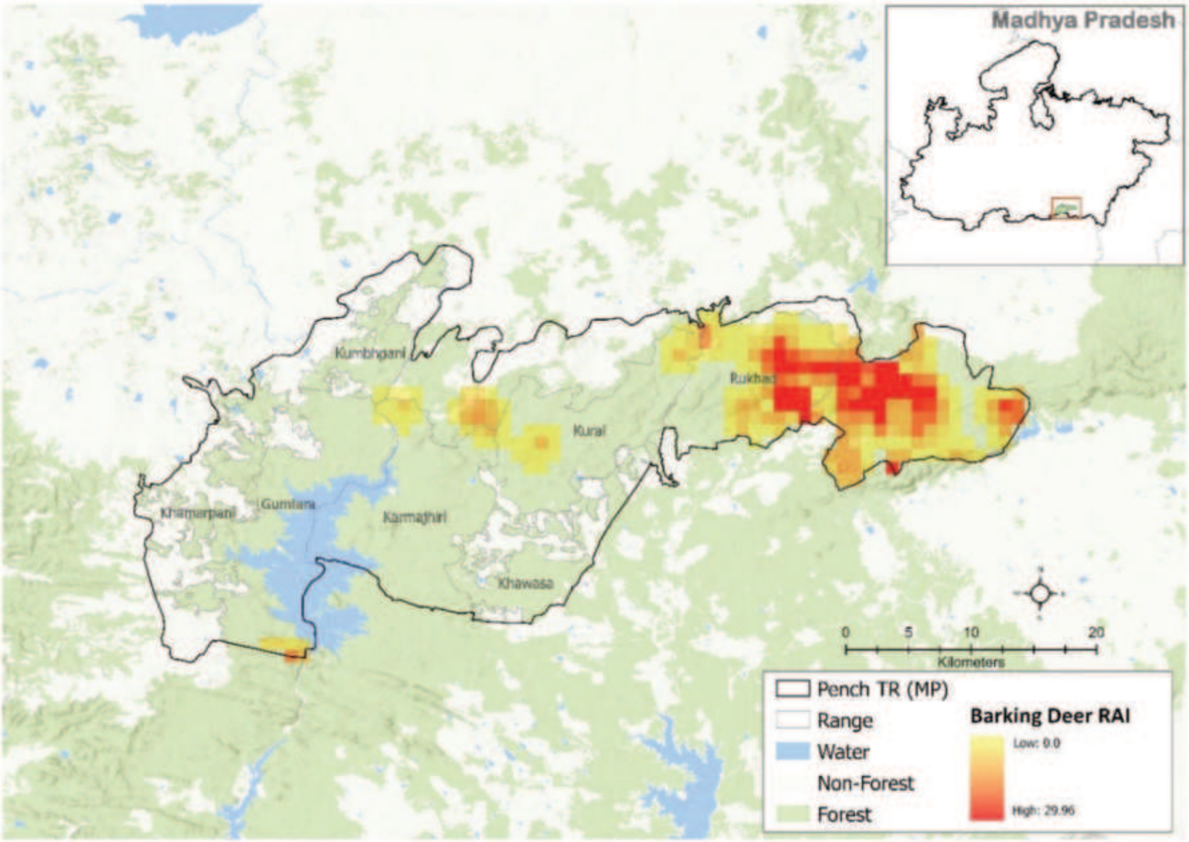

Figure IV. 51: Spatial relative abundance of baking deer in Pench tiger reserve.

Sanjay-Dubri Tiger Reserve

Sanjay-Dubri tiger reserve, located in the Madhya Pradesh, spans approximately 1,674 km^2. The tiger reserve is situated within the Baghelkhand plateau of central India. The reserve has diverse landscapes, which include tropical dry and moist deciduous forests, and grasslands (Champion & Seth, 1968). These habitats are interspersed with rocky terrain, seasonal rivers, and wetlands that support a variety of flora and fauna. The reserve is home to species like tiger, leopard, dhole, jackal, jungle cat, Indian fox, sloth bear, and herbivores such as chital, nilgai, sambar, and wild pigs. The presence of the Gopad and Banas rivers provides vital water resources, sustaining aquatic life and enriching the surrounding ecosystems. Movement of animals between Sanjay dubri and Palamau, Bandhavgarh, Guru Ghasidas and Tamor Pingla WLS has been recorded (Yadav *et al*., 2023). Hence, this reserve acts as an important area in the landscape.

Ungulate observations in Sanjay Dubri's line transects are minimal, and the data is insufficient for analysis. Therefore, chital and sambar abundance are predicted using landscape models, while barking deer, gaur, nilgai, and wild pig abundance are mapped using camera trap photo captures. The encounter rate for chital is 0.1537 (±0.0258) and for sambar is 0.0199 (±0.0113). A prey recovery and supplementation plan is needed for Sanjay Dubri tiger reserve. Additionally, village relocations within the reserve should be carried out to improve habitat and facilitate the creation of suitable environments for ungulate populations. The landscape model predicts chital presence across all ranges of Sanjay Dubri tiger reserve (Figure IV. 52), with the highest density in the Dubri range, followed by the Pondi range. Sambar presence is predicted to be very low across the reserve, with the highest density in the Pondi range (Figure IV. 53), and some moderate to low presence in Midwas, Tamsar, and Bhuimand.

Camera trap data shows the highest barking deer presence in the Pondi range, followed by the Midwas range (Figure IV. 54). The Dubri and Bastua ranges show very low to no barking deer presence. Wild pig and nilgai are present throughout the reserve, with the highest abundance of wild pig in the Pondi range (Figure IV. 57), and nilgai in the Bastua range (Figure IV. 56). Gaur has recently been reintroduced in the Dubri range of Sanjay Dubri Tiger Reserve (Figure IV. 55).

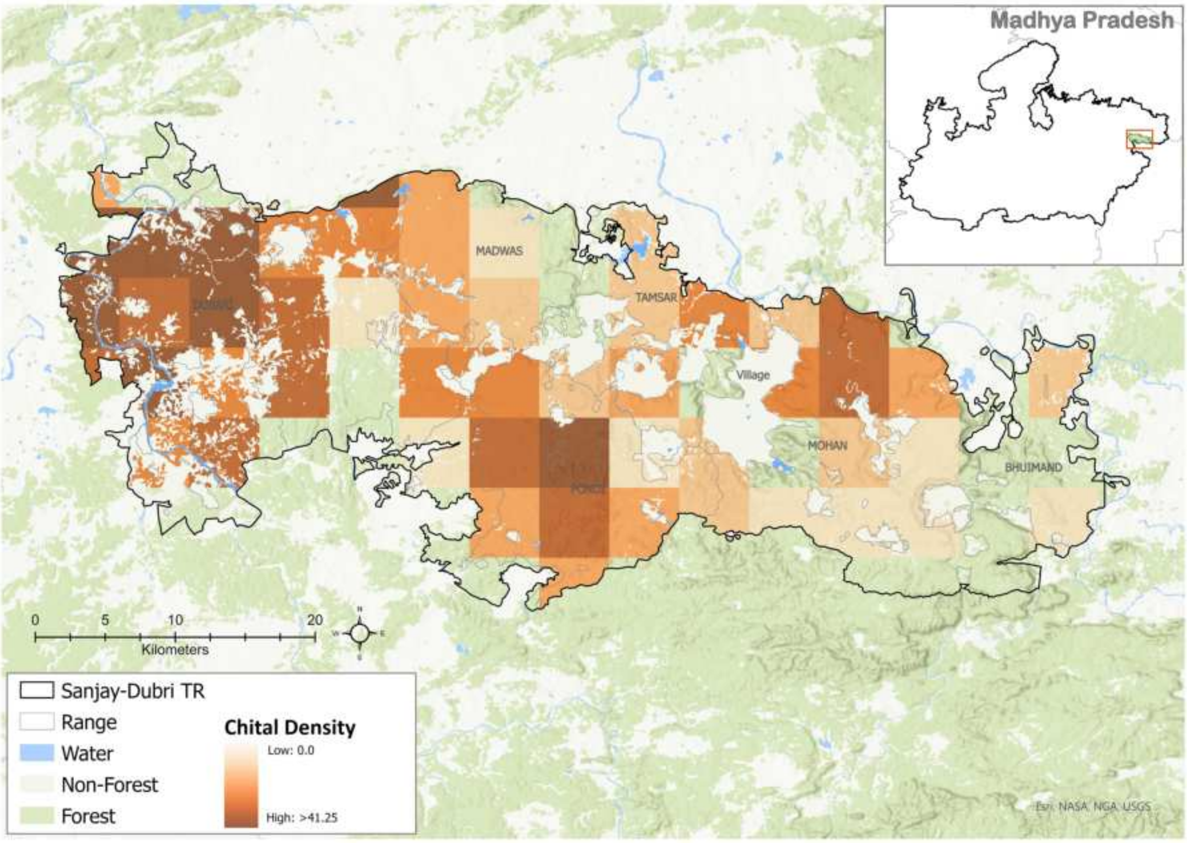

Figure IV. 52: Density of chital (per 25 km²) in Sanjay-Dubri tiger reserve: Landscape-level DSM

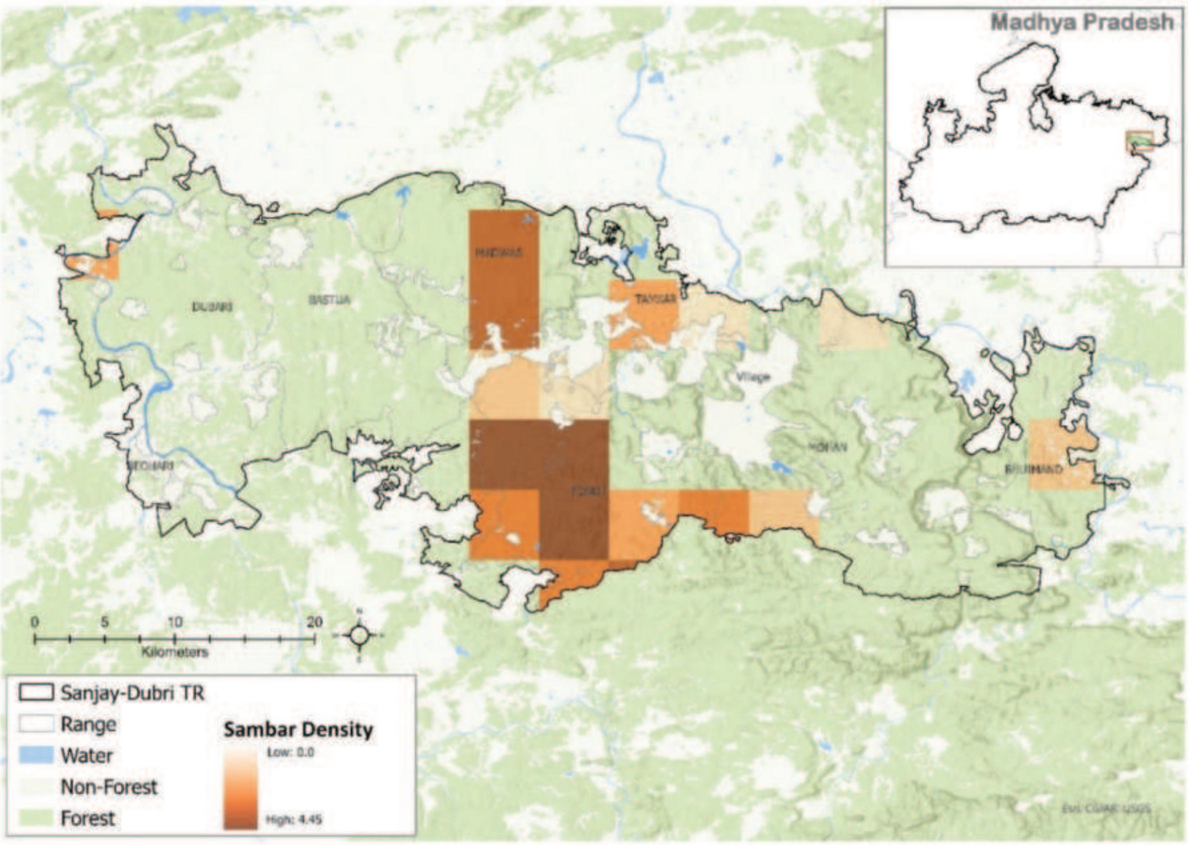

Figure IV. 53: Density of sambar (per 25 km²) in Sanjay-Dubri tiger reserve: Landscape-level DSM

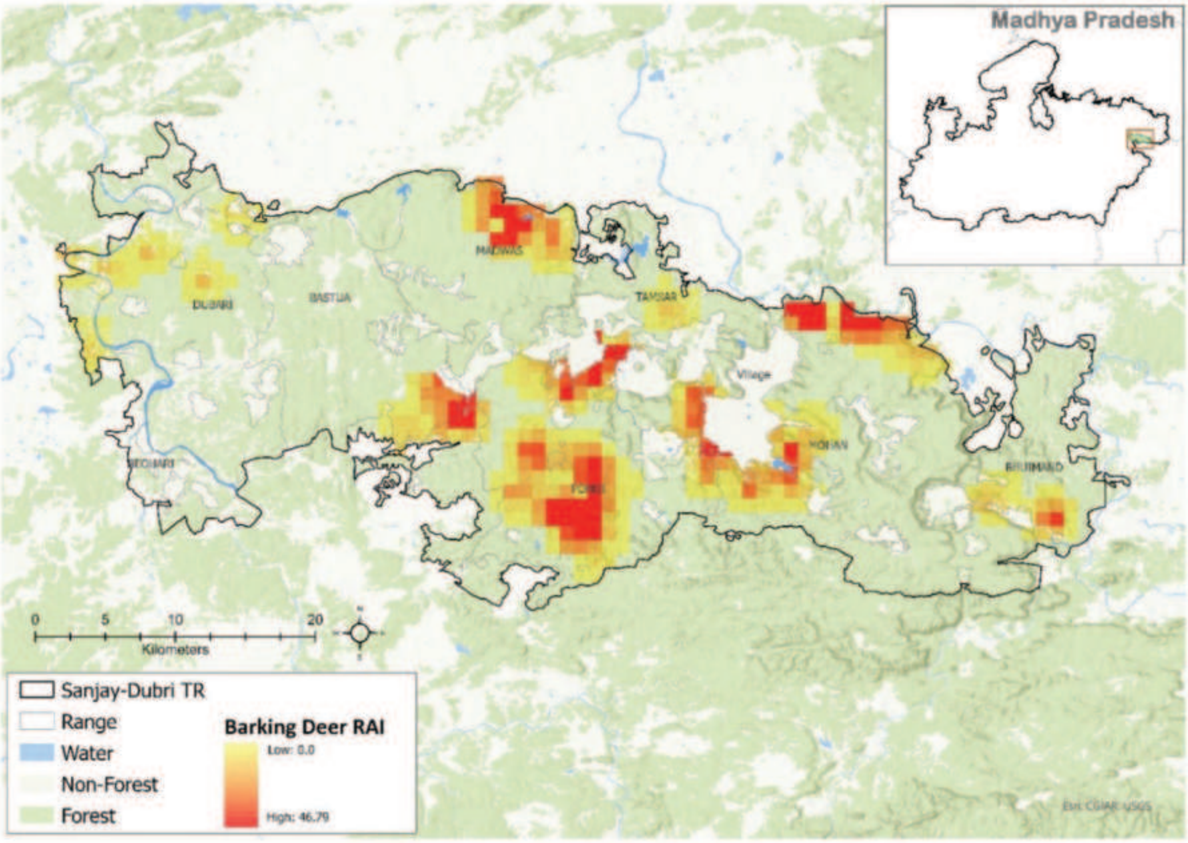

Figure IV. 54: Spatial relative abundance of baking deer in Sanjay-Dubri tiger reserve.

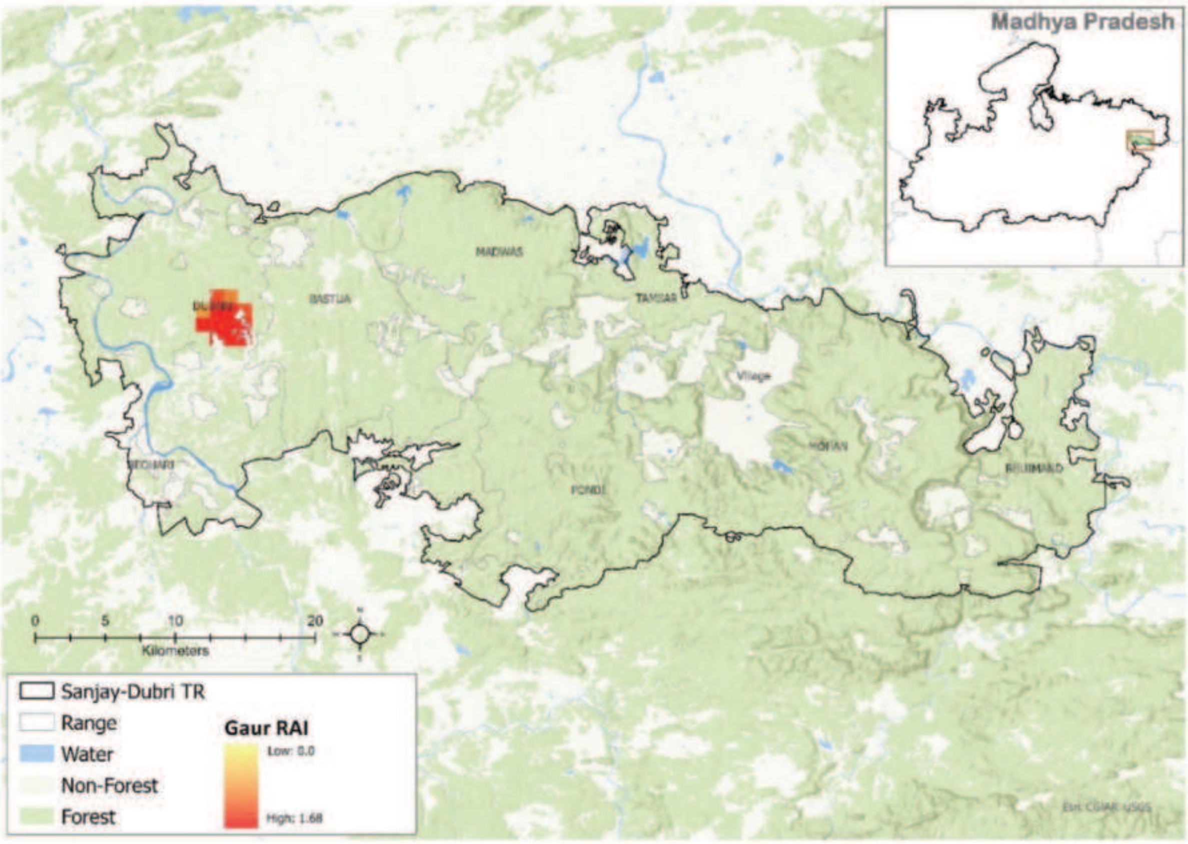

Figure IV. 55: Spatial relative abundance of gaur in Sanjay-Dubri tiger reserve.

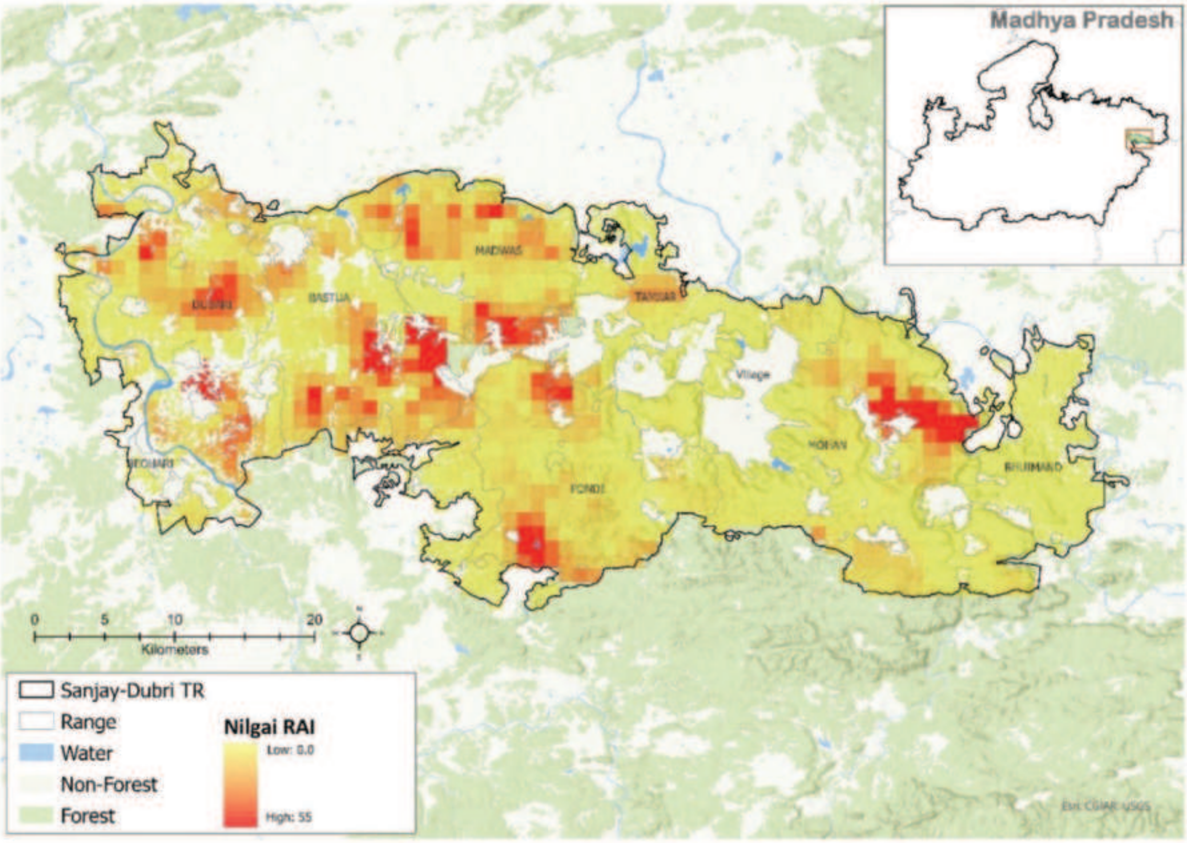

Figure IV. 56: Spatial relative abundance of nilgai in Sanjay-Dubri tiger reserve.

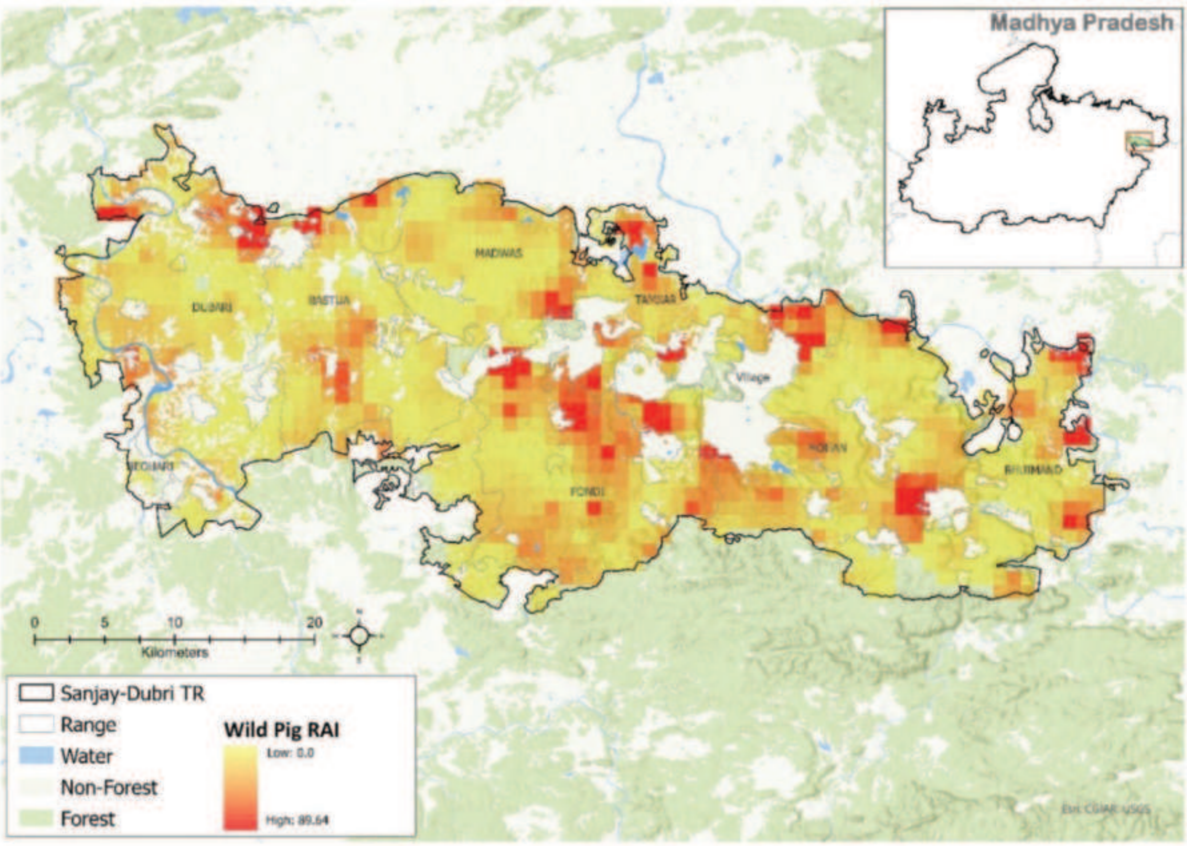

Figure IV. 57: Spatial relative abundance of wild pig in Sanjay-Dubri tiger reserve.

Satpura Tiger Reserve

Satpura Tiger Reserve, spanning 2,133 km² in Madhya Pradesh, is part of the Satpura-Maikal Landscape and features tropical dry deciduous forests dominated by sal, teak, and bamboo (Borah *et al*., 2009), along with grasslands and riverine ecosystems nourished by Tawa and Denwa rivers. Its rugged terrain, characterized by deep valleys, sandstone peaks, gorges, and dense forests, supports diverse wildlife, including tigers, leopards, dhole, sloth bears, Indian wolves, and herbivores like chital, sambar, gaur, and nilgai, alongside rich bird, reptile, and amphibian diversity. The Panchmarhi plateau is covered with sal forests on Gondwana sandstone, while teak forests dominate the lower basaltic hills. Recently, the endangered central Indian hard-ground swamp deer was reintroduced from Kanha Tiger Reserve to establish a separate population.

Different prey species exhibit varying abundance across the Satpura tiger reserve. Among them, chital is the most abundant, though its abundance is clustered in specific areas (Figure IV. 58). Some areas, especially near water sources in the Kamti and Churna ranges, have very high chital densities, while the more rugged areas of Satpura, like West Panchmarhi, have low to no chital presence. Sambar is present in nearly all ranges of Satpura tiger reserve, with higher density in the Matkuli and West Panchmarhi ranges, followed by Churna (Figure IV. 59).

Gaur is highly abundant in the West Panchmarhi range, followed by the Bori range (Figure IV. 61). Gaur presence in the Pipariya and Denwa buffers is very low. The rugged West Panchmarhi area has the highest barking deer presence (Figure IV. 60), followed by East Panchmarhi, as barking deer prefers rugged terrain. Less rugged areas like Churna and Kamti, near the reservoirs, have the least barking deer density. Wild pig is abundant throughout Satpura, except in the rugged areas of the Kamti range (Figure IV. 63). East and West Panchmarhi have the highest density of wild pig in Satpura. Nilgai is most abundant in the eastern part of the Satpura Tiger Reserve, with the highest density in the East Panchmarhi range, followed by the Denwa buffer (Figure IV. 62). The reintroduced barasingha population is well established now in Satpura and their relative abundance is estimated using camera trap photo captures. Presence of barasingha is restricted to Bori range only during camera trapping for 2022 AITE (Figure IV. 64).

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Table IV. 6: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Satpura tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Barking	98	0.084 (0.008)	0.57 (0.04)	1.28 (0.06)	0.95 (0.11)	1.3 (0.15)
Chital	49	0.042 (0.006)	0.42 (0.04)	6 (0.92)	0.34 (0.06)	1.83 (0.25)
Gaur	89	0.077 (0.008)	0.64 (0.04)	4.37 (0.43)	0.66 (0.08)	3.13 (0.25)
Nilgai	217	0.187 (0.012)	0.42 (0.02)	4.96 (0.31)	2.02 (0.18)	10.61 (0.69)
Sambar	238	0.205 (0.013)	0.49 (0.02)	2.11 (0.09)	2.08 (0.17)	4.19 (0.28)
Wild pig	121	0.104 (0.009)	0.61 (0.04)	6.97 (0.46)	1.23 (0.14)	8.99 (0.67)

B)

Species	Chital	Sambar	Gaur	Wild pig	Nilgai
Detection model	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	24.504	6.884	8.673	25.69	25.8
s(Aridity)	1.002	-	-	-	-
s(NDVI difference)	2.819	3.35	1.001	-	1.92
s(Elevation)	-	-	-	-	1.93

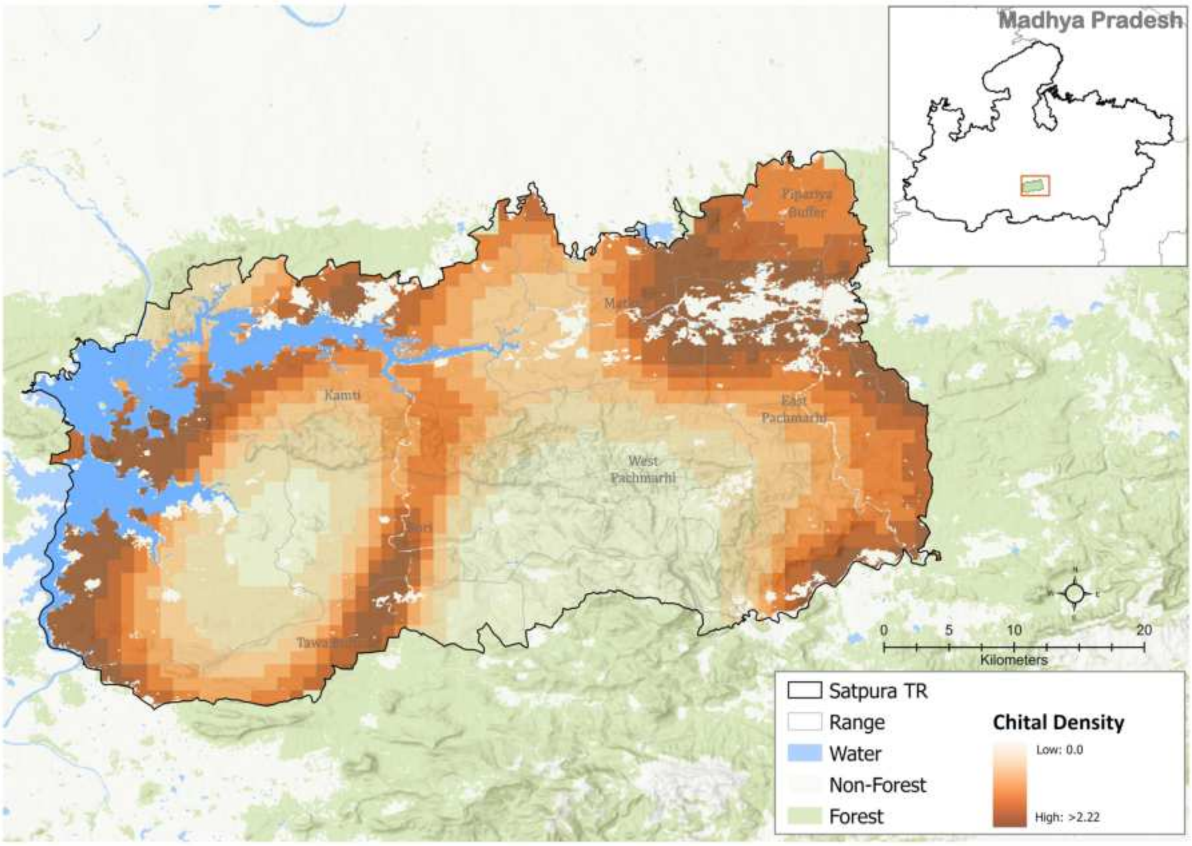

Figure IV. 58: Density of chital (per km^2) in Satpura tiger reserve: Site-Level DSM

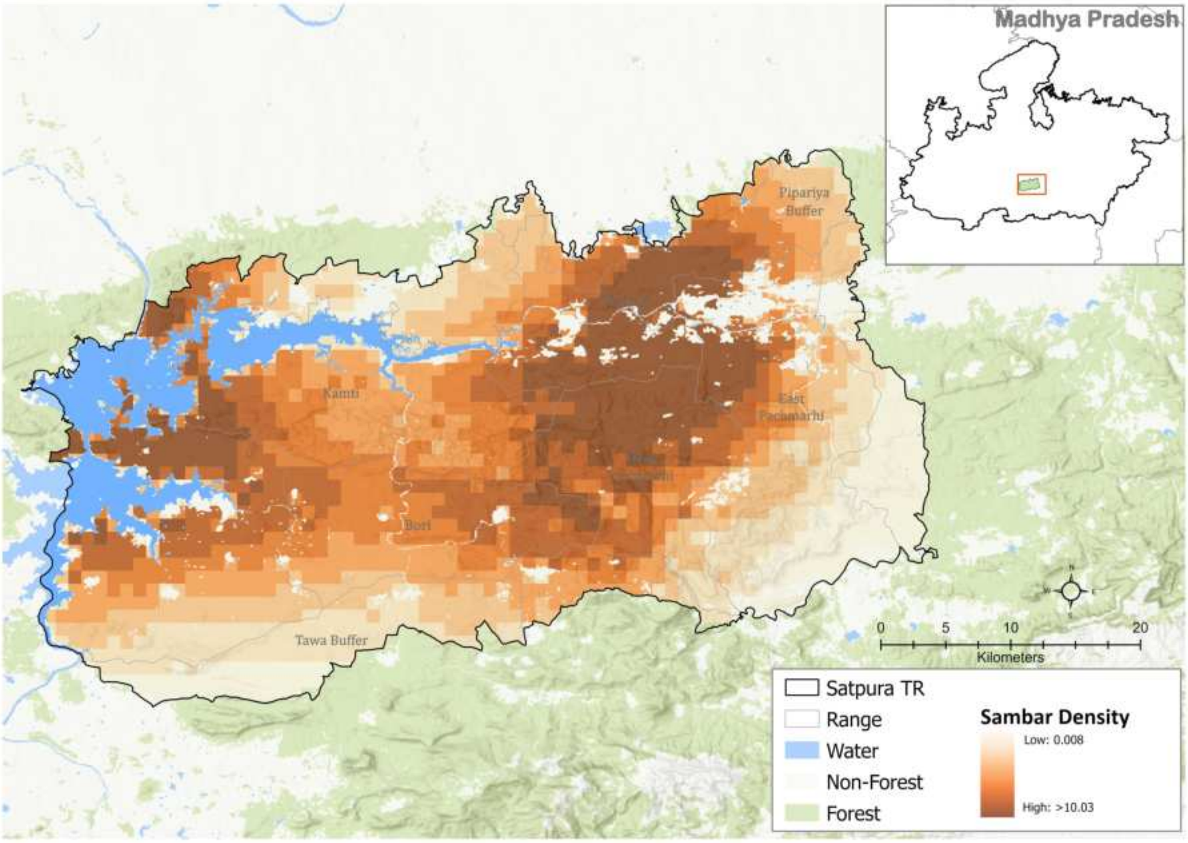

Figure IV.59: Density of sambar (per km^2) in Satpura tiger reserve: Site-Level DSM

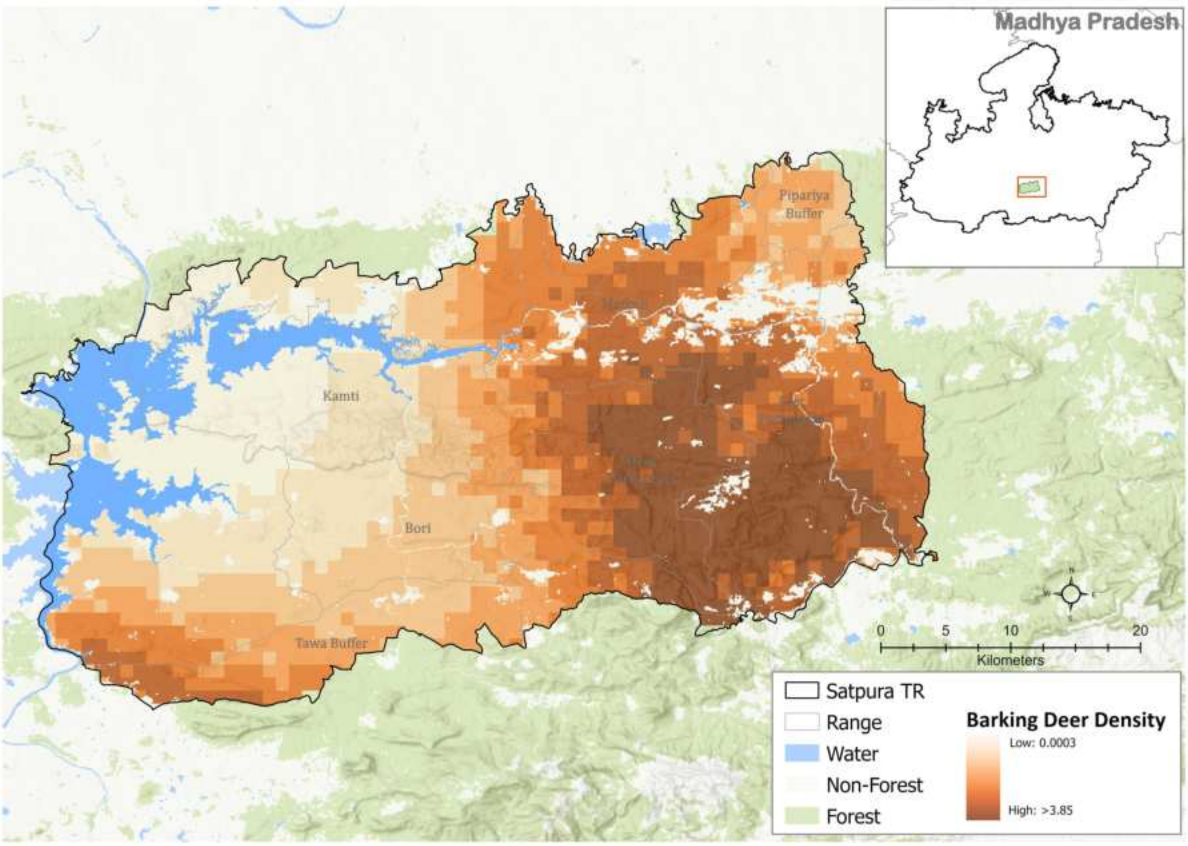

Figure IV. 60: Density of barking deer (per km^2) in Satpura tiger reserve: Site-Level DSM

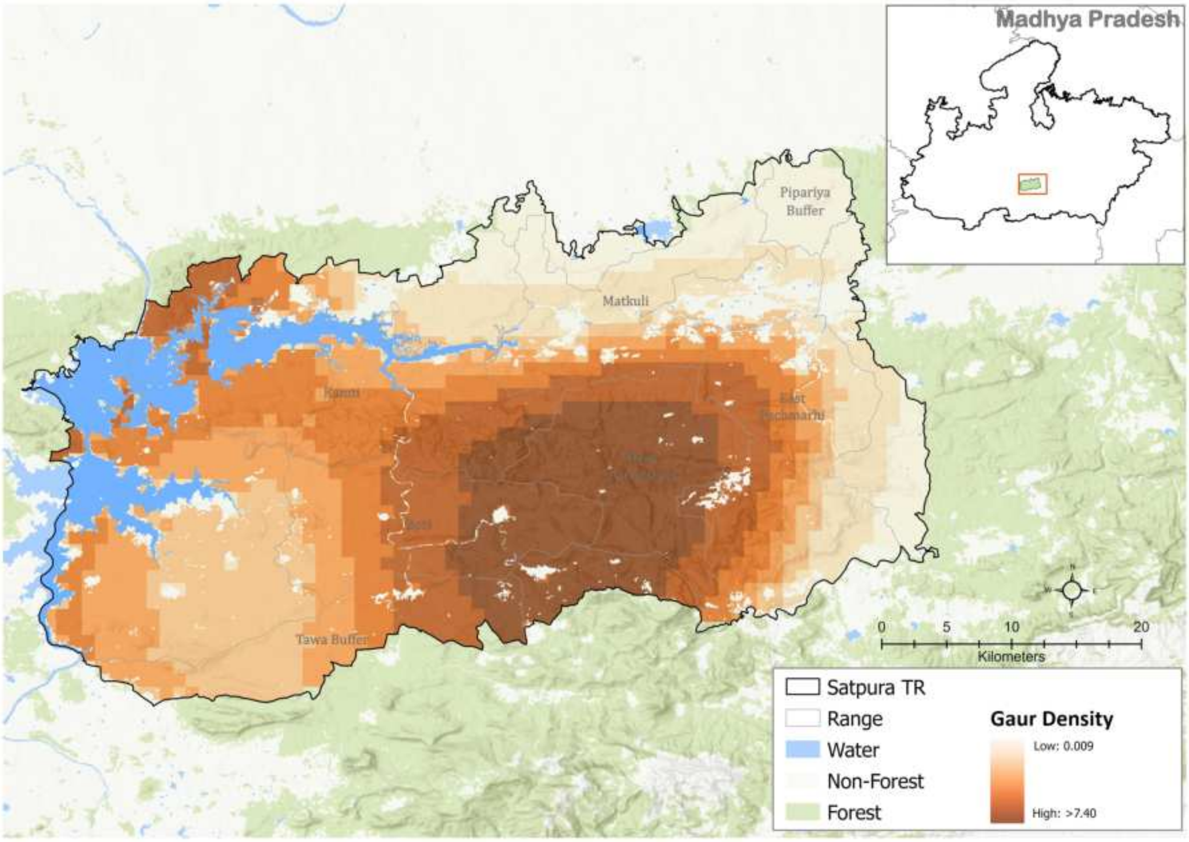

Figure IV. 61: Density of gaur (per km²) in Satpura tiger reserve: Site-Level DSM

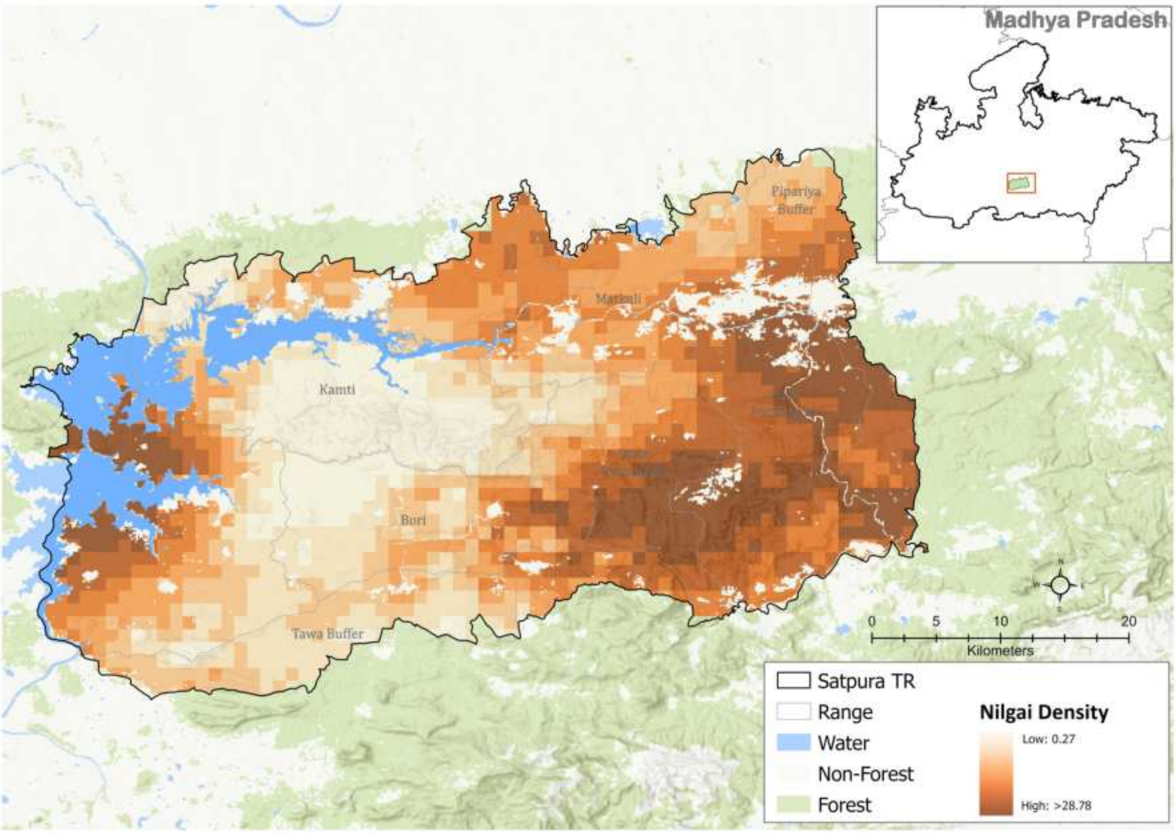

Figure IV. 62: Density of nilgai (per km²) in Satpura tiger reserve: Site-Level DSM

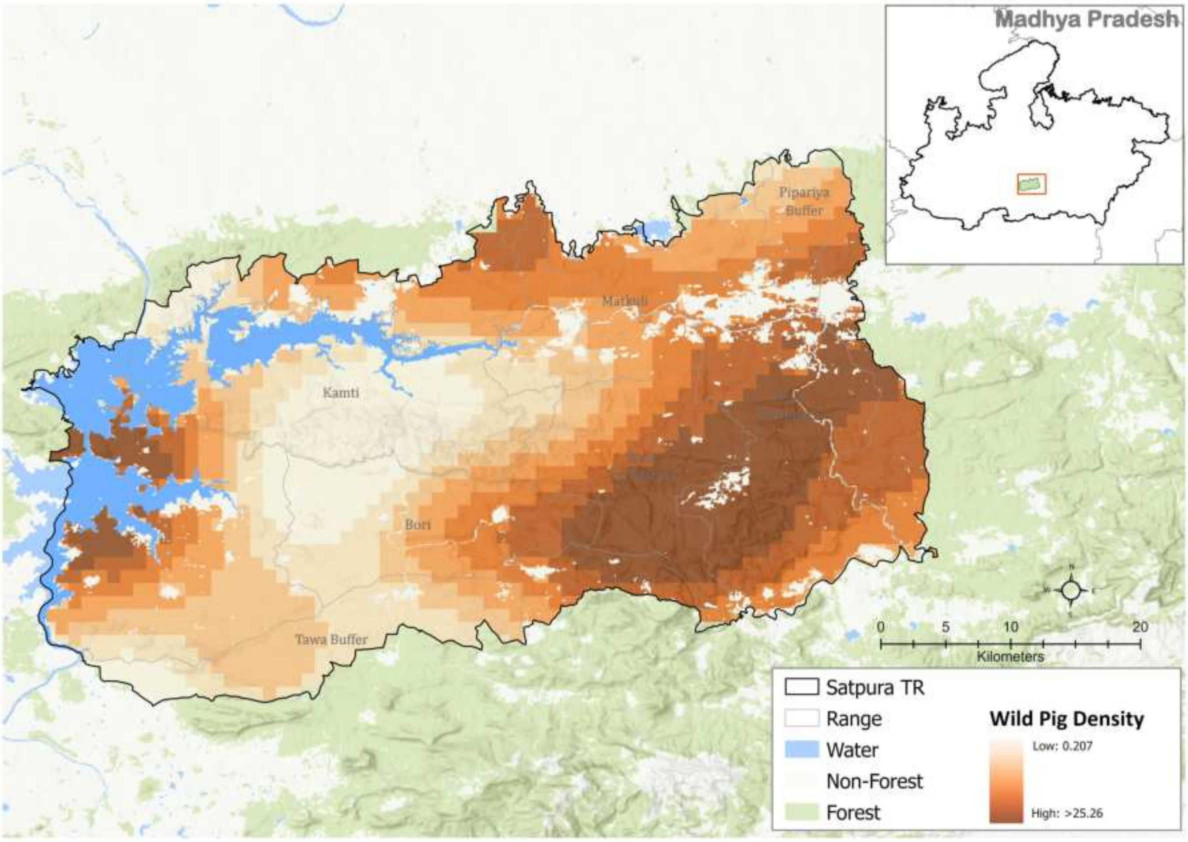

Figure IV. 63: Density of wild pig (per km^2) in Satpura tiger reserve: Site-Level DSM

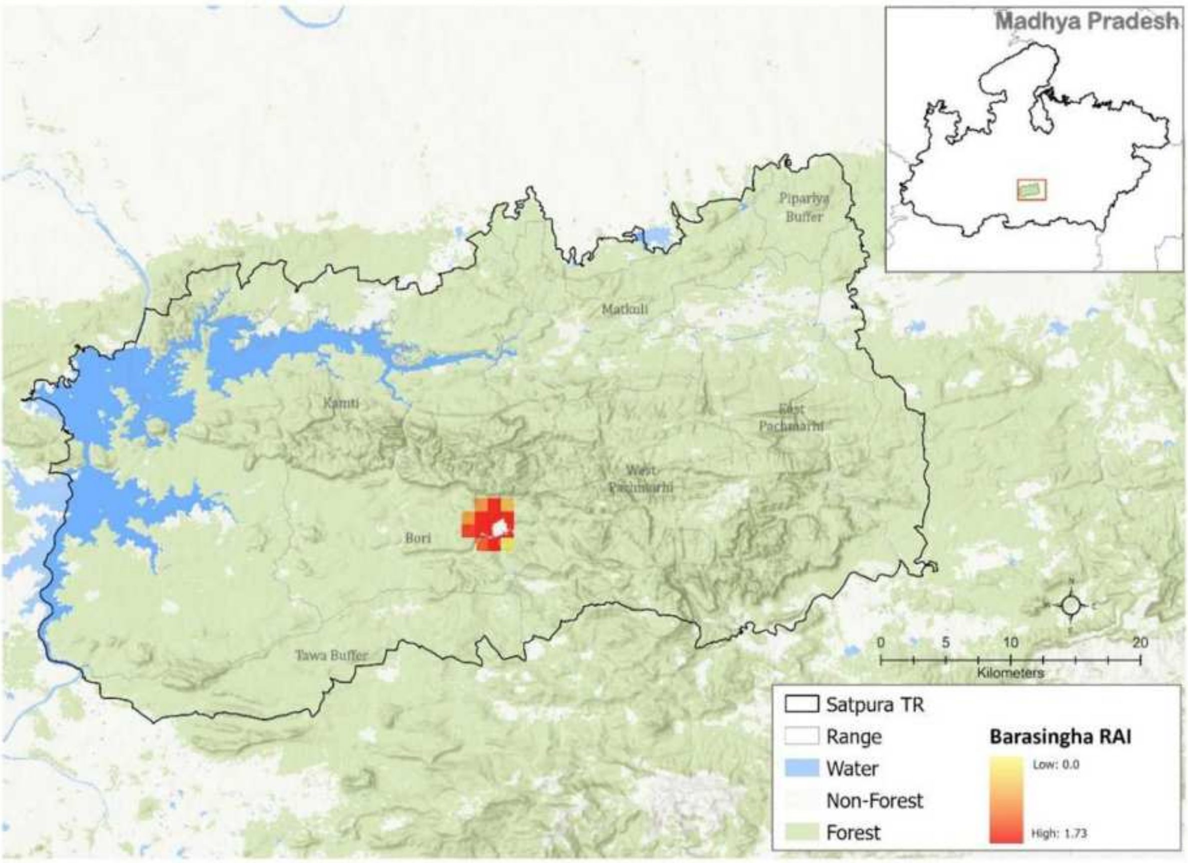

Figure IV.64: Spatial relative abundance of barasingha in Satpura tiger reserve.

Veerangana Durgavati Tiger Reserve

Veerangana Durgavati Tiger Reserve, located in the Sagar, Damoh, and Narsinghpur districts of Madhya Pradesh, spans approximately 2,339 km^2, making it the state's seventh tiger reserve. The reserve encompasses the Nauradehi Wildlife Sanctuary and Durgavati Wildlife Sanctuary, featuring a diverse landscape of tropical dry deciduous forests, teak groves, bamboo thickets, and grasslands (Sambath and Chandra, 2012). This varied terrain supports a rich array of wildlife, including tigers, leopards, Indian wolves, jackal, Indian foxes, striped hyenas, sloth bears, and herbivores such as sambar, chital, barking deer, and nilgai. The reserve also provides habitat for critically endangered white-rumped and Indian vultures. Moreover, Nauradehi is identified as a potential site for the reintroduction of cheetahs.

Ungulate observations in the line transects of Veerangana Rani Durgawati Tiger Reserve are sparse, and data is insufficient for analysis. The encounter rate for chital is 0.0471 (±0.0116) and for sambar is 0.0018 (±0.0167). Therefore, Chital and Sambar abundance are predicted using landscape models, while Nilgai and Wild Pig abundance is mapped using camera trap photo captures for informed management decisions. Management interventions are necessary for prey management and population increase. Chital abundance is predicted across all ranges of the reserve, although their density is generally low (Figure IV. 65). The highest density is predicted in the Singrampur range, followed by the Mohli and Nauradehi ranges. The highest Sambar density is predicted in the Singrampur range (Figure IV. 66), with other ranges showing very low density according to the landscape model. Wild Pig has the highest abundance in the Singpur range (Figure IV. 68), with lower abundance in surrounding ranges. Nilgai abundance is highest in the Singpur range, followed by Nauradehi, Jhapan, Sarra, and Mohli ranges (Figure IV. 67).

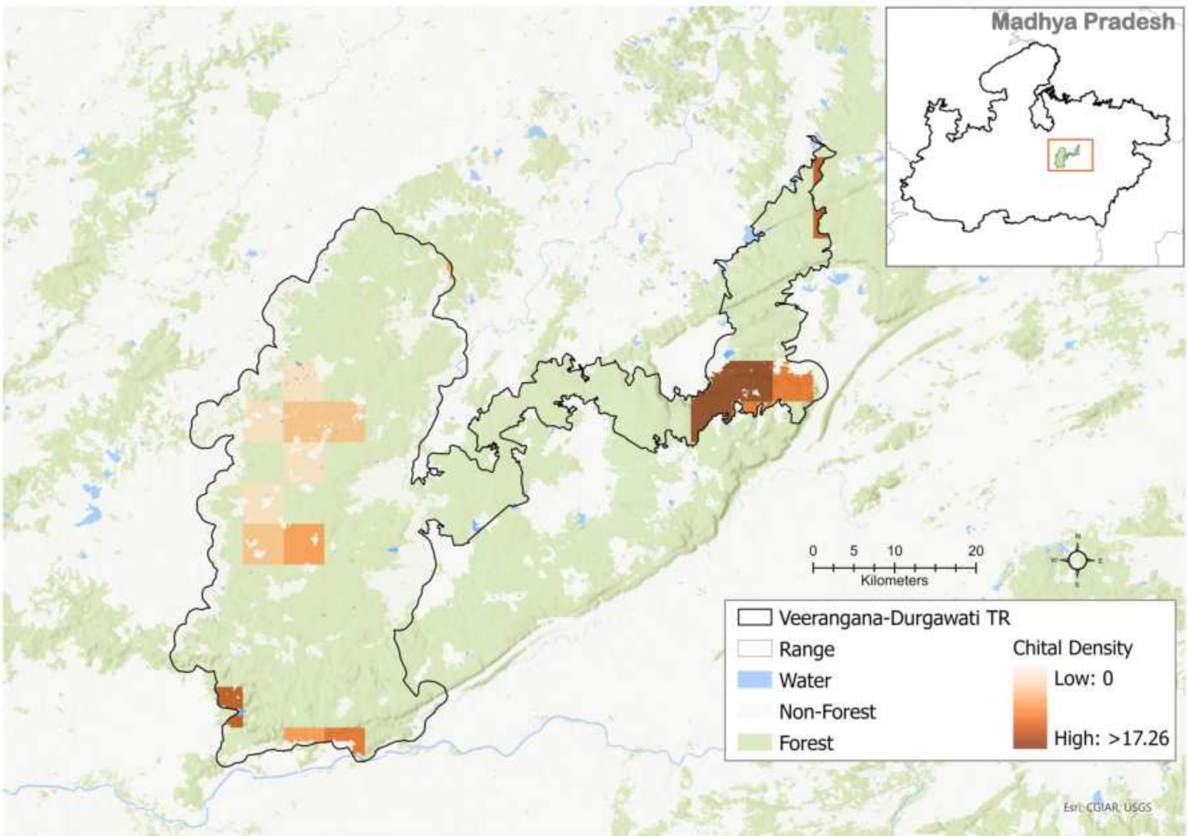

Figure IV. 65: Density of chital (per 25 km^2) in Veerangana Durgavati tiger reserve: Landscape-level DSM

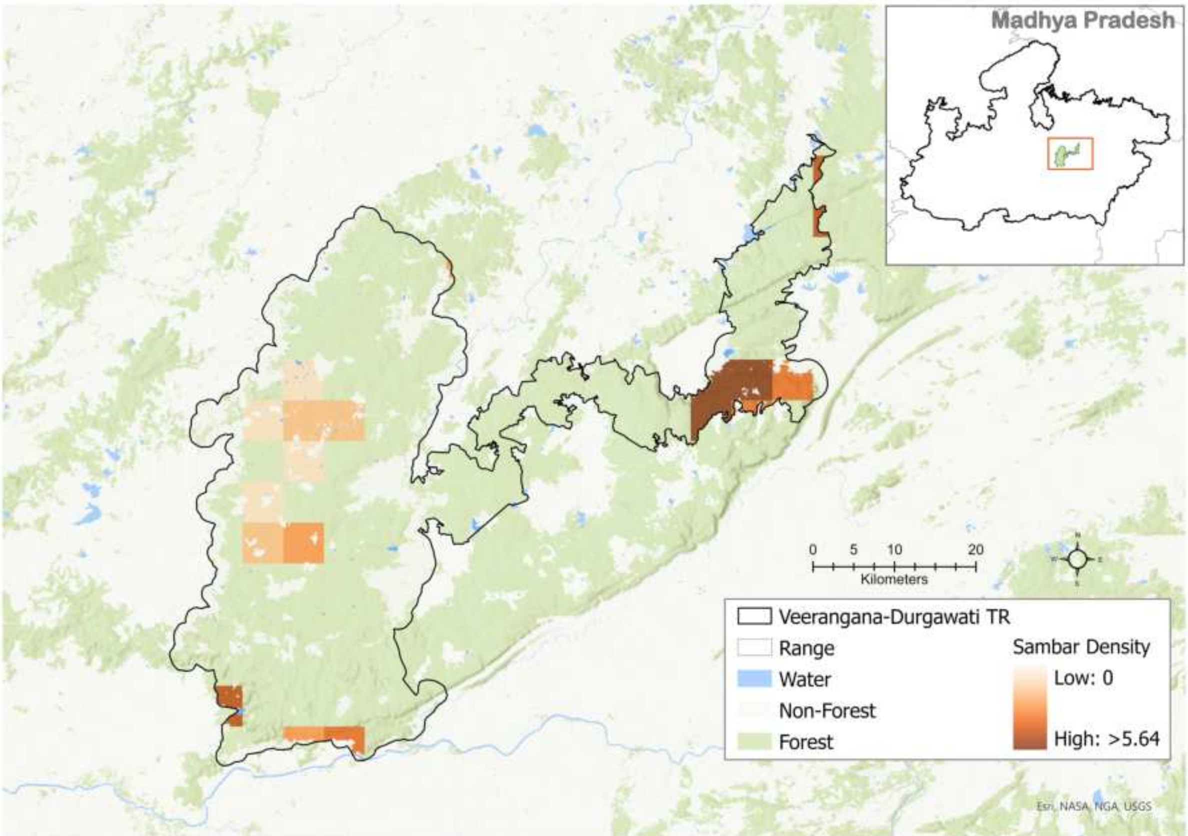

Figure IV. 66: Density of sambar (per 25 km²) in Veerangana Durgavati tiger reserve: Landscape-level DSM

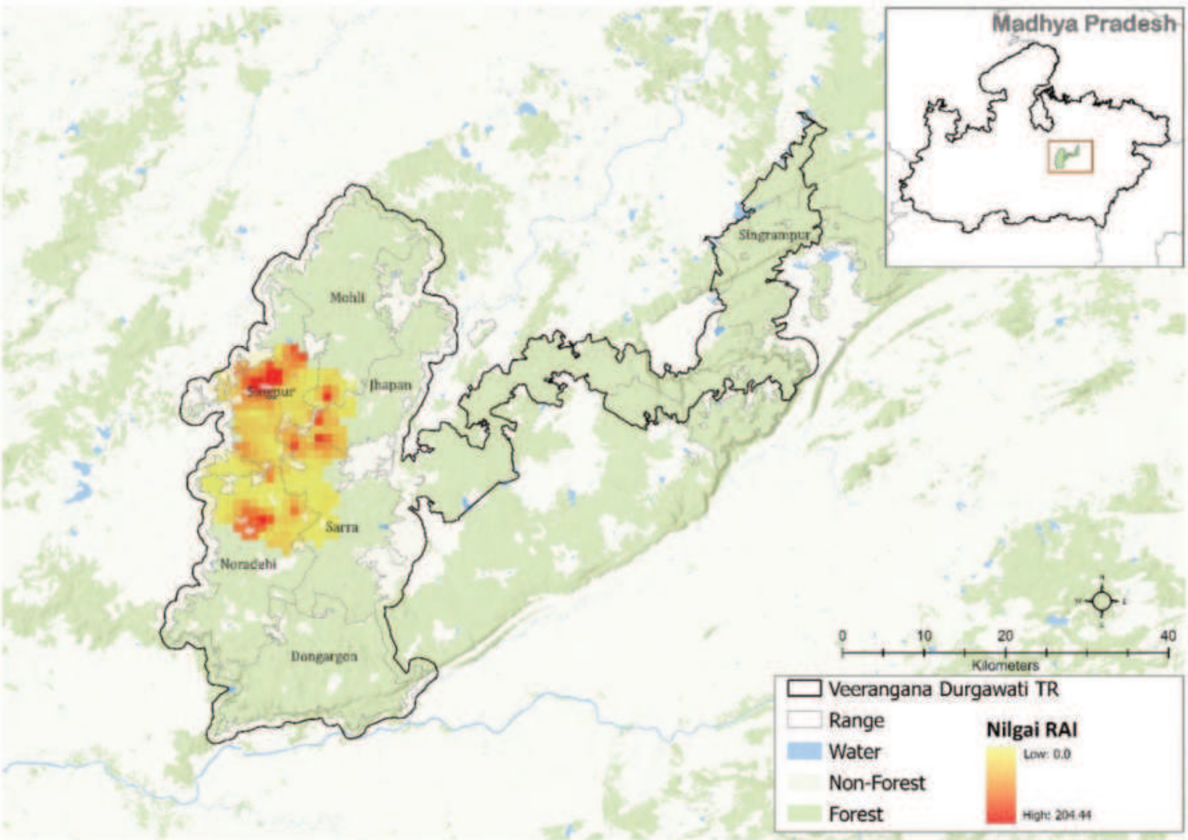

Figure IV. 67: Spatial relative abundance of nilgai in Veerangana Durgavati tiger reserve.

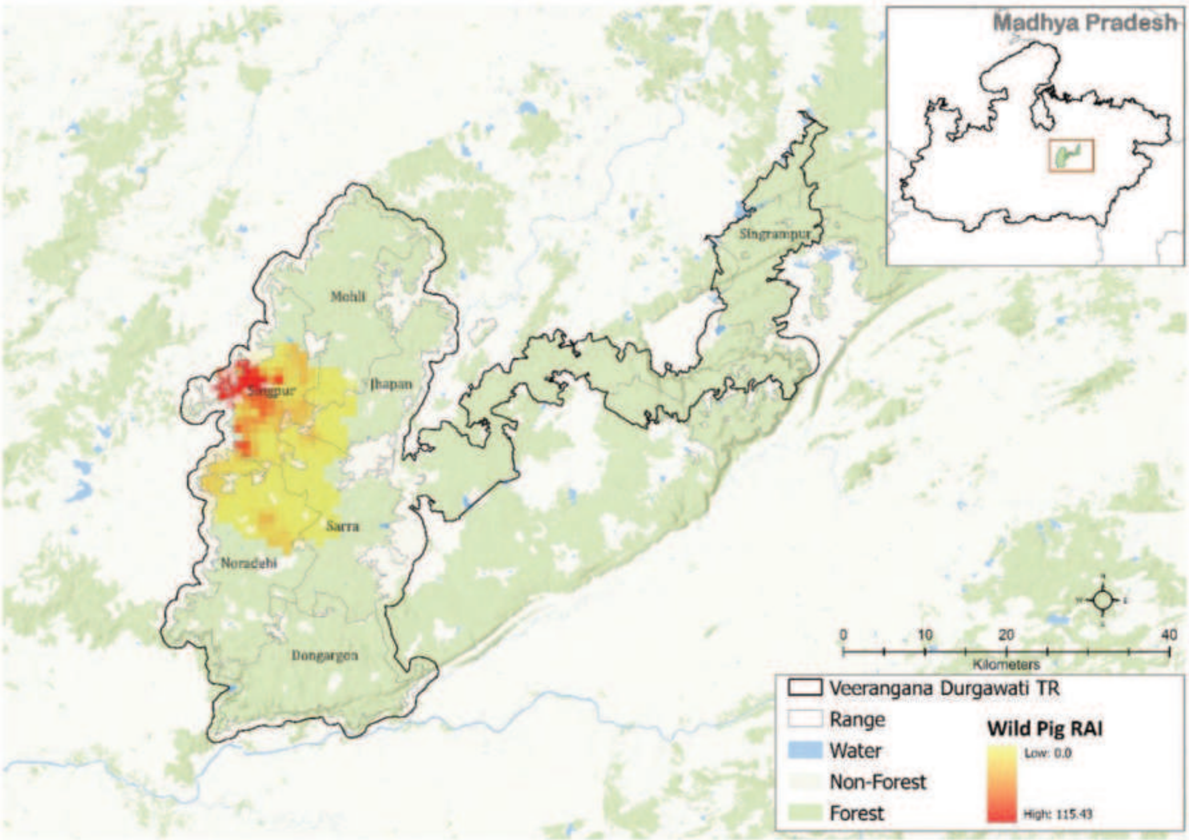

Figure IV. 68: Spatial relative abundance of wild pig in Veerangana Durgavati tiger reserve.

MAHARASHTRA

Bor Tiger Reserve

Bor tiger reserve, located in the Wardha district of Maharashtra, covering an area of approximately 816 km². Despite its size, it serves as a vital corridor connecting the Pench and Tadoba-Andhari Tiger Reserves. The reserve is characterized by dry deciduous forests interspersed with grasslands and riverine patches along the Bor River, with seasonal variations enhancing its biodiversity. It is home to a range of species, including tiger, leopard, dhole, sloth bear, gaur, sambar, and wild boar, along with a variety of birds and reptiles.

Due to insufficient observations of ungulates on line transects, the densities of chital and sambar were predicted using landscape models. The encounter rate for chital is 0.2043 (±0.1522) and for sambar is 0.2433 (±0.0638). Chital, the most abundant prey species in Bor, has its highest spatial density in the Bordharan range, followed by the Hingana and New Extended Bor ranges (Figure IV. 69). These areas can serve as source populations for supplementing chital in other ranges. Management efforts should focus on removing invasive plant species and creating additional habitat for ungulates.Sambar is present in moderate to low densities throughout the reserve, with the highest densities recorded in the New Extended Bor and Bordharan ranges (Figure IV. 70). Sambar populations also require management interventions, such as thinning undergrowth and promoting forest regeneration, to improve grazing opportunities and support population recovery.

Due to insufficient data, the spatial densities of chousingha, nilgai, and wild pigs were not estimated. Instead, their relative abundances were assessed using camera trap-based photo captures. Wild pigs are abundant in the Karanja, Hingana, and Kharangana ranges (Figure IV. 73). Nilgai are most abundant in the Bordharan range and in the peripheral areas of the Karanja and Kharangana ranges, while chousingha are primarily found in the New Extended Bor and Bordharan ranges (Figure IV. 72).

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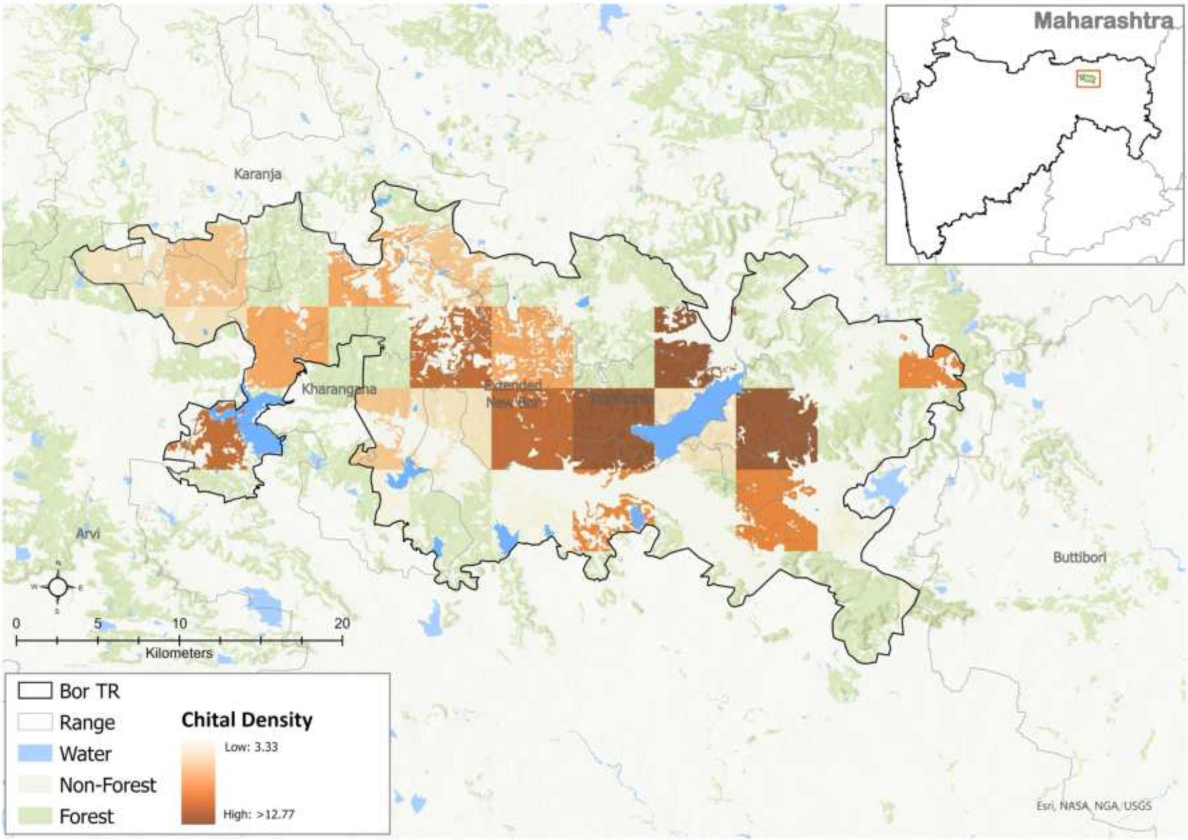

Figure IV. 69: Density of chital (per 25 km^2) in Bor tiger reserve: Landscape-level DSM

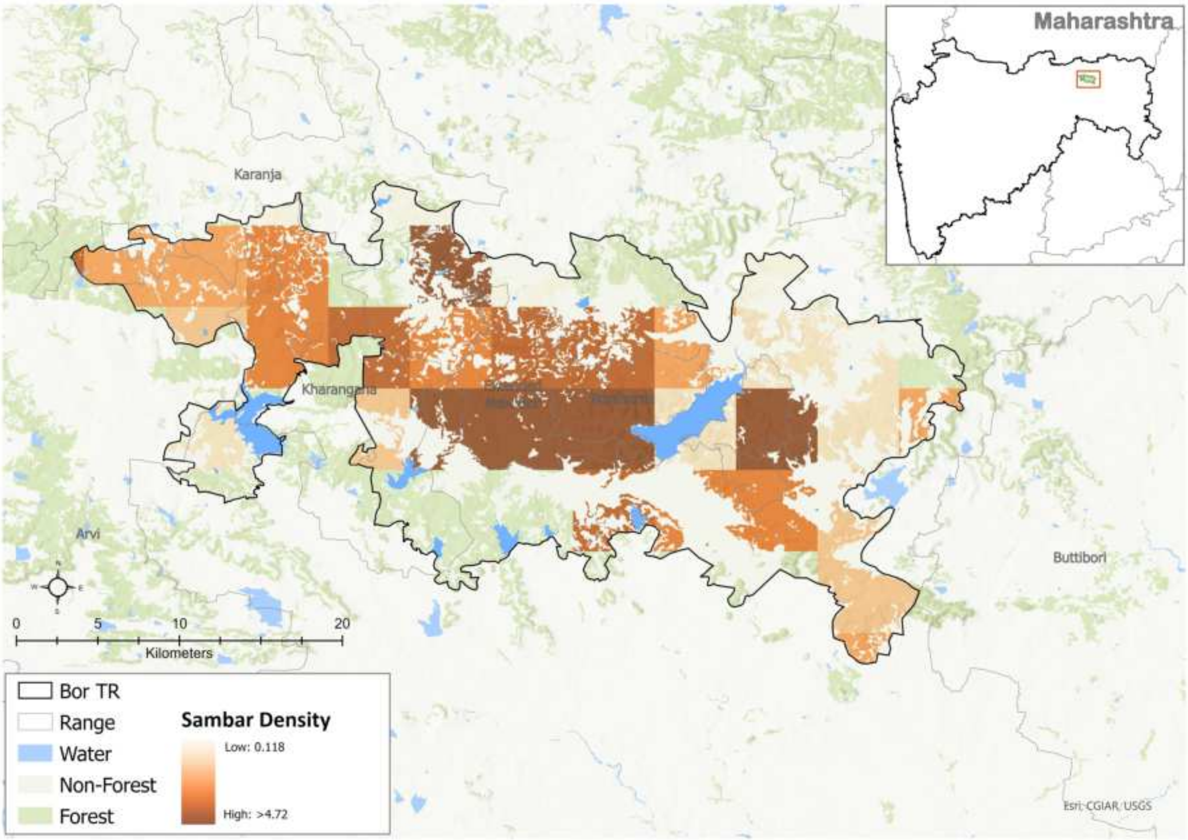

Figure IV. 70: Density of sambar (per 25 km^2) in Bor tiger reserve: Landscape-level DSM

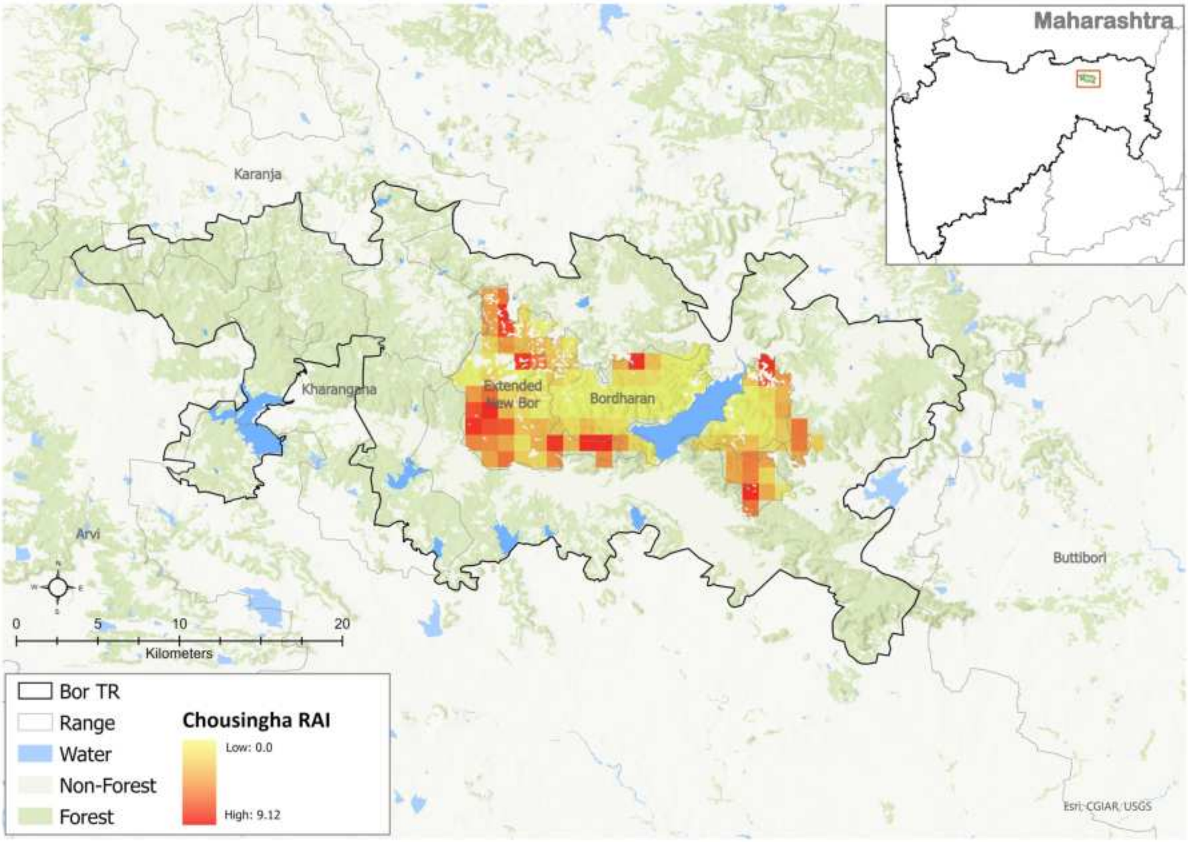

Figure IV. 71: Spatial relative abundance of chousingha in Bor tiger reserve.

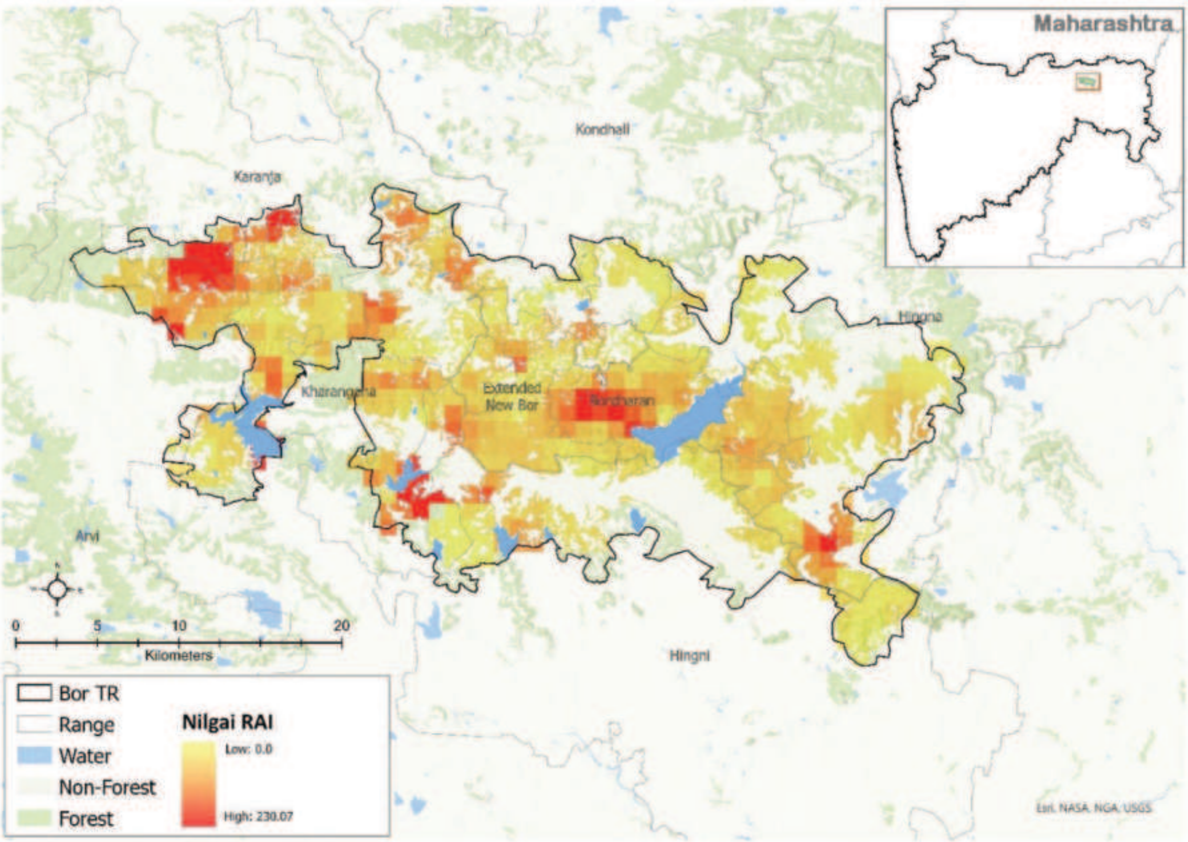

Figure IV. 72: Spatial relative abundance of nilgai in Bor tiger reserve.

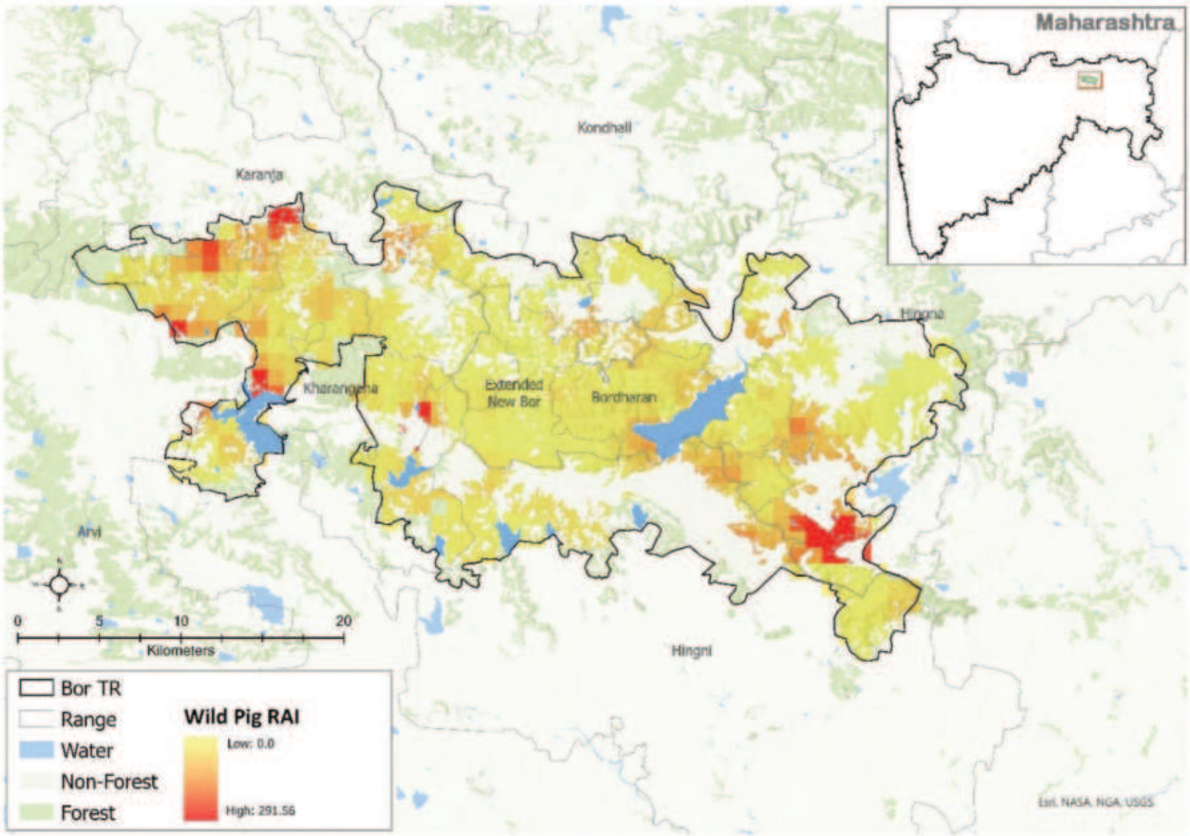

Figure IV. 73: Spatial relative abundance of wild pig in Bor tiger reserve.

Melghat Tiger Reserve

Melghat tiger reserve, located in the Amravati district of Maharashtra, spans approximately 2,768 km^2 and is a part of the Satpura Mountain Range. Its unique landscape, shaped by the convergence of the Deccan Plateau and the Satpura Hills, supports rich biodiversity. The reserve features a mosaic of tropical dry deciduous forests with dense teak forests, bamboo thickets, and grasslands (Kazi, 2012). Melghat is home to tigers, leopards, sloth bears, gaurs, dhole, chital, sambars, nilgai, chousingha, wild pigs, as well as various birds, reptiles, amphibians, and invertebrates.

Sambar is the most abundant prey species in Melghat (Table IV. 7). The highest densities of sambar are observed in the Dhargad, Akot, Narnala, and Somthana ranges, followed by the Dhakna and Chikhaldhara ranges (Figure IV. 75). Chital populations are relatively sparse across the reserve, with higher densities recorded in the Dhargad, Dhulghat, Somthana, Narnala, and Wan ranges, followed by Akot and Dhakna (Table IV. 7, Figure IV. 74). Population supplementation in suitable ranges could enhance their numbers further. Voluntary village relocation from inside tiger reserve can create more inviolate areas to the wild animals.

Gaurs occur at moderate densities (Table IV. 7), with the highest concentrations in the Chikhaldhara and Semadoh ranges, followed by the Dhargad, Dhakna, Tarubanda, Akot, and Jamli ranges (Figure IV. 77). Nilgai populations are also moderate, with dense distributions in the Somthana, Narnala, and Dhargad ranges, as well as in peripheral areas throughout the reserve (Figure IV. 78). Barking deer are present at low densities (Table IV. 7), with the highest densities recorded in the Dhargad range, followed by Akot, Somthana, Narnala, and Chikhaldhara. The species also occurs in significant numbers in the peripheral areas of Sonala, Ghatang, Jarida, Hatru, and the fringe forests of the Gavilgad range. Wild pigs are well-distributed across the reserve, with the highest densities observed along the periphery, particularly in the Somthana, Narnala, and Akot ranges, followed by Dhargad and Jarida (Figure IV. 79).

Table IV. 7: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Melghat Tiger Reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (DSM) (SE)
Barking	156	0.065 (0.005)	0.22 (0.02)	1.33 (0.04)	0.72 (0.08)	0.96 (0.1)
Chital	32	0.013 (0.002)	0.69 (0.14)	5.63 (1.01)	0.19 (0.05)	1.04 (0.23)
Gaur	56	0.023 (0.003)	0.32 (0.05)	3.14 (0.47)	0.28 (0.06)	1.03 (0.16)
Nilgai	241	0.1 (0.006)	0.28 (0.02)	4.54 (0.35)	1.01 (0.09)	4.24 (0.31)
Sambar	199	0.083 (0.006)	0.55 (0.03)	2.61 (0.13)	0.83 (0.08)	2.21 (0.16)
Wild pig	132	0.055 (0.005)	0.31 (0.03)	6.08 (0.59)	0.6 (0.08)	4.49 (0.36)

B)

Species	Chital	Sambar	Barking deer	Gaur	Wild pig	Nilgai
Detection model	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	14.992	5.667	12.49	8.427	8.648	13.4
s(Aridity)	-	-	-	1	-	-
s(NDVI Pre-Monsoon)	-	2.876	-	-	1.005	-
s(NDVI Post-Monsoon)	-	-	1	-	-	-
s(NDVI difference)	1	-	-	-	-	1.01
s(Ruggedness)	3.842	-	-	-	-	-

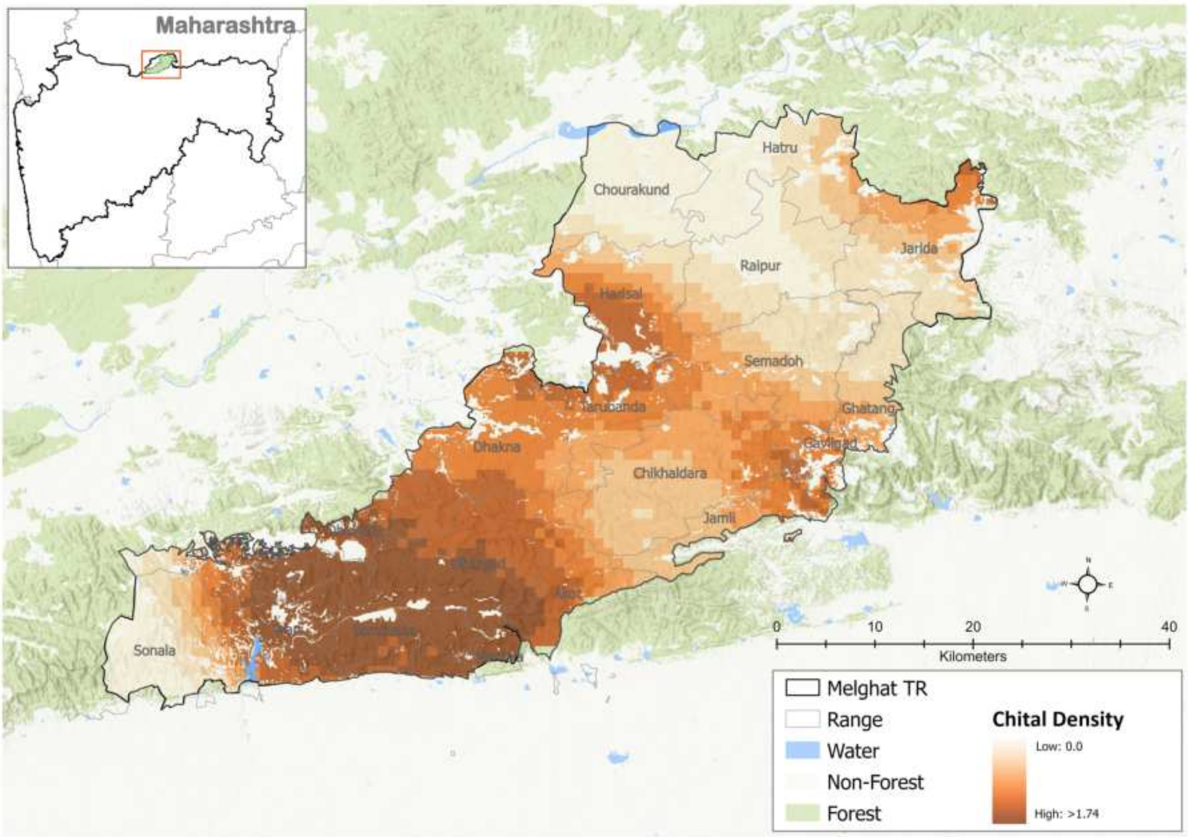

Figure IV. 74: Density of chital (per km²) in Melghat Tiger Reserve: Site-level DSM

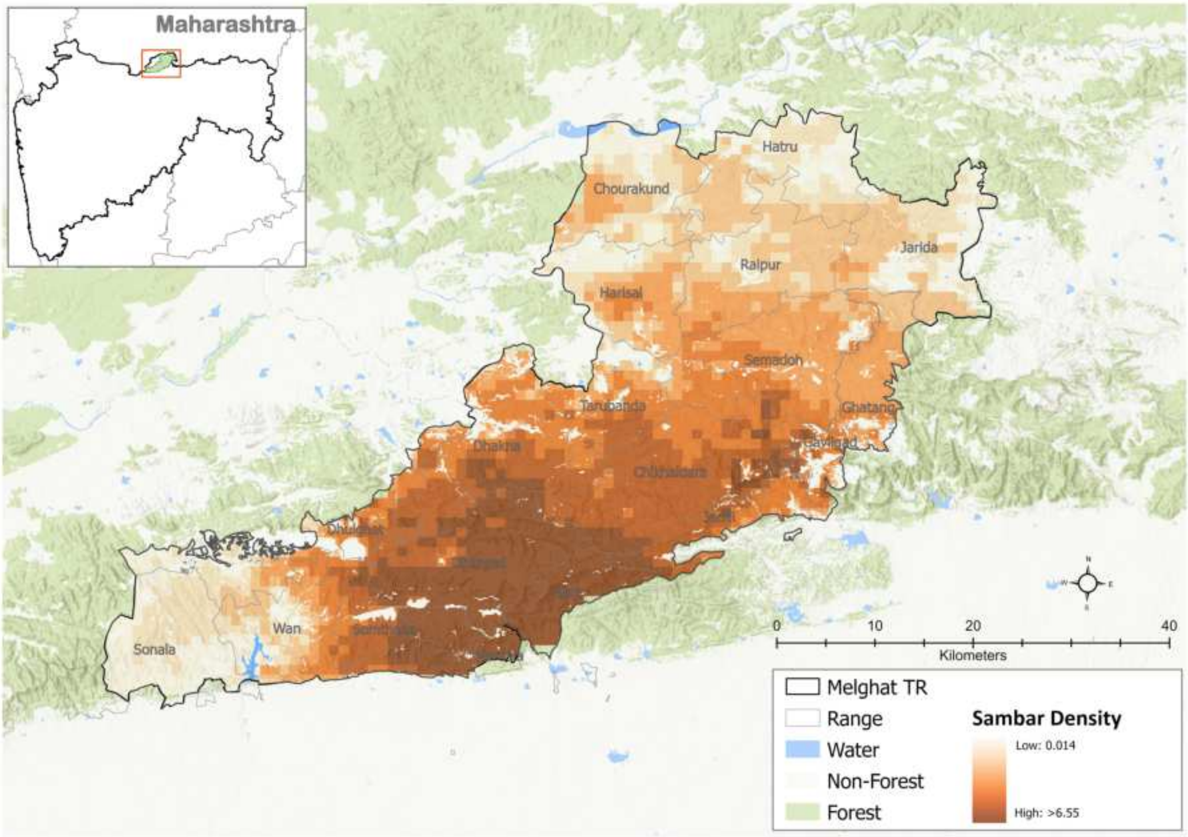

Figure IV. 75: Density of sambar (per km^2) in Melghat tiger reserve: Site-level DSM

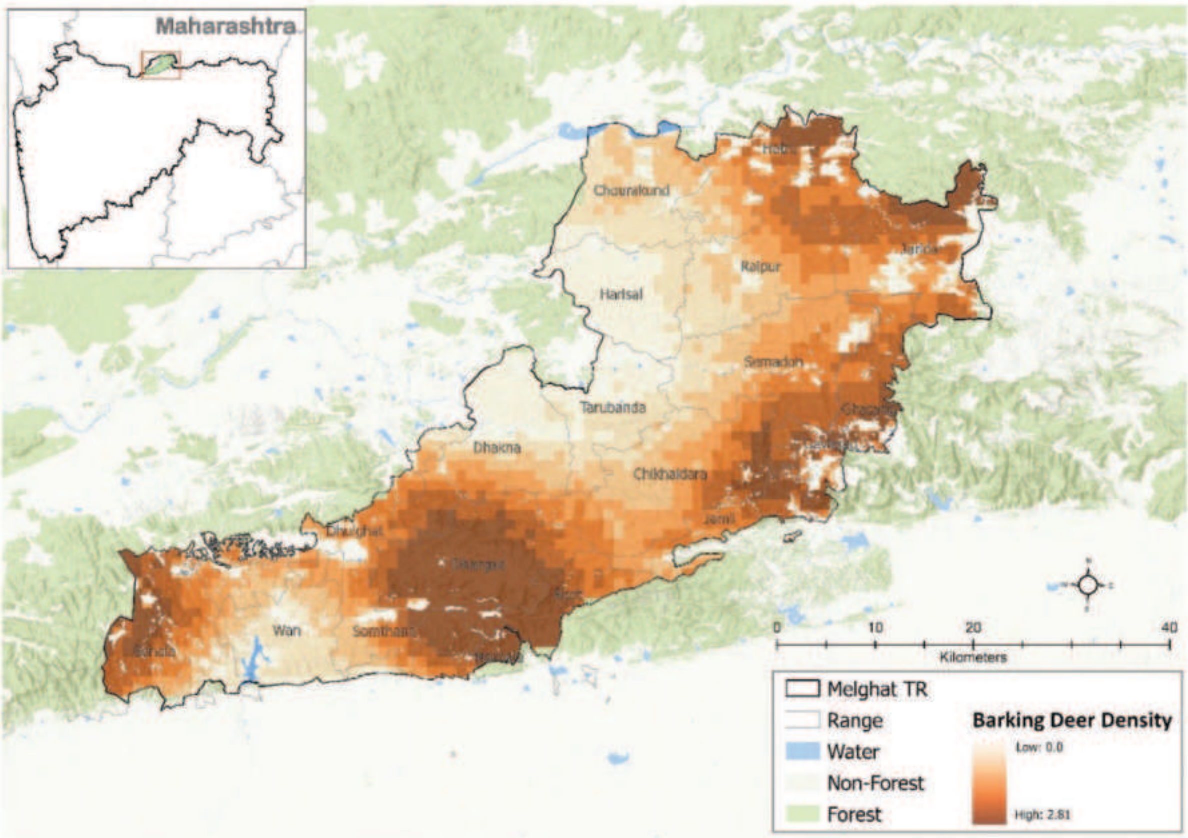

Figure IV. 76: Density of barking deer (per km^2) in Melghat tiger reserve: Site-level DSM

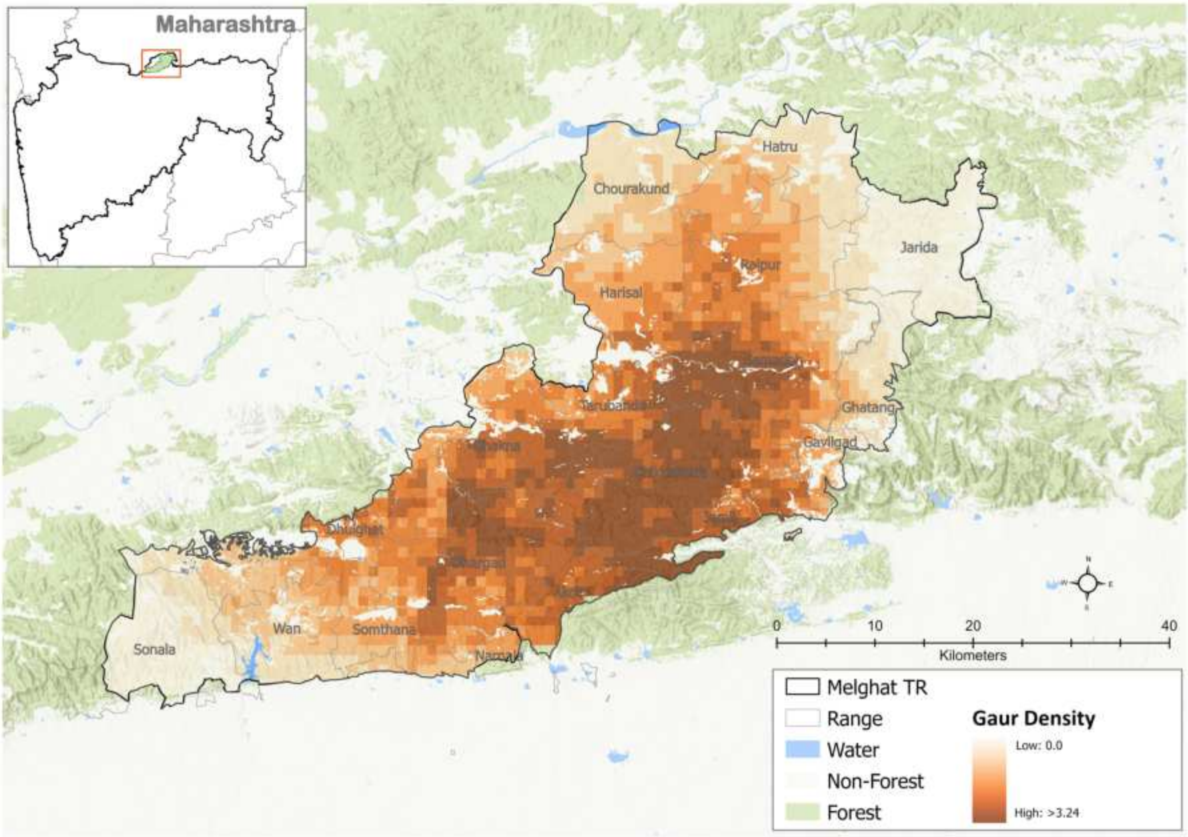

Figure IV. 77: Density of gaur (per km²) in Melghat tiger reserve: Site-level DSM

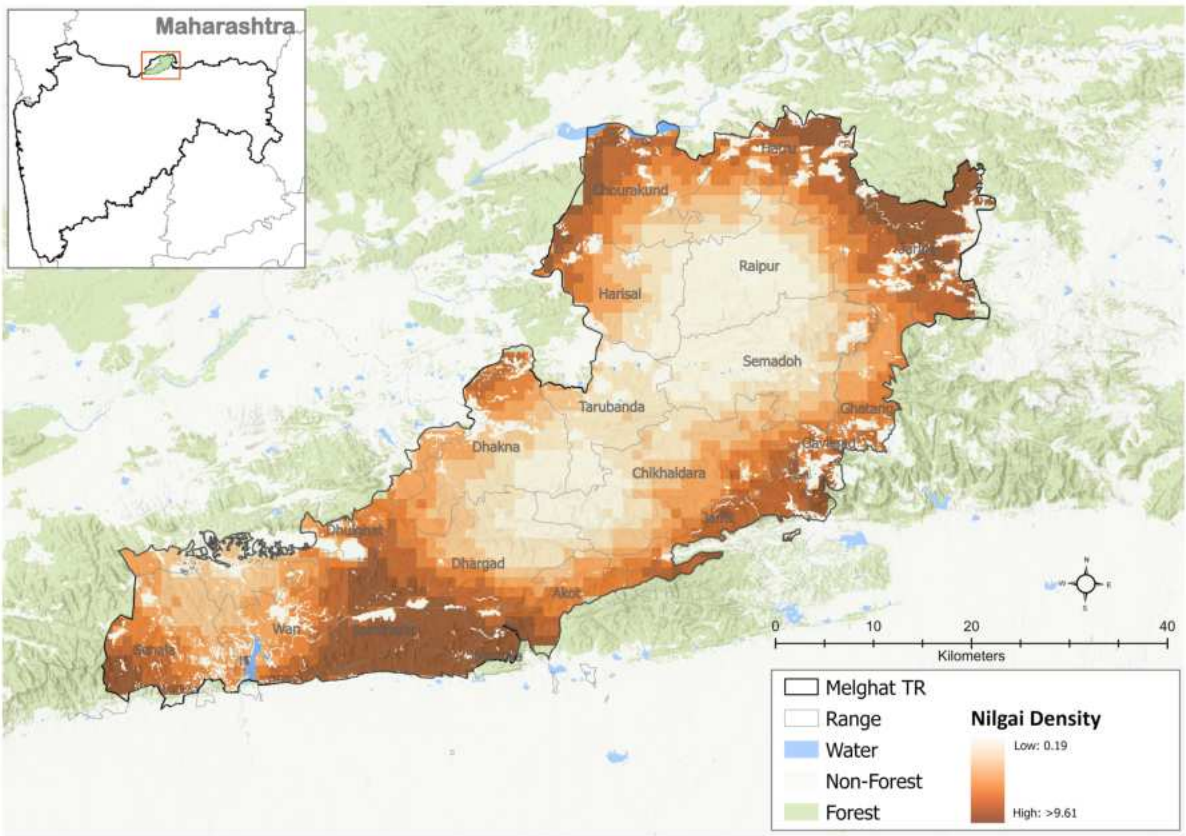

Figure IV. 78: Density of nilgai (per km²) in Melghat tiger reserve: Site-level DSM

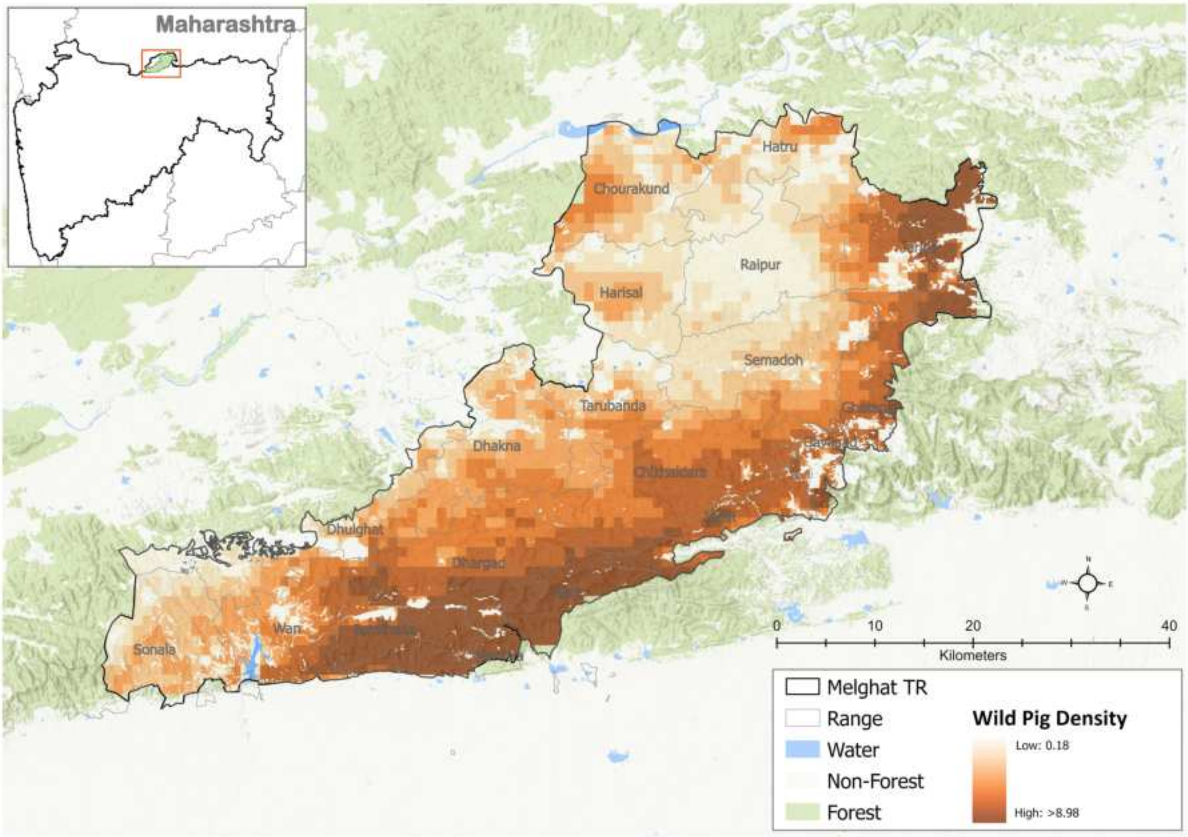

Figure IV. 79: Density of wild pig (per km^2) in Melghat tiger reserve: Site-level DSM

Nawegaon Nagzira Tiger Reserve

Navegaon Nagzira tiger reserve, established in 2013, is located in the Gondia and Bhandara districts of Maharashtra and spans approximately 1,895 km². Nestled within the Nagzira Hills of the Satpura Range, the reserve lies at the intersection of the Deccan Plateau and the Central Indian Highlands. Its vegetation reflects the region's transitional climate, bridging the arid landscapes of the west and the humid forests of the east. The reserve has a rich diversity of habitats, including tropical dry deciduous forests (Champion and Seth 1968) with Sal and Teak woodlands, bamboo groves, and several reservoirs. Navegaon Nagzira is home to a variety of fauna, including tiger, leopard, dhole, jungel cat, jackal, sloth bear, Indian wolf, sambar, chital, gaur, nilgai, chousingha, chinkara, wild pig and a wide range of birds, reptiles, and insects.

NNTR has very low detections in line transects, making it impossible to analyse the data effectively. The encounter rate for chital is 0.0292 (±0.0083) and for sambar is 0.0146(±0.0061). Therefore, the abundance of chital and sambar was estimated using a landscape prediction model, while the abundance of gaur, nilgai, wild pig, and barking deer was assessed using relative abundance derived from camera trap data.

The landscape prediction model indicates that chital are present in all ranges of NNTR (Figure IV. 80). Highest density is predicted in the Pitezari range, followed by the Nagzira and Koka ranges. The eastern part of the tiger reserve, including the Navegaon, Dongargaon, and Bondae ranges, shows very low chital density. The prediction for sambar density indicates the highest density in the Nagzira range, followed by the Pitezari and Umarzari ranges (Figure IV. 81). Relative abundance based on camera trap photos shows that gaur have the highest abundance in the Navegaon range, with low abundance recorded in other ranges (Figure IV. 83). Wild pig abundance is higher near village areas along the fringes of NNTR. Similarly, nilgai abundance is greater in the buffer zones (Figure IV. 85). Barking deer are very rare in NNTR, with captures recorded in only a few areas, including the Navegaon and Bondae ranges (Figure IV. 82). Although, different areas of NNTR have varying availability of prey species, their overall abundance is low. Consequently, prey recovery efforts are essential for the tiger reserve.

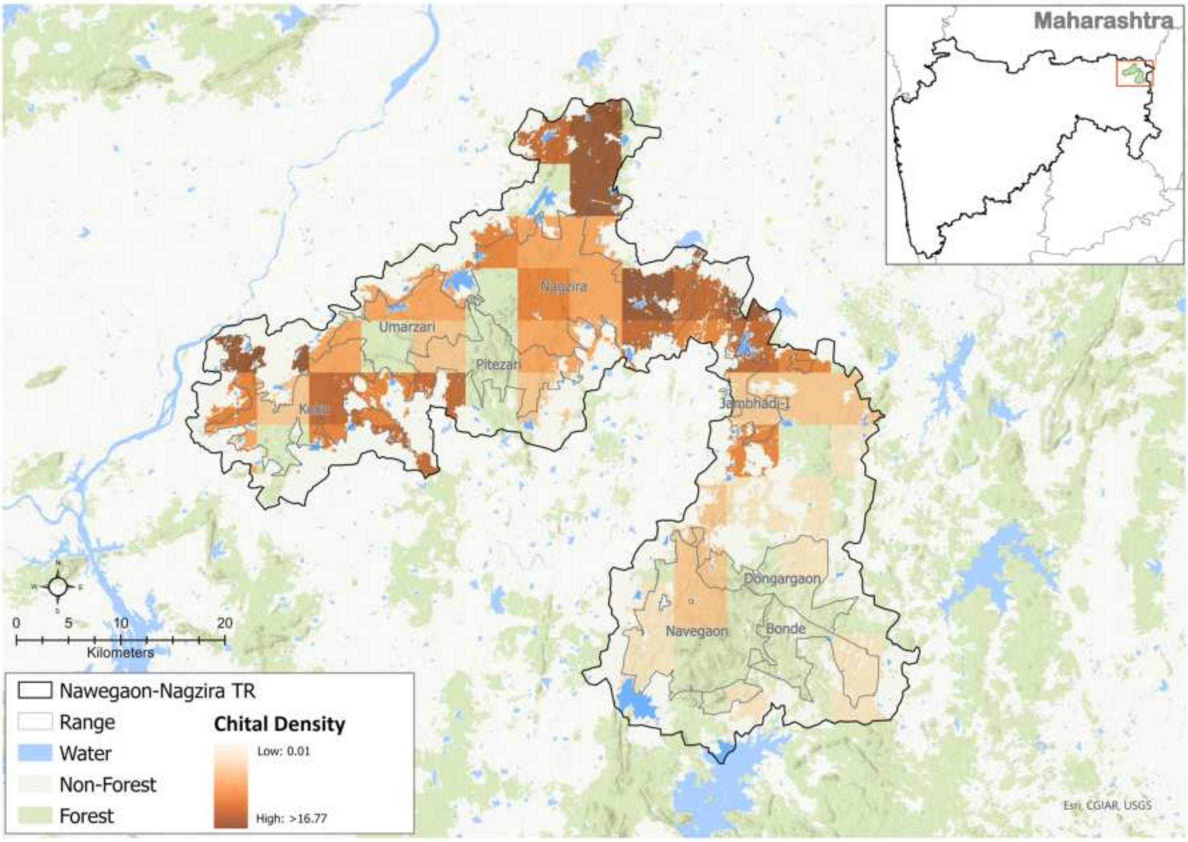

Figure IV. 80: Density of chital (per 25 km^2) in NNTR: Landscape-level DSM

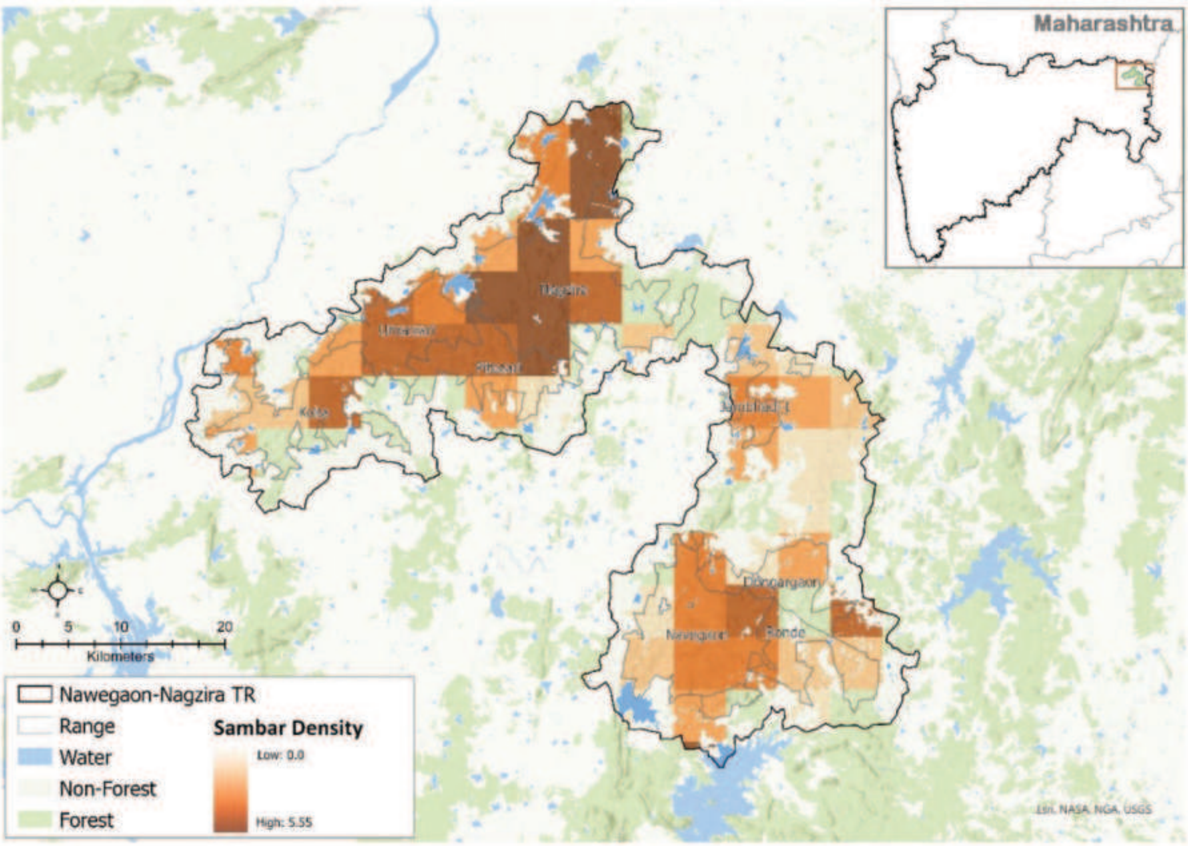

Figure IV. 81: Density of sambar (per 25 km^2) in NNTR: Landscape-level DSM

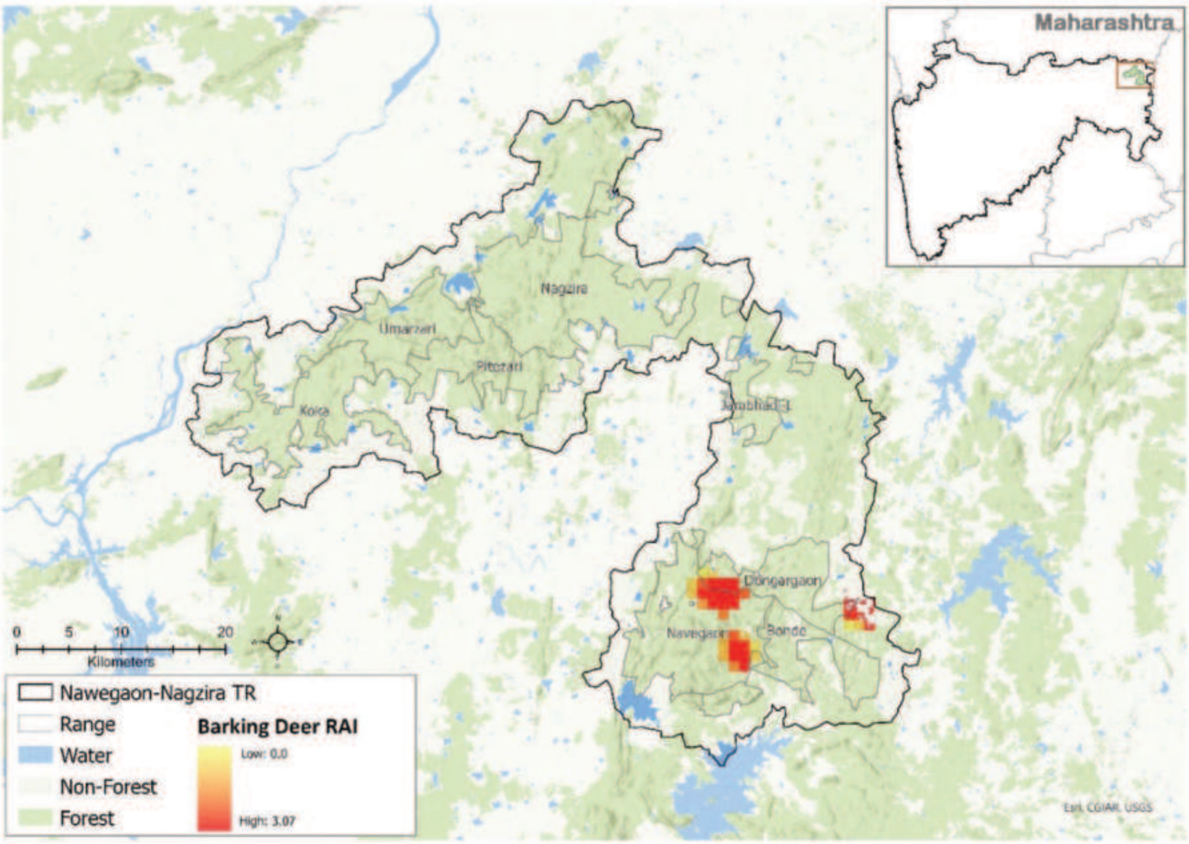

Figure IV. 82: Spatial relative abundance of baking deer in NNTR.

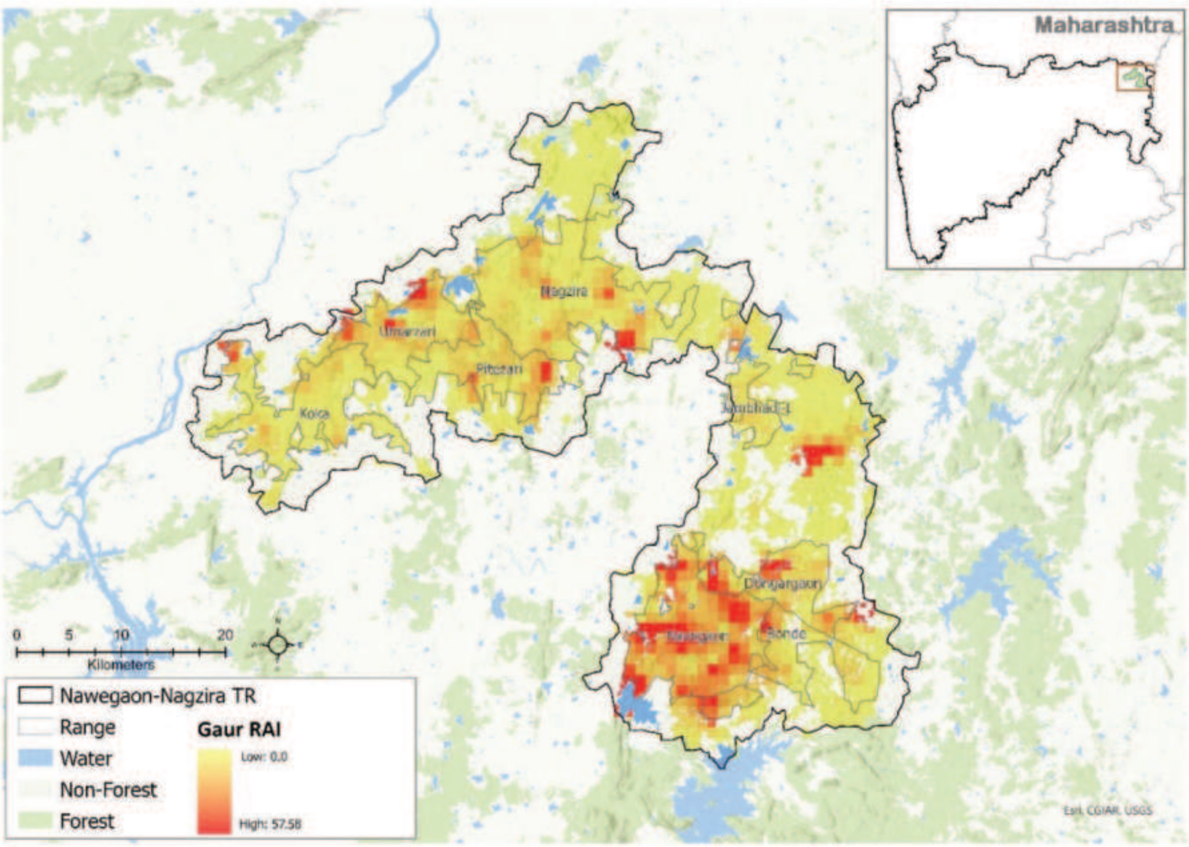

Figure IV. 83: Spatial relative abundance of gaur in NNTR.

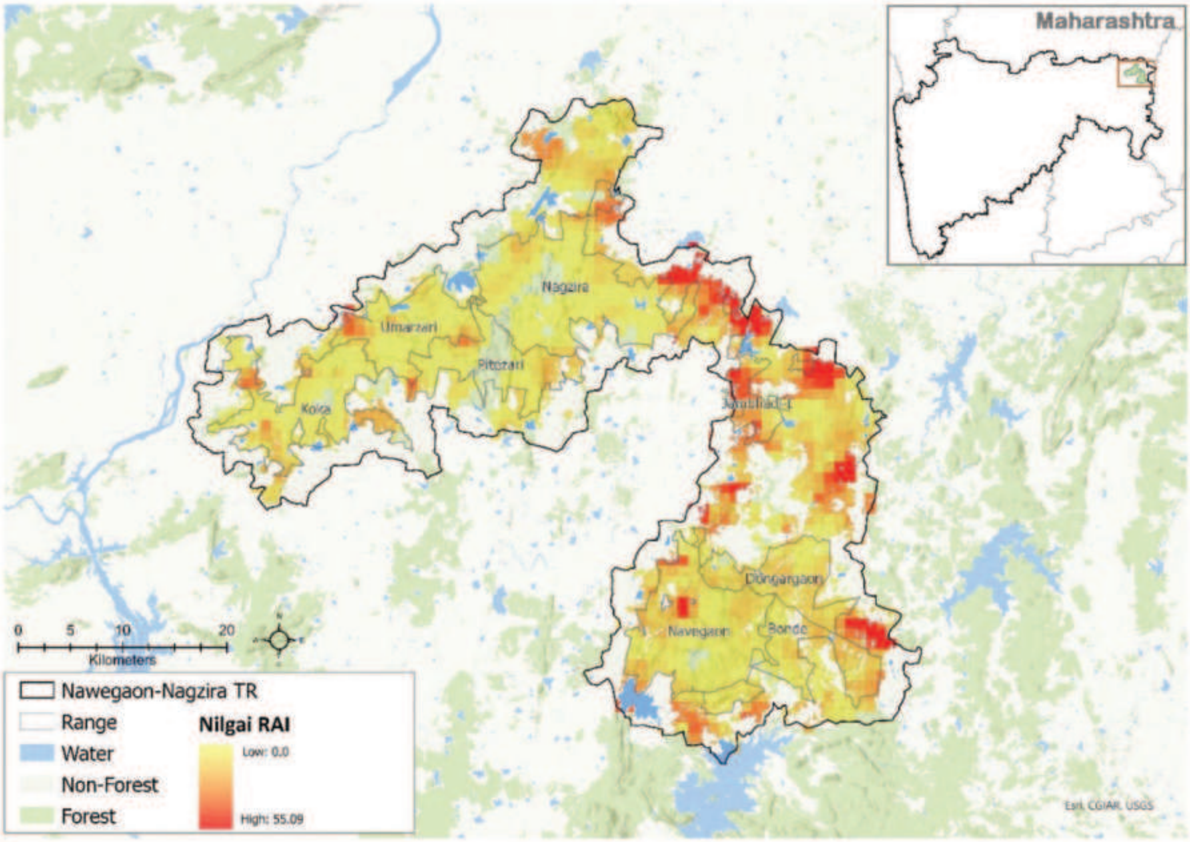

Figure IV. 84: Spatial relative abundance of nilgai in NNTR.

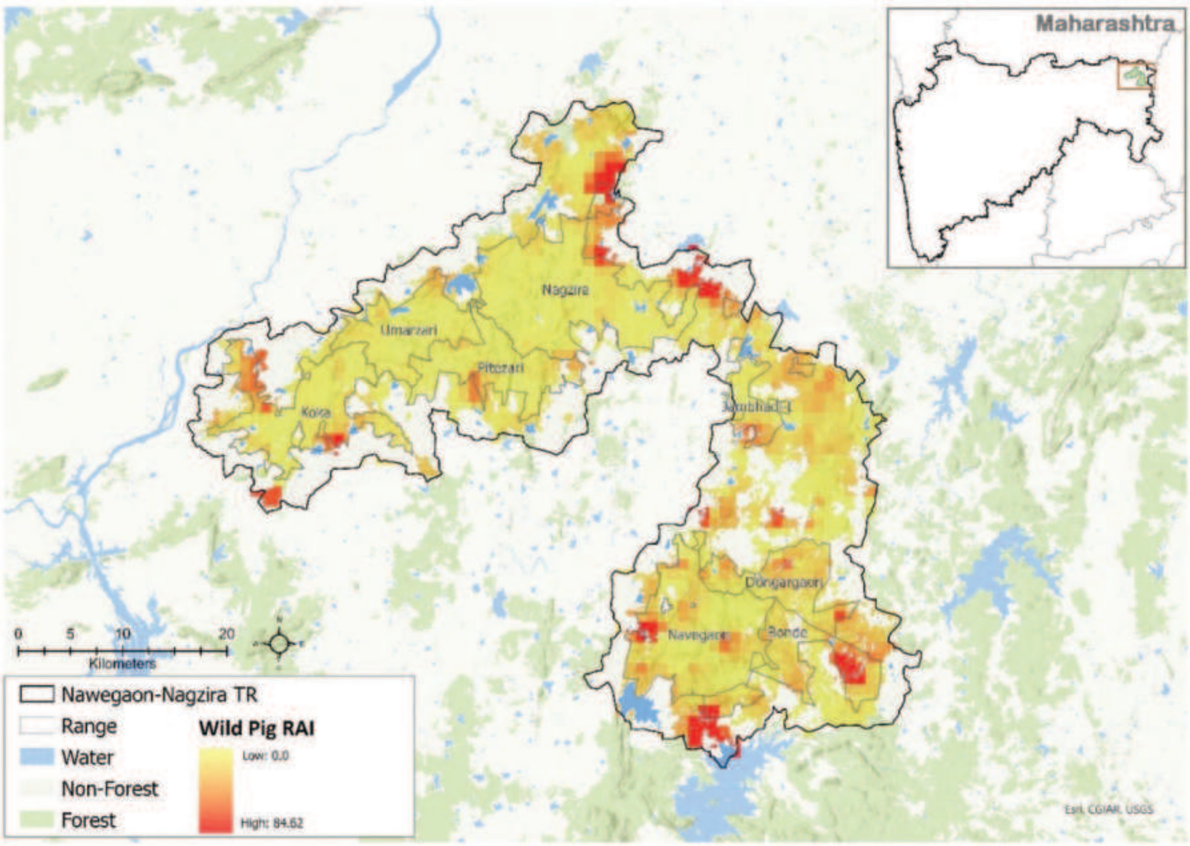

Figure IV. 85: Spatial relative abundance of wild pig in NNTR.

Pench Tiger Reserve - Maharashtra

Pench (MH) tiger reserve, located in the Nagpur district of Maharashtra, spans approximately 741 km^2. It is the southern part of the larger Pench landscape. This reserve is characterized by tropical dry deciduous forests (Champion and seth, 1968), dominated by species like teak, mahua, tendu, and bamboo, along with open grasslands and patches of dense undergrowth. The Pench River flows through its core, creating riparian zones that support diverse flora and fauna (Dudipala *et al.*, 2023). The reserve is home to tiger, leopard, wild dog, jackal, jungle cat, sloth bear, Indian wolf and a variety of ungulates including chital, sambar, nilgai, chousingha, muntjac, wild pig, and Indian gaur alongside over 310 bird species, including Malabar pied hornbills and crested hawk eagles.

The eastern side of the Pench River has a higher abundance of chital, sambar, and nilgai. Among these, chital is the most abundant prey species in Pench Maharashtra. The highest chital density is recorded in the Chorbawali range, followed by East Pench and Deolapar (Figure IV. 86). Sambar is also highly abundant in the East Pench, Chorbawali, and Deolapar ranges (Figure IV. 87). However, both chital and sambar density is low in the West Pench range, where management interventions are required. Nilgai are highly abundant in the eastern part of the tiger reserve and along the northern boundary of the West Pench range (Figure IV. 88). Due to insufficient observations of gaur, barking deer, and wild pig during line transects for spatial density analysis, their distribution was mapped using photo-capture data from camera traps. Gaur is sparsely present in the western ranges of Pench Maharashtra (Figure IV. 90), with the highest photo captures recorded in the West Pench range, and followed by Saleghat. The eastern ranges have very few photo captures of gaur. Barking deer were photo-captured in only a few pockets of the West Pench, East Pench, Nagalwadi, and Paoni ranges (Figure IV. 89). Wild pigs are present across all ranges of Pench Maharashtra, with the highest abundance recorded in the West Pench range (Figure IV. 91).

Table IV. 8: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Pench tiger reserve (Maharashtra).

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (DSM) (SE)
Chital	89	0.207 (0.022)	0.42 (0.04)	8.75 (0.87)	1.64 (0.24)	11.48 (1.25)
Nilgai	78	0.181 (0.02)	0.41 (0.04)	4.14 (0.51)	1.7 (0.26)	6.46 (0.79)
Sambar	58	0.135 (0.017)	0.43 (0.04)	3.09 (0.25)	1.29 (0.2)	3.61 (0.44)

B)

Species	Chital	Sambar	Nilgai
Detection model	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	18.176	11.848	16.8
s(Aridity)	1.954	-	-
s(NDVI Pre-Monsoon)	3.846	3.787	4.52
s(NDVI difference)	-	-	3.01

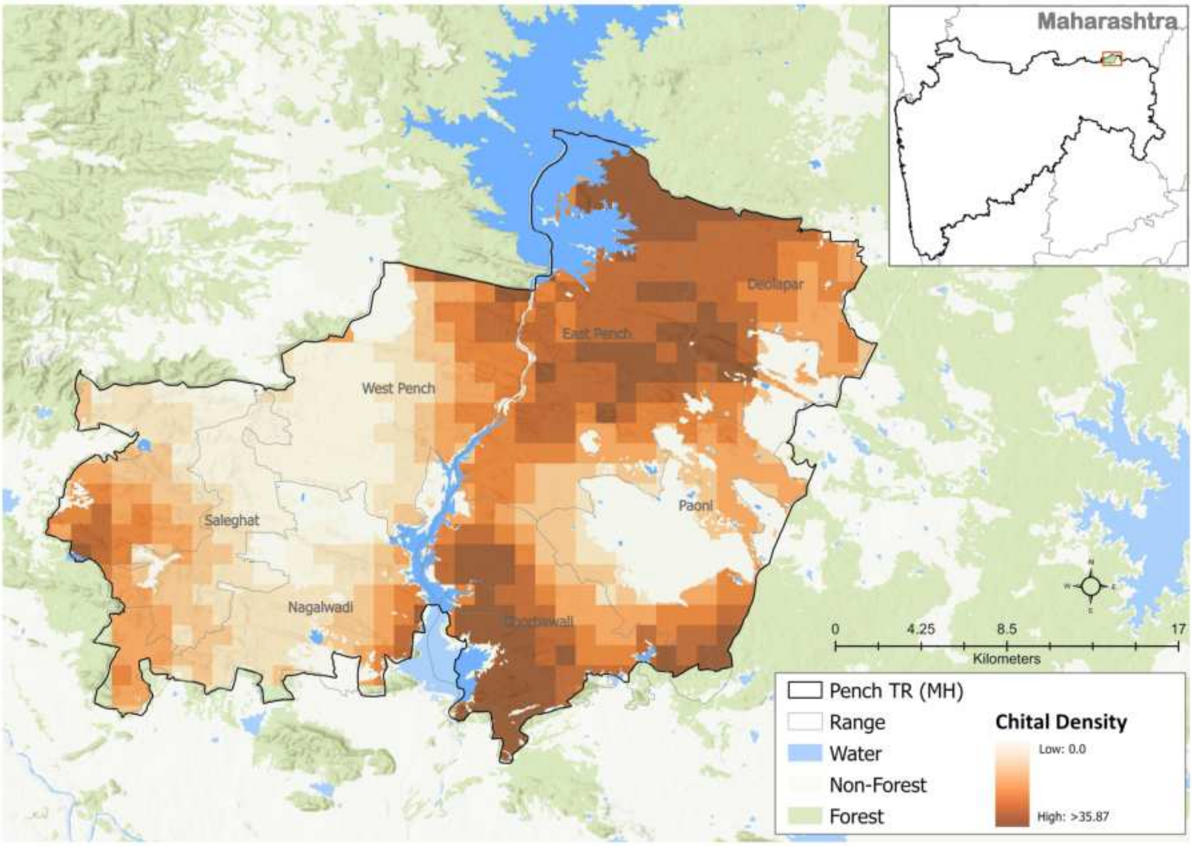

Figure IV. 86: Density of chital (per km²) in Pench tiger reserve (Maharashtra): Site-level DSM

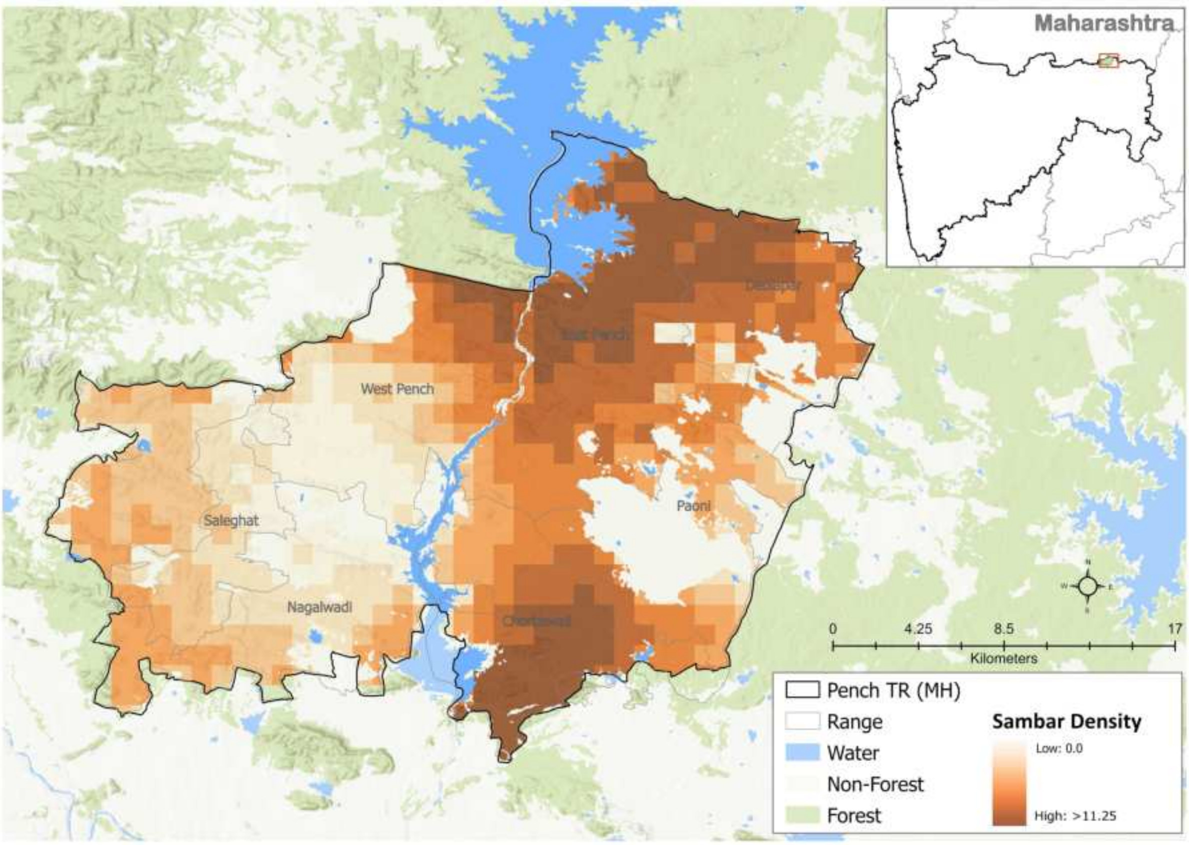

Figure IV. 87: Density of sambar (per km²) in Pench tiger reserve (Maharashtra): Site-level DSM

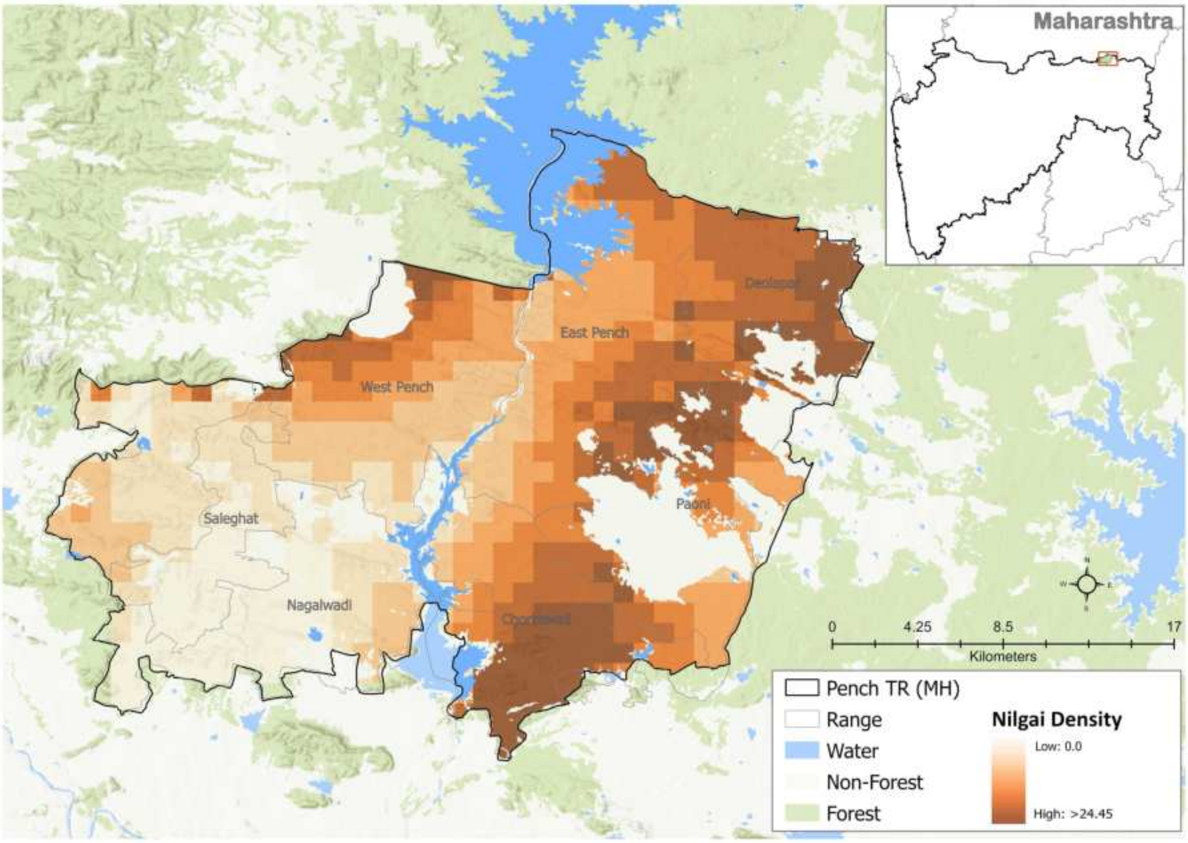

Figure IV. 88: Density of nilgai (per km^2) in Pench tiger reserve (Maharashtra): Site-level DSM

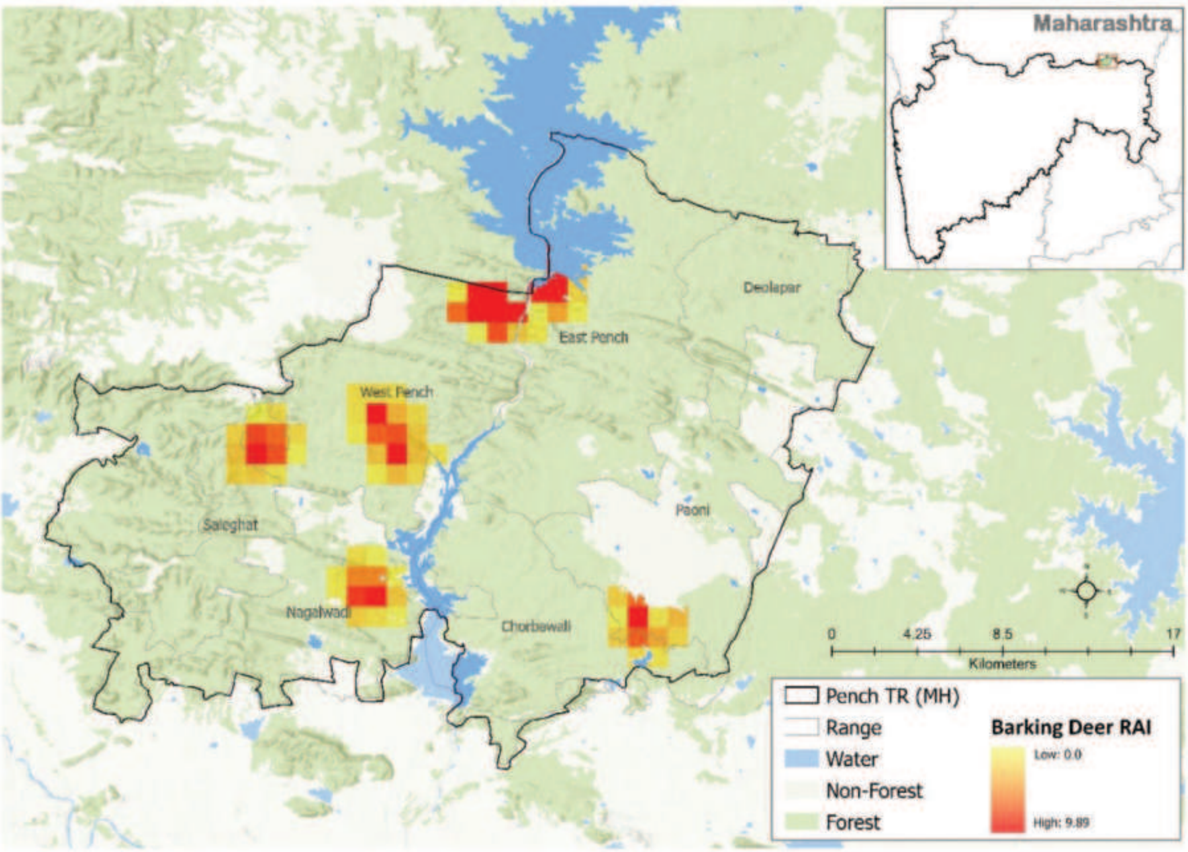

Figure IV. 89: Spatial relative abundance of baking deer in Pench tiger reserve (Maharashtra).

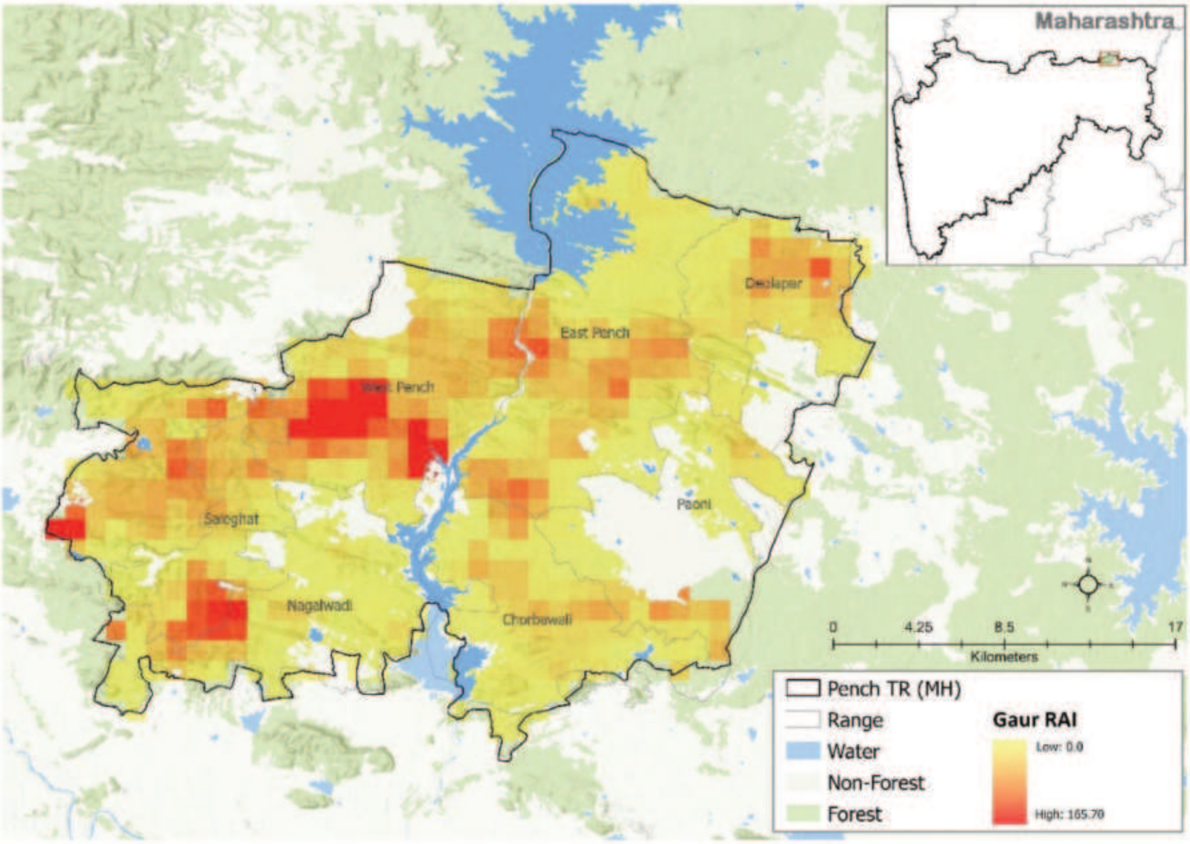

Figure IV. 90: Spatial relative abundance of gaur in Pench tiger reserve (Maharashtra).

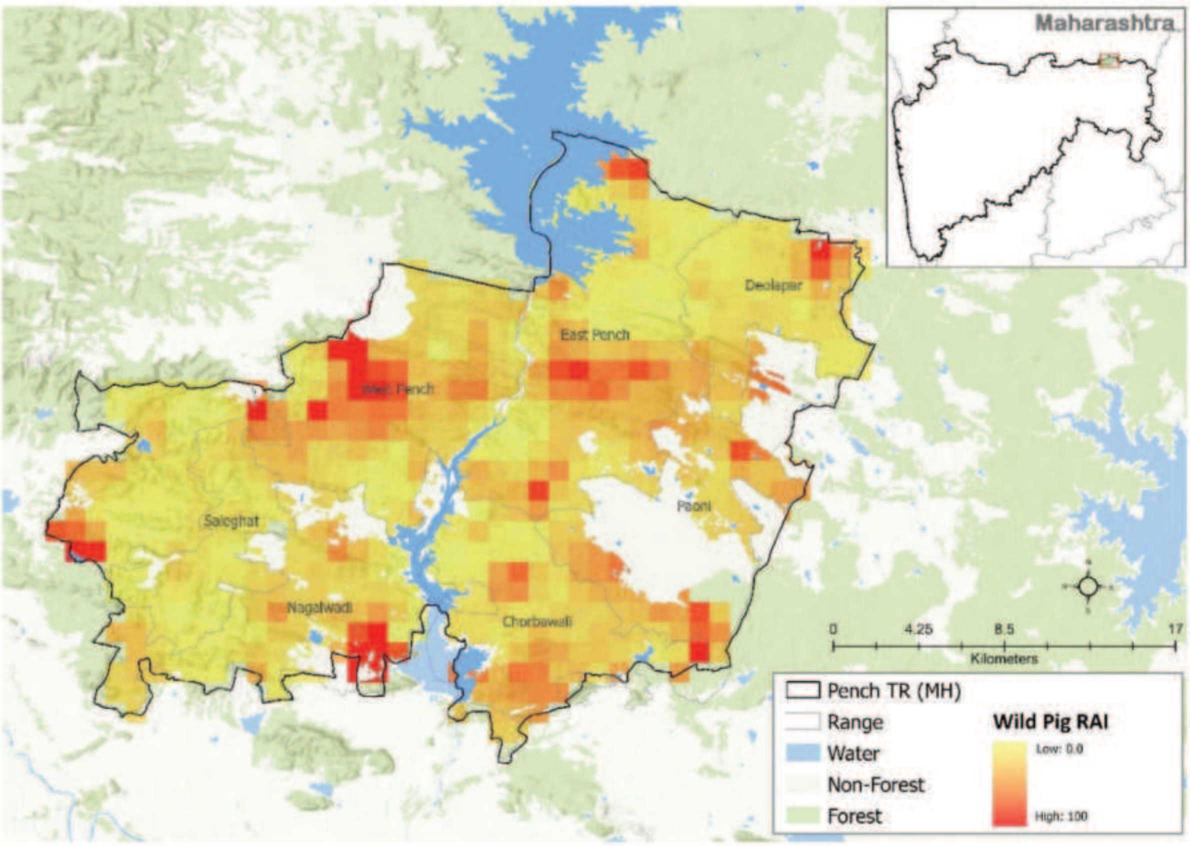

Figure IV. 91: Spatial relative abundance of wild pig in Pench tiger reserve (Maharashtra).

Sahyadri Tiger Reserve

Sahyadri tiger reserve, located in the Northern Western Ghats of Maharashtra, spans approximately 1,165 km^2 and comprises of Koyna Wildlife Sanctuary and Chandoli National Park. The landscape formed by basaltic rocks, this hilly terrain holds dry savannahs, mesic savannahs, dry deciduous forests, moist deciduous forests, and patches of montane rainforest, along with water systems fed by the Koyna River and its tributaries. It is home to a variety of flora and fauna, including the Bengal tiger, leopard, Indian gaur, sloth bear, and mouse deer, along with endemic species such as the Malabar civet, giant squirrel, and Indian pangolin.

Observations of Chital and Sambar in the line transects of Sahyadri are insufficient for analysis. The encounter rate for sambar is 0.0702 (±0.0348). Therefore, predictions are based on landscape models for these species. Spatial density of chital is predicted in a few areas of the Bamnoli and Koyna ranges (Figure IV. 92), while sambar is predicted across all ranges of the Sahyadri tiger reserve (Figure IV. 93). The habitat in Sahyadri is suitable for sambar, and management efforts are required for sambar population recovery.

Gaur is abundant in the Sahyadri Tiger Reserve, with the highest abundance in the Koyna and Bamnoli ranges, although other ranges also show high Gaur abundance (Figure IV. 94). Since data on barking deer and wild pig densities are deficient, their relative abundance is mapped using camera trap-based photo captures for informed decision-making. barking deer captures in Sahyadri are very low, and they are only recorded in a few patches of the Dhewawadi, Chandoli, Bamnoli, and Helwak ranges (Figure IV. 95). Koyna range has the lowest barking deer captures. Wild pig is also captured in only a few patches (Figure IV. 96), with the Chandoli range showing relatively better abundance.

Table IV. 8: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Sahyadri tiger reserve (Maharashtra).

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (DSM) (SE)
Gaur	43	1.95 (0.23)	0.63 (0.08)	0.216 (0.032)	2.44 (0.48)	5.05 (0.83)

B)

Species	Gaur
Detection model	Hazard rate (Null)
s(x,y)	3.738
s(NDVI Pre-Monsoon)	1.884

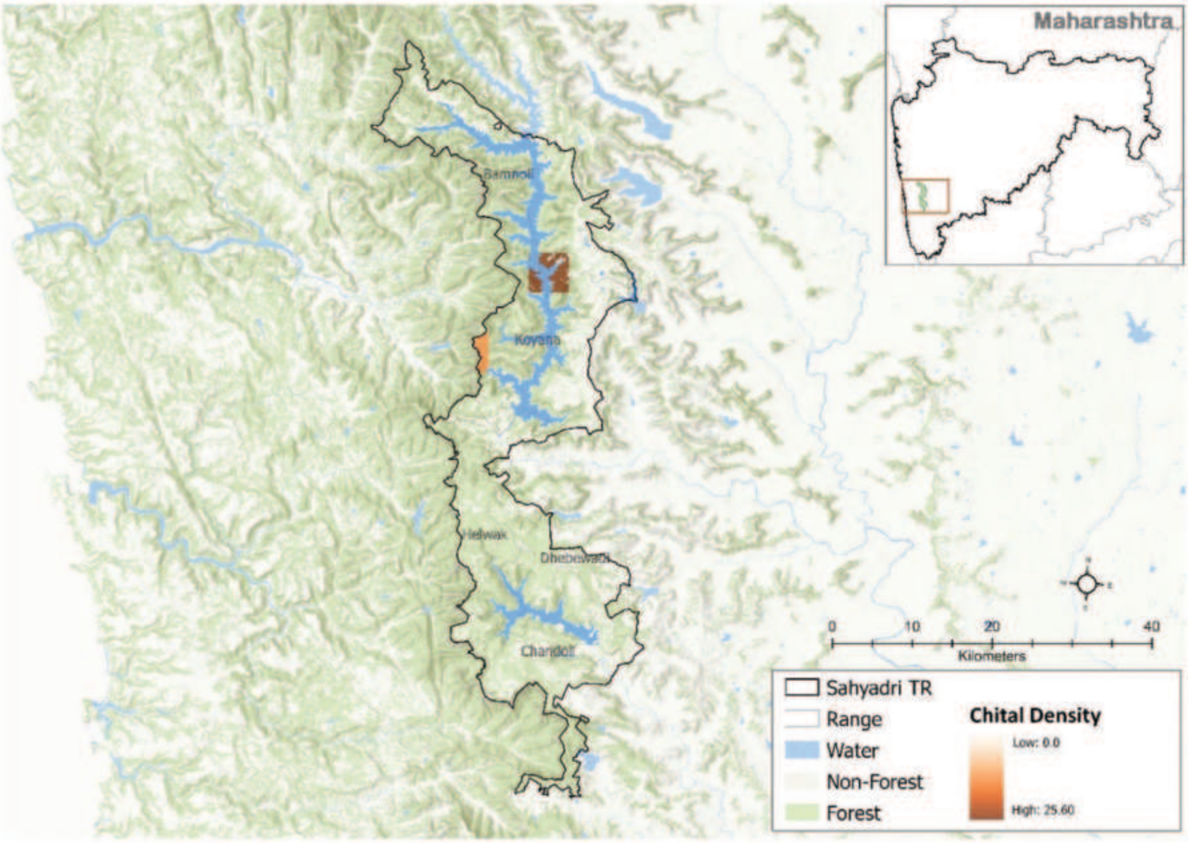

Figure IV. 92: Density of chital (per 25 km^2) in Sahyadri tiger reserve: Landscape-level DSM

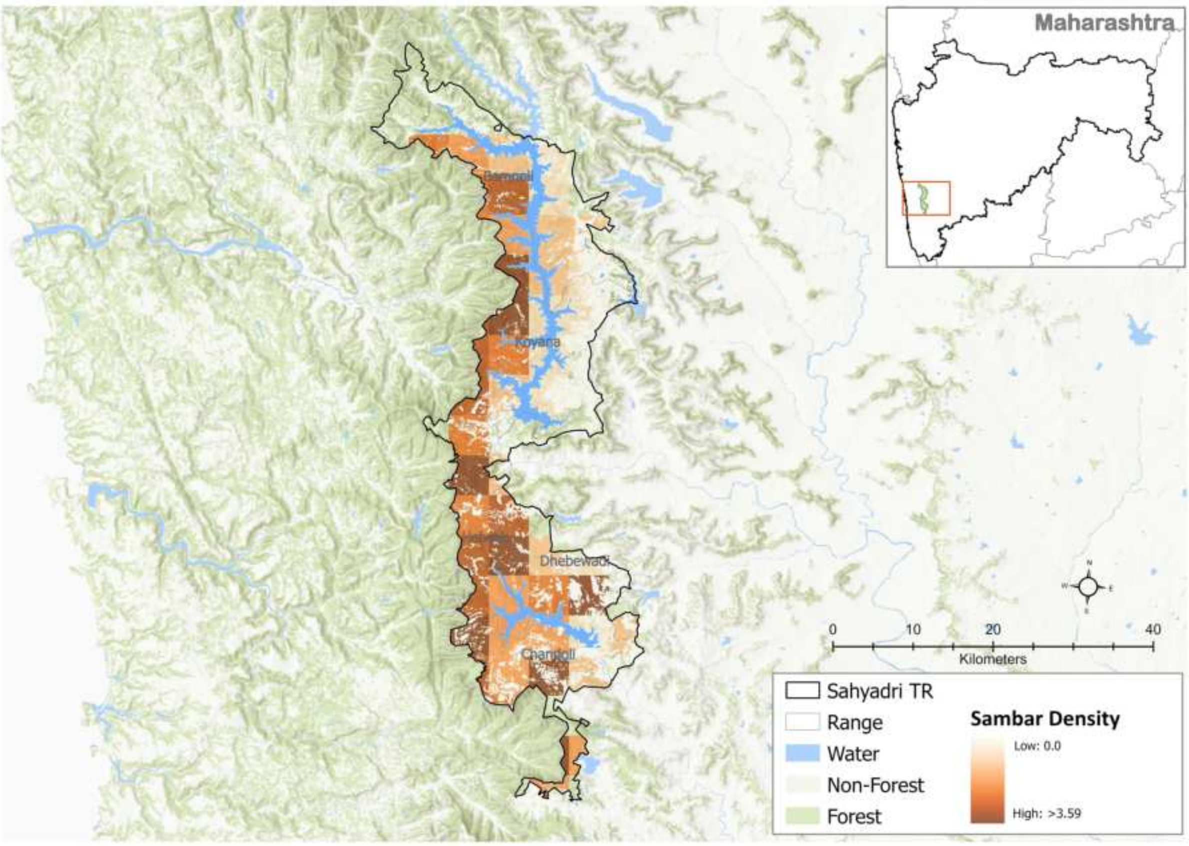

Figure IV. 93: Density of sambar (per 25 km^2) in Sahyadri tiger reserve: Landscape-level DSM

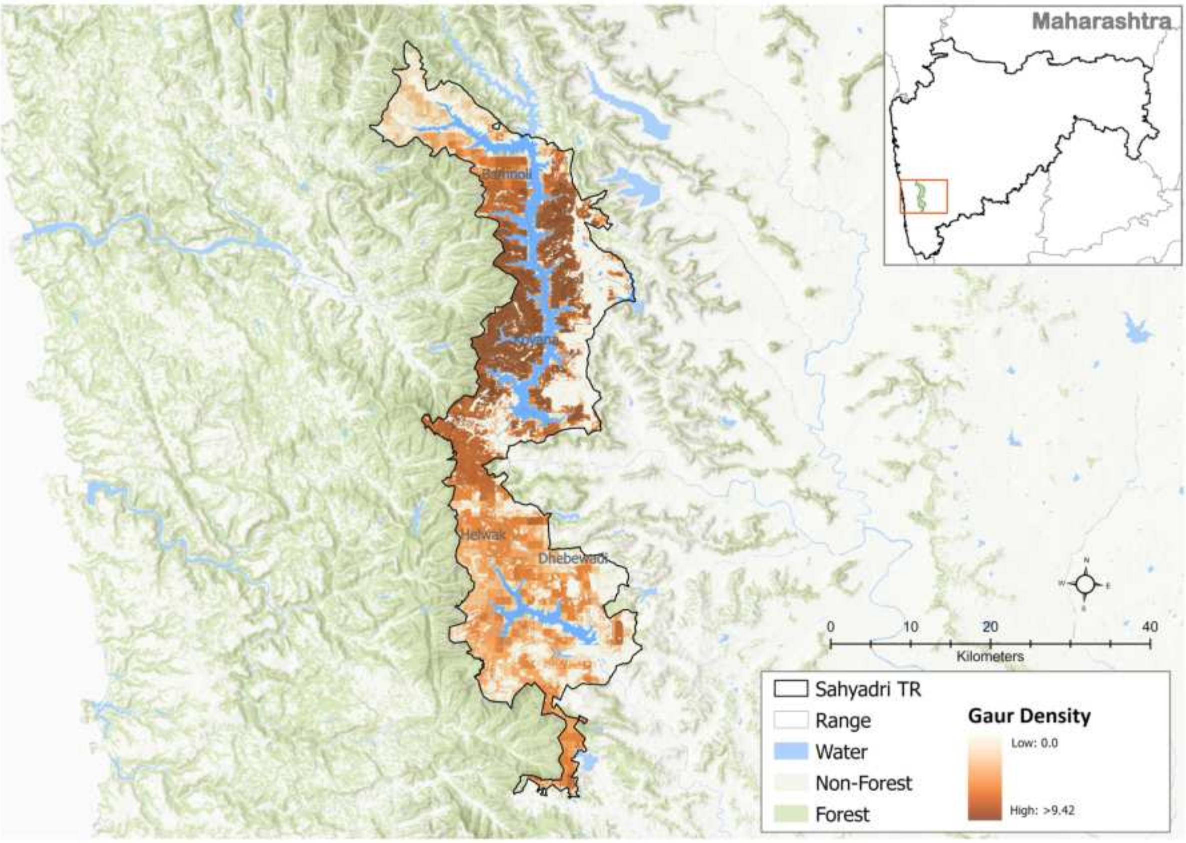

Figure IV. 94: Density of gaur (per km^2) in Sahyadri tiger reserve: Site-level DSM

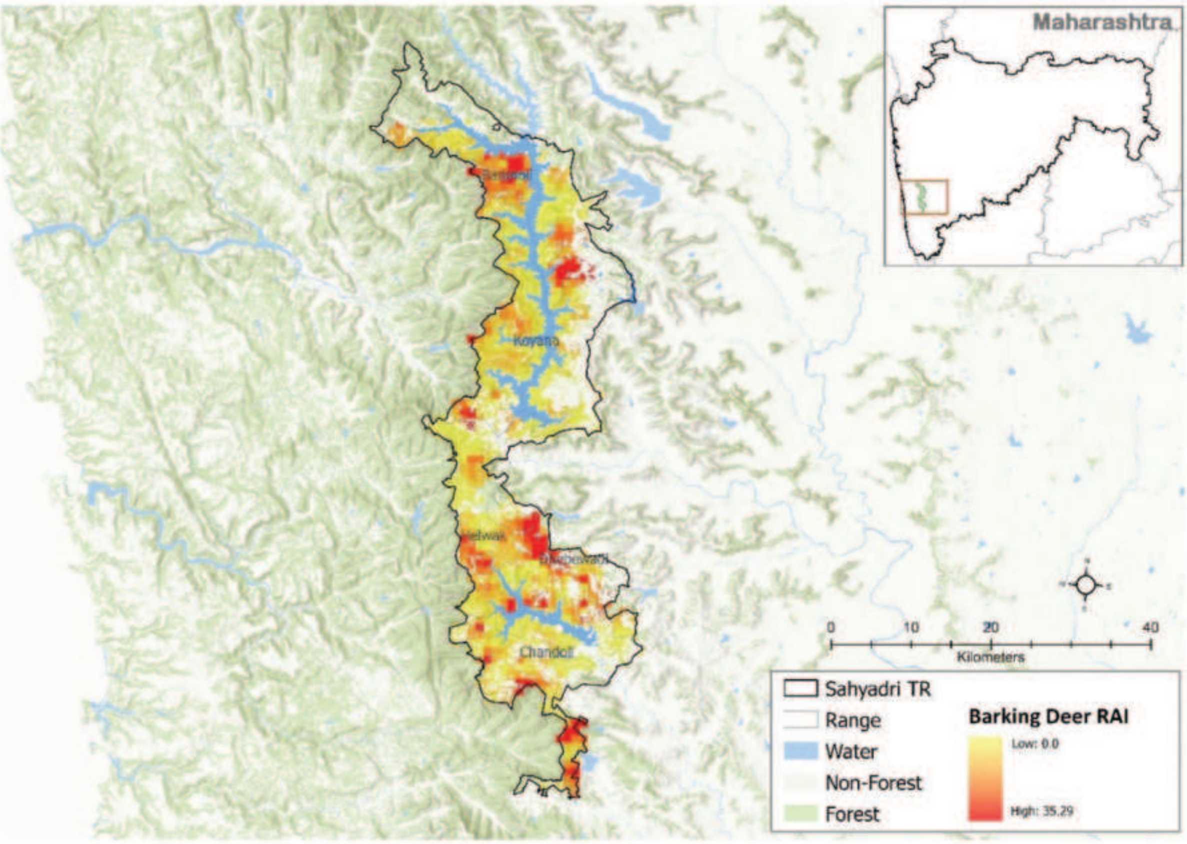

Figure IV. 95: Spatial relative abundance of baking deer in Sahyadri tiger reserve.

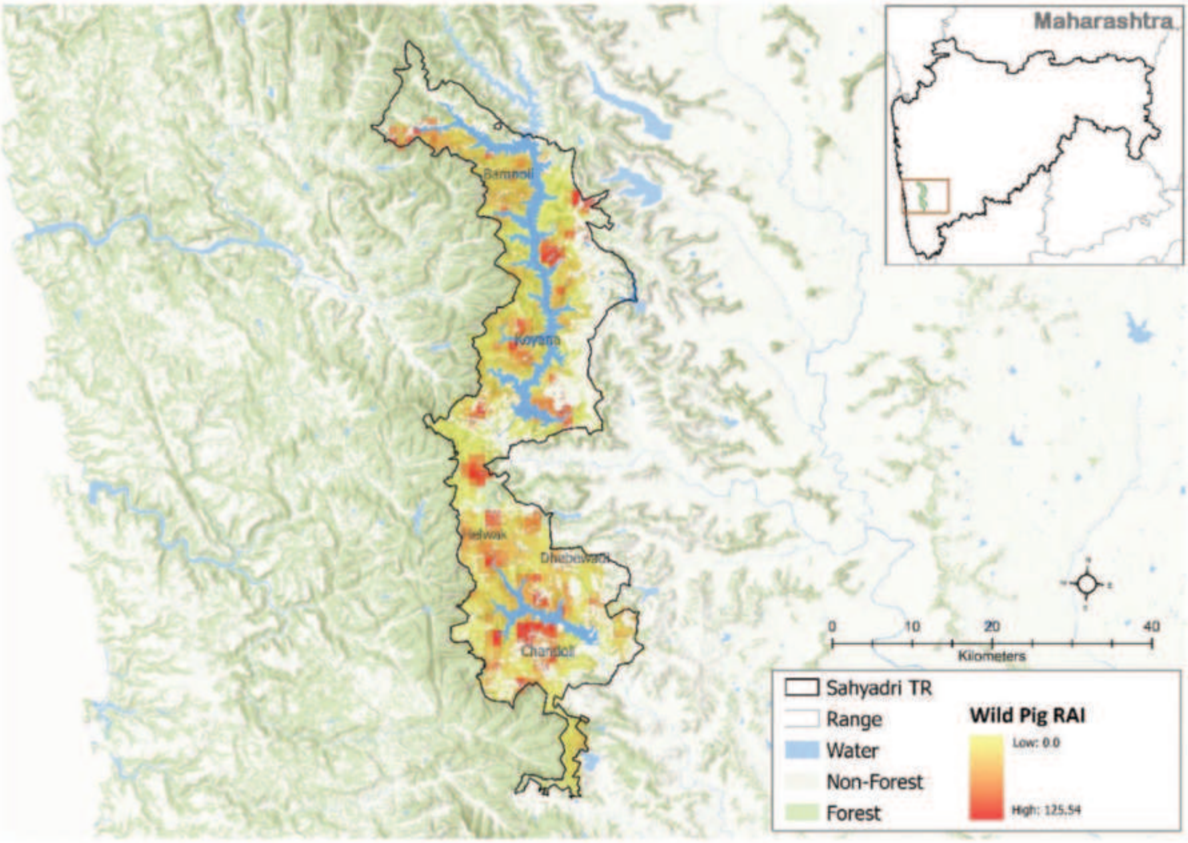

Figure IV. 96: Spatial relative abundance of wild pig in Sahyadri tiger reserve.

Tadoba Andhari Tiger Reserve

Tadoba-Andhari tiger reserve, located in the Chandrapur district of Maharashtra, spans approximately 1,727 km². The reserve features a mix of tropical dry deciduous forests, teak and bamboo woodlands, riverine habitats, and grasslands, with Tadoba Lake and the Andhari River serving as key water sources. Major fauna present in the reserve includes tiger, leopard, dhole, jackal, sloth bear, gaur, Indian Pangolin and a variety of ungulates, including the sambar, chital, chousingha, and nilgai. The diversity of flora includes sal, tendu, bamboo, and Indian gooseberry, which support a dynamic food web.

Ungulate observations in the line transects of Tadoba Andhari are minimal, and data is deficient for analysis. The encounter rate for chital is 0.0553 (±0.0119) and for sambar is 0.0592 (±0.0108). Therefore, chital and sambar abundance are predicted using landscape models, while barking deer, gaur, nilgai, and wild pig abundance is mapped using camera trap photo capture data. This helps in making informed management decisions. The landscape model predicts chital abundance in all ranges of Tadoba tiger reserve, with the highest abundance in the Kolara and Tadoba ranges (Figure IV. 97). Sambar is abundant throughout the reserve, with the highest abundance in the Tadoba range, followed by the Kolara range (Figure IV. 98). The highest gaur photo captures are from the Kolsa range, followed by the Karwa range (Figure IV. 100). Though gaur detection in line transects is minimal, it shows moderate relative abundance in camera trap data. Barking deer has a high relative abundance in the Moharli, Kolara, Karwa, and Chandrapur buffer ranges (Figure IV. 99). Wild pig abundance is highest in the Kadsangi range, followed by Kolara, Tadoba, and Palasgaon (Figure IV. 102). Nilgai abundance is highest in the Kadsangi range, followed by Shioni, Tadoba, and Muli (Figure IV. 101).

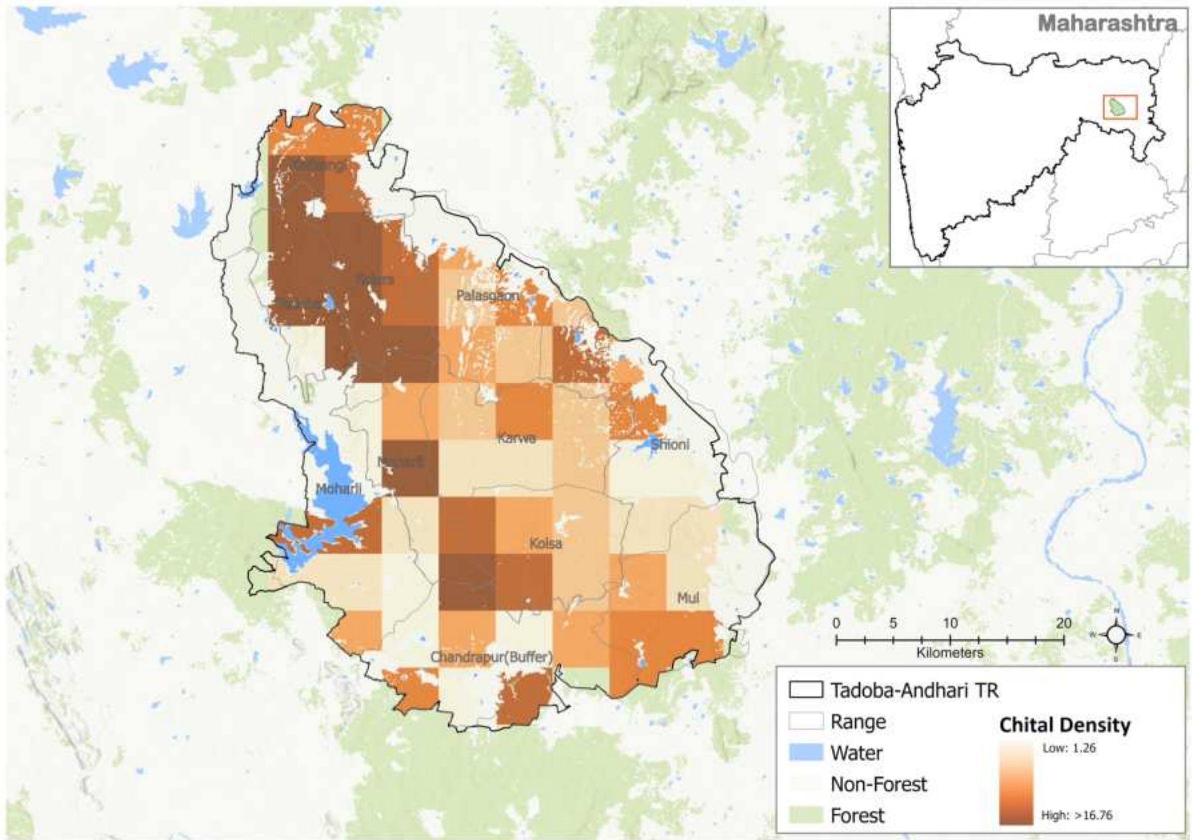

Figure IV. 97: Density of chital (per 25 km²) in Tadoba-Andhari tiger reserve: Landscape-Level DSM

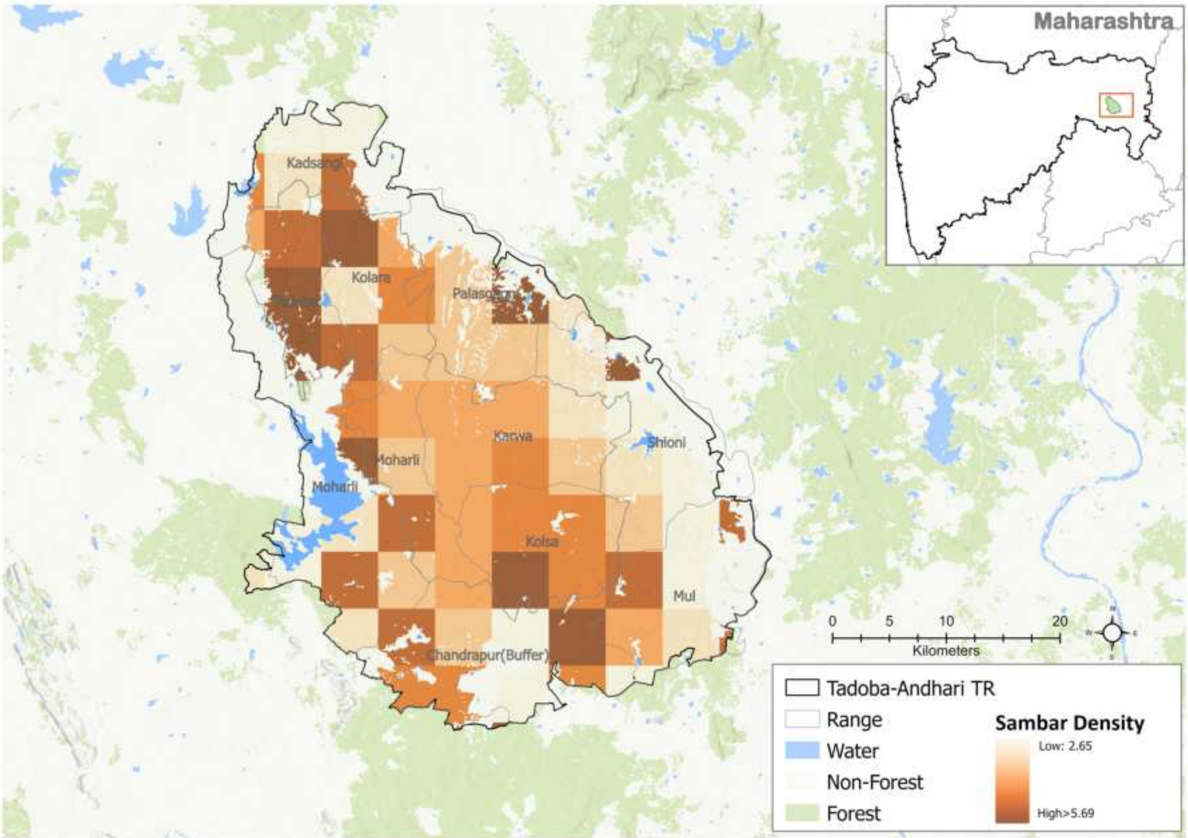

Figure IV. 98: Density of sambar (per 25 km²) in Tadoba-Andhari tiger reserve: Landscape-Level DSM

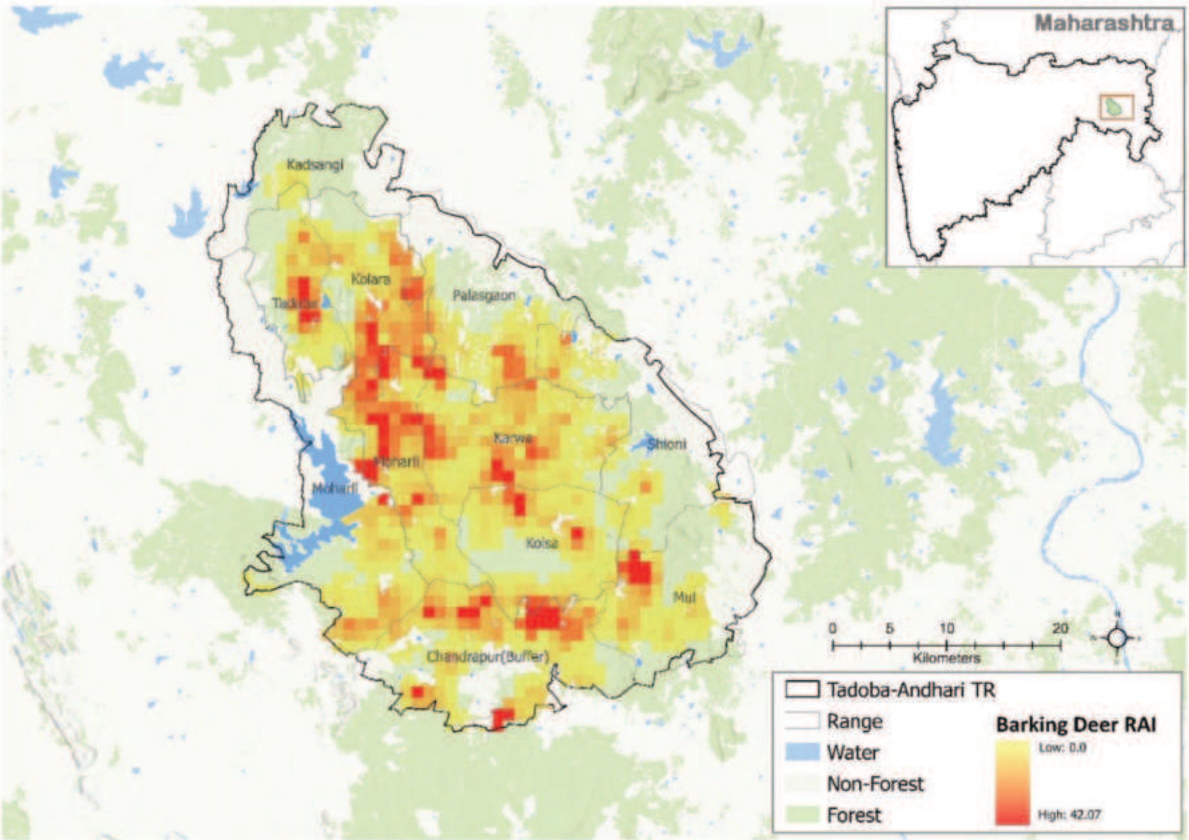

Figure IV. 99: Spatial relative abundance of barking deer in Tadoba-Andhari tiger reserve.

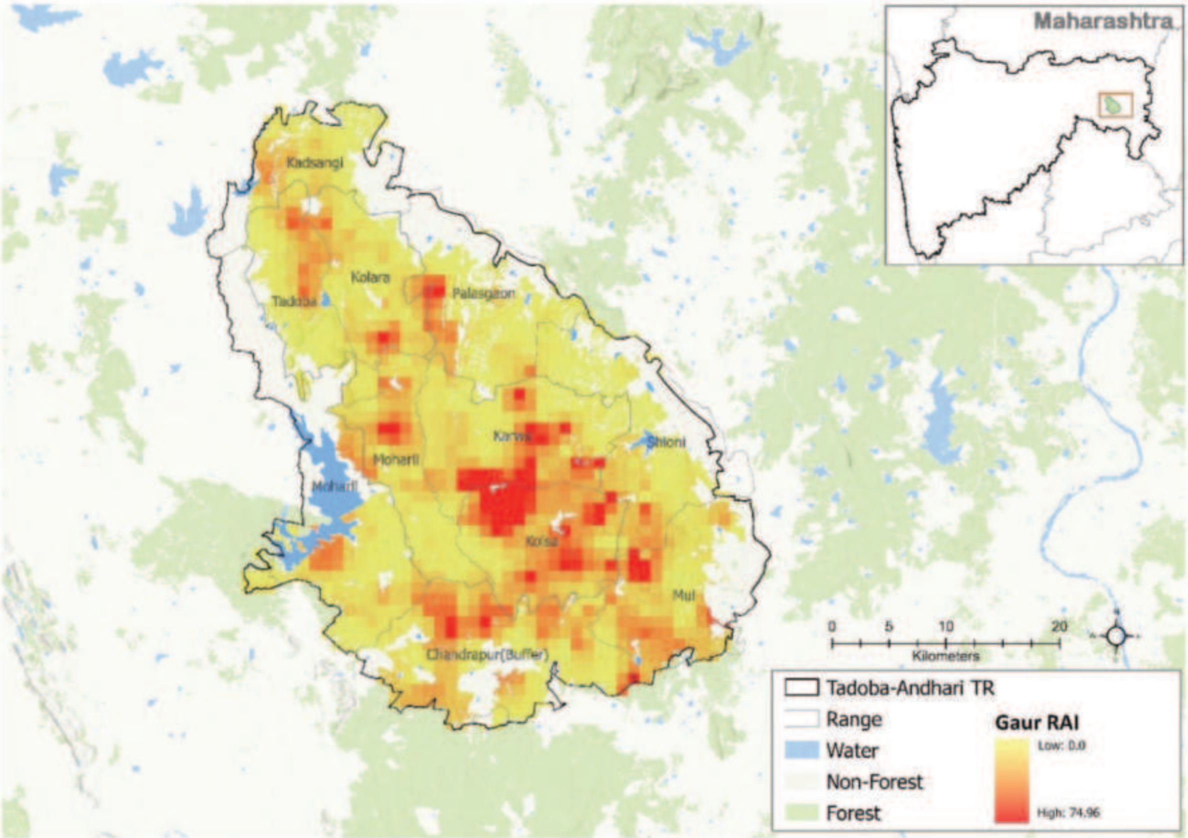

Figure IV. 100: Spatial relative abundance of gaur in Tadoba-Andhari tiger reserve.

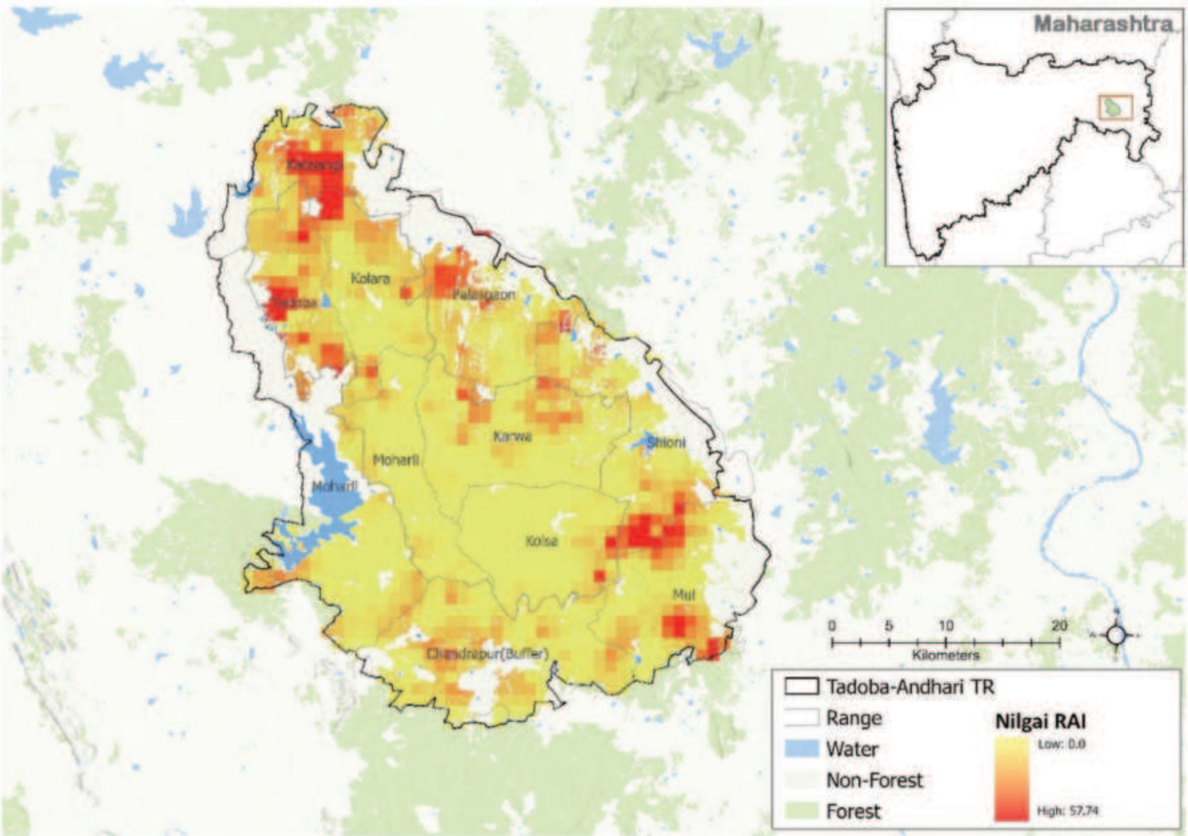

Figure IV. 101: Spatial relative abundance of nilgai in Tadoba-Andhari tiger reserve.

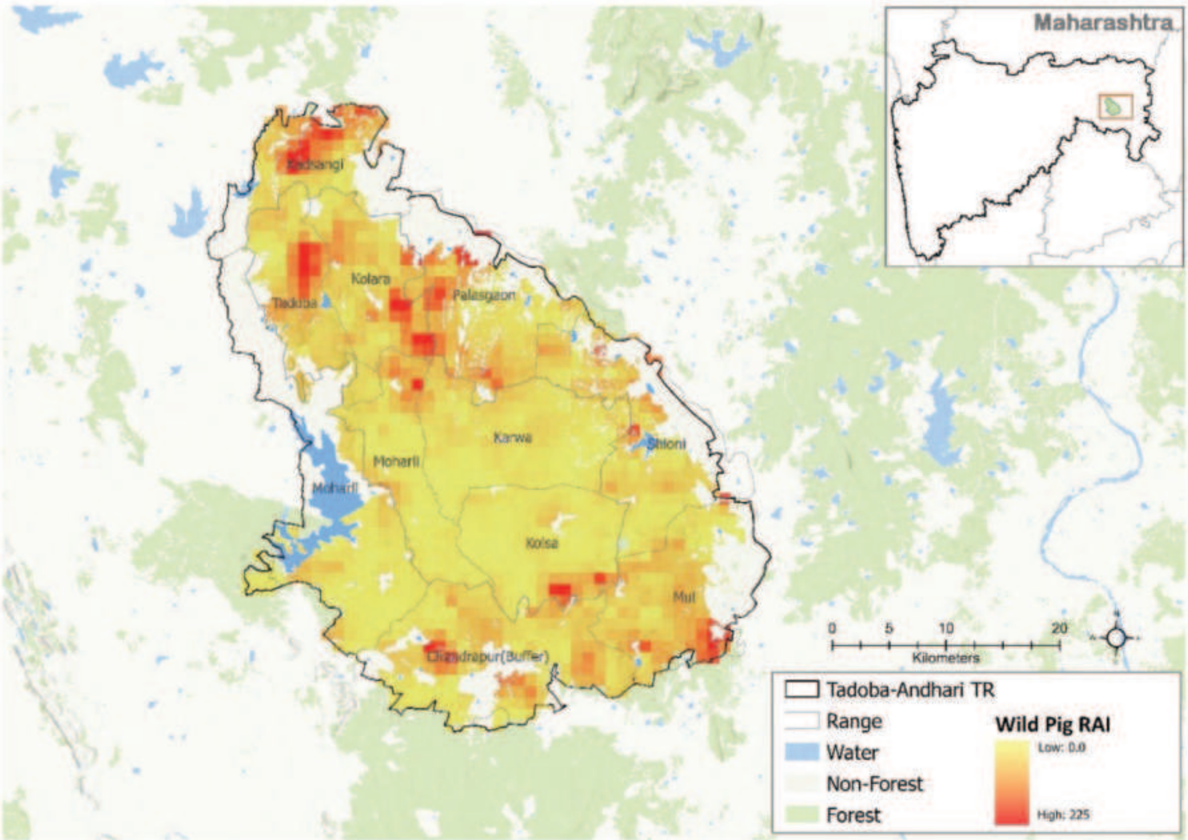

Figure IV. 102: Spatial relative abundance of wild pig in Tadoba-Andhari tiger reserve.

ODISHA

Satkosia Tiger Reserve

Satkosia tiger reserve, located in the Angul district of Odisha, comprises two wildlife sanctuaries: Satkosia Gorge Sanctuary and Baisipalli Sanctuary. The reserve spans 963 km² across four districts—Angul, Cuttack, Nayagarh, and Boudh. It lies at the confluence of two biogeographic regions, the Deccan Peninsula and the Eastern Ghats, resulting in high biodiversity. The tiger reserve is divided into two parts by Mahanadi River. Floral diversity is typical with Mahanadian hilly sal forests and largely comprises northern tropical moist deciduous, dry deciduous, and mixed forests. The reserve is home to herbivores such as chital, sambar, gaur, barking deer, and wild boar, which play a vital role in maintaining ecological balance by supporting apex predators like tigers and leopards. Satkosia's riparian zones also provide critical habitats for species such as the Indian giant squirrel and the endangered gharial, alongside numerous fish species that support local livelihoods.

Ungulate observations from line transects are minimal, and data is deficient for analysis. The encounter rate for chital is 0.1912 (±0.0827) and for sambar is 0.1326 (±0.1105). Therefore, the density of chital and sambar is predicted using landscape models, while the abundance of barking deer, gaur, and wild pigs is estimated through camera trap photo-capture data. Landscape models predict higher chital densities in the northern ranges of the Mahanadi River. The highest spatial densities of chital are found in the Purunakote and Raigoda ranges, followed by Pampasar and Jilinda (Figure IV. 103). Chital presence in limited in southern side of Mahanadi diver due to the rugged and hilly terrain. Sambar densities are relatively low, with the highest concentrations recorded in Purunakote and Raigoda, followed by Tikarpada and Chhamundia (Figure IV. 104).

Gaur is distributed across the reserve, with high photo-capture rates in the northern ranges of the Mahanadi River (Figure IV. 106). Barking deer are most abundant in the peripheral areas along the northern boundary, with the highest photo-capture rates in Raigoda, followed by Pampasar and Purunakote (Figure IV. 105). Wild pigs are well-distributed throughout the reserve, with high abundance in small pockets across most ranges (Figure IV. 107). Ongoing management efforts, including incentivizing voluntary village relocation and habitat restoration, are expected to stabilize herbivore populations of Satkosia tiger reserve.


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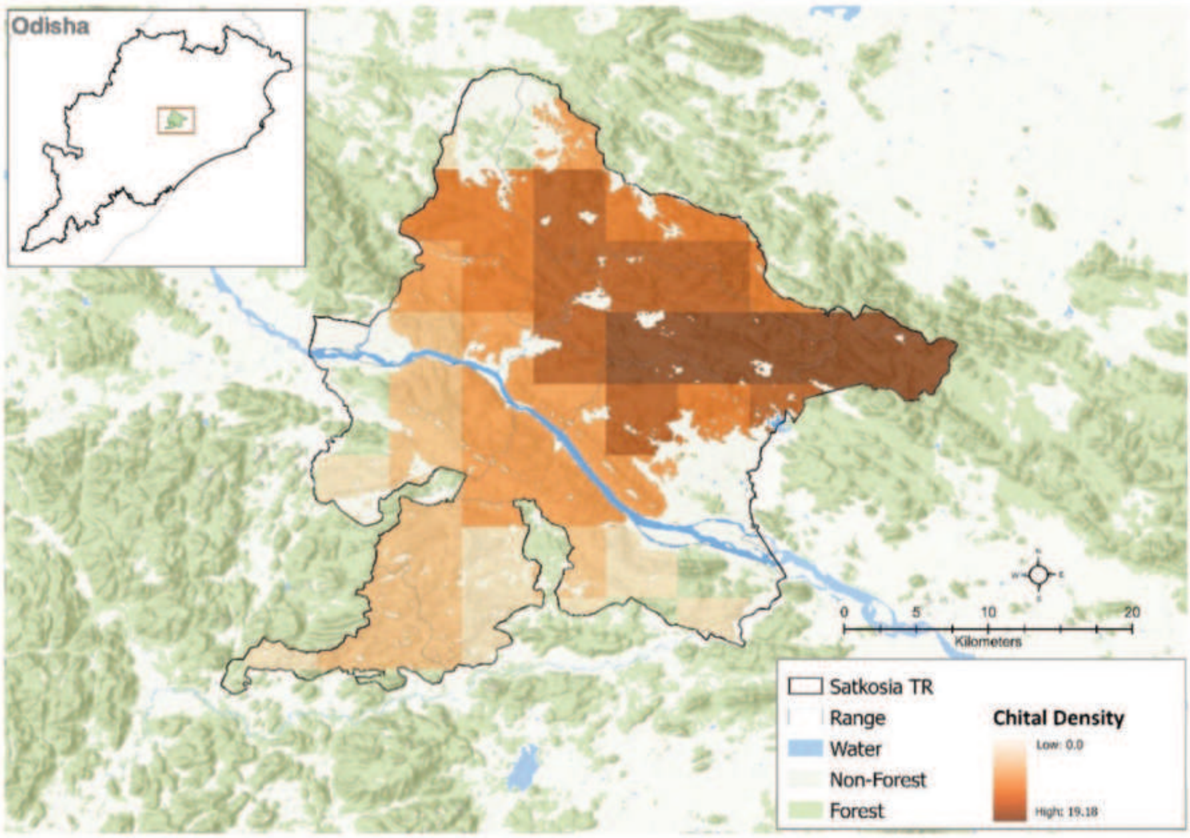


Figure IV. 103: Density of chital (per 25 km²) in Satkosia tiger reserve: Landscape-level DSM

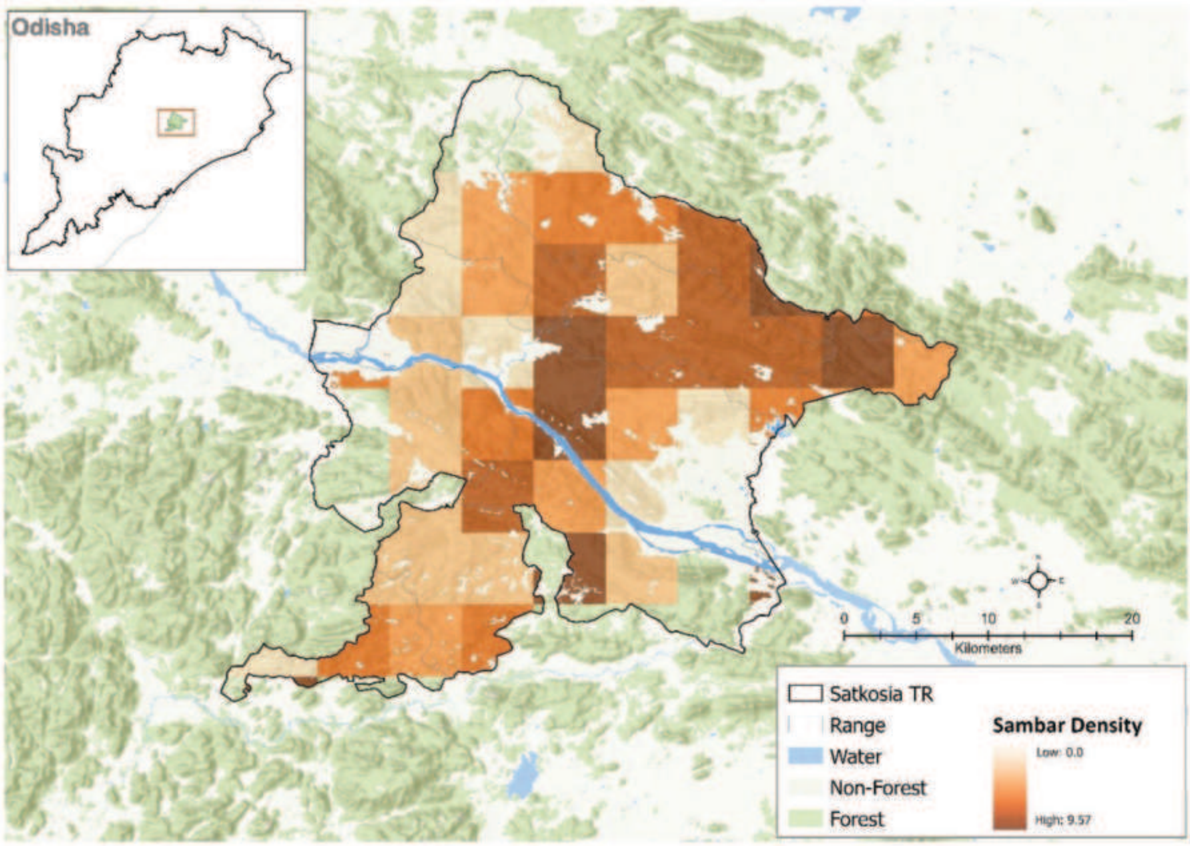


Figure IV. 104: Density of sambar (per 25 km²) in Satkosia tiger reserve: Landscape-level DSM

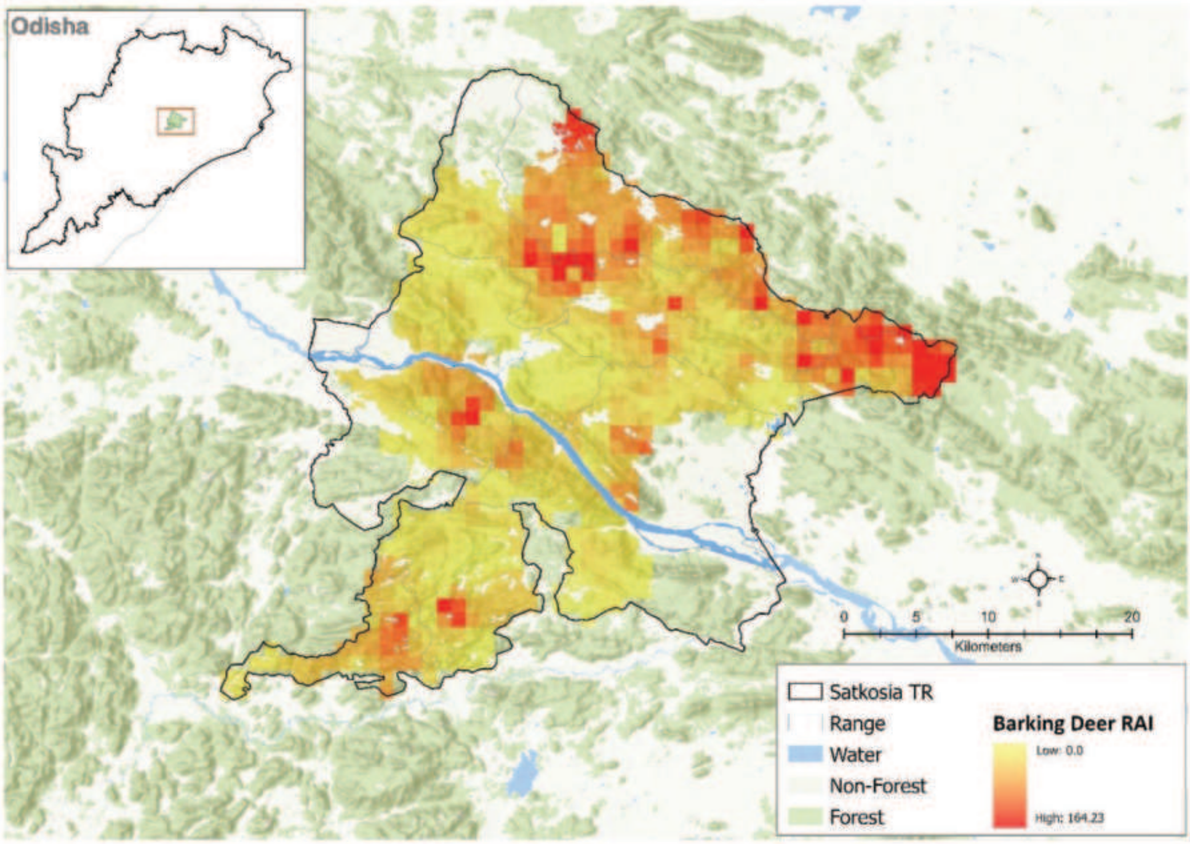


Figure IV. 105: Spatial relative abundance of barking deer in Satkosia tiger reserve.

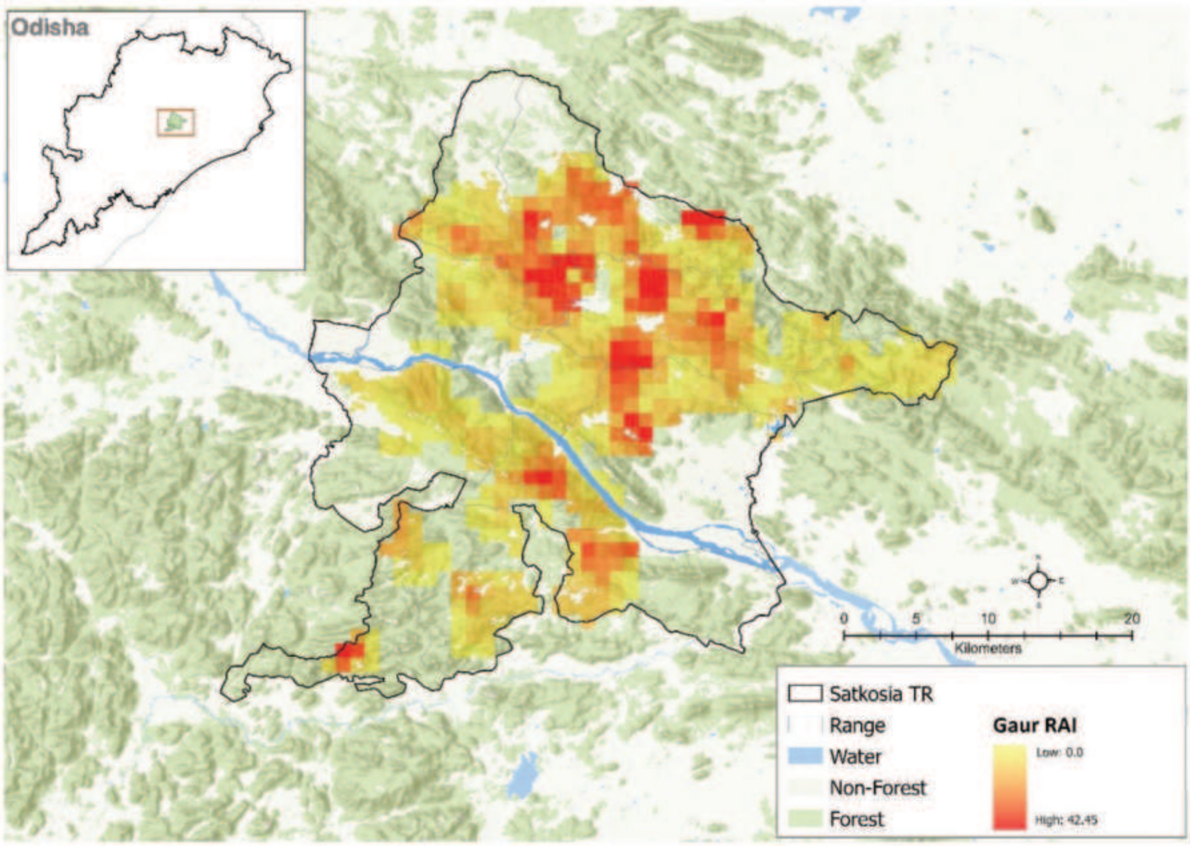


Figure IV. 106: Spatial relative abundance of gaur in Satkosia tiger reserve.

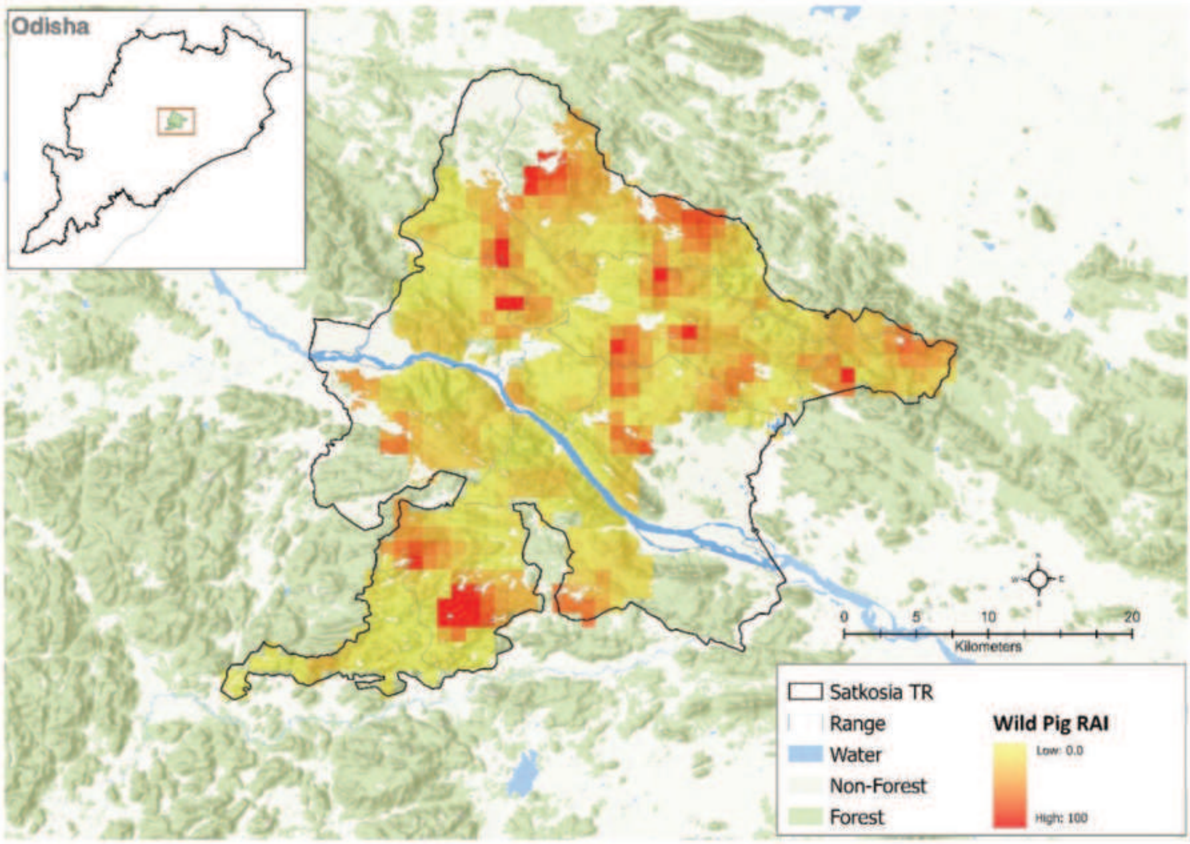


Figure IV. 107: Spatial relative abundance of wild pig in Satkosia tiger reserve.

Similipal Tiger Reserve

Similipal tiger reserve is located in the northern part of Odisha. The reserve is part of Similipal biosphere reserve and spans approximately 2,750 km^2. It is situated at the northern part of Eastern Ghats and north – east corner of the Deccan plateau. The vegetation is a mix of semi-evergreen forest, northern tropical moist deciduous forest, dry deciduous hill forest, high level sal forest, and grassland (Misra 2004; Saxena & Brahmam 1989). Its unique topography and varied vegetation types create habitats that support an incredible diversity of flora and fauna. Its unique landscape has the only population of rare melanistic tigers. Apart from tiger, and leopard similipal has herbivores like gaur, sambar, chital, mouse deer, and wild boar. The reserve also serves as a key habitat for Asian elephant.

Chital is the most abundant prey species in Similipal Tiger Reserve (Table IV. 9). The highest spatial densities of chital is in UBK range followed by Jenabil, Bhanjabasa, National Park, Chahala and Gurguria Range (Figure IV. 108). The species densely occupies most of the core area. As practiced in southern similipal, voluntary village relocation potentials can be further explored in the northern region followed by subsequent habitat restoration. Sambar densely occupies the core area in southern Similipal and has relatively sparse distribution in the northern part (Figure IV. 109). The highest density of Sambar is in UBK and Bhanjabasa ranges followed by Jenabil and National Park. Barking deer is well distributed throughout Similipal with highest density in Jenabil, UBK and Bhanjabasa followed by National Park range (Figure IV. 110).

Gaur and wild pig spatial densities were not estimated due to insufficient data, the relative abundance through camera trap based photo-captures were mapped for informed decisions. Gaur is less abundant as compared to other ungulates and its distribution is quite patchy (Figure IV. 111). It is largely restricted to a few patches in Kendumundi, Bhanjabasa, National Park and Nawana North ranges. Wild pig is well distributed throughout Similipal. Most photo captures of wild pig were from Chahala and Gurguria ranges followed by Kendumundi and National park (Figure IV. 112).

Table IV. 9: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Similipal Tiger Reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	77	0.058 (0.007)	0.34 (0.04)	5.65 (0.36)	1.07 (0.17)	4.73 (0.58)
Sambar	131	0.099 (0.009)	0.36 (0.03)	2.75 (0.2)	2.04 (0.24)	4.69 (0.47)
Barking Deer	237	0.0002 (0.00001)	0.23 (0.01)	1.10 (0.02)	3.90 (0.34)	4.54 (0.38)

B)

Species	Chital	Sambar	Barking Deer
Detection model	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	8.293	4.512	4.512
s(NDVI difference)	6.082	2.902	1
s(Elevation)	4.607	1	2.902
s(Distance from built-up)	2.862	5.92	5.92

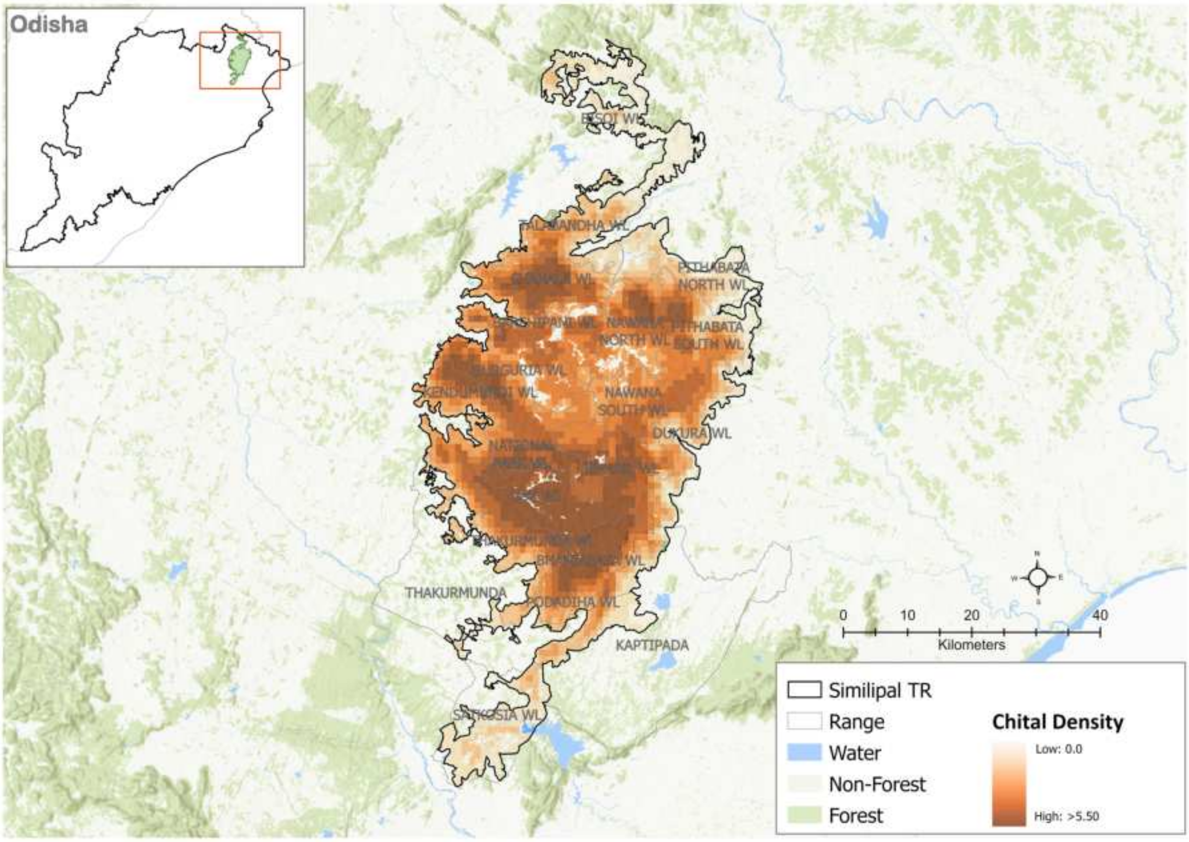


Figure IV. 108: Density of Chital (per km²) in Similipal Tiger Reserve: Site- Level DSM

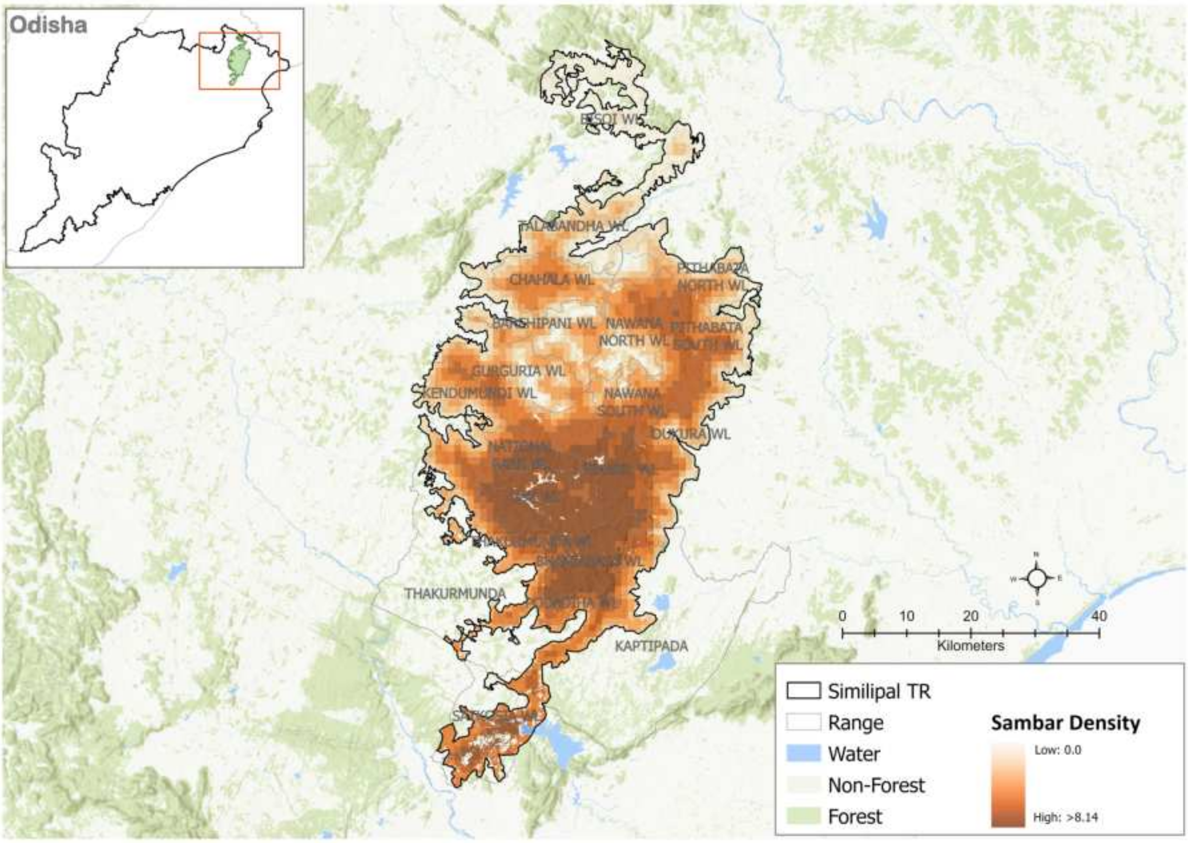


Figure IV. 109: Density of sambar (per km²) in Similipal tiger reserve: Site- level DSM

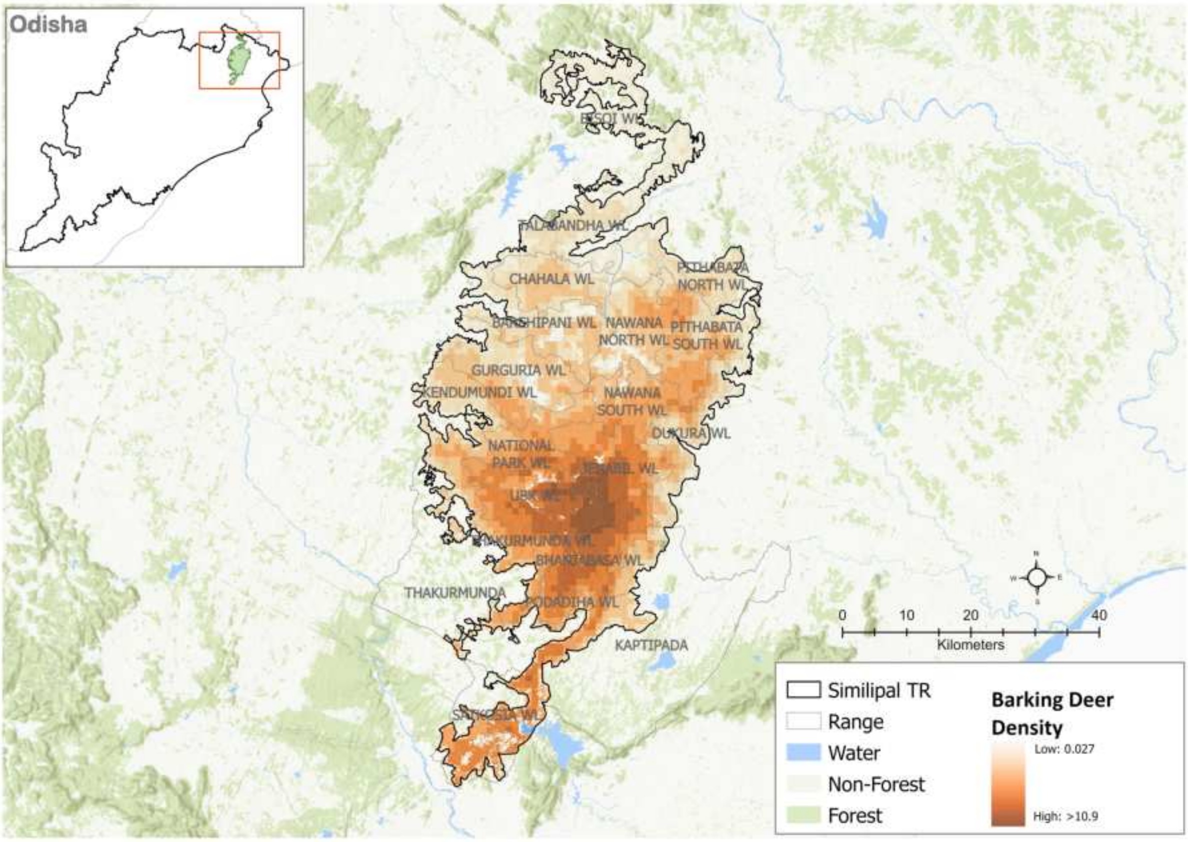


Figure IV. 110: Density of barking deer (per km^2) in Similipal tiger reserve: Site- level DSM

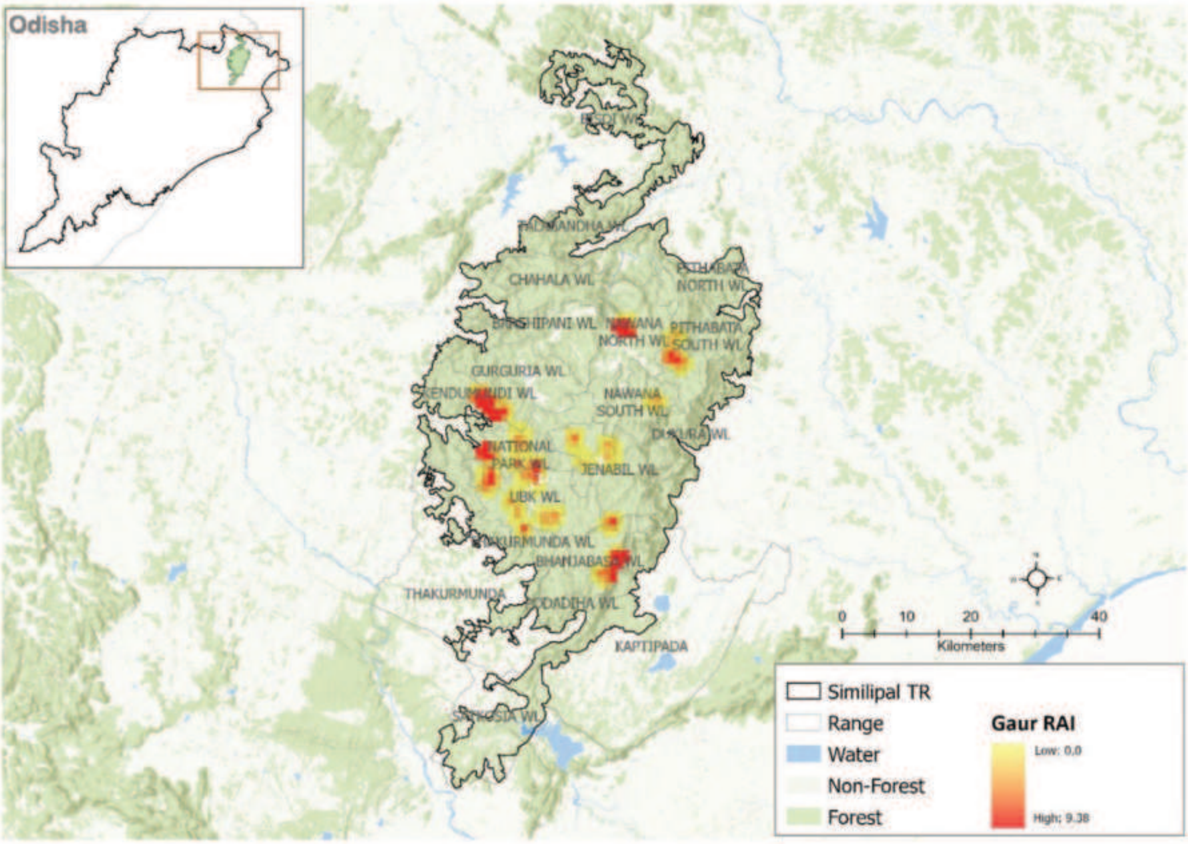


Figure IV. 111: Spatial relative abundance of gaur in Similipal tiger reserve.

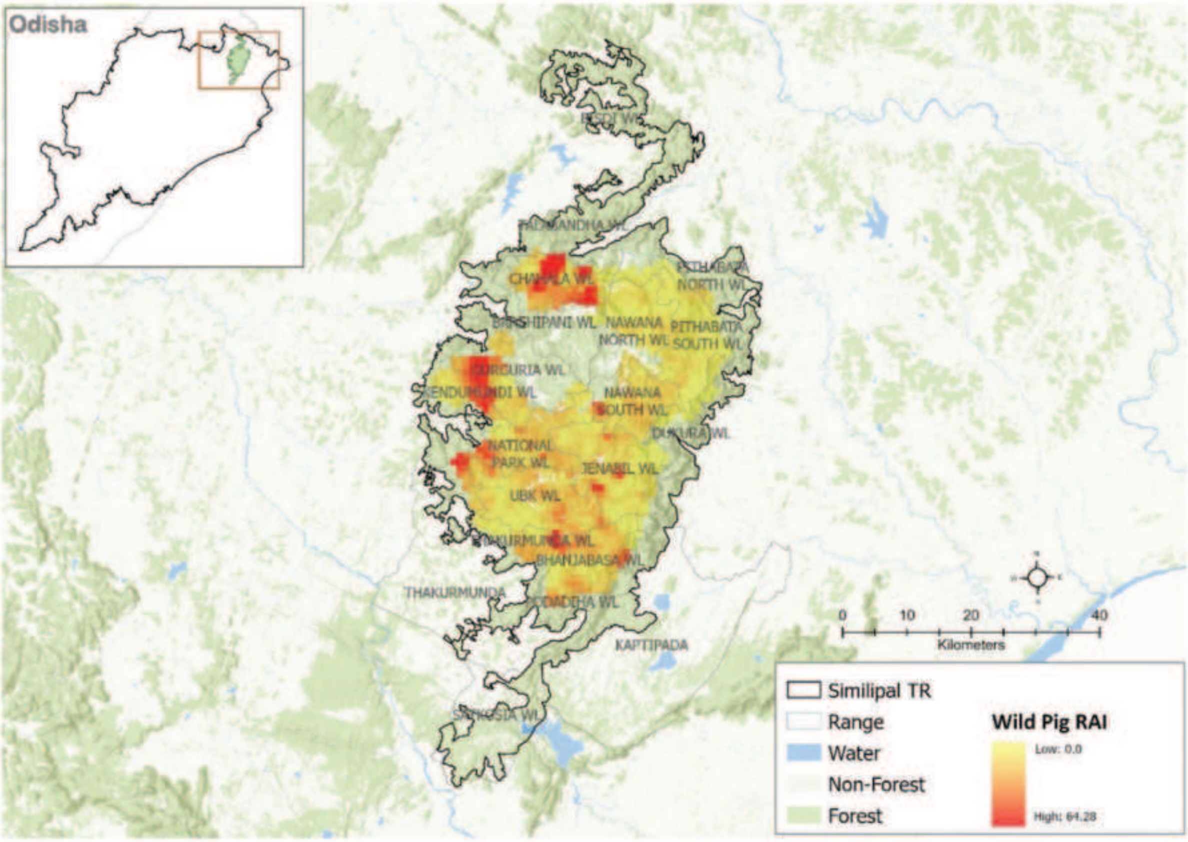
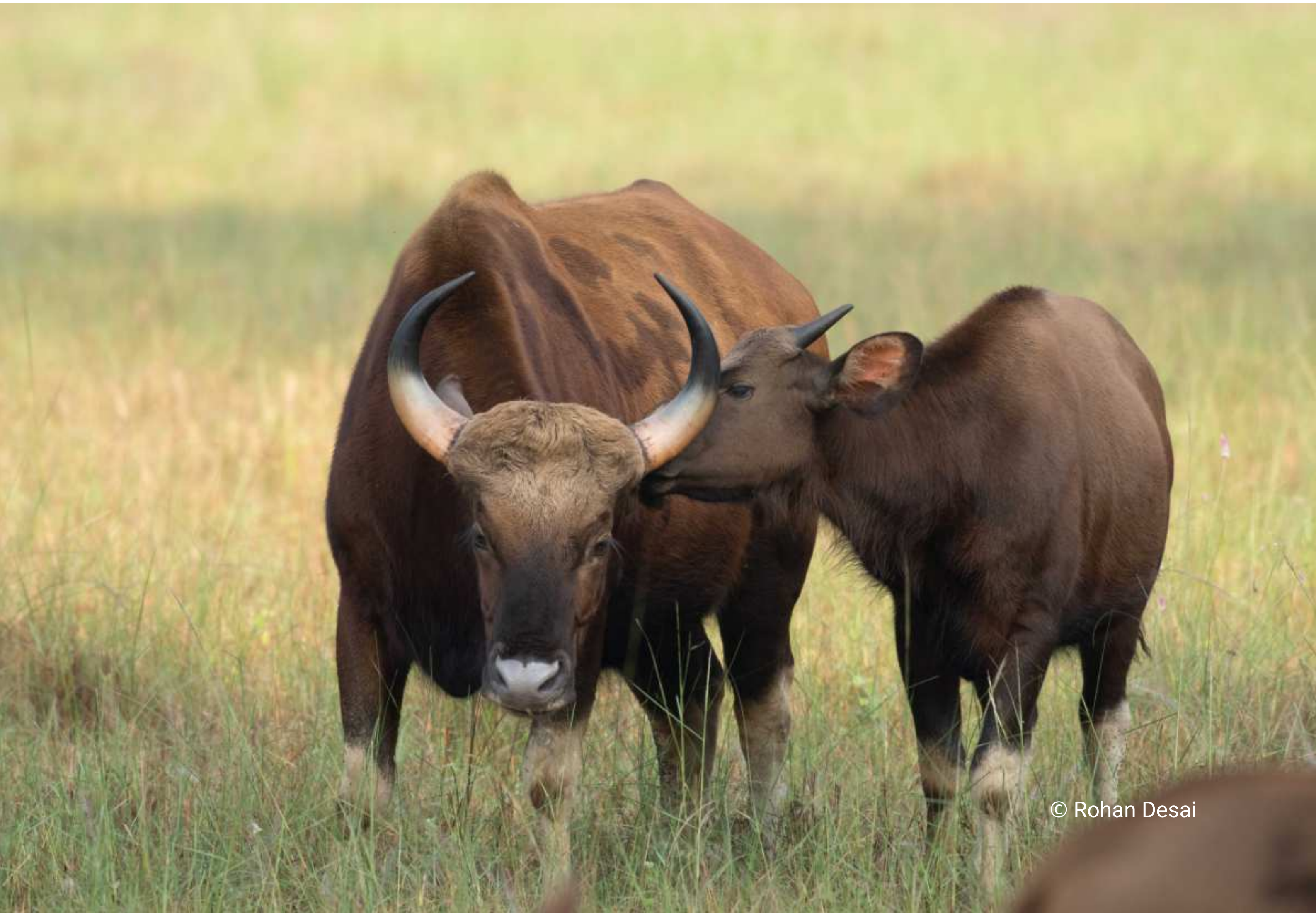


Figure IV. 112: Spatial relative abundance of wild pig in Similipal tiger reserve.



RAJASTHAN

Mukundara Hills Tiger Reserve

Mukundara Hills tiger reserve, located in the Kota Bundi, Chittorgarh, and Jhalawar districts of Rajasthan, spans approximately 760 km^2 and is situated at the edge of the Aravalli Range. The reserve is divided into distinct ecological zones, with the Chambal River providing water to the region (Envis, 2013) and is significant for its unique transition between the semi-arid landscapes of Rajasthan and the more verdant habitats of central India. It is characterized by dry deciduous forests, scrublands, and open grasslands (Champion and Seth, 1968), interspersed with hills, ravines, and riverine ecosystems, including the Chambal River that flows along its southern boundary. The Mukundara Hills are home to tiger, leopard, Indian fox, striped hyaena, jackal, sloth bear, chital, sambar, nilgai, chinkara, and wild pig as well as a huge diversity of birds and reptiles.

Ungulate observations from line transects are minimal, and data is deficient for analysis. Therefore, the density of chital and sambar is predicted using landscape models, while the abundance of nilgai and wild pigs is estimated through camera trap photo-capture data. The chital distribution is restricted to Rawtha, Daraha, Borabas and Kolipura ranges (Figure IV. 113). The highest spatial density of chital is in Rawtha (Figure IV. 113). This range can act as a source area for management and supplementation of chital. Sambar density in Mukundara is predicted to be very low densities. It is limited to Rawtha range only. Sambar requires management input for recovery.

Wild pig is abundant in Rawtha, Borabas, Daraha and a few patches in Gagron ranges (Figure IV. 116) while Nilgai is abundant in the Rawtha, Daraha, Gagron and outer most region of Borabas range (Figure IV. 115). Management efforts should be focused towards mitigating excessive grazing by cattle and maintaining healthy populations of herbivores to distribute predation pressure more evenly.

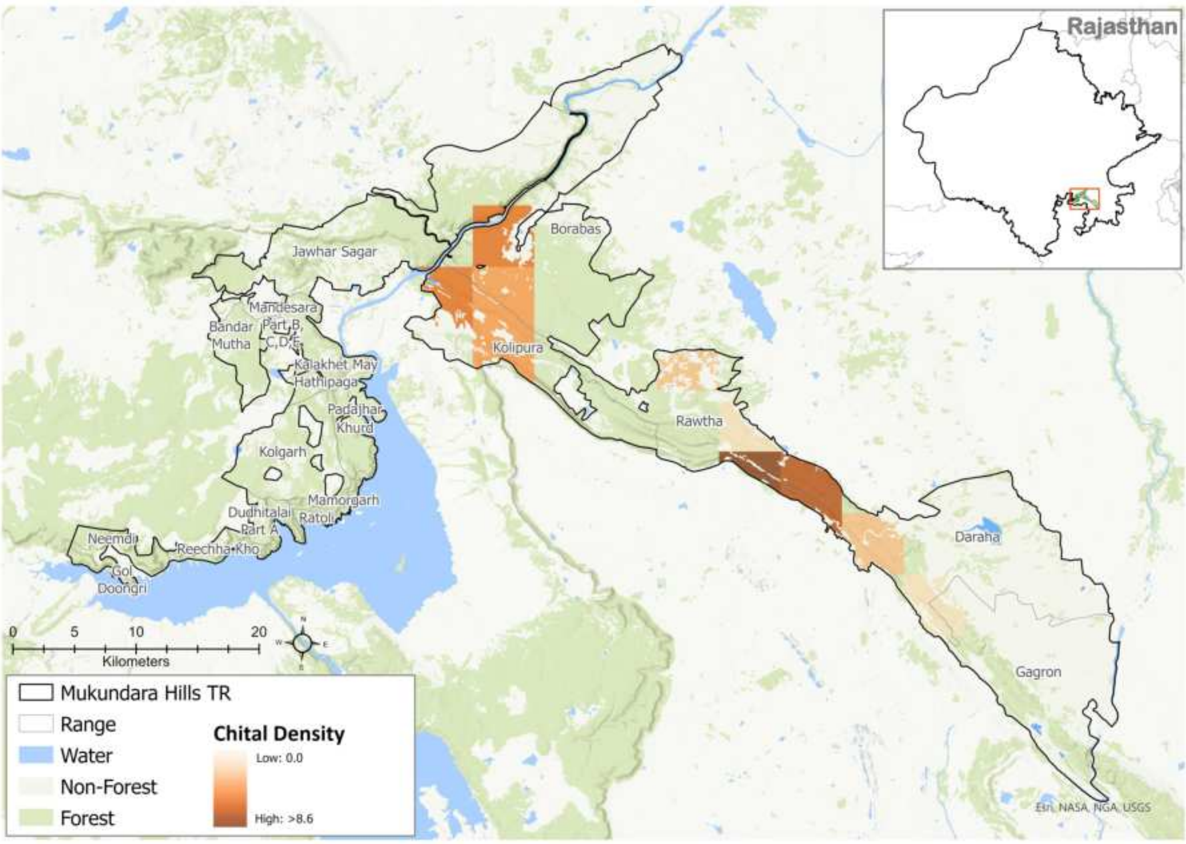


Figure IV. 113: Density of chital (per 25 km^2) in Mukundara hills tiger reserve: Landscape-level DSM

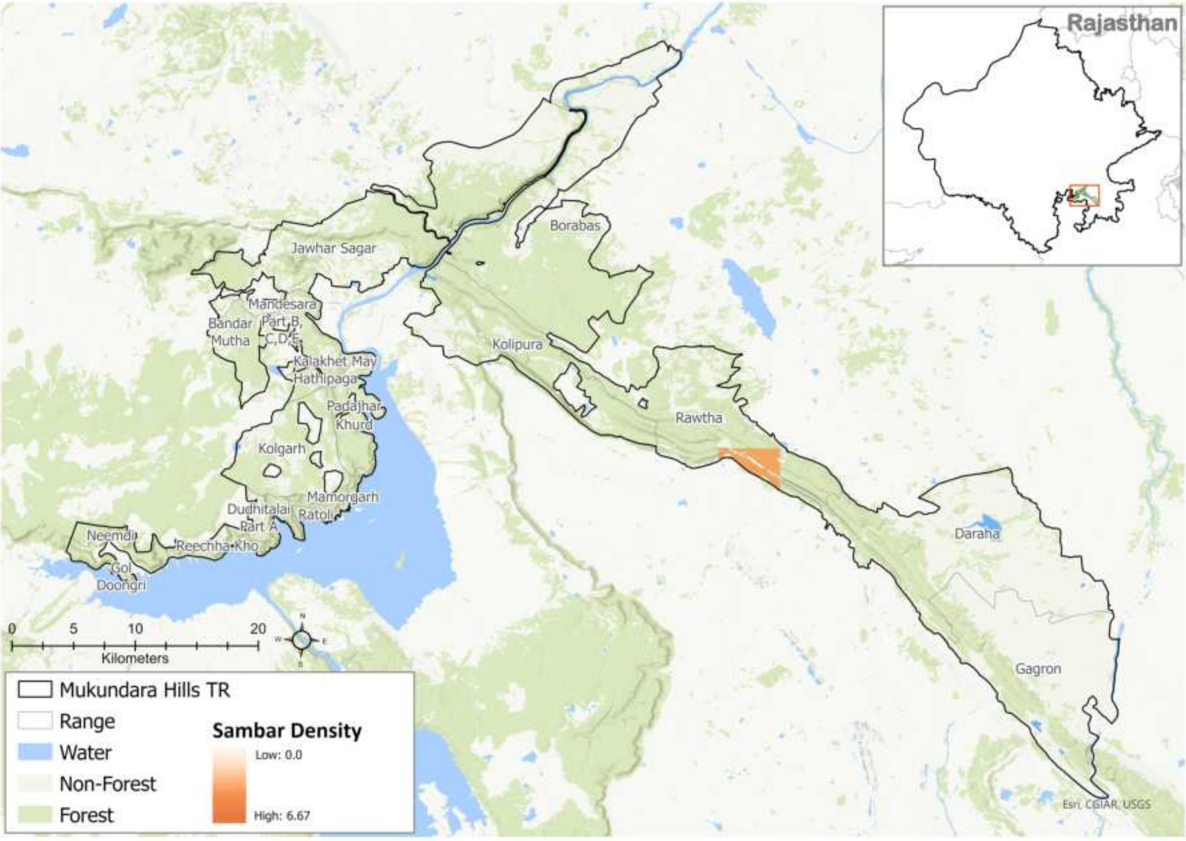


Figure IV. 114: Density of sambar (per 25 km²) in Mukundara hills tiger reserve: Landscape-level DSM

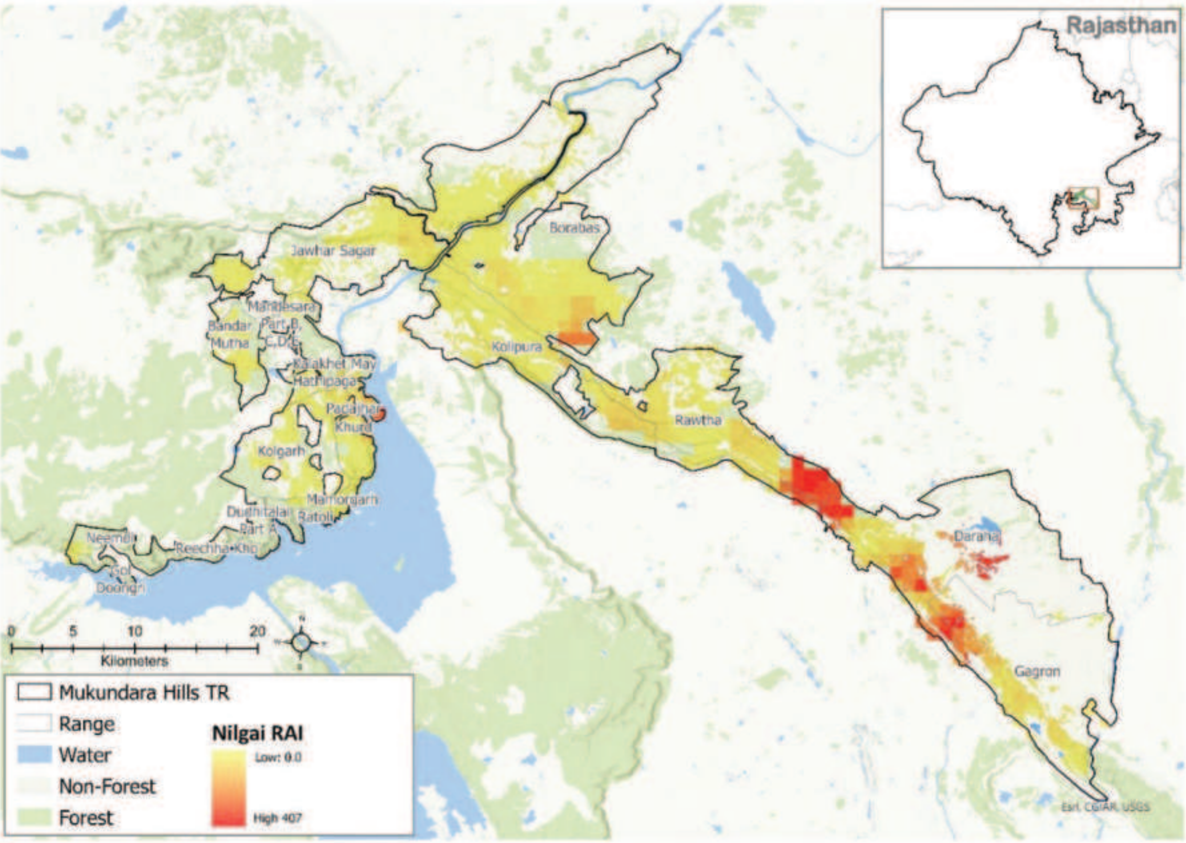


Figure IV. 115: Spatial relative abundance of nilgai in Mukundara hills tiger reserve.

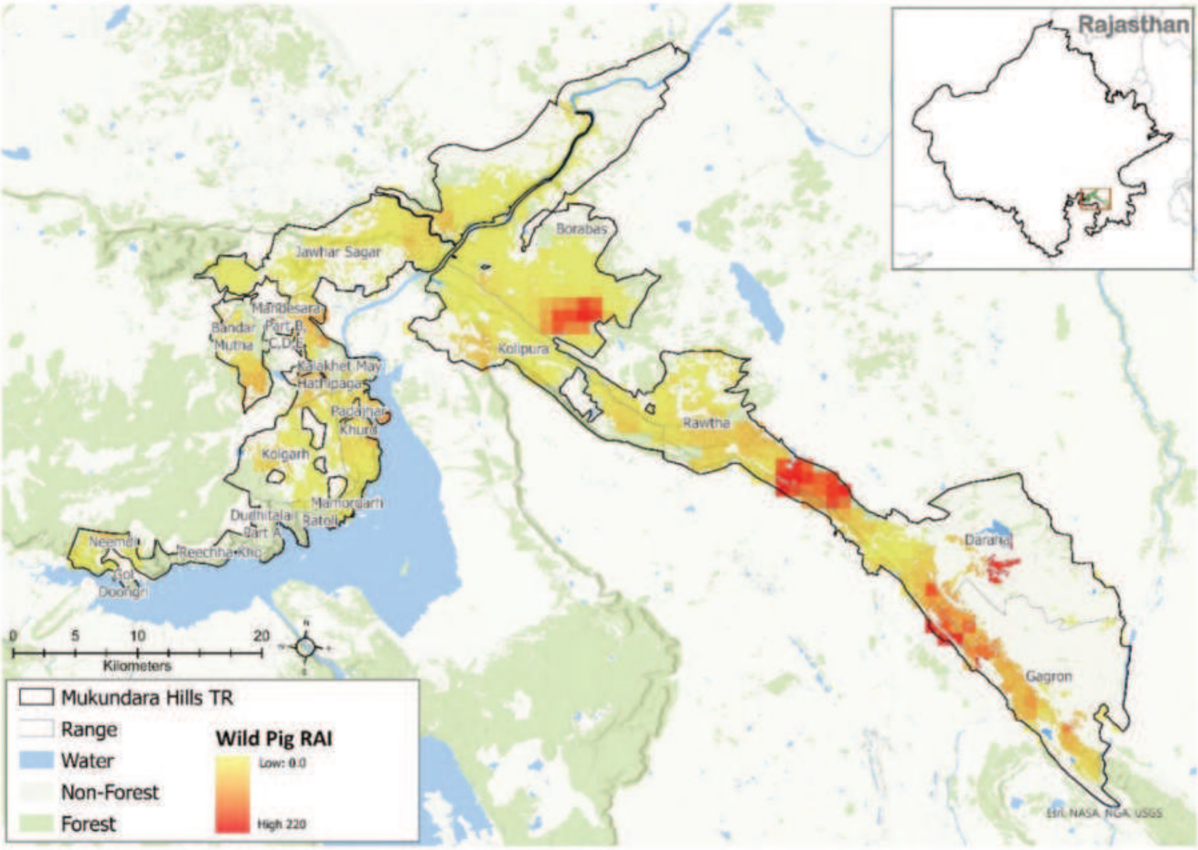


Figure IV. 116: Spatial relative abundance of wild pig in Mukundara hills tiger reserve.

Ramgarh-Visdhari Tiger Reserve

Ramgarh Vishdhari tiger reserve, located in the Bundi district of Rajasthan, spans approximately 1,502 km² and serves as a crucial wildlife corridor between the Ranthambore and Mukundara Hills Tiger Reserves. The area comprises tropical dry deciduous forests, thorny scrublands, and grasslands, interspersed with rugged rocky terrain and seasonal streams (Sharma, 2022). The faunal diversity includes tiger, leopard, striped hyena, sloth bear, jackal, Indian fox, jungle cat, and ungulates such as chital, sambar, wild pig, and nilgai, alongside a variety of birds and reptiles.

Ungulate observations from line transects are minimal and data is not sufficient for detailed analysis. Therefore, the densities of chital and sambar are predicted using landscape models, while the abundance of nilgai and wild pigs is estimated through camera trap photo-capture data. The landscape model predicts chital as the most abundant ungulate species in Ramgarh Vishdhari Tiger Reserve, followed by sambar. High spatial densities of chital and sambar are predicted in the Jaitpur and Ramgarh ranges (Figure IV. 117 & Figure IV. 118). To enhance the ungulate population, habitat improvement efforts should be prioritized within the reserve. Additionally, voluntary village relocation should be encouraged to reduce livestock grazing pressure and create more habitat for wild ungulates.

The relative abundance of wild pigs and nilgai is predominantly restricted to the western side of the reserve. Wild pigs are abundant in the Ramgarh range (Figure IV. 120), whereas nilgai are more frequently observed in Jaitpur and the outermost regions of the Ramgarh range (Figure IV. 119).

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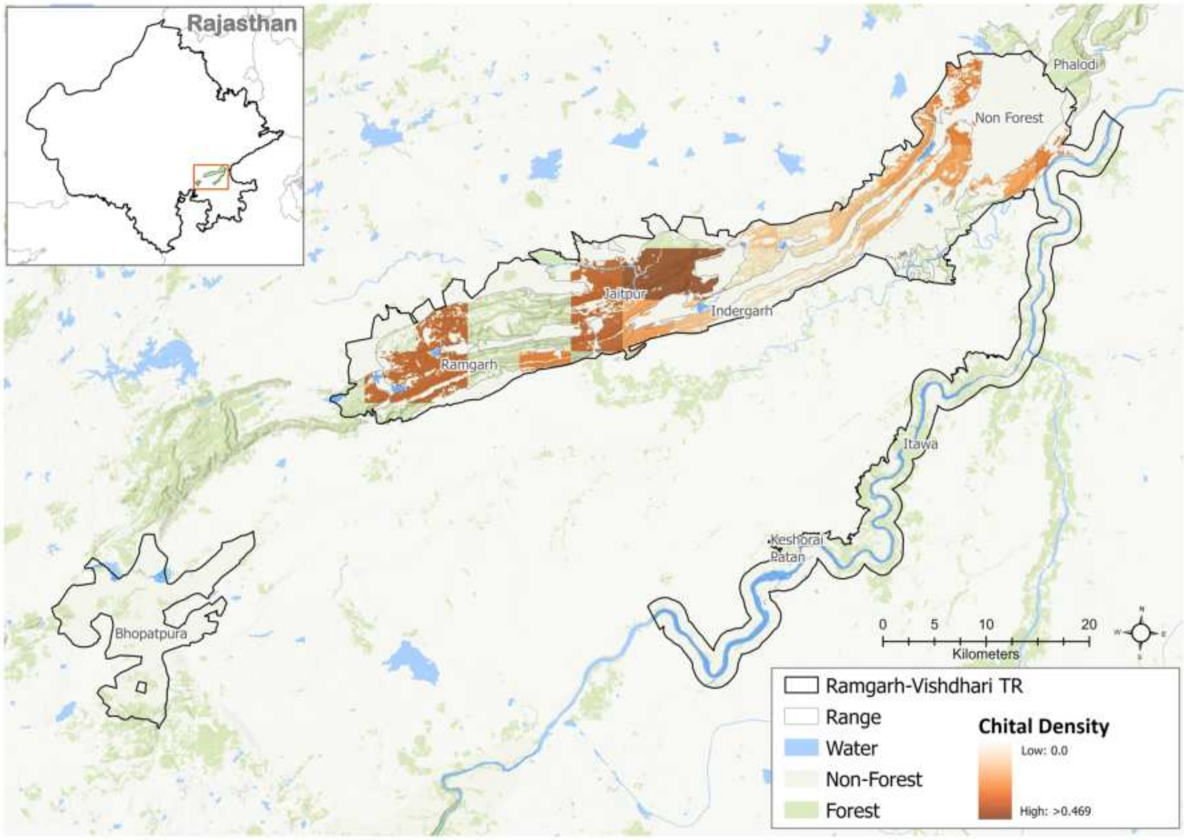

Figure IV. 117: Density of chital (per 25 km²) in Ramgarh Vishdhari tiger reserve: Landscape-level DSM

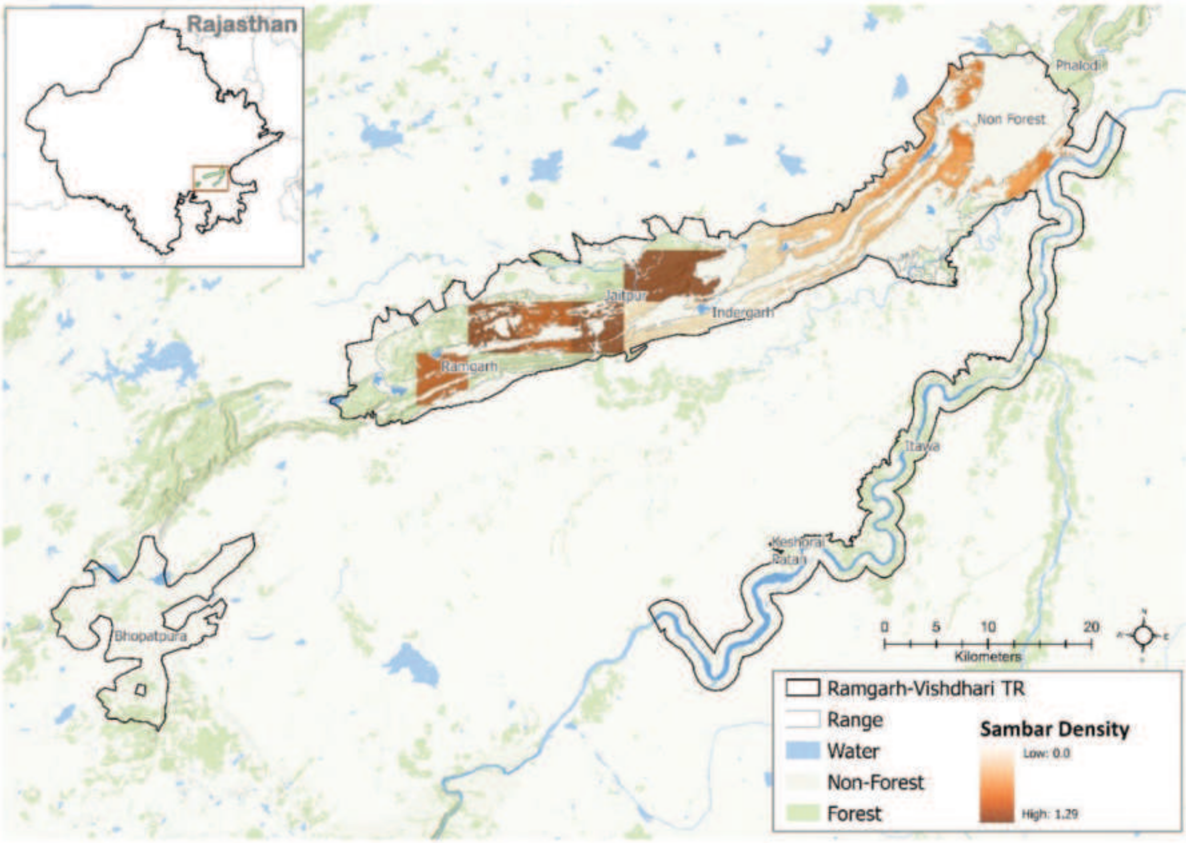

Figure IV. 118: Density of sambar (per 25 km²) in Ramgarh Vishdhari tiger reserve: Landscape-level DSM

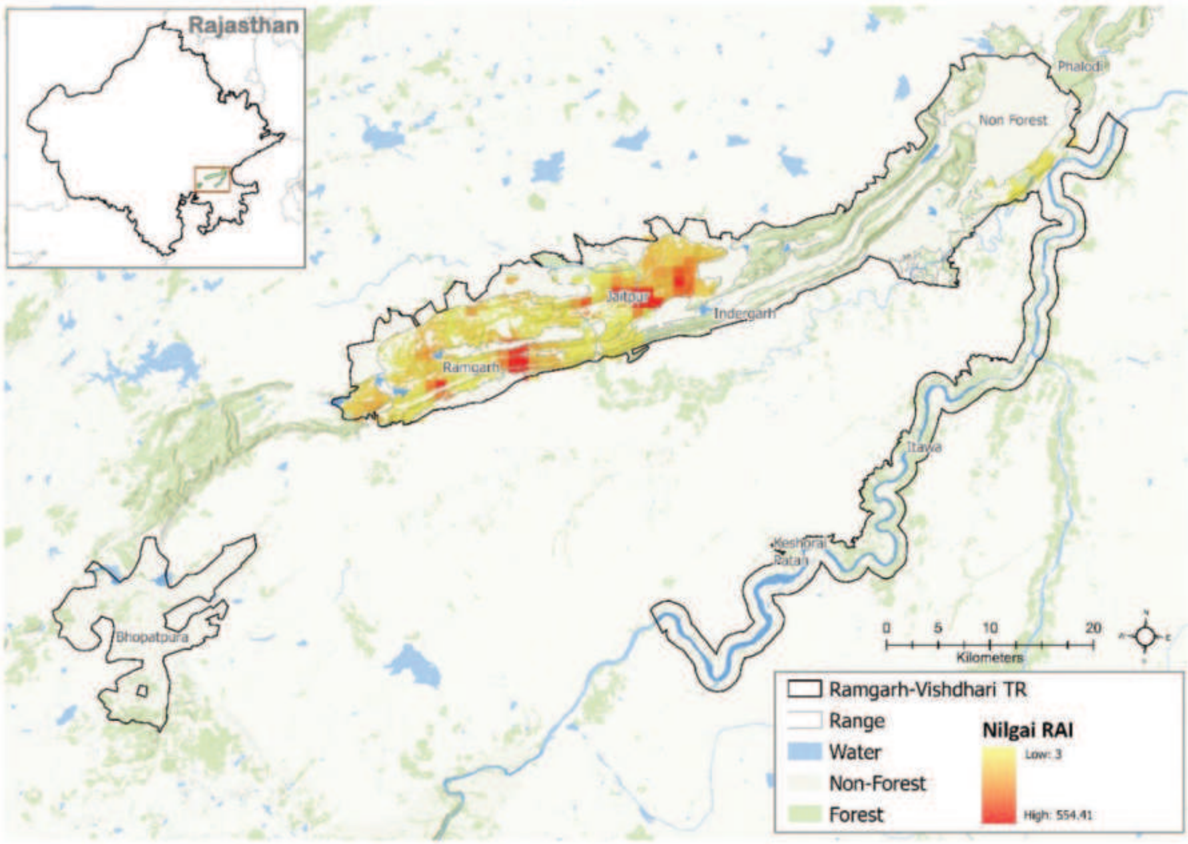

Figure IV. 119: Spatial relative abundance of nilgai in Ramgarh Vishdhari tiger reserve.

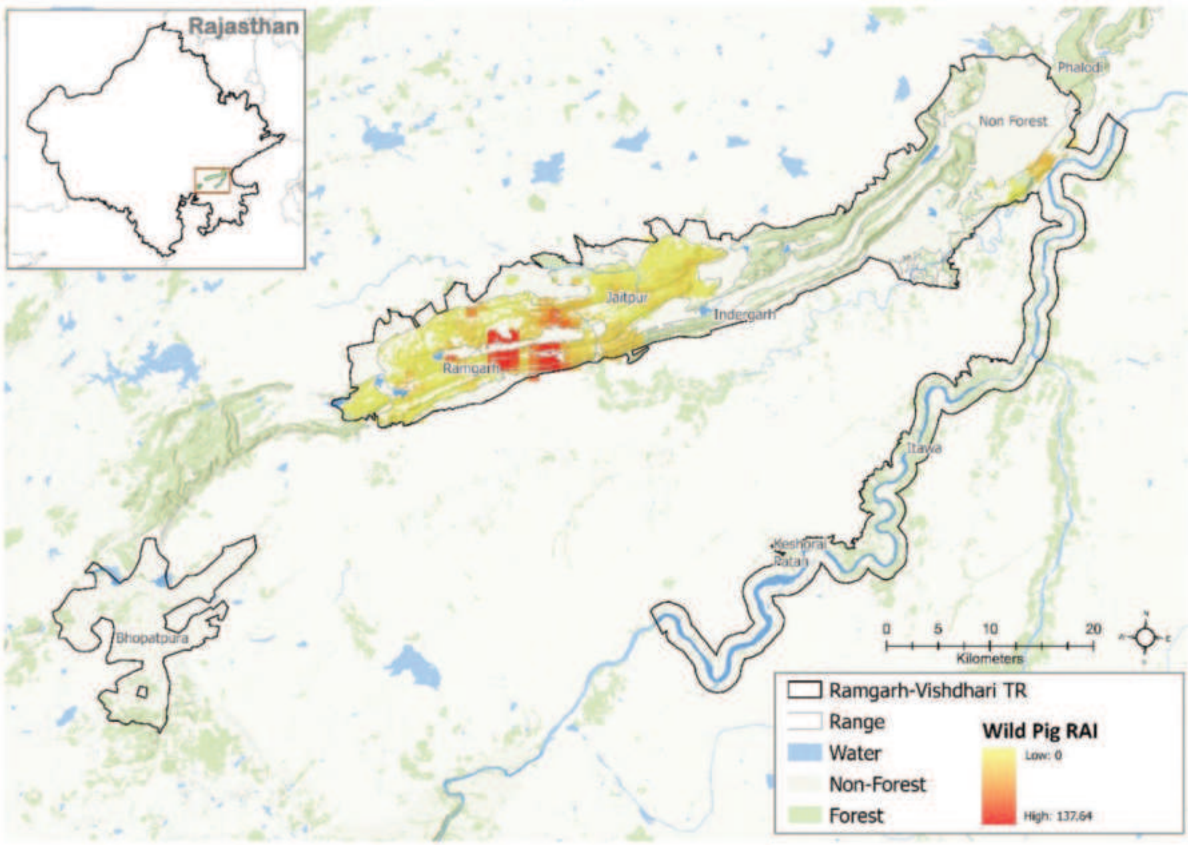

Figure IV. 120: Spatial relative abundance of wild pig in Ramgarh Vishdhari tiger reserve.

Ranthambhore Tiger Reserve

Ranthambore tiger reserve, located in Sawai-Madhopur district of Rajasthan, spans approximately 1,411 km^2. Renowned for its dramatic landscape, the reserve blends the rugged Vindhyan Hills and Aravalli Range (Singh 2021). The reserve features a mosaic of dry deciduous forests, thorn scrub, open grasslands, and rocky outcrops, with prominent water bodies like Mansarovar dam, Padam Talao, Rajbagh Lake, and the Banas River (Chauhan and Jhala, 2022). The wildlife includes tiger, Indian leopard, sloth bear, striped hyena, jungle cat, caracal, Indian fox, and herbivores like sambar, chital, chinkara, nilgai, and wild pig.

Although, chital is the most abundant ungulate in Ranthambore TR, its distribution is mostly limited to the southern part (Figure IV. 121). The highest spatial densities of chital is observed in Khundera followed by Talra and Khandar (Figure IV. 121). Management efforts should be focused towards augmenting chital population to the northern part of Ranthambhore and improving the connectivity between fragmented habitats. Sambar density in Ranthambore is moderate (Table IV. 10) with highest density in Khandar followed by Sawai Madhopur and Kundera. Although, predominantly distributed in the southern part of the reserve, sambar exhibits considerable density in the northern area also (Figure IV. 122). Nilgai density is highest near the border areas of Ranthambore (Figure IV. 123), while the central areas have very low nilgai presence. In contrast to chital and sambar, wild pig density is mostly concentrated in the northern part of the reserve, with the highest densities observed in Karanpur, followed by the Mandrayal range (Figure IV. 124).

Table IV. 10: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Ranthambhore tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	59	0.087 (0.012)	0.49 (0.07)	8.54 (1.42)	1.11 (0.19)	8.01 (0.88)
Nilgai	261	0.383 (0.024)	0.35 (0.02)	3.88 (0.2)	3.87 (0.33)	15.74 (1.06)
Sambar	84	0.123 (0.015)	0.24 (0.03)	2.54 (0.21)	1.72 (0.31)	4.44 (0.68)
Wild pig	61	0.09 (0.012)	0.39 (0.05)	5.61 (0.43)	0.98 (0.18)	5.78 (0.8)

B)

Species	Chital	Sambar	Wild pig	Nilgai
Detection model	Half-normal (Null)	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	8.281	2.99	8.548	30.1
s(NDVI Pre-Monsoon)	1.986	3.884	2.251	-
s(NDVI Post-Monsoon)	-	-	-	7.18
s(Ruggedness)	2.549	-	-	-

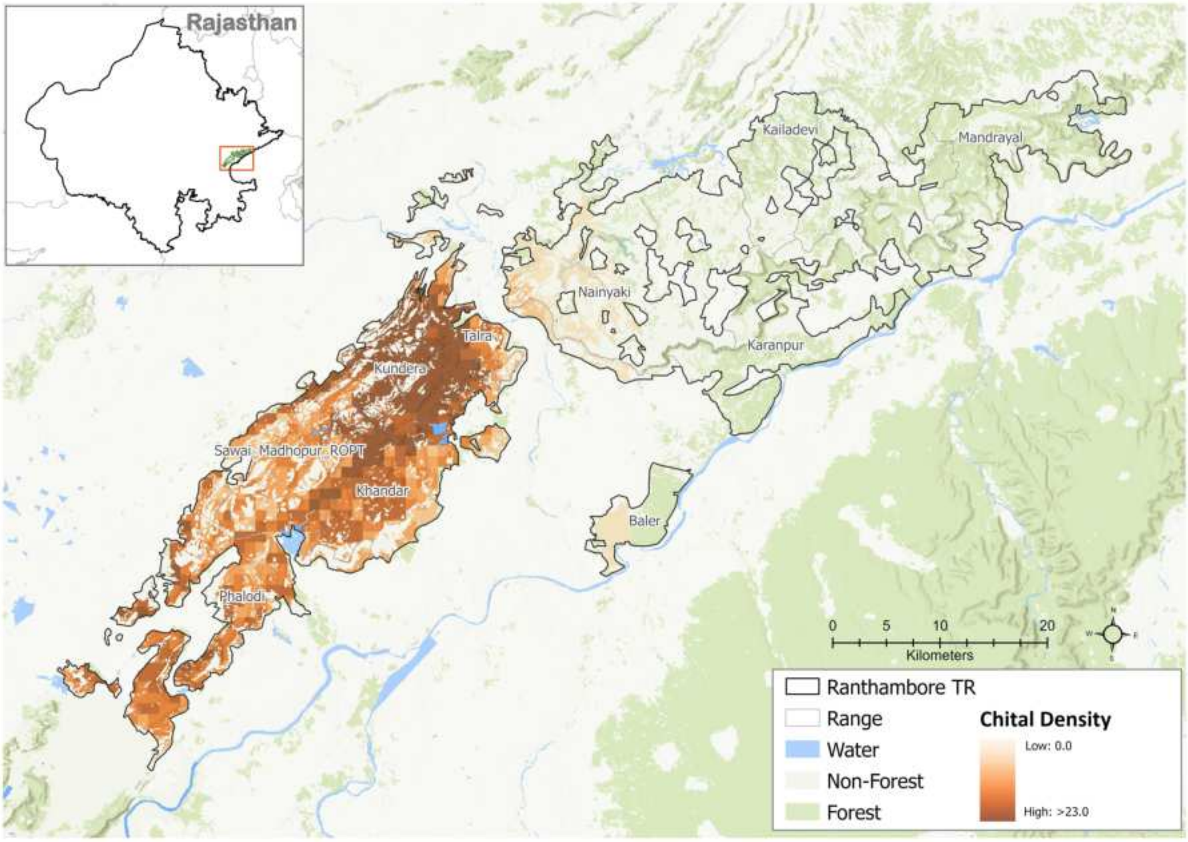

Figure IV. 121: Density of chital (per km^2) in Ranthambore tiger reserve: Site-level DSM

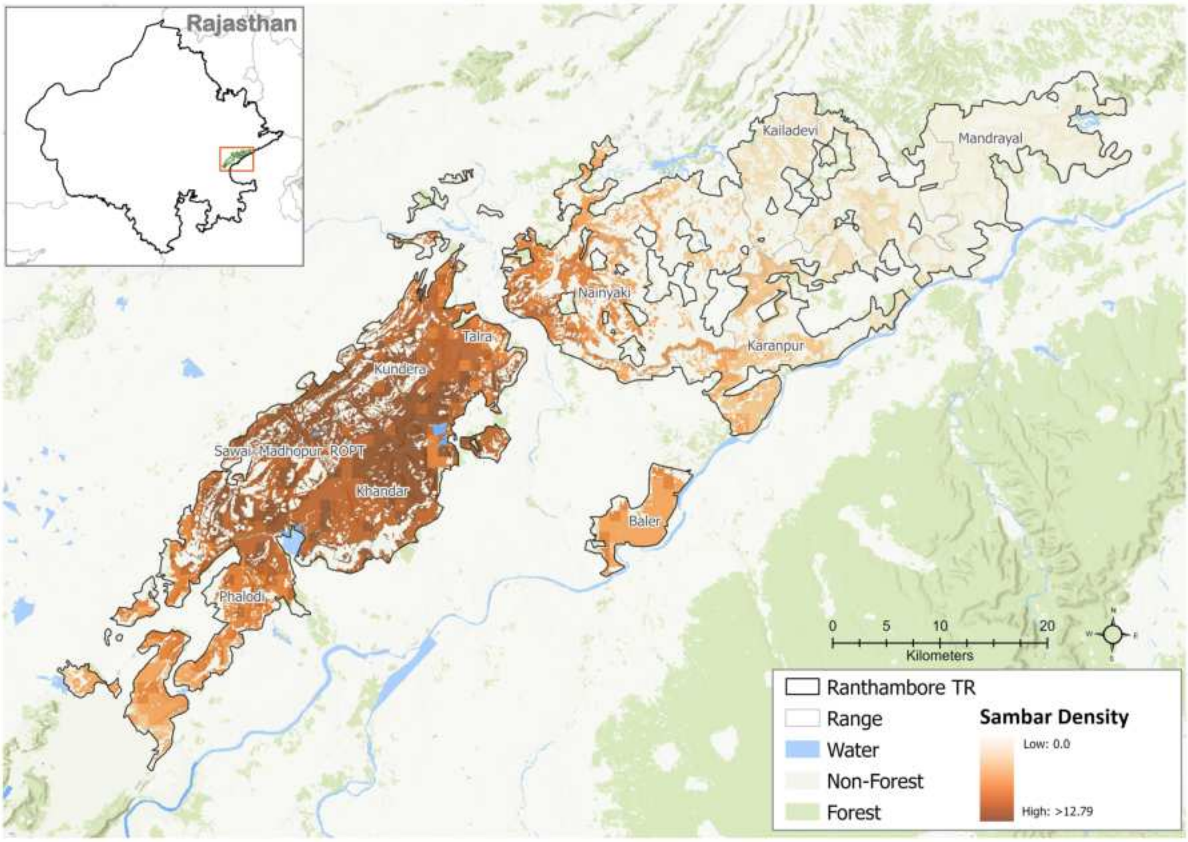

Figure IV. 122: Density of sambar (per km^2) in Ranthambore tiger reserve: Site-level DSM

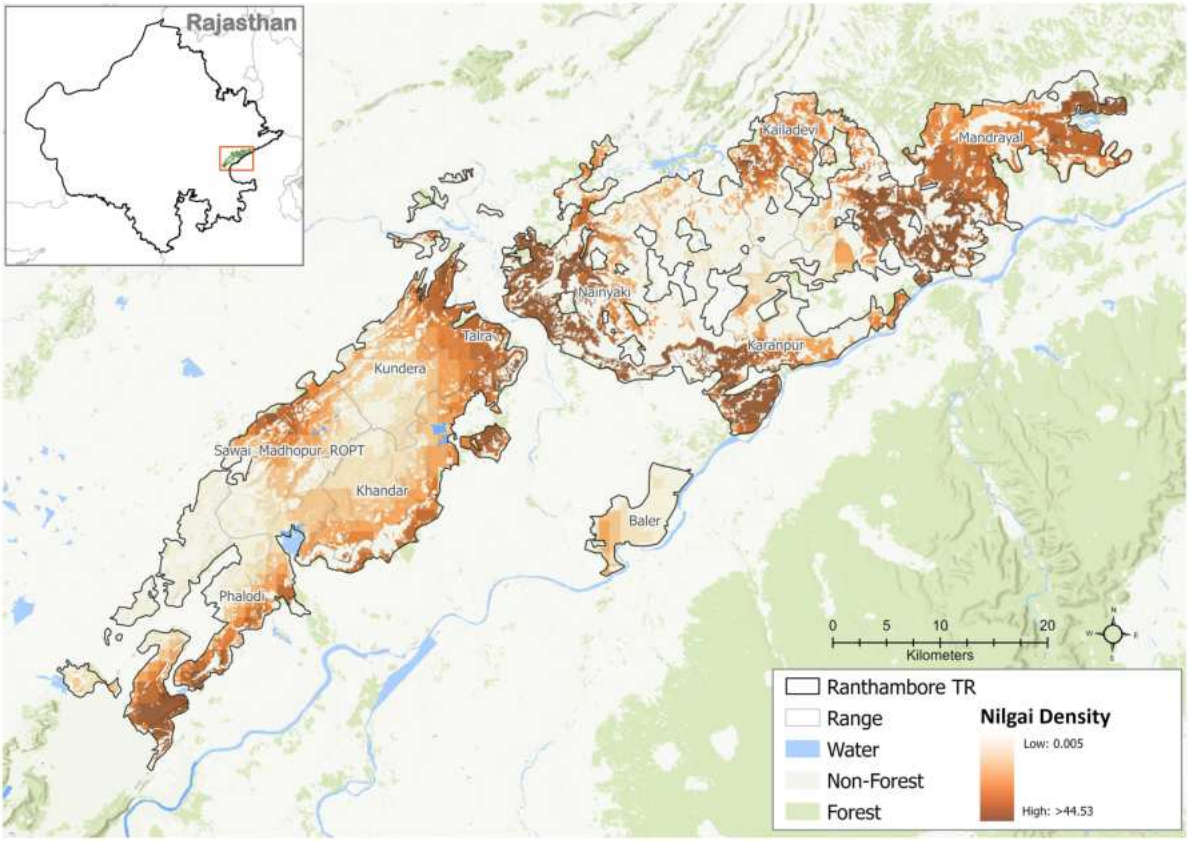

Figure IV. 123: Density of nilgai (per km²) in Ranthambore tiger reserve: Site-level DSM

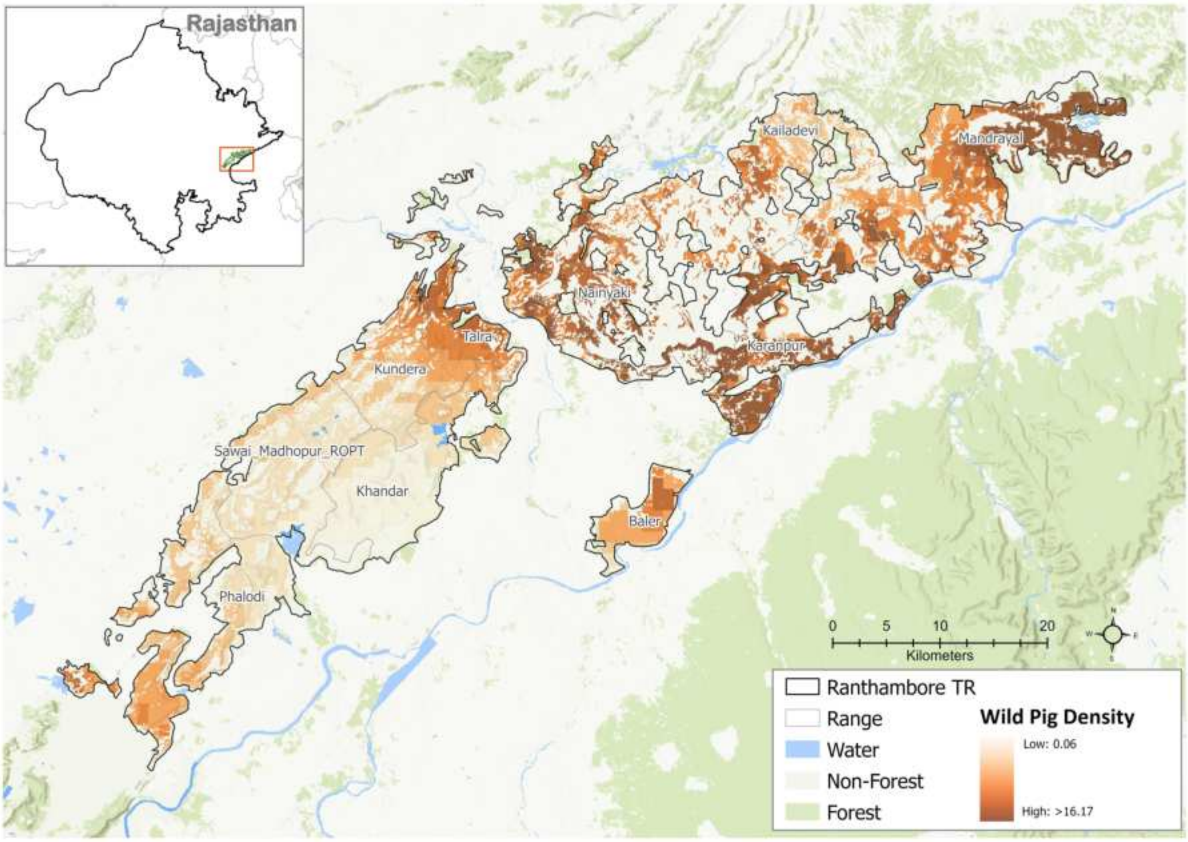

Figure IV. 124: Density of wild pig (per km²) in Ranthambore tiger reserve: Site-level DSM

Sariska Tiger Reserve

Sariska tiger reserve, located in the Alwar district of Rajasthan, spans approximately 1,213 km^2 and is situated in the Aravalli Range. The reserve has Northern tropical dry deciduous forests, thorn scrub, rocky hills, and grasslands (Champion and Seth, 1968), interspersed with perennial water sources such as Siliserh Lake and seasonal streams. It provides a critical habitat for tiger, leopard, caracal, jungle cat, jackal, striped hyena, and herbivores like sambar, nilgai, chital, and wild pig. Sariska also supports a rich avian diversity, Historically, Sariska has been a focal point for tiger conservation, serving as the site of India's first successful tiger reintroduction program following local extinction in the early 2000s, which is a significant milestone in global conservation efforts.

Chital is the most abundant prey in Sariska tiger reserve (Table IV. 11). The highest spatial densities of chital is in Sariska range followed by Tahla range (Figure IV. 125). The encounter rate for sambar is 0.0975 (±0.0281) and it occurs at moderate density across the tiger reserve, with highest density recorded at Sariska range followed by Talvriksh (Figure IV. 126). Nilgai is distributed throughout the tiger reserve with highest density in Sariska range followed by Tahla range (Figure IV. 127).

Due to insufficient data, wild pig spatial densities could not be estimated. However, relative abundance, derived from camera trap photo-capture data, indicates that wild pigs are most abundant in the Tahla range (Figure IV. 128). All ungulates are found in higher density in Sariska range, suggesting that this range could serve as a source for ungulate population management in the tiger reserve. Collaboration with local communities to reduce livestock grazing pressure for habitat improvement is recommended.

Table IV. 11: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Sariska tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	27	0.12 (0.024)	0.51 (0.08)	7.33 (0.92)	1.17 (0.3)	5.98 (1.14)
Nilgai	99	0.439 (0.044)	0.31 (0.03)	3.63 (0.35)	4.68 (0.63)	14.71 (1.78)

B)

Species	Chital	Nilgai
Detection model	Half-normal (Null)	Hazard rate (Null)
s(x,y)	2.987	4.92
s(NDVI Pre-Monsoon)	2.449	-
s(NDVI Post-Monsoon)	-	1
s(Ruggedness)	-	2.75

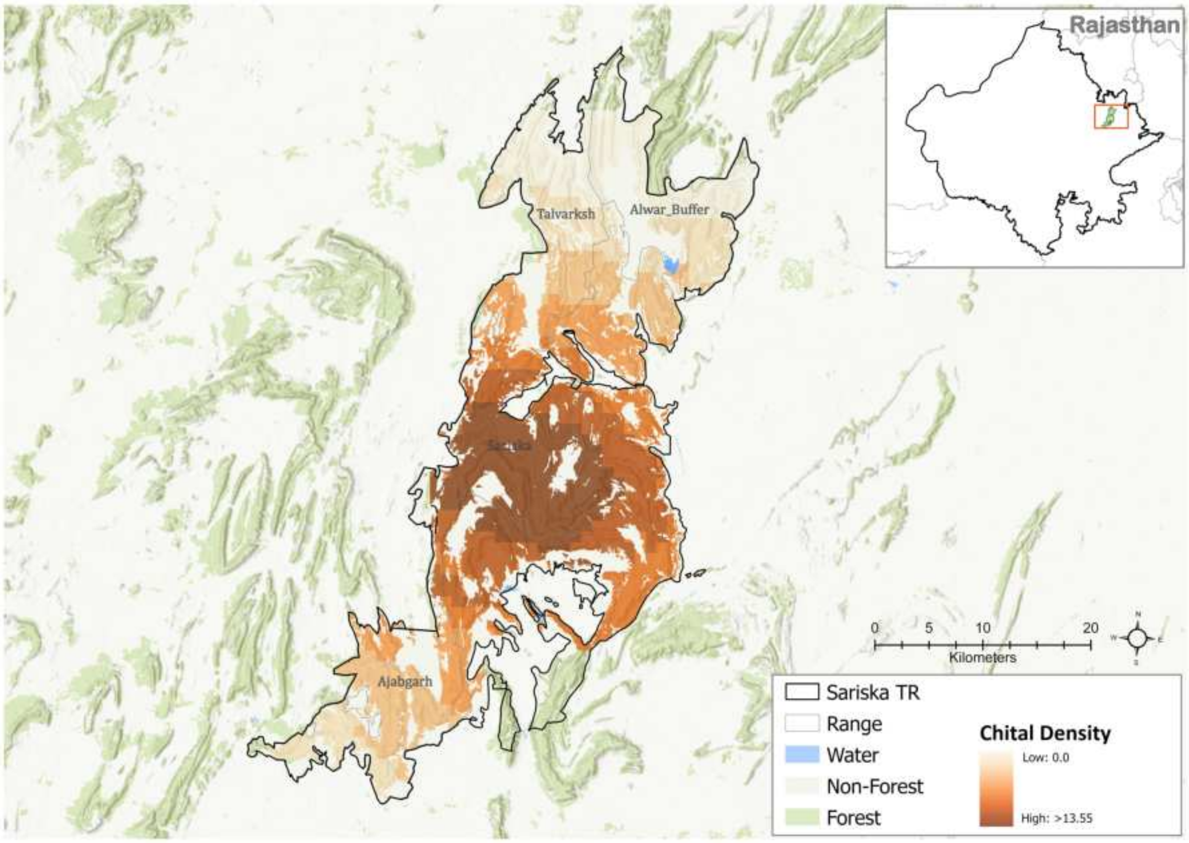

Figure IV. 125: Density of chital (per km^2) in Sariska tiger reserve: Site-level DSM

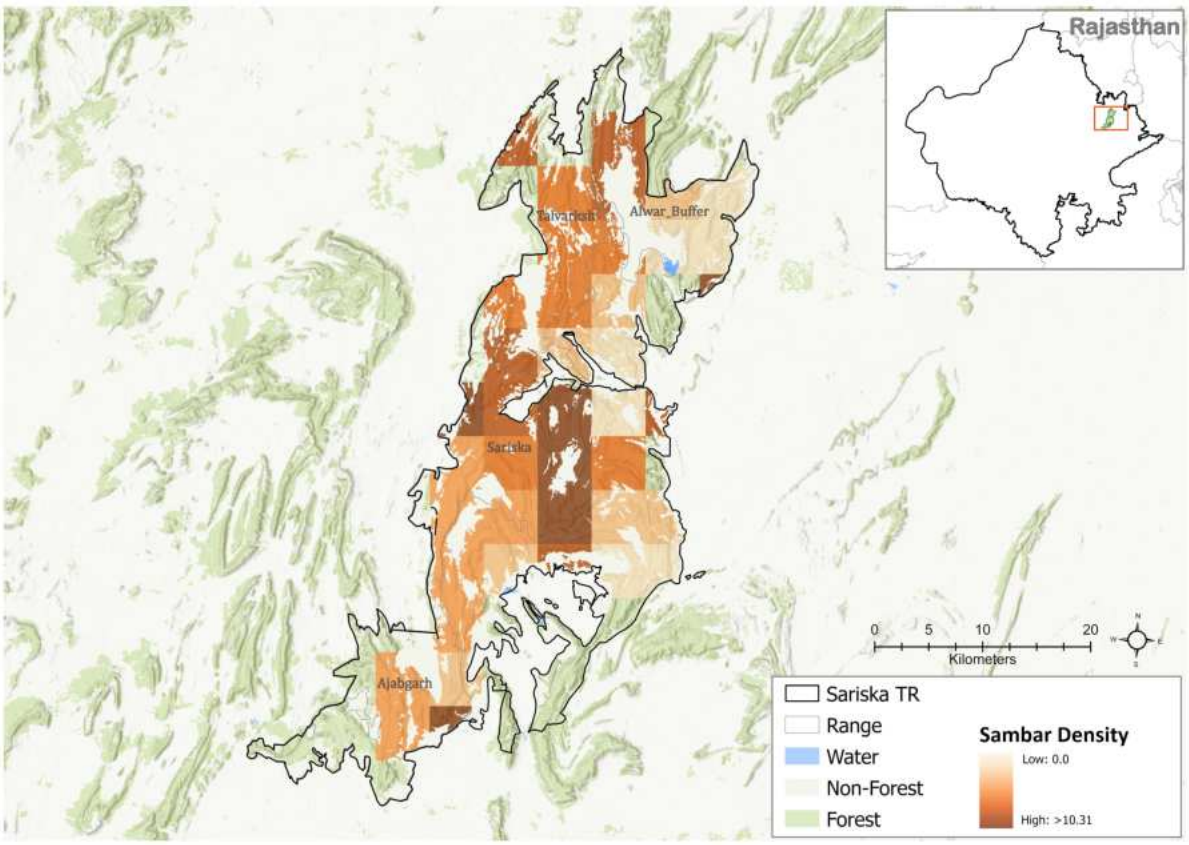

Figure IV. 126: Density of sambar (per 25 km^2) in Sariska tiger reserve: Landscape-level DSM

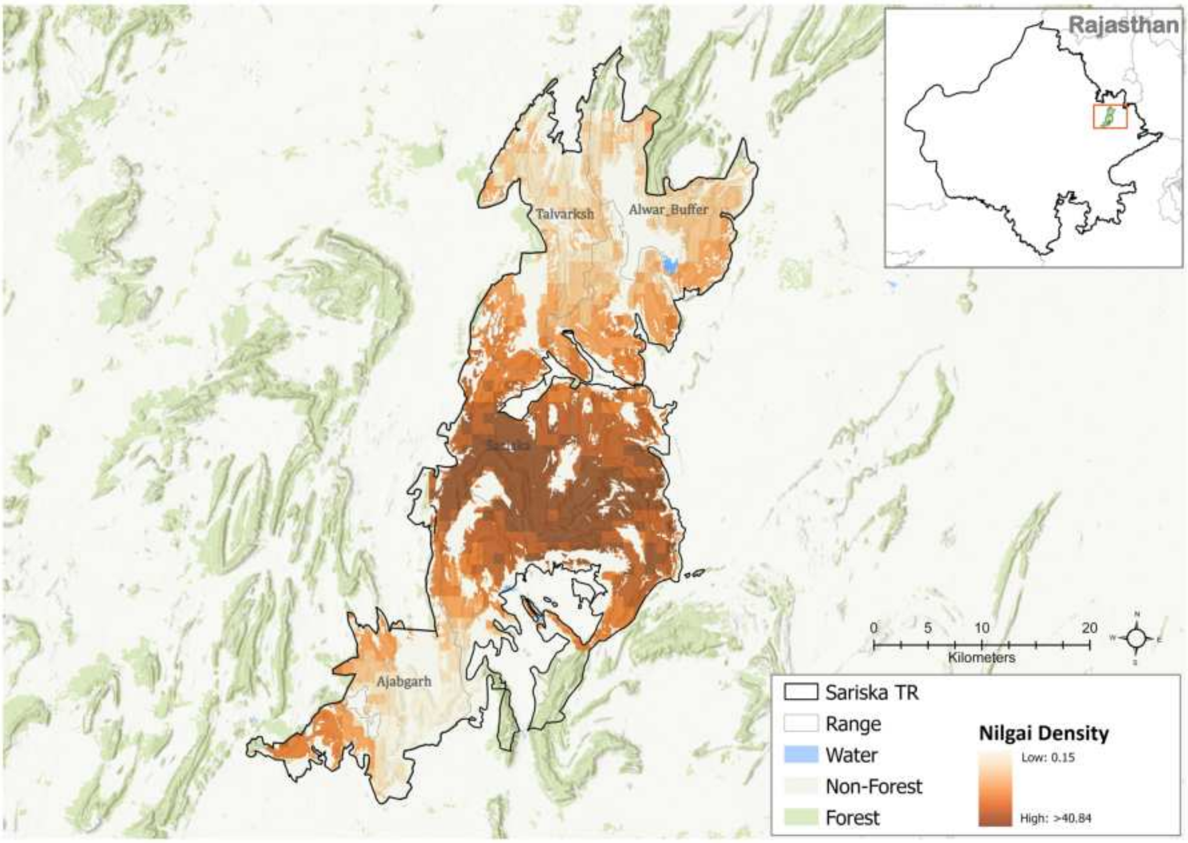

Figure IV. 127: Density of nilgai (per km²) in Sariska tiger reserve: Site-level DSM

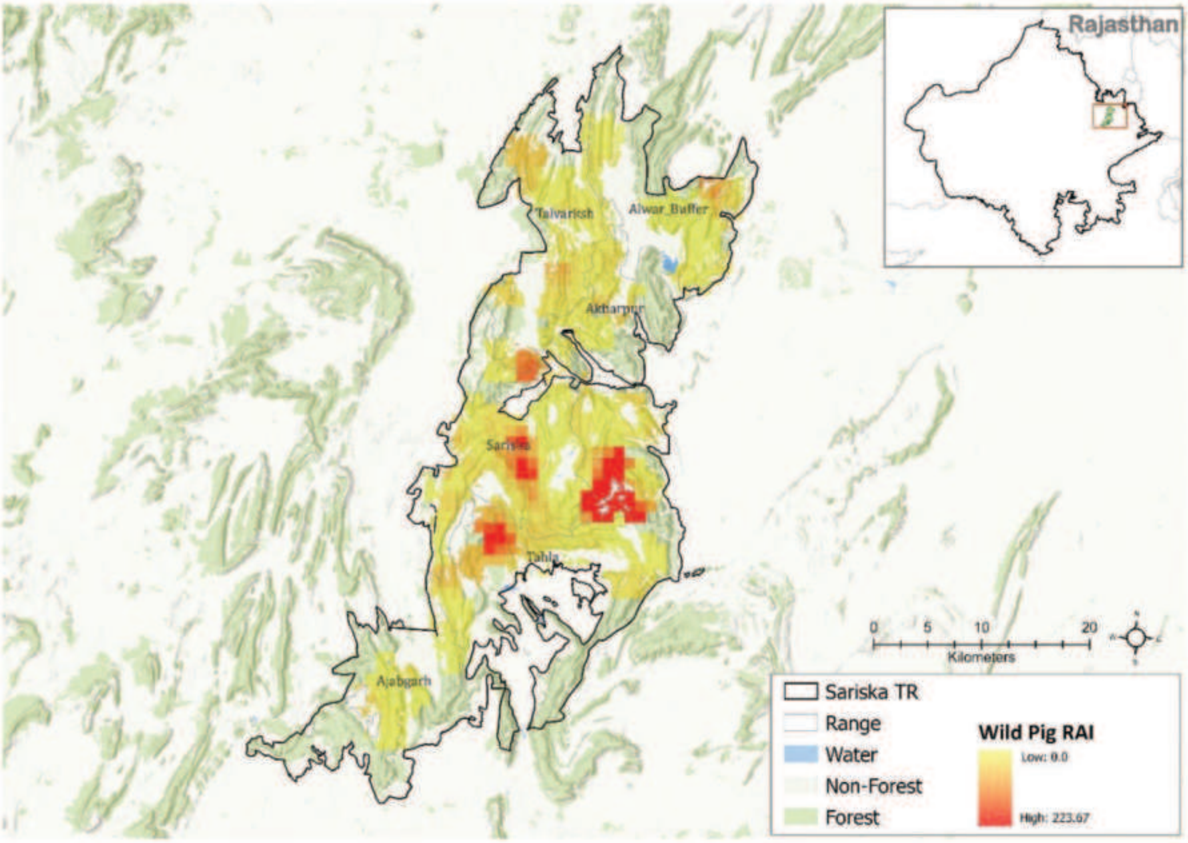

Figure IV. 128: Spatial relative abundance of wild pig in Sariska tiger reserve.

TELANGANA

Amrabad Tiger Reserve

Amrabad tiger reserve is located in the Nagarkurnool and Nalgonda districts of Telangana. It spans approximately 2,611 km^2 in the Nallamala Hills with rugged terrain deep gorges, plateaus, and river valleys. The reserve's forest Type is mainly Tropical Dry Deciduous (Champion and Seth, 1968) hosting different habitats including scrublands, and riverine habitats, which support a variety of wildlife. It is a critical habitat for tiger, leopards, sloth bears, Indian wolf, chital, sambar, nilgai, chousingha, chinkara, and Indian pangolin, along with rich avifaunal and reptile diversity. Amrabad is a crucial part of the NSTR landscape, which forms one of the largest contiguous tiger habitats in India.

Chital, sambar, nilgai, and wild pig density are mapped using line transect data. The western side of the tiger reserve has higher prey density compared to the eastern side. Chital is abundant on the western side of the park (Figure IV. 129). Sambar is most abundant in the Kollapur range, followed by Mannanur (Figure IV. 130). Nilgai is most abundant in the Maddimadugu range, followed by Mannanur and Kollapur (Figure IV. 131). Wild Pig is most abundant in Kollapur, followed by Maddimadugu. Chousingha abundance is moderate in Amrabad (Figure IV. 133) with higher abundance in Kollapur range and along the northern boundary of Achampet range. Eastern ranges of Amrabad tiger reserve, like Devarakonda and Kambala pally, have very low density of all prey species. Management intervention is required in these ranges for prey population recovery.

Table IV. 12: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Amrabad tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (DSM) (SE)
Chital	40	0.038 (0.006)	0.59 (0.08)	4.38 (0.51)	0.54 (0.11)	2.36 (0.44)
Nilgai	49	0.05 (0.007)	0.44 (0.05)	1.48 (0.11)	0.63 (0.11)	1.17 (0.19)
Sambar	67	0.064 (0.008)	0.27 (0.04)	2.19 (0.17)	1.21 (0.25)	2.39 (0.71)
Wild pig	37	0.035 (0.006)	0.27 (0.06)	3.95 (0.49)	0.43 (0.12)	1.65 (0.39)

B)

Species	Chital	Sambar	Wild pig	Nilgai
Detection model	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)	Half-normal (Null)
s(x,y)	17.628	4.823	7.903	7.61
s(Aridity)	-	3.416	-	-
s(NDVI Pre-Monsoon)	2.427	2.455	2.802	-
s(NDVI difference)	-	-	-	2.56
s(Ruggedness)	2.807	-	-	-

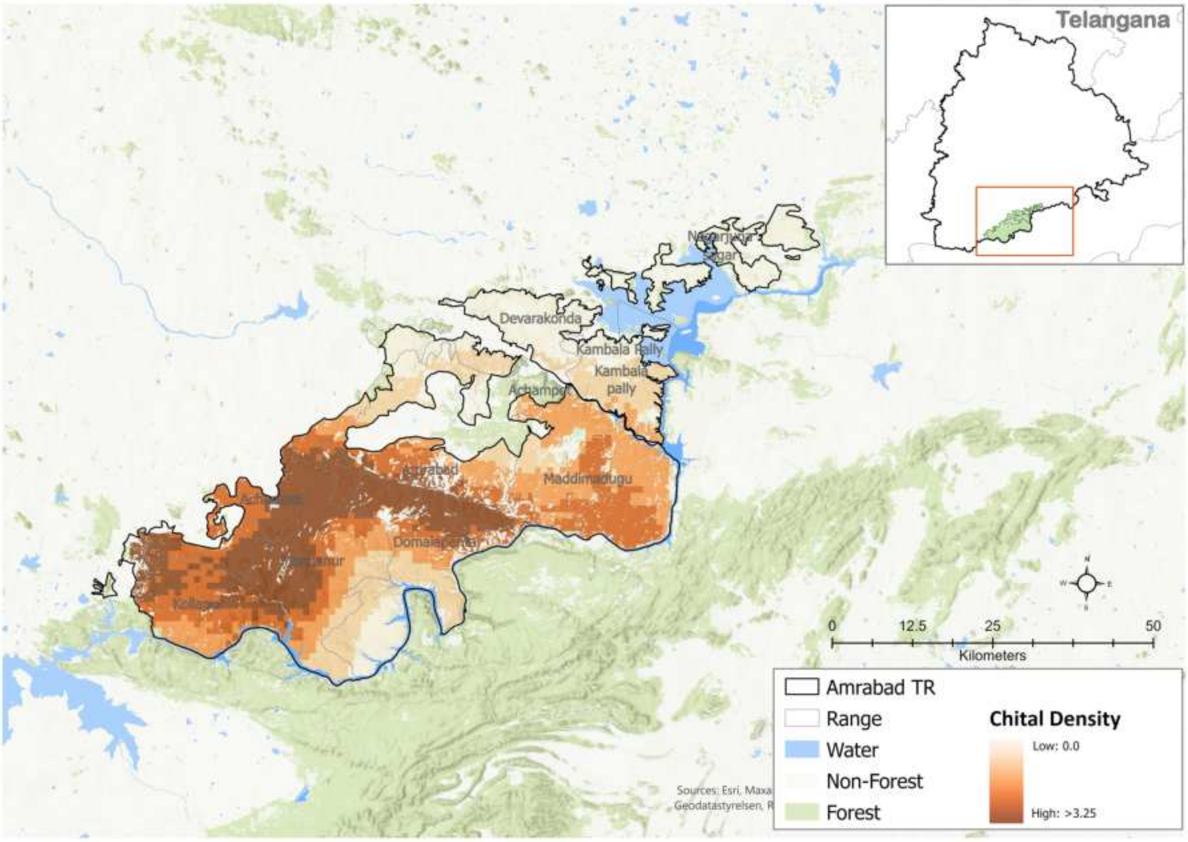

Figure IV. 129: Density of chital (per km^2) in Amrabad tiger reserve: Site-level DSM

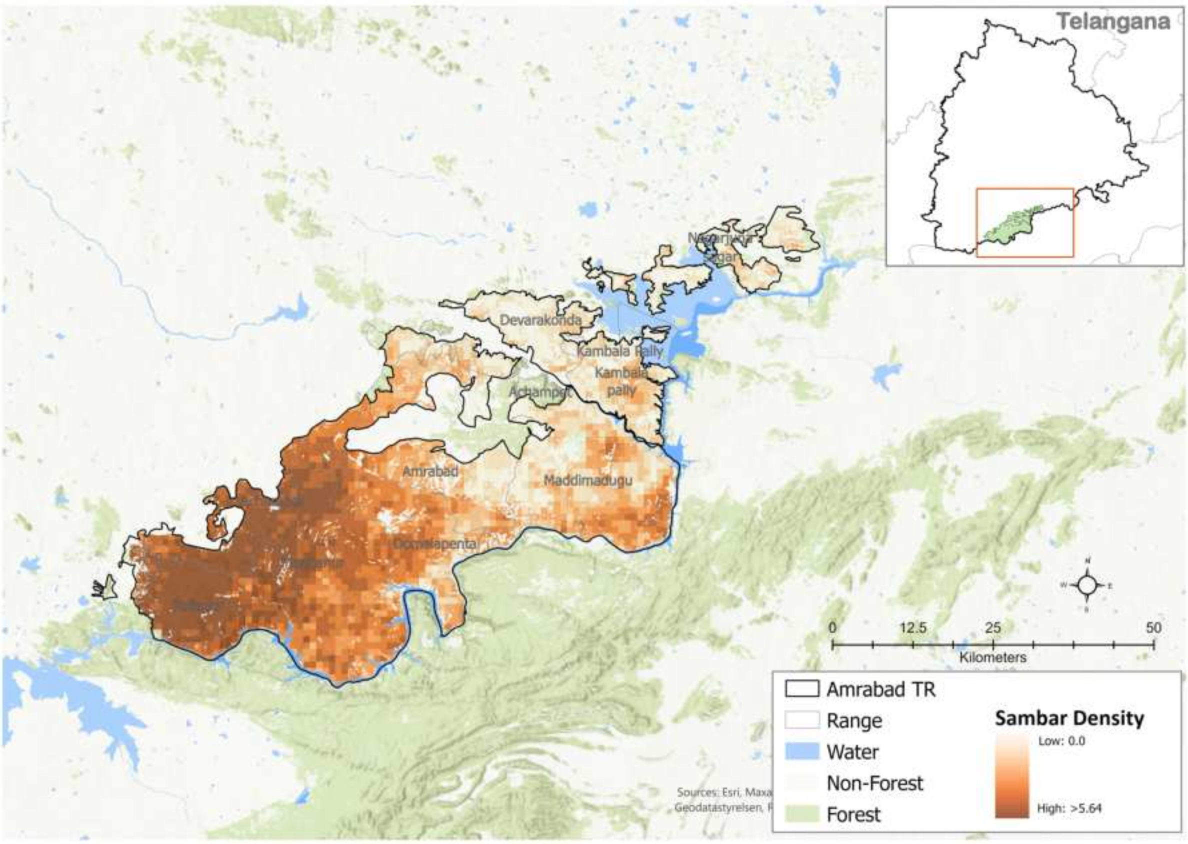

Figure IV. 130: Density of sambar (per km^2) in Amrabad tiger reserve: Site-level DSM

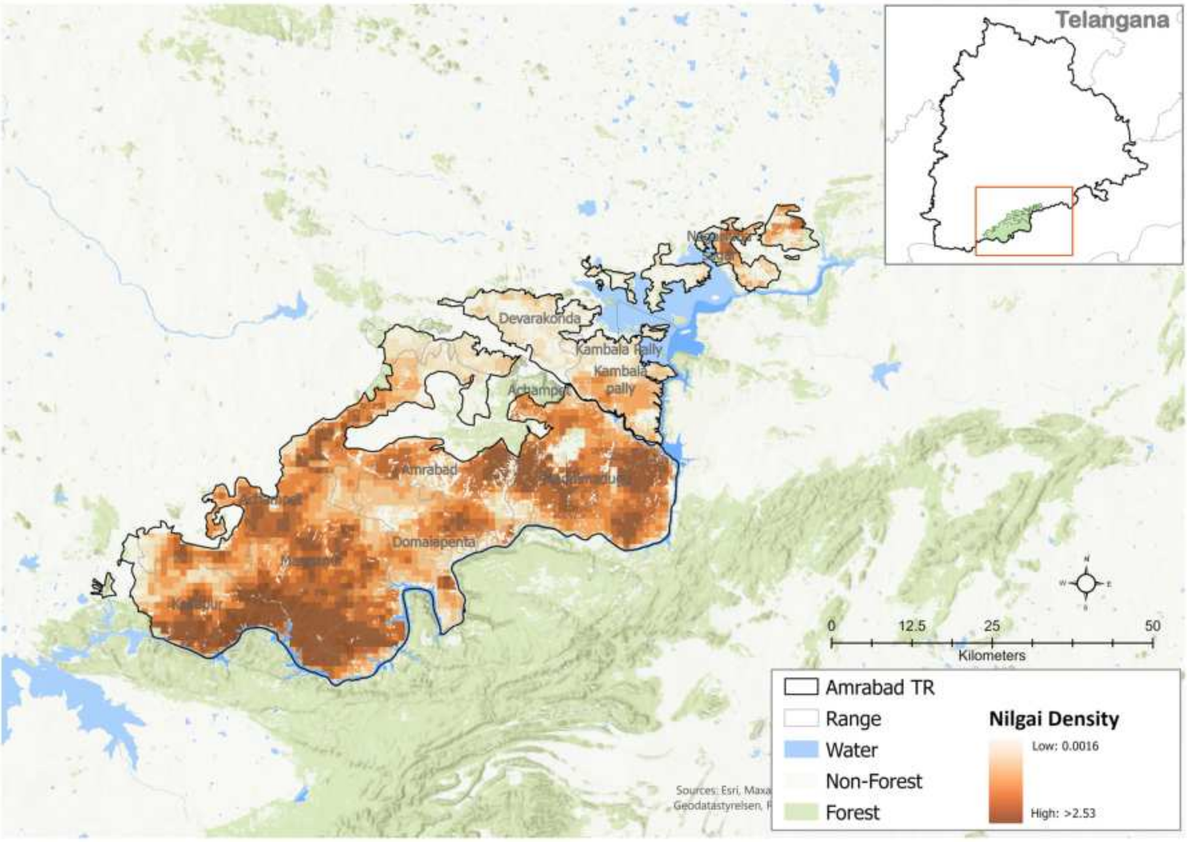

Figure IV. 131: Density of nilgai (per km^2) in Amrabad tiger reserve: Site-level DSM

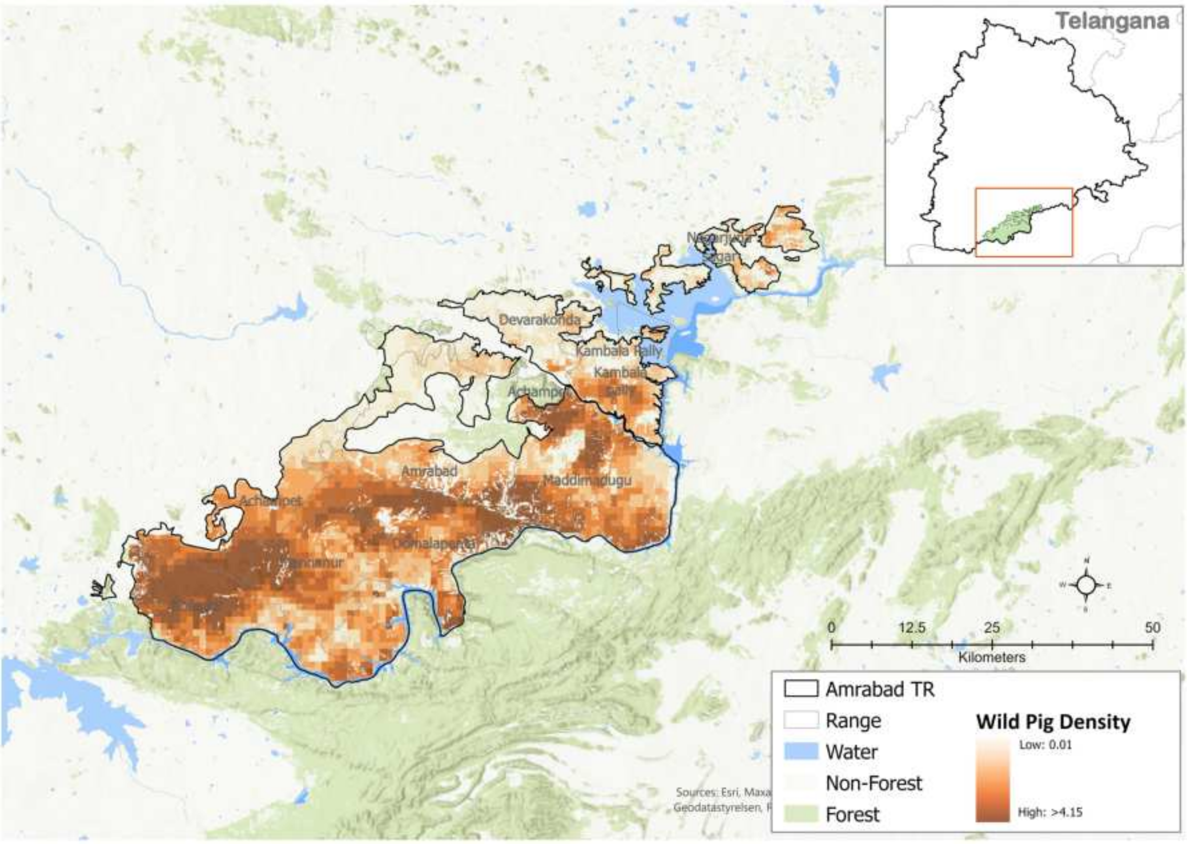

Figure IV. 132: Density of wild pig (per km^2) in Amrabad tiger reserve: Site-level DSM

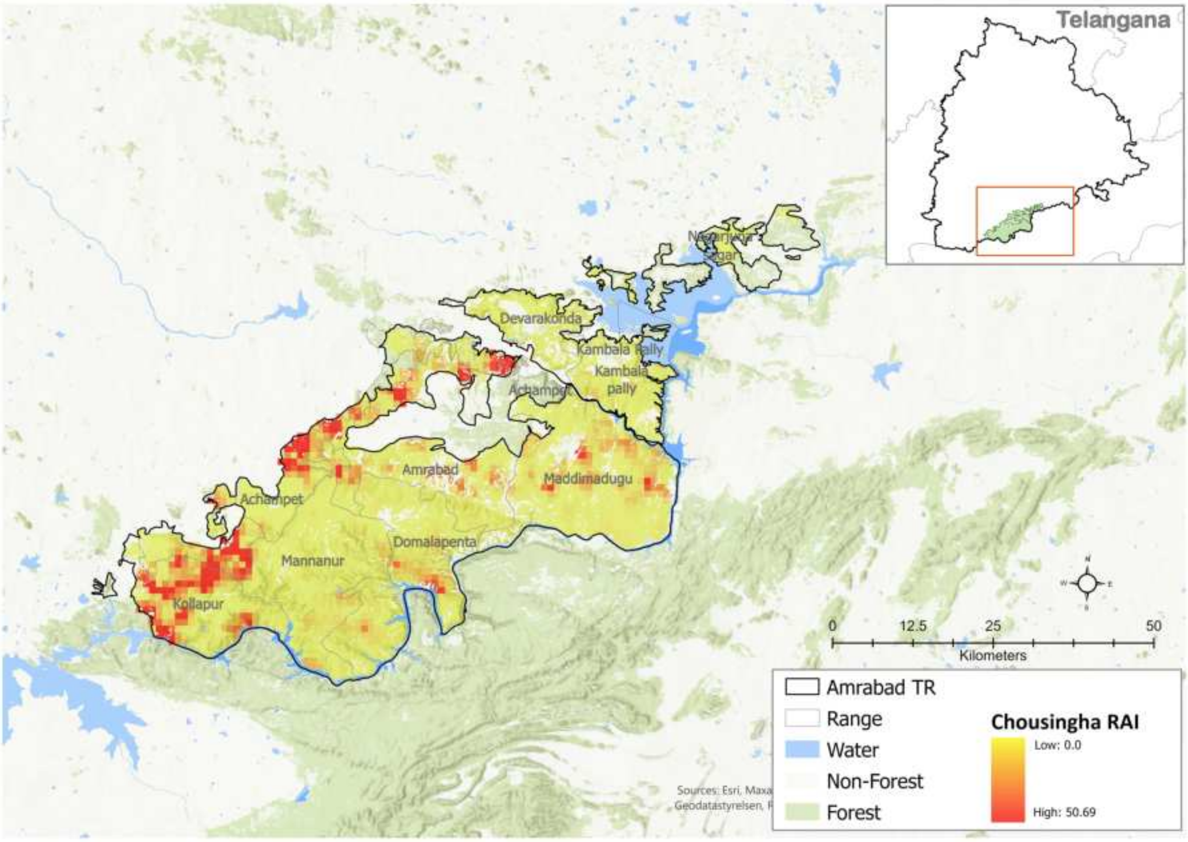

Figure IV. 133: Spatial relative abundance of chousingha in Amrabad tiger reserve.

Kawal Tiger Reserve

Kawal tiger reserve, located in the Mancherial district of Telangana along the banks of the Godavari River, spans approximately 2,015 km² and is part of the Central Indian Highlands. The reserve's landscape blends the semi-arid conditions of the Deccan Plateau with the moist monsoonal influences of the Eastern Ghats. It is characterized by diverse forest types, including Southern tropical dry deciduous forests (Champion and Seth, 1968), sal and teak woodlands, and bamboo thickets, interspersed with seasonal rivers that serve as critical water sources (Jaiswal *et al*., 2023). The reserve supports a variety of fauna, including tigers, leopards, sloth bears, and herbivores such as chital, sambar, nilgai, and wild pigs.

The densities of chital, nilgai, and wild pigs were estimated using line transect data, while sambar density was predicted using a landscape model due to limited data availability. The encounter rate for sambar is 0.0131 (±0.0031). Chital density is highest in the Khanapur and Jannaram ranges, followed by Tadlapet, Indanpally, Kaddam, and Pembi (Figure IV. 134). Landscape model predicts sambar density across most ranges of Kawal, except Jodeghat and Ginnedhari. The highest sambar density is observed in the Tandra range (Figure IV. 135). Nilgai density is highest in Indanpally, followed by Pembi (Figure IV. 136). Wild pigs are abundant throughout the reserve, with the highest densities recorded in the Birsaipet, Udumpur, and Indanpally ranges (Figure IV. 137).

Spatial densities for gaur could not be estimated due to insufficient line transect data. However, relative abundance based on camera trap photo-captures indicates very low gaur presence in Kawal, with the highest relative abundance in Indanpally (Figure IV. 139). The chousingha was primarily found in the central area of Kawal, with its relative abundance highest in the Kaddam range, followed by the Tadlapet and Udumpur ranges (Figure IV.138).

Table IV. 13: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Kawal tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	79	0.074 (0.008)	0.47 (0.04)	6.24 (0.78)	1.1 (0.28)	3.9 (0.36)
Nilgai	123	0.116 (0.011)	0.45 (0.03)	3.95 (0.41)	1.08 (0.12)	4.17 (0.31)
Wild pig	47	0.044 (0.006)	0.21 (0.05)	7.21 (0.88)	0.53 (0.16)	3.5 (0.92)

B)

Species	Chital	Wild pig	Nilgai
Detection model	Half-normal (Null)	Hazard rate (Null)	Half-normal (Null)
s(x,y)	6.889	6.721	12.8
s(NDVI Pre-Monsoon)	1.949	-	-
s(NDVI difference)	-	1.944	4.02
s(Elevation)	1.813	-	-

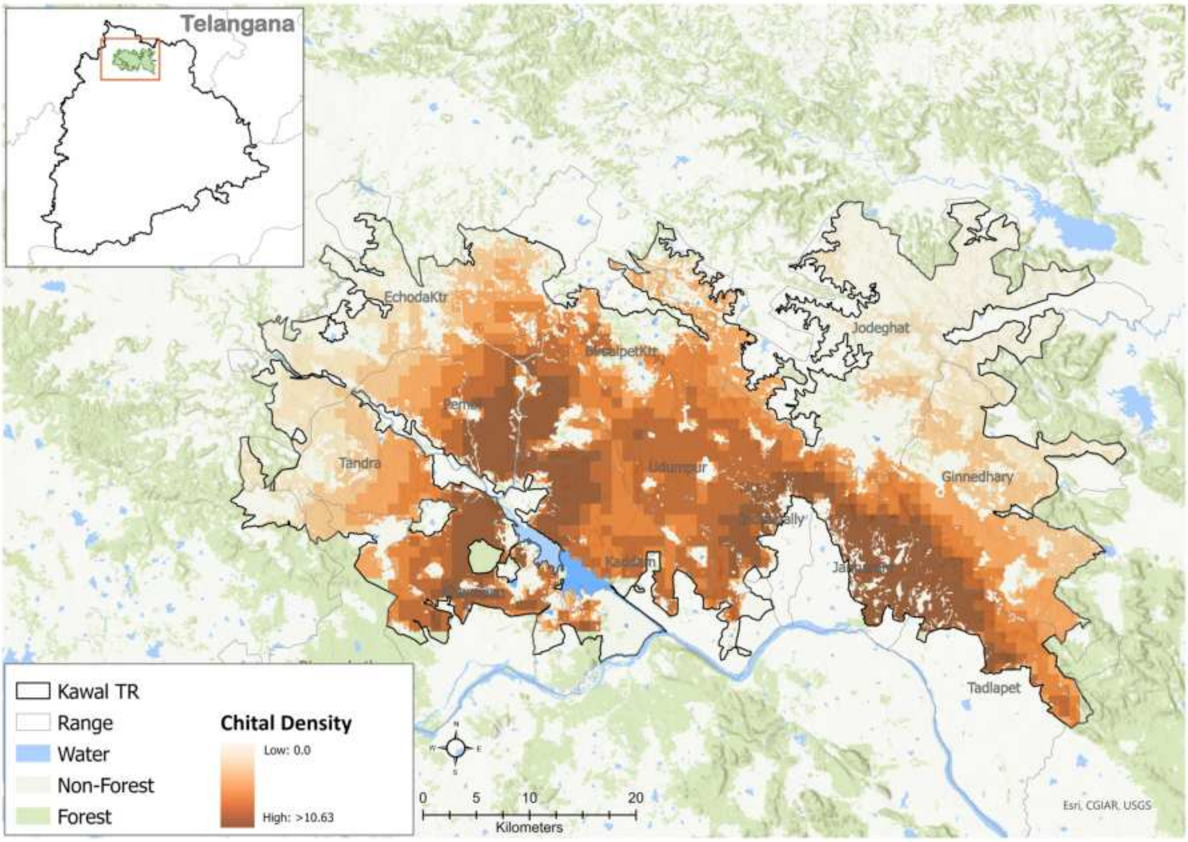

Figure IV. 134: Density of chital (per km²) in Kawal tiger reserve: Site-level DSM

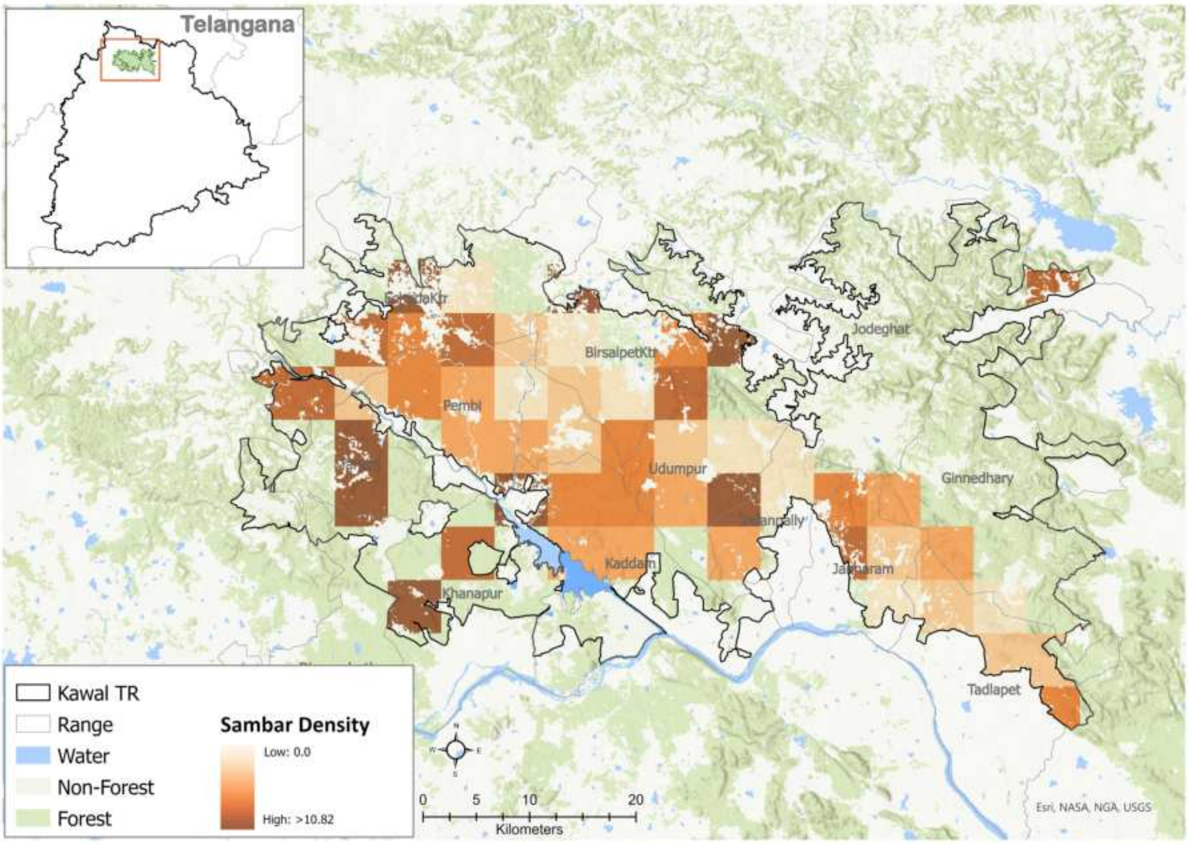

Figure IV. 135: Density of sambar (per 25 km²) in Kawal tiger reserve: Landscape-level DSM

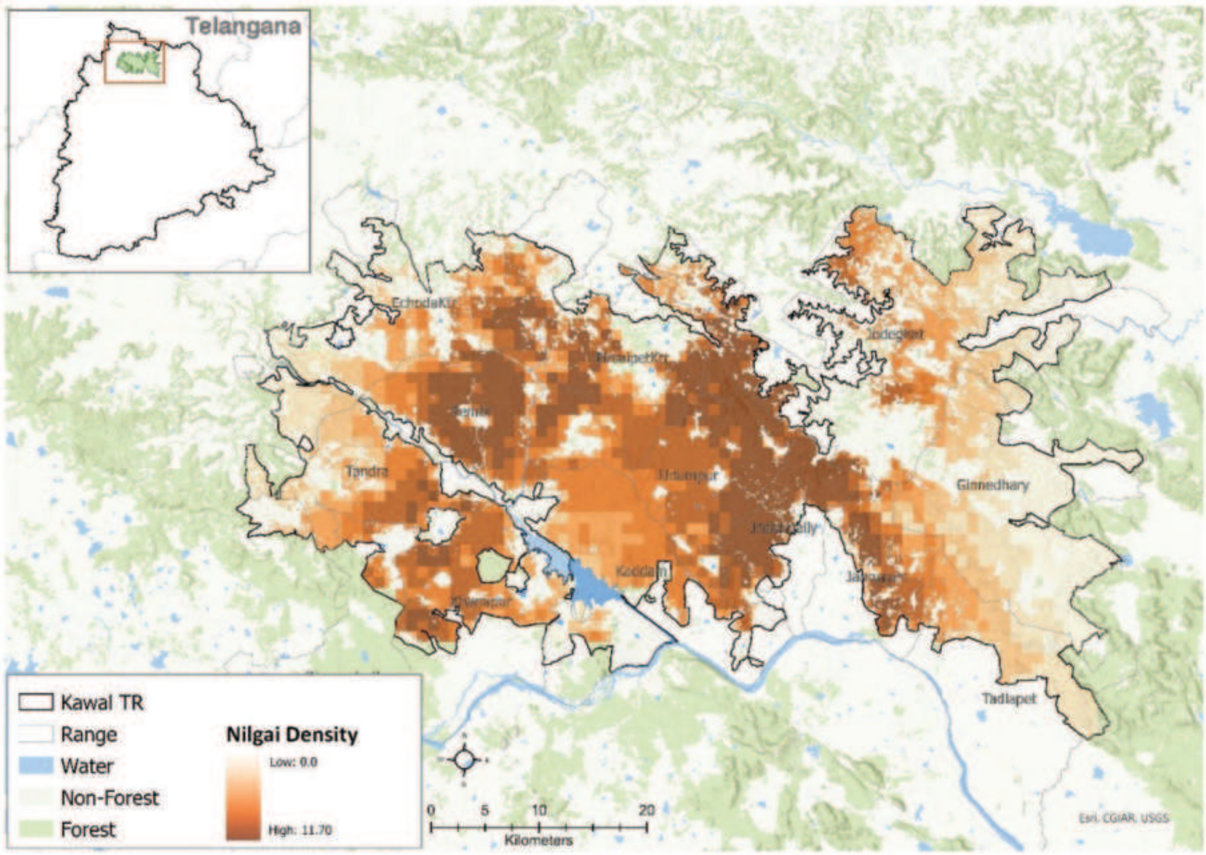

Figure IV. 136: Density of nilgai (per km^2) in Kawal tiger reserve: Site-level DSM

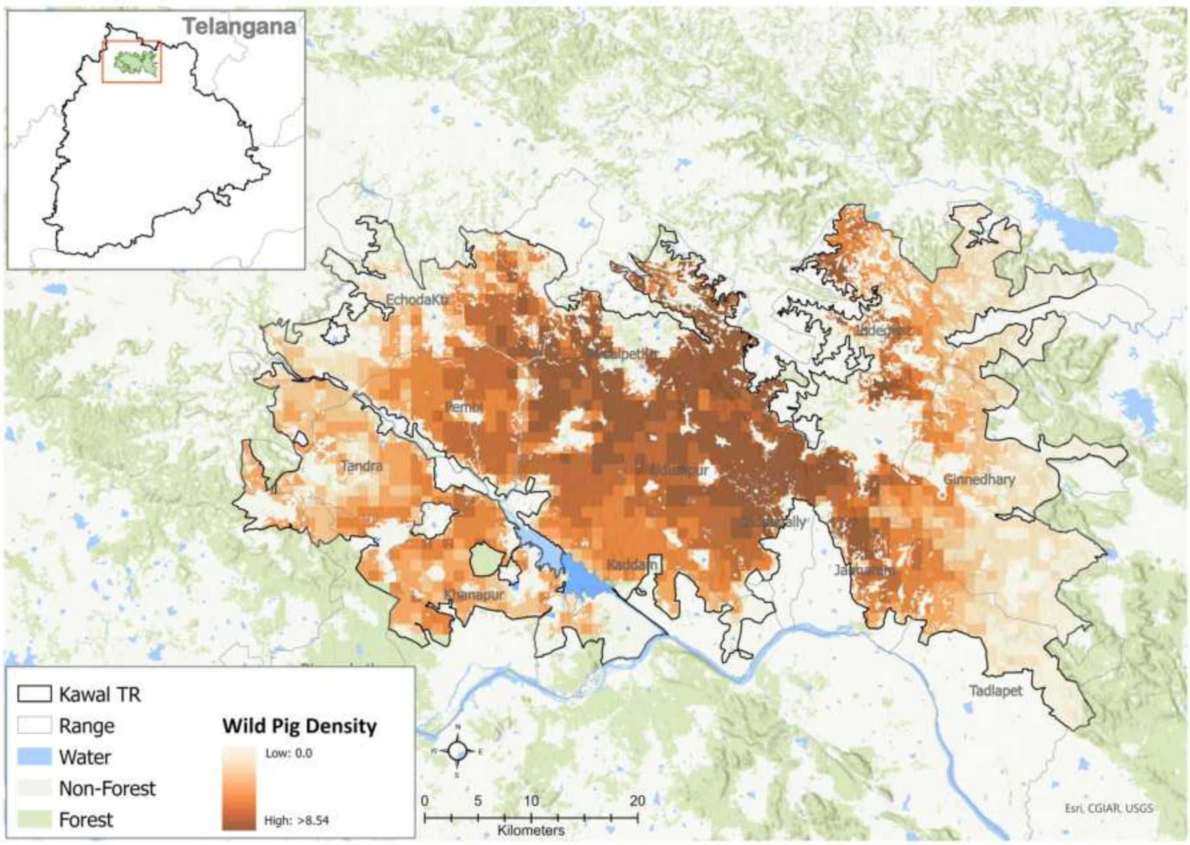

Figure IV. 137: Density of wild pig (per km^2) in Kawal tiger reserve: Site-level DSM

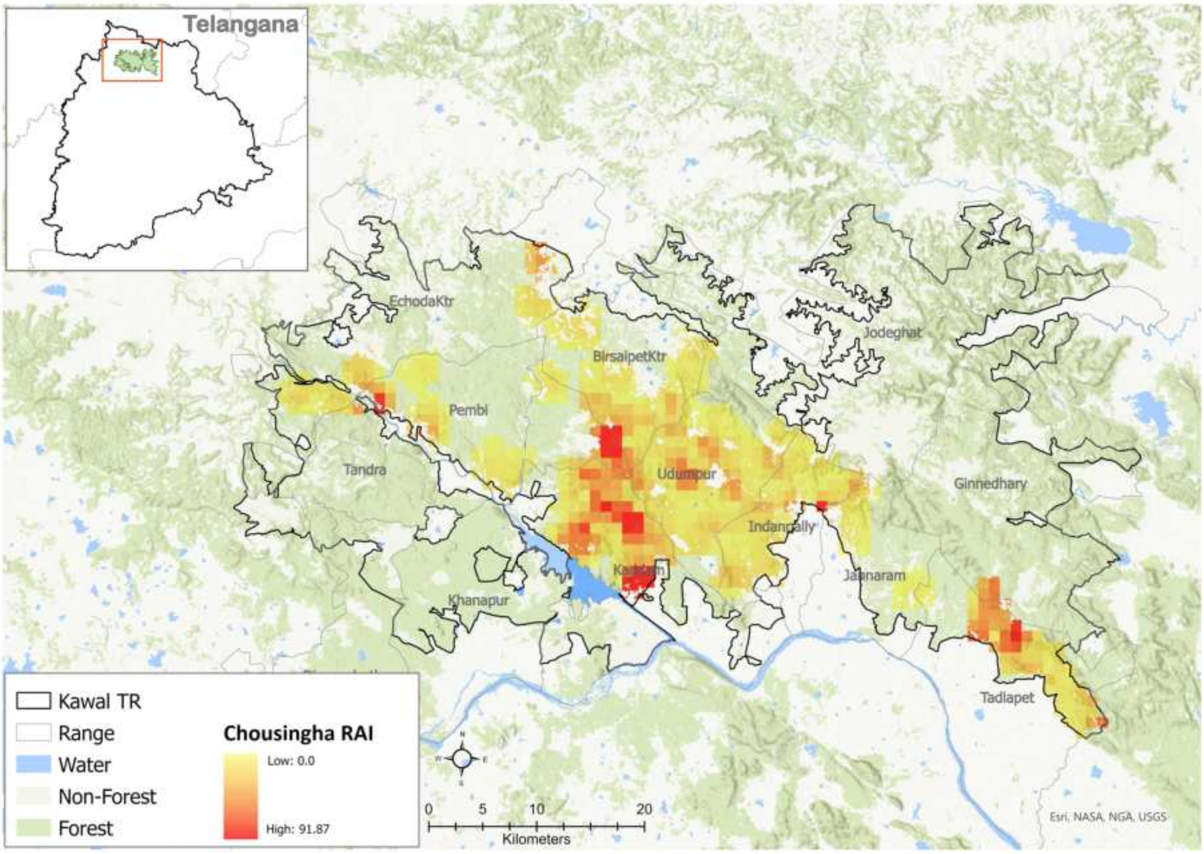

Figure IV. 138: Spatial relative abundance of chousingha in kawal tiger reserve.

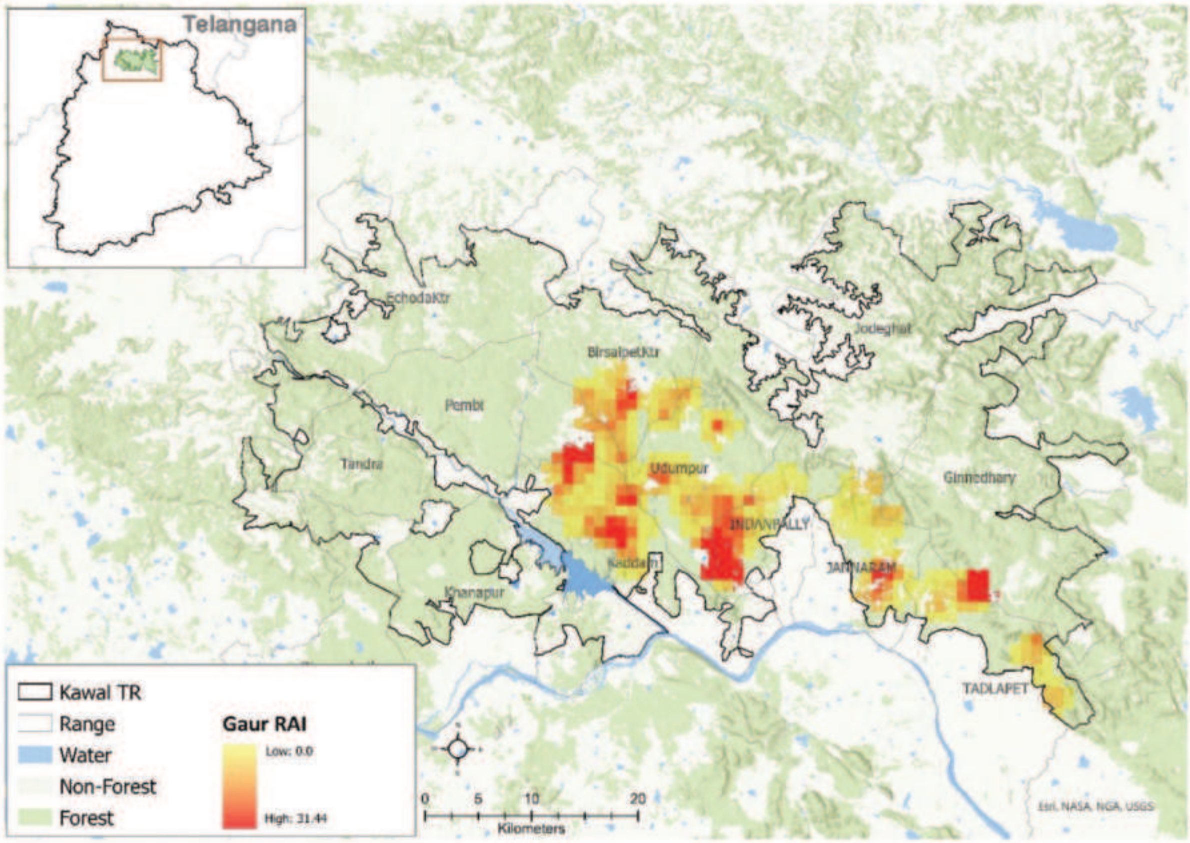

Figure IV. 139: Spatial relative abundance of gaur in Kawal tiger reserve.

UTTAR PRADESH

Ranipur Tiger Reserve

Ranipur tiger reserve, located in the Chitrakoot district of Uttar Pradesh, spans approximately 529 km^2 and is one of the newest tiger reserves in India. Situated in the Vindhyan Hills, the reserve is characterized by its rugged terrain with dry deciduous forests, rocky outcrops, and grasslands, with seasonal rivers and streams enriching its biodiversity. The vegetation is dominated by species like sal, teak, bamboo, and ber. Faunal diversity includes tiger, leopard, sloth bear, and ungulate species such as chital, sambar, and nilgai.

Data from Ranipur is limited, primarily comprising the core zone only. The encounter rate for chital is 0.2089 (±0.0646) and for sambar is 0.0298 (±0.0173). Hence, chital and sambar density is predicted from landscape model whereas relative abundance of nilgai and wild pig are mapped using photo capture of camera trap data. Chital is more abundant than other ungulates present in Ranipur (Figure IV. 140). It has medium to low density with highest density in Manikpur (core) range, whereas Markundi (core) range has the higher sambar density (Figure IV. 141). Wild pig is more abundant in Markundi (core) ranges (Figure IV. 143) while nilgai is abundant in both Markundi (core) and Manikpur (core) range (Figure IV. 142).

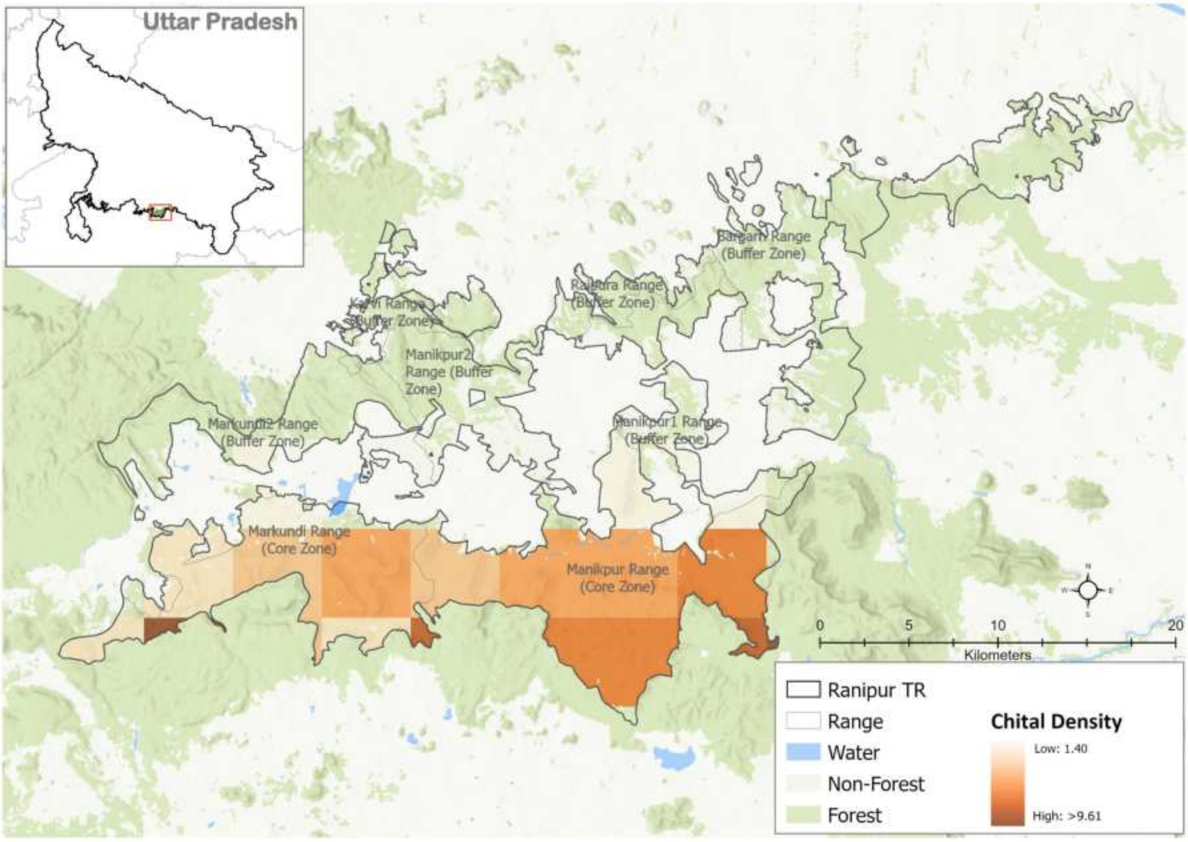

Figure IV. 140: Density of chital (per 25 km²) in Ranipur tiger reserve: Landscape-level DSM

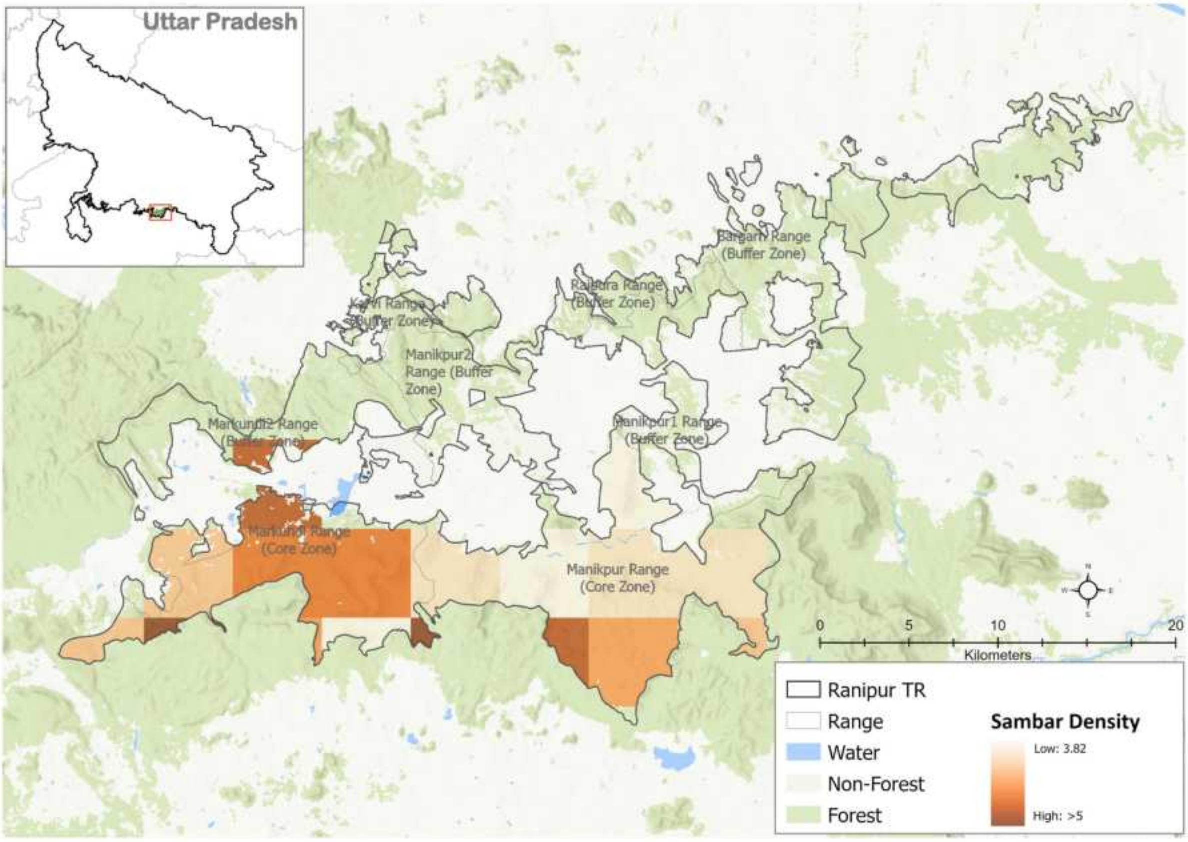

Figure IV. 141: Density of sambar (per 25 km²) in Ranipur tiger reserve: Landscape-level DSM

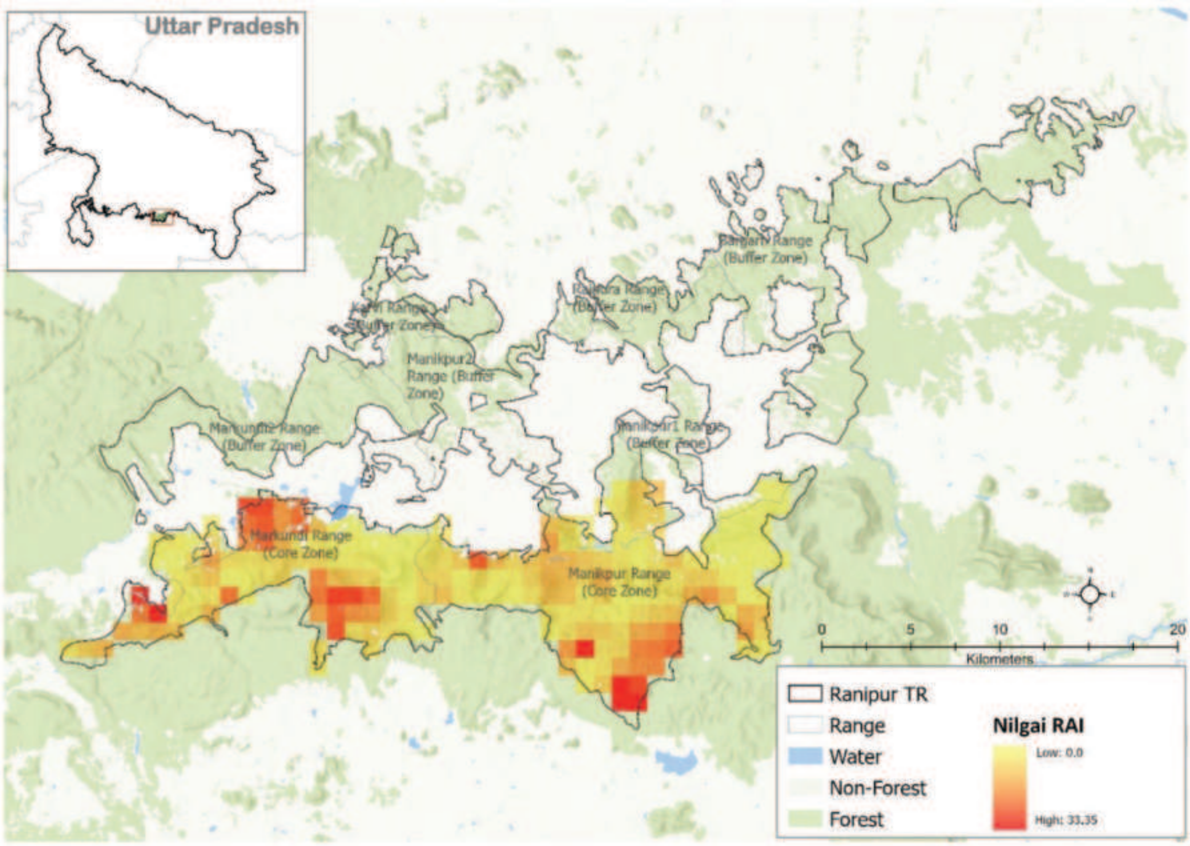

Figure IV. 142: Spatial relative abundance of nilgai in Ranipur tiger reserve.

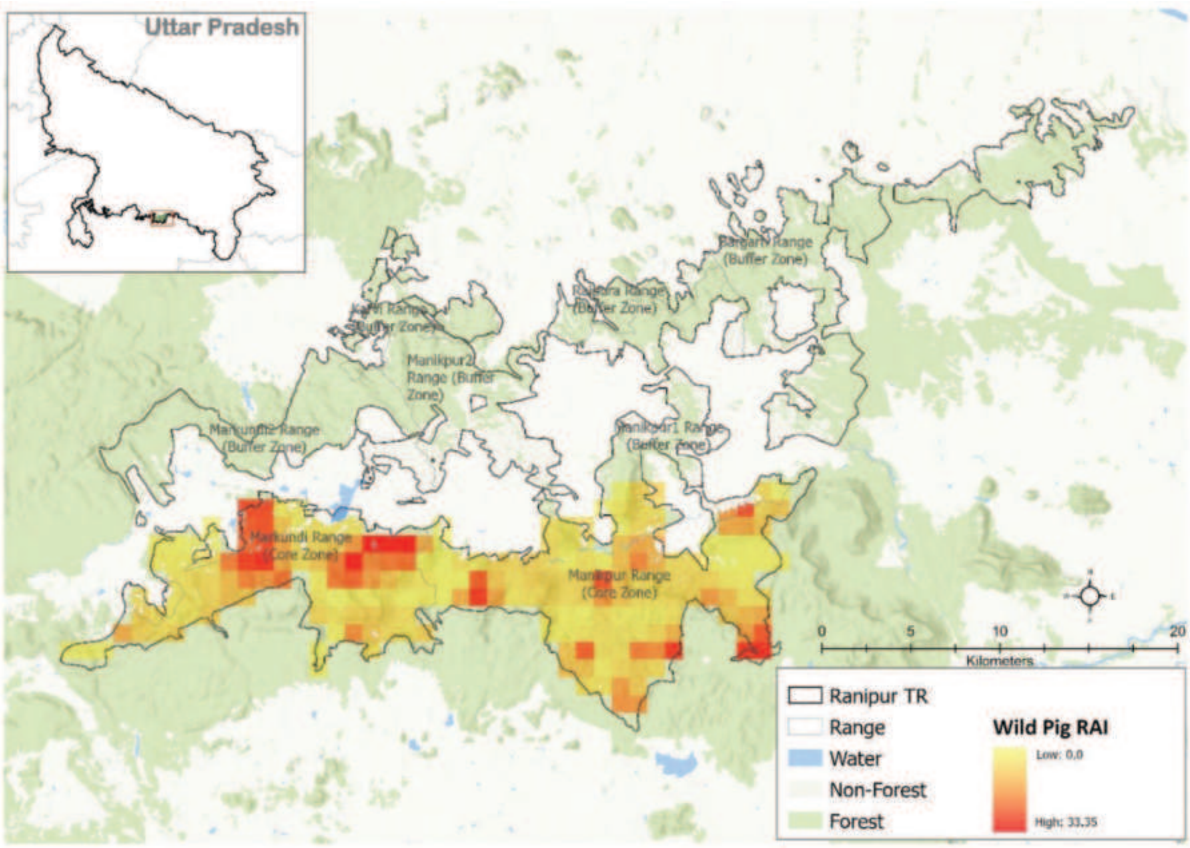

Figure IV. 143: Spatial relative abundance of wild pig in Ranipur tiger reserve.


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SECTION V

Western Ghats Landscape

Abhishek Shukla, Shravana Goswami, Omkar Nar, Vaishnavi Gusain, Dhruv Jain, Ujjwal Kumar, Vishnupriya Kolipakam, Ayan Sadhu, Yadvendradev Jhala, Qamar Qureshi

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The Western Ghats, stretch for approximately 1,600 km along India's west coast, spanning six states from the Tapti River in Gujarat to Kanyakumari in Tamil Nadu. This region includes subranges such as the Nilgiris, Anamalais, Cardamom Hills, and Agasthyamalai, with altitudes rising from sea level to the Anaimudi Peak (2,695 m). The Ghats' topographic gradients and monsoonal influence create a variety of climates, from tropical to temperate, with annual rainfall ranging from 1,000 mm on the eastern rain-shadow slopes to over 9,000 mm in certain windward areas.

The Western Ghats are a mosaic of landscapes, including rolling hills, rugged plateaus, steep valleys, and lateritic plateaus. The forest types are equally varied, reflecting the diverse climatic and topographical conditions. Key vegetation types include:

Tropical Wet Evergreen Forests: Dominating high-rainfall zones, these forests host species like *Dipterocarpus indicus, Palaquium ellipticum, and Mesua ferrea*.

Moist and Dry Deciduous Forests: Found in transitional and rain-shadow areas, with species such as teak (*Tectona grandis*), *Terminalia paniculata*, and *Dalbergia latifolia*.

Montane Shola Forests and Grasslands: Unique to higher altitudes, these ecosystems are critical habitats for endemic species like *Rhododendron arboreum and Michelia nilagirica*.

Lateritic Plateaus: Supporting seasonal flora, including insectivorous plants like *Drosera and Utricularia*.

Endangered Ecosystems: Myristica swamps and lowland dipterocarp forests in the western lowlands are among the region's most threatened habitats.

Flora

The Western Ghats are home to diverse vegetation types, reflecting variations in altitude, rainfall, and soil. Tropical wet evergreen forests dominate the lowland and windward slopes, with species like *Dipterocarpus indicus, Palaquium ellipticum, Mesua ferrea, and Calophyllum apetalum*. Moist deciduous forests in intermediate zones feature species such as *Tectona grandis, Lagerstroemia microcarpa, Terminalia paniculata, Dalbergia latifolia, and Bambusa spp*. Dry deciduous forests in the rain-shadow regions are characterized by *Acacia spp., Anogeissus latifolia, Terminalia chebula, and Dendrocalamus strictus*.

At higher altitudes, shola forests and grasslands create unique montane ecosystems, hosting endemic species such as *Rhododendron arboreum* and *Michelia nilagirica*. The lateritic plateaus in Maharashtra support specialized seasonal flora, including insectivorous plants like *Drosera spp*. and *Utricularia spp*. Rare and endangered ecosystems like Myristica swamps are home to species such as *Myristica magnifica* and *Gymnacranthera canarica.*

Fauna

Mammalian diversity includes tiger, leopard, dhole, nilgiri marten, and nilgiri langur along with ungulates. Ungulates present in this area includes five species of Bovides: blackbuck (*Antilope cervicapra*), gaur (*Bos gaurus*), nilgai (*Boselaphus tragocamelus*), chinkara (*Gazella benetti*), and chowsingha (*Tetracerus quadricornis*), along with several other ungulates such as chital (*Axis axis*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), mouse deer (*Moschiola indica*), wild pig (*Sus scrofa*), and Asiatic elephant (*Elephas maximus*).

Ungulate Distribution and Abundance in the landscape

The ungulate abundance is highest along the western aspect of Western Ghats that got varying forest types from drier scrub, deciduous forests to semievergreen and evergreen forests. Chital, sambar, and wild pig are most widely distributed and abundant ungulates followed by barking deer, and gaur.

Chital present in high density in tiger reserves as well as outside tiger reserve areas. Highest density is from Bandipur, Mudumalai, Sathyamangalam cluster and its surrounding area (Figure V. 1). Towards southern area, density decreases. Periyar and KMTR have very less chital presence in this landscape. Sambar density is moderate in most part of Western Ghats (Figure V. 2). Density is higher in both inside and some area outside tiger reserve as well. Highest density areas in this landscape are Periyar-SMTR cluster, forest areas between Mudumalai and Silent valley national park and from cauvery to BRT. Annamalai and Kali have least density of Smabra in the landscape among the tiger reserves.

Gaur abundance is very high in Western Ghats landscape (Figure V. 4). The nilgiri cluster has highest gaur abundance followed by parambikulam and SMTR. Other than Nilgiri cluster gaur presence outside tiger reserve is rare. Barking deer abundance is highest in forested areas that are outside any protected area but in Nilgiri biosphere reserve. Its abundance is low in most of the tiger reserves (Figure V. 3). All areas inside and outside tiger reserve of Western Ghats have wild pig presence (Figure V. 5). Higher abundance is outside protected areas than inside which may lead to conflict situation in the landscape.

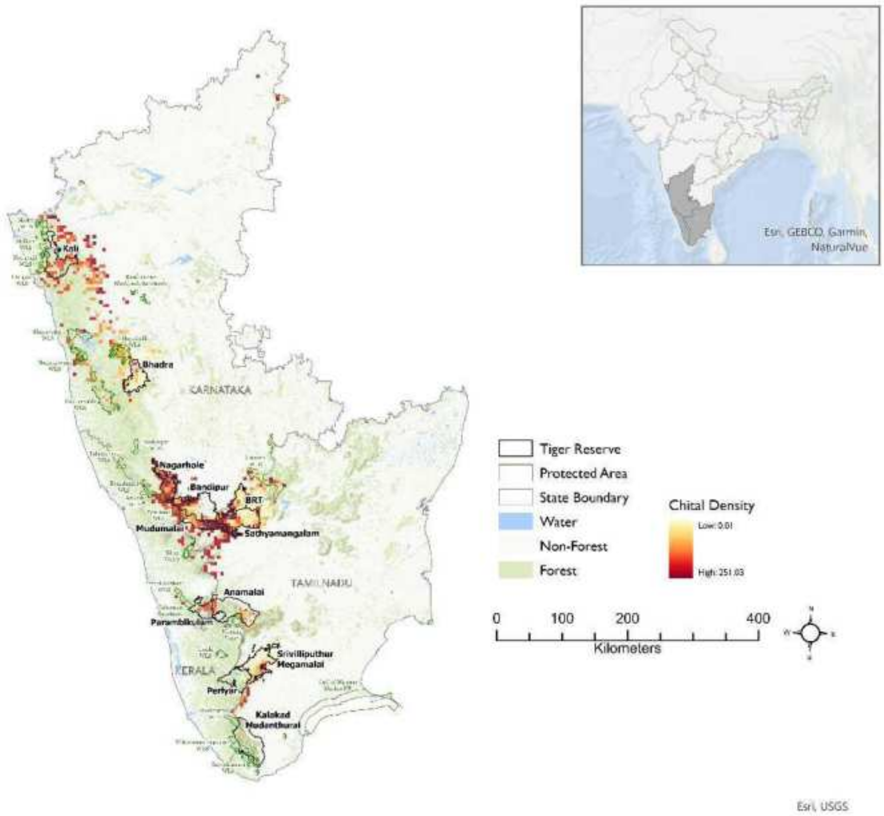


Figure V. 1: Distribution and density of chital (per 25 km^2) in Western Ghats landscape.

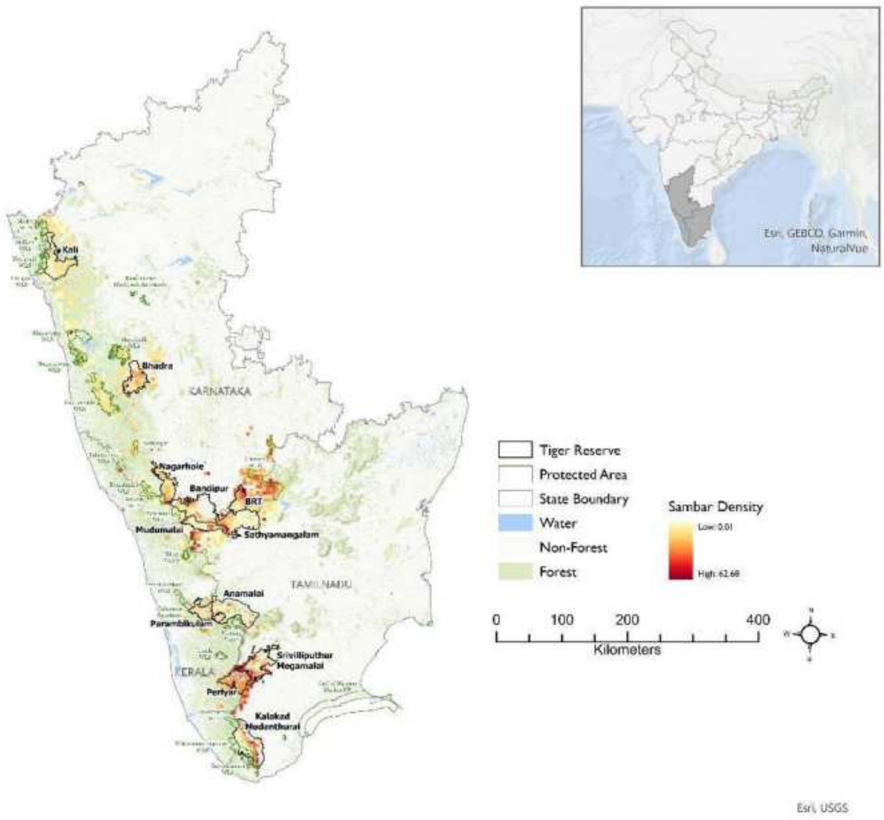


Figure V. 2: Distribution and density of sambar (per 25 km^2) in Western Ghats landscape.

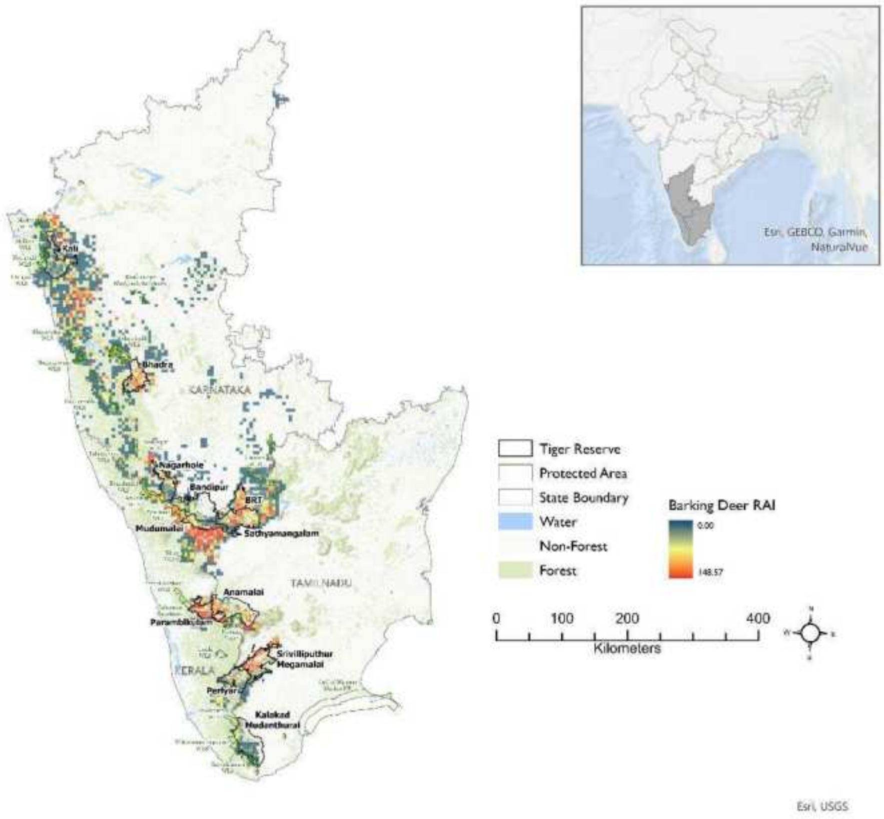


Figure V. 3: Spatial relative abundance of barking deer (per 25 km^2) in Western Ghats landscape.

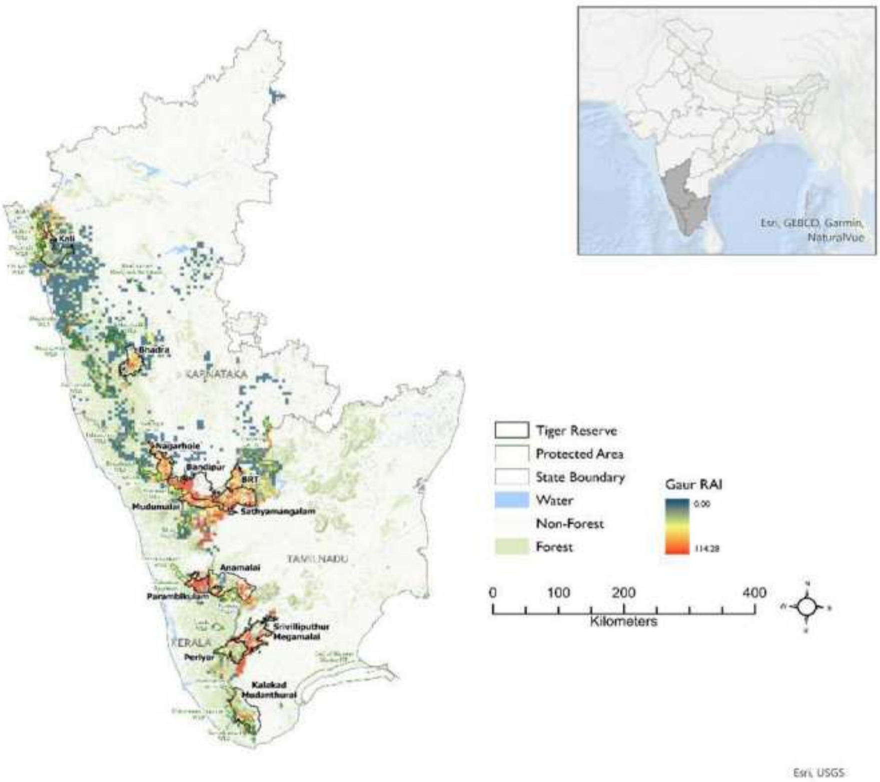


Figure V. 4: Spatial relative abundance of gaur (per 25 km^2) in Western Ghats landscape.

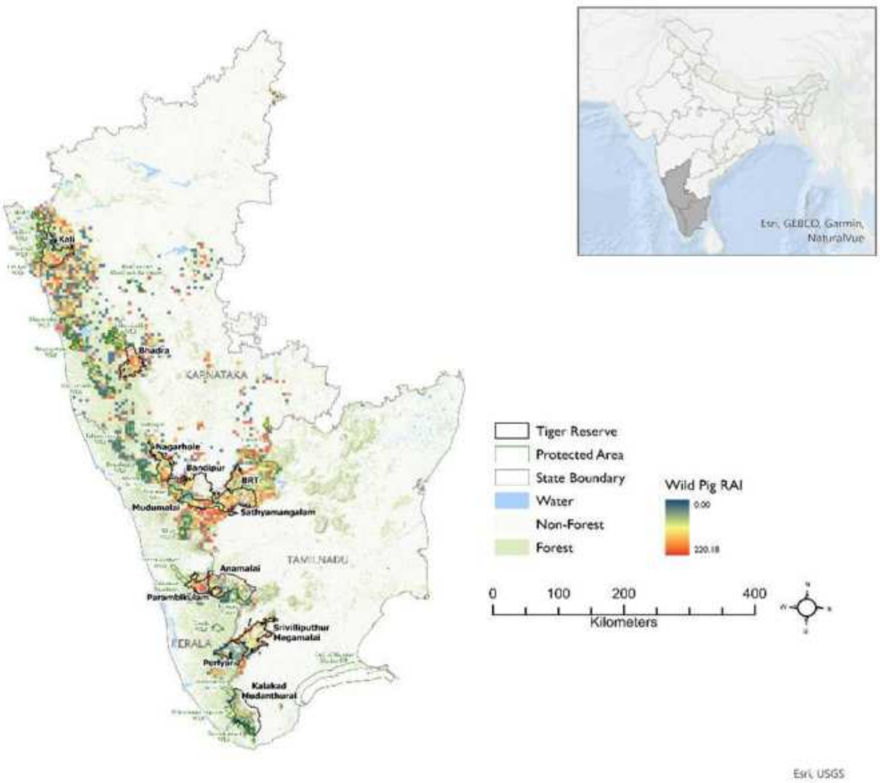


Figure V. 5: Spatial relative abundance of wild pig (per 25 km^2) in Western Ghats landscape.

KARNATAKA

Kali (Anshi-Dandeli) Tiger Reserve

Kali tiger reserve, located in the Uttara Kannada district of Karnataka, spans over 1,097 km^2. The reserve is named after the Kali River, which flows through its rugged terrain, creating riparian ecosystems that support diverse wildlife. The habitat of the tiger reserve includes a mix of tropical semi-evergreen forests, moist deciduous forests, and dry deciduous forests, dominated by species like teak, rosewood, bamboo, and endemic flora (Tripathy *et al*., 2024). The reserve is home to the tiger, leopard, elephant, gaur, Malabar giant squirrel, sloth bear *etc*.

The encounter rate for chital is 0.0149 (±0.0075) and for sambar is 0.0357 (±0.0119). Due to insufficient observations of ungulates during line transects, chital and sambar densities were predicted using a landscape model, while relative abundances of gaur, barking deer, and wild pigs were assessed using camera trap data. Sambar is the most abundant ungulate species in the Kali Tiger Reserve, with the highest densities predicted in the Kulgi, Phansoli, and Gund ranges (Figure V. 6). In contrast, the western regions of the Anshi and Kadra Wildlife Ranges show the lowest densities of sambar (Figure V. 7). Chital populations exhibit a clustered distribution within the reserve, primarily concentrated in its southern regions at moderate densities. The Anshi and Kadra Wildlife Ranges have higher but patchy densities, whereas the Phansoli and Kulgi Ranges show relatively lower densities across their ranges. In the northern part of the reserve, the landscape model predicts only a small, clustered populations in the Castlerock Range. Contrary to chital, Gaur abundance is more concentrated in northern part *i.e.* Castlerock and Kumbharwada range (Figure V. 9). Wild pig abundance is highest in southern part of the tiger reserve. Anshi, Kadra, and Kulgi range have highest abundance of wild pigs (Figure V. 10). Barking deer has a patchy abundance throughout the tiger reserve (Figure V. 8). Highest Abundance is from Kulgi, and Castlerock range. Management should encourage voluntary resettlement of villages inside the tiger reserve followed by habitat/ grassland restoration to make more inviolate space for ungulate population of the area. This can help increase both prey-predator population.

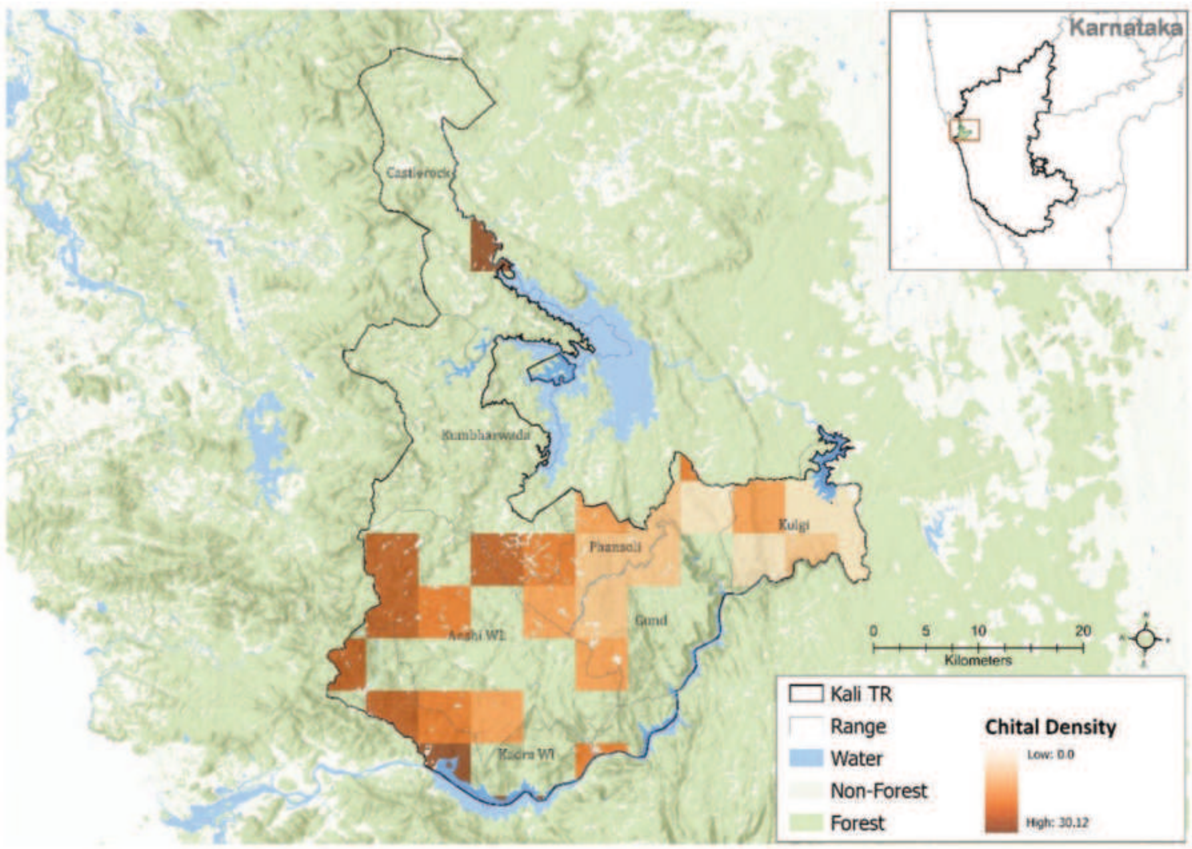


Figure V. 6: Density of chital (per 25 km^2) in Kali tiger reserve: Landscape-level DSM

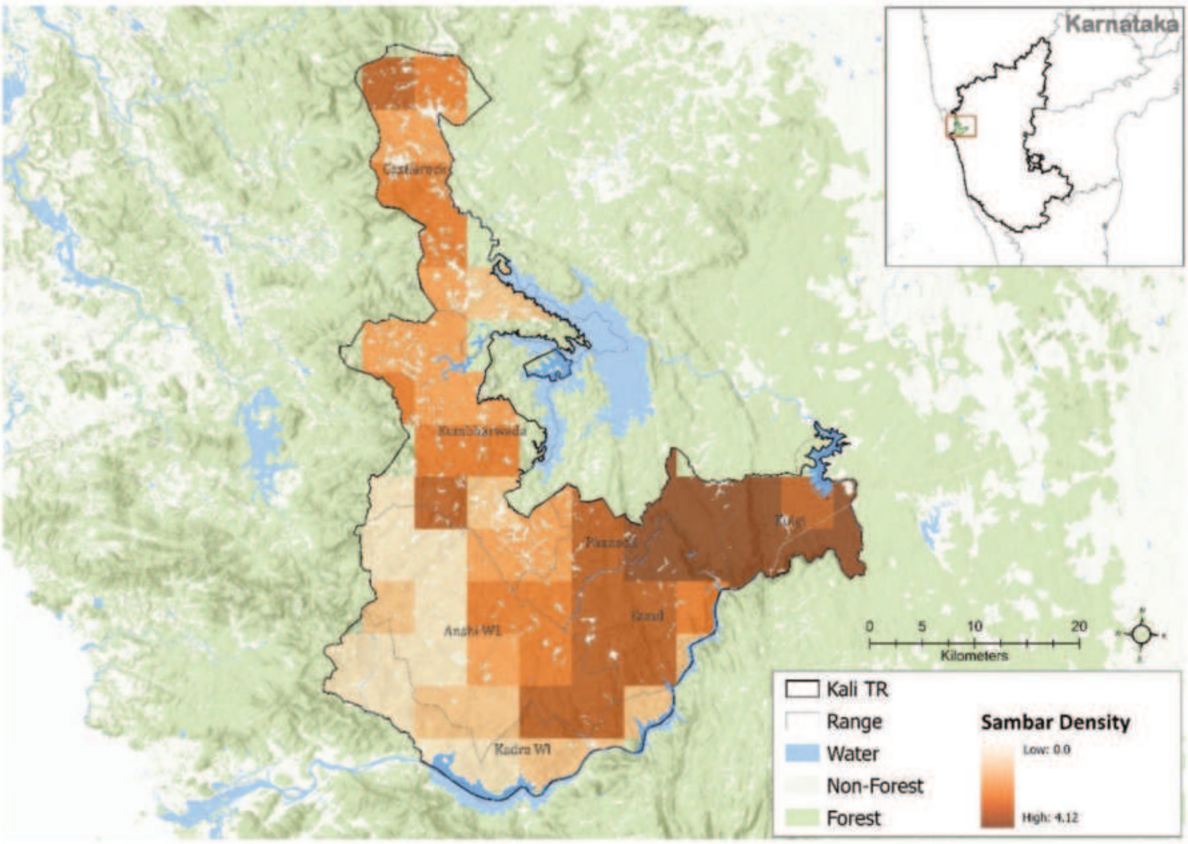


Figure V. 7: Density of sambar (per 25 km^2) in Kali tiger reserve: Landscape-level DSM

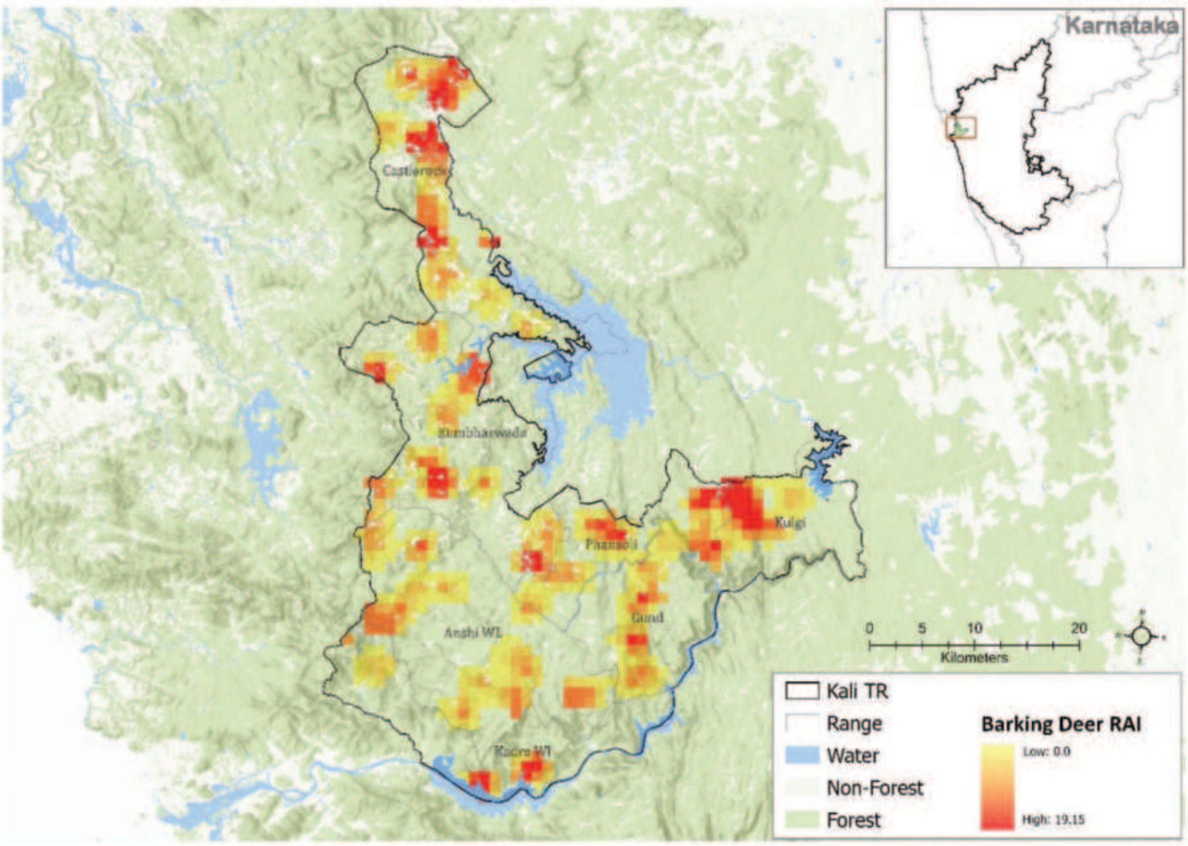


Figure V. 8: Spatial relative abundance of barking deer in Kali tiger reserve.

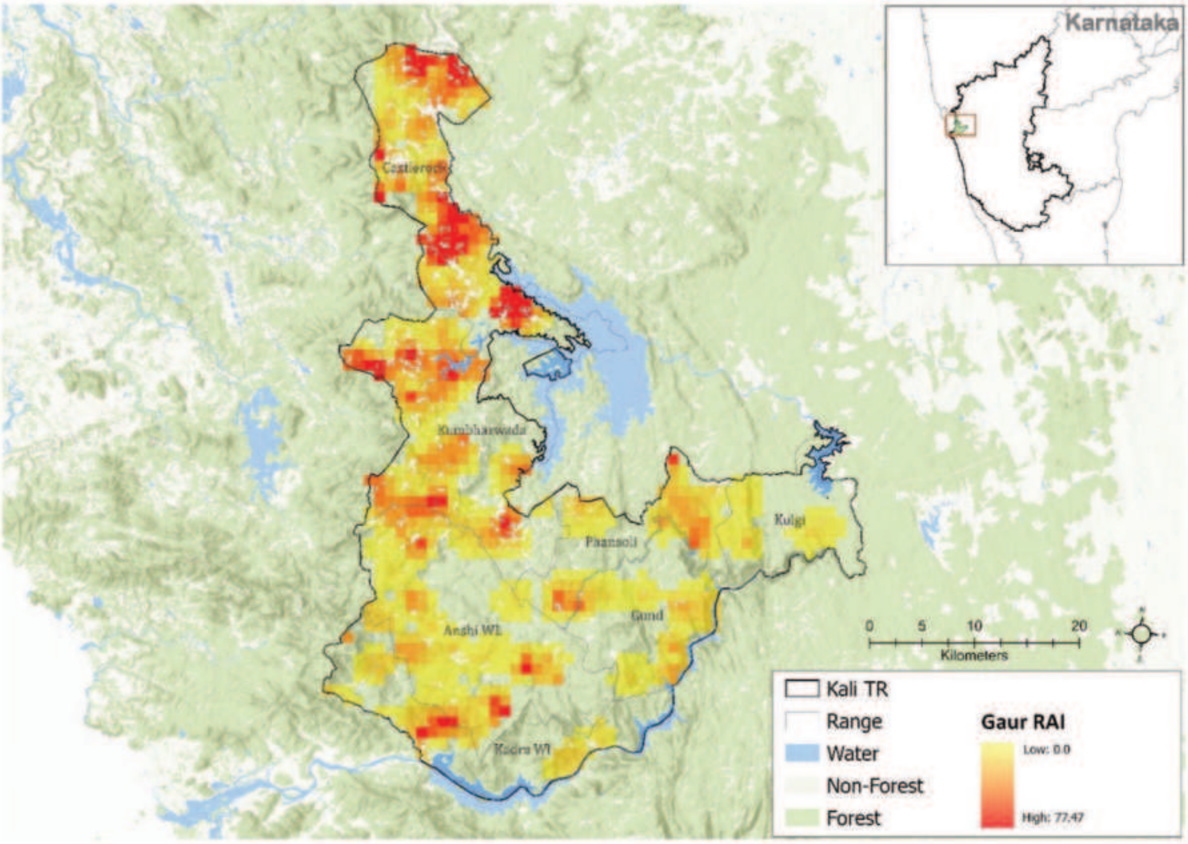


Figure V. 9: Spatial relative abundance of gaur in Kali tiger reserve.

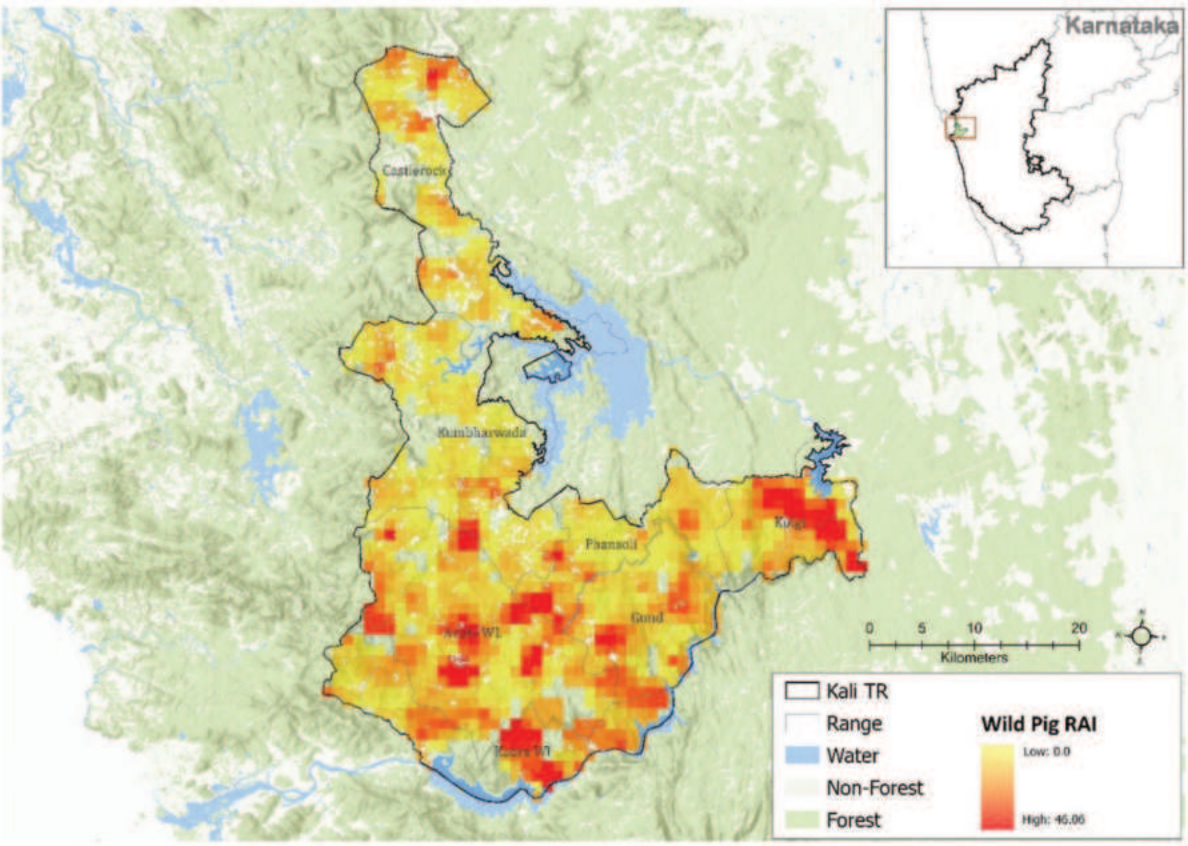


Figure V. 10: Spatial relative abundance of wild pig in Kali tiger reserve.

Bandipur Tiger Reserve

Bandipur tiger reserve, located in Karnataka, spans approximately 1,456 km^2 and forms part of the Nilgiri Biosphere Reserve. The reserve's varied habitats include moist deciduous forests, dry deciduous forests, and scrublands, interspersed with open grasslands (Neginhal, 1974). The region is dominated by teak, rosewood, sandalwood, and bamboo and is home to tiger, elephant, leopard, Nilgiri marten, stripe-necked mongoose, gaur, chital, sambar, chousingha, sloth bear, and dhole. Bandipur is also known for its diverse avifauna.

In Bandipur, the spatial density of chital and sambar was calculated using line transect data while relative abundance of gaur, wild pig, and barking deer was mapped using photo-capture data from camera traps due to insufficient data from line transects. The Moliyur, A.M. Gudi, Hediyala, and Gundre ranges have the highest chital density, followed by the Omkar range in Bandipur (Figure V. 11). Sambar has a high density in the Hediyala and G.S. Betta ranges (Figure V. 12). These high-abundance areas can serve as source populations for prey management in Bandipur Tiger Reserve, enabling more effective management decisions. Gaur was primarily captured in Bandipur, Hediyala, and A.M. Gudi ranges (Figure V. 14), with very low captures recorded in other areas. Barking deer is abundant across all ranges in Bandipur, with the highest abundance recorded in the A.M. Gudi range (Figure V. 13). Wild pigs were most abundant in the Omkar and Gundlupet buffer zones, followed by Hediyala (Figure V. 15).

Table V. 1: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Bandipur tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	142	0.225 (0.018)	0.25 (0.01)	6.98 (0.6)	3.79 (0.38)	25.91 (1.78)
Sambar	90	0.126 (0.014)	0.32 (0.02)	1.91 (0.12)	1.96 (0.26)	4.18 (0.45)

B)

Species	Chital	Sambar
Detection model	Half-normal (Cosine)	Half-normal (Null)
s(x,y)	27.779	21.052
s(Aridity)	1.905	2.983

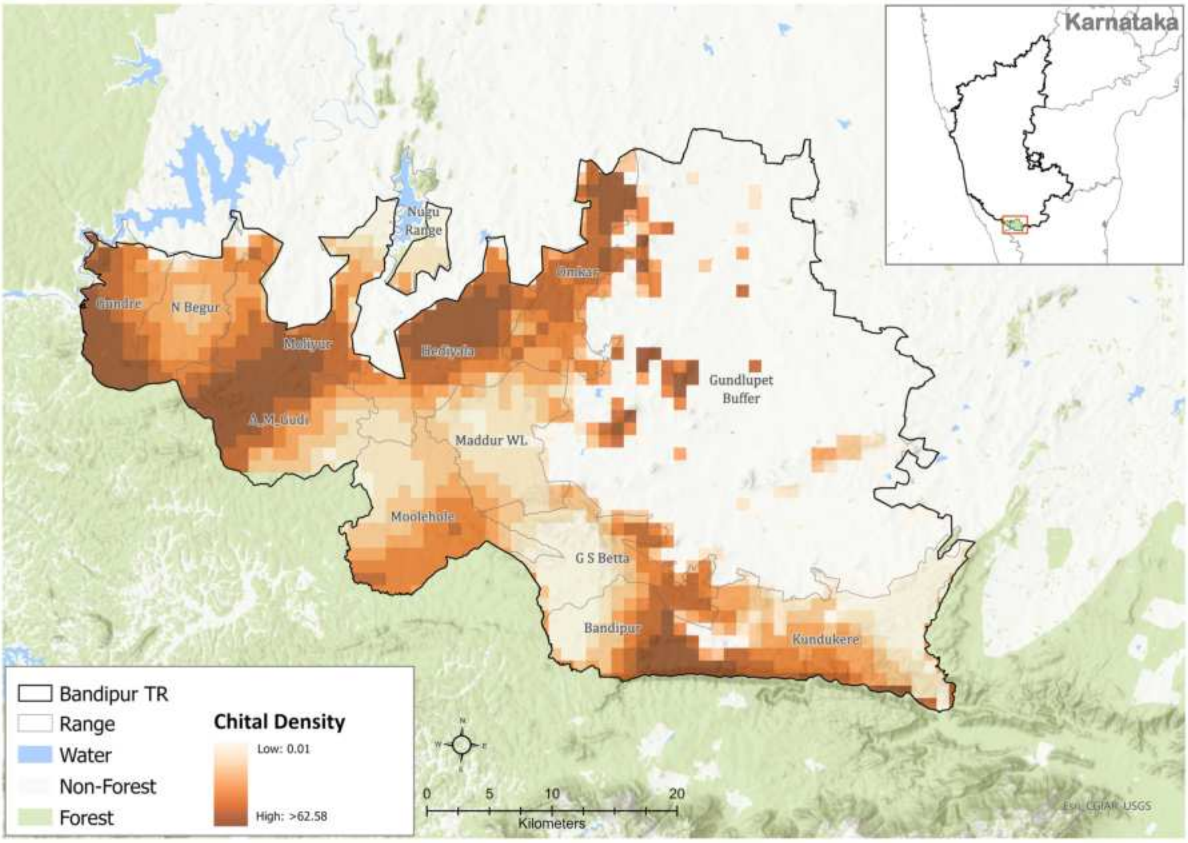


Figure V. 11: Density of chital (per km^2) in Bandipur tiger reserve: Site-level DSM

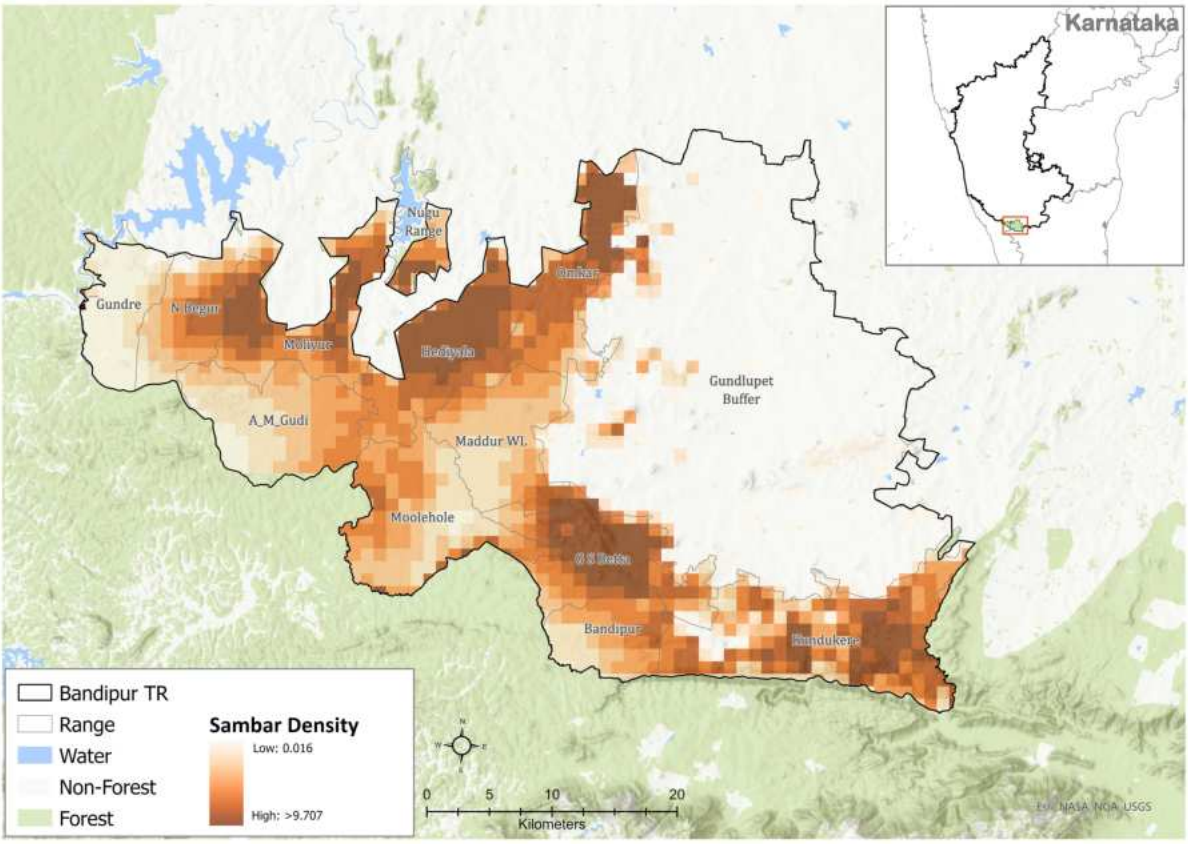


Figure V. 12: Density of sambar (per km^2) in Bandipur tiger reserve: Site-level DSM

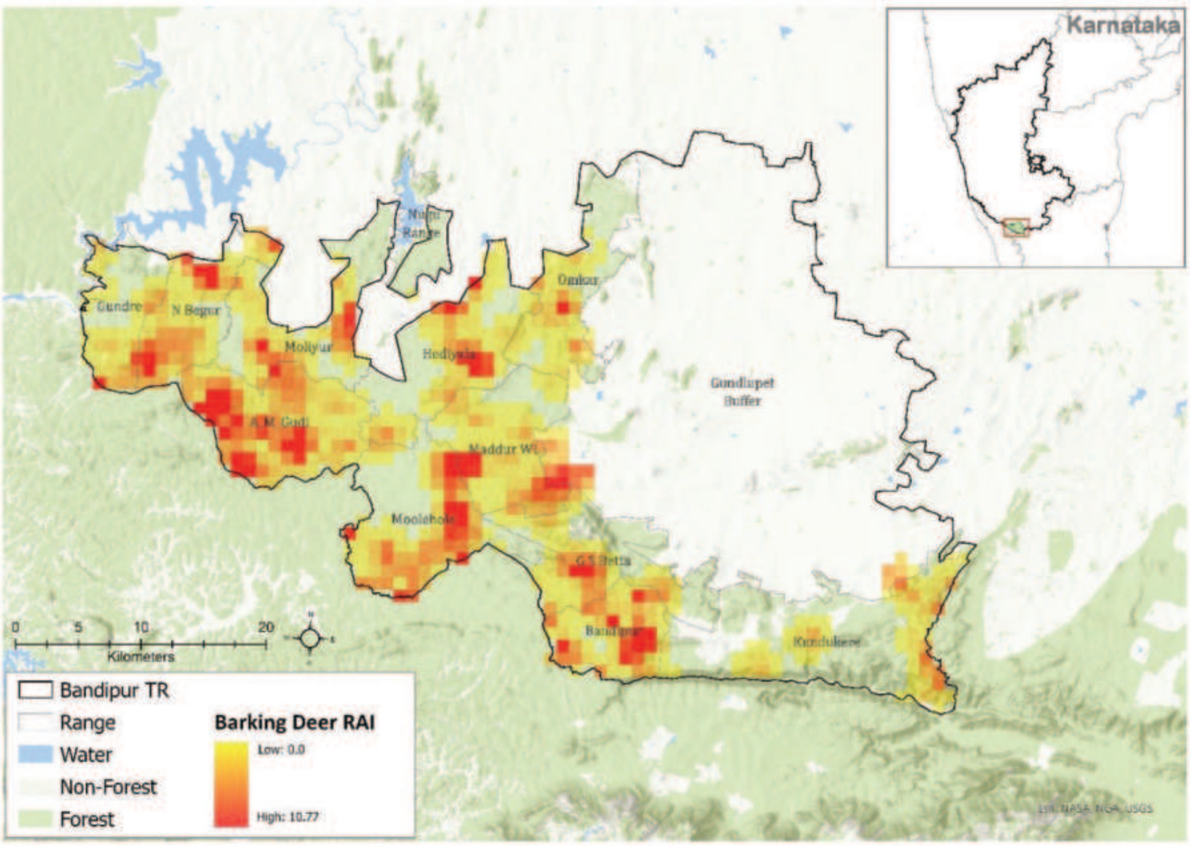


Figure V. 13: Spatial relative abundance of barking deer in Bandipur tiger reserve.

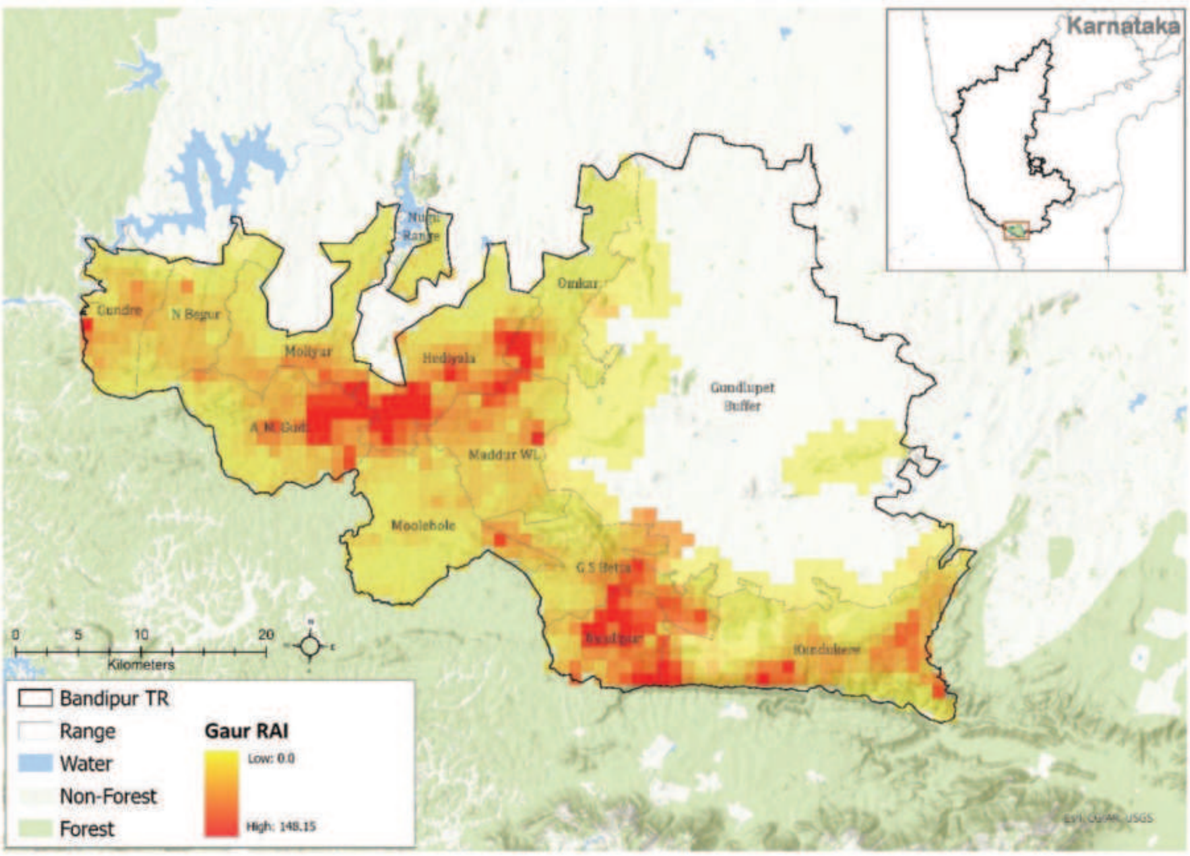


Figure V. 14: Spatial relative abundance of gaur in Bandipur tiger reserve.

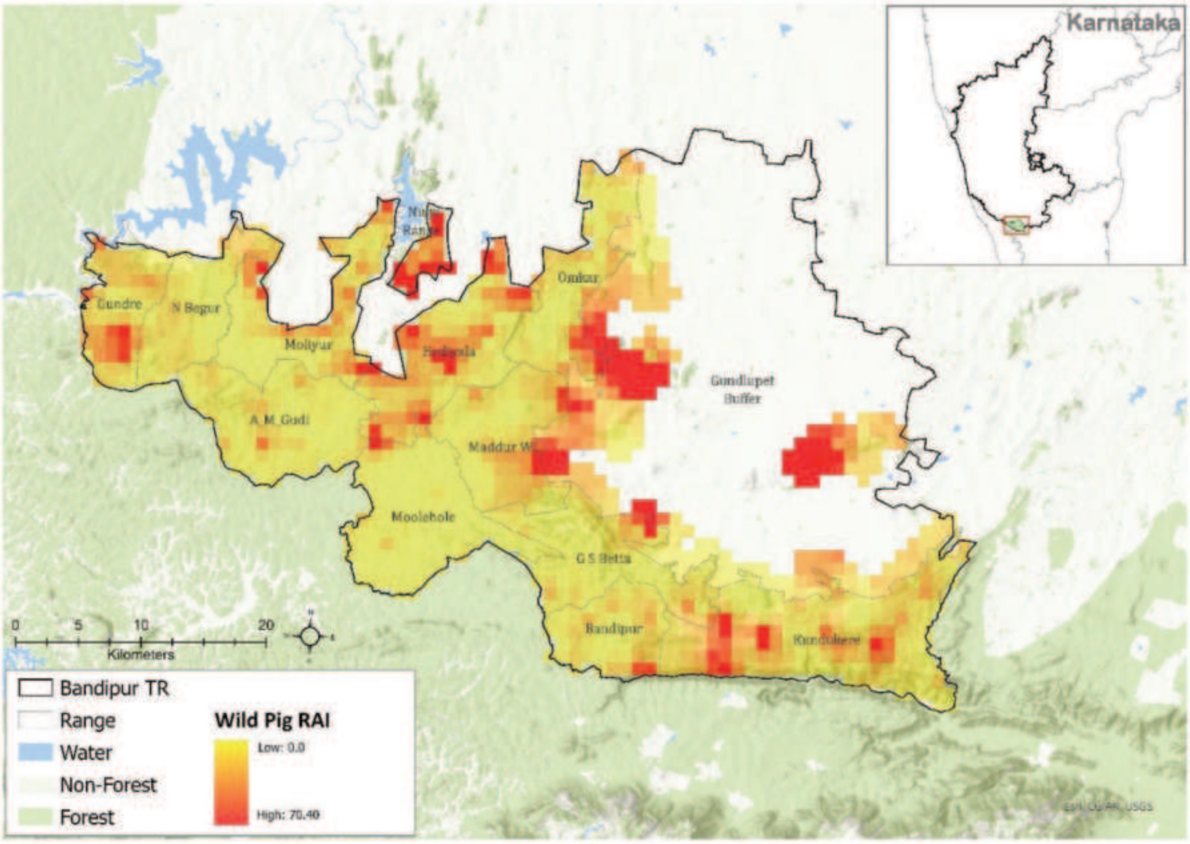


Figure V. 15: Spatial relative abundance of wild pig in Bandipur tiger reserve.

Bhadra Tiger Reserve

Bhadra tiger reserve, located in the Chikkamagaluru and Shivamogga districts of Karnataka, spans approximately 1,064 km^2. The reserve's unique blend of semi-evergreen forests, tropical moist deciduous forests, dry deciduous and shola-grassland ecosystems (Wikramanayake *et al*., 1999), interwoven with rivers and streams along the Bhadra Reservoir supports a diverse herbivore community (Jathanna *et al*., 2001). Dominant vegetation includes species like teak, rosewood, nandi, and a variety of endemic plants. The reserve is home to tiger, leopard, sloth bear, gaur, elephants, sambar, chital, barking deer, *etc.* along with an equally remarkable avifauna.

Chital, sambar and gaur are abundant prey in Bhadra TR (Table V. 2). Spatial densities of Chital is highest in Lakkawalli WL, and Chikka Agrahara range (Figure V. 16). Density of chital decreases towards the eastern side of the reserve. Sambar populations are well-distributed across the reserve (Figure V. 17). However, their population in the region north of Bhadra reservoir is very low and needs investigation pertaining to connectivity of the population. The gaur density is high in, Hebbe WL, and Muthodi WL as well as in the southern part of the Lakkavalli Wildlife Range near the Bhadra Reservoir (Figure V. 18).

Due to low number of observations during line transect, spatial densities of barking deer and wild pig could not be estimated. Instead, relative abundance index is calculated from camera trap data to supplement the information regarding their presence. Highest abundance of Barking deer is in Muthodi WL range (Figure V. 19). Wild pig abundant in Lakkawalli WL followed by Muthodi and Thanigebyle range (Figure V. 20).

Table V. 2: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Bhadra tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	40	0.132 (0.021)	0.45 (0.06)	5.15 (0.63)	1.46 (0.3)	7.33 (1.21)
Gaur	39	0.126 (0.021)	0.26 (0.04)	3.97 (0.42)	1.23 (0.27)	3.96 (0.67)
Sambar	62	0.204 (0.026)	0.66 (0.07)	1.97 (0.17)	2.57 (0.41)	4.61 (0.73)

B)

Species	Chital	Sambar	Gaur
Detection model	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	8.734	9.466	8.168
s(Aridity)	1.906	3.052	1.003
s(Ruggedness)	2.733	-	-

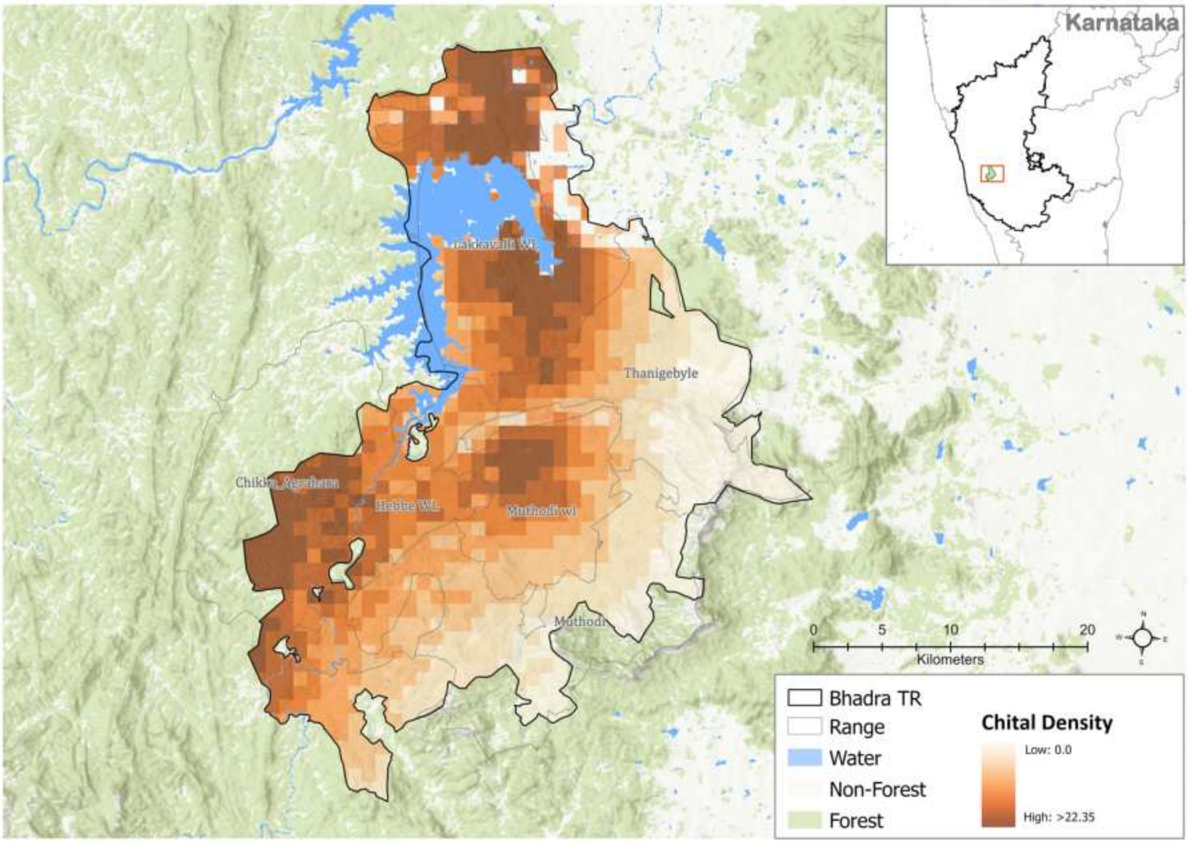


Figure V. 16: Density of chital (per km^2) in Bhadra tiger reserve: Site-level DSM

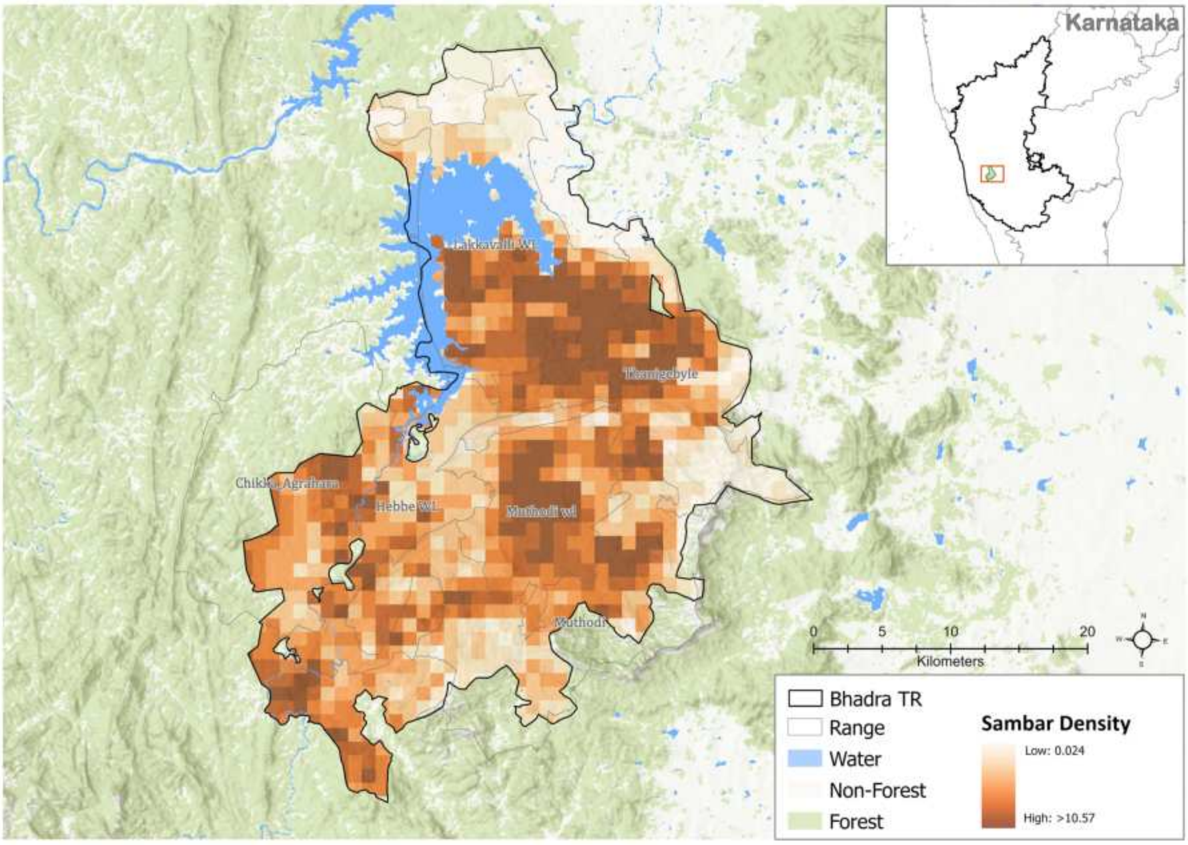


Figure V. 17: Density of sambar (per km^2) in Bhadra tiger reserve: Site-level DSM

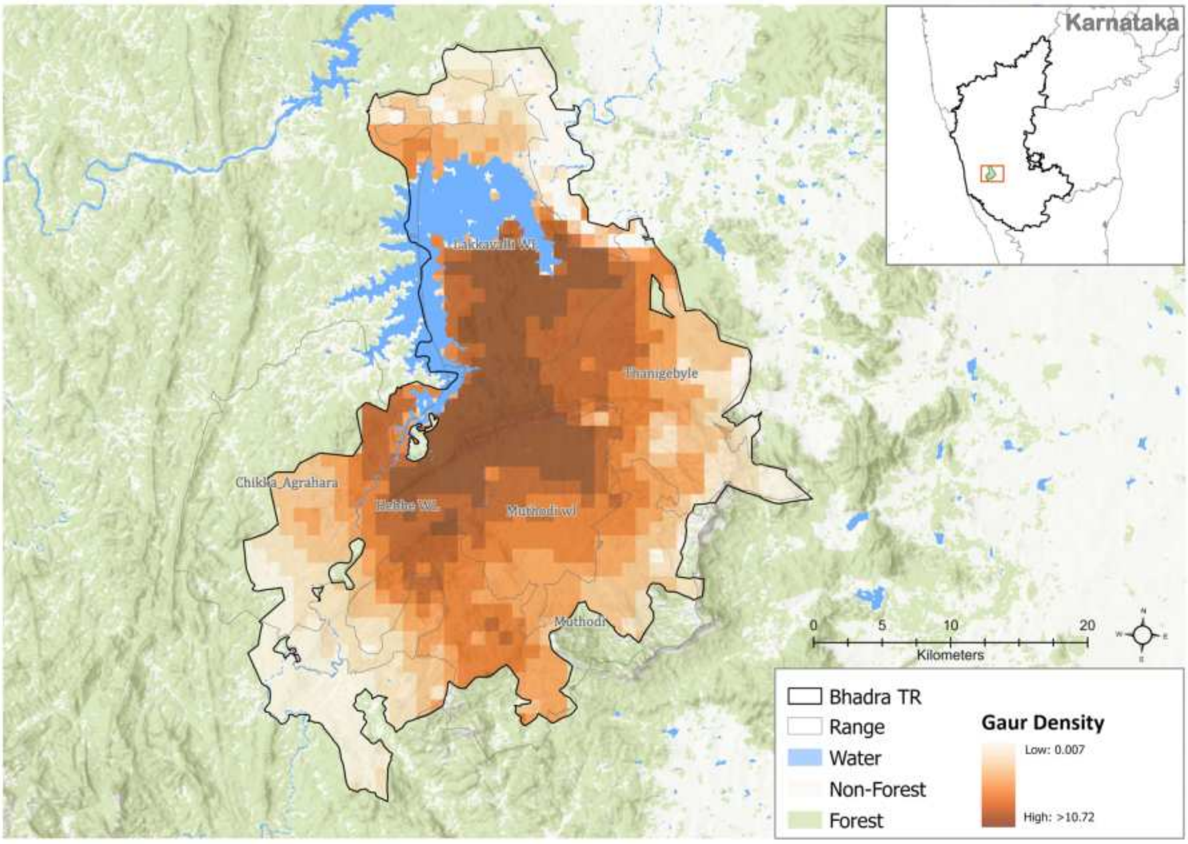


Figure V. 18: Density of gaur (per km^2) in Bhadra tiger reserve: Site-level DSM

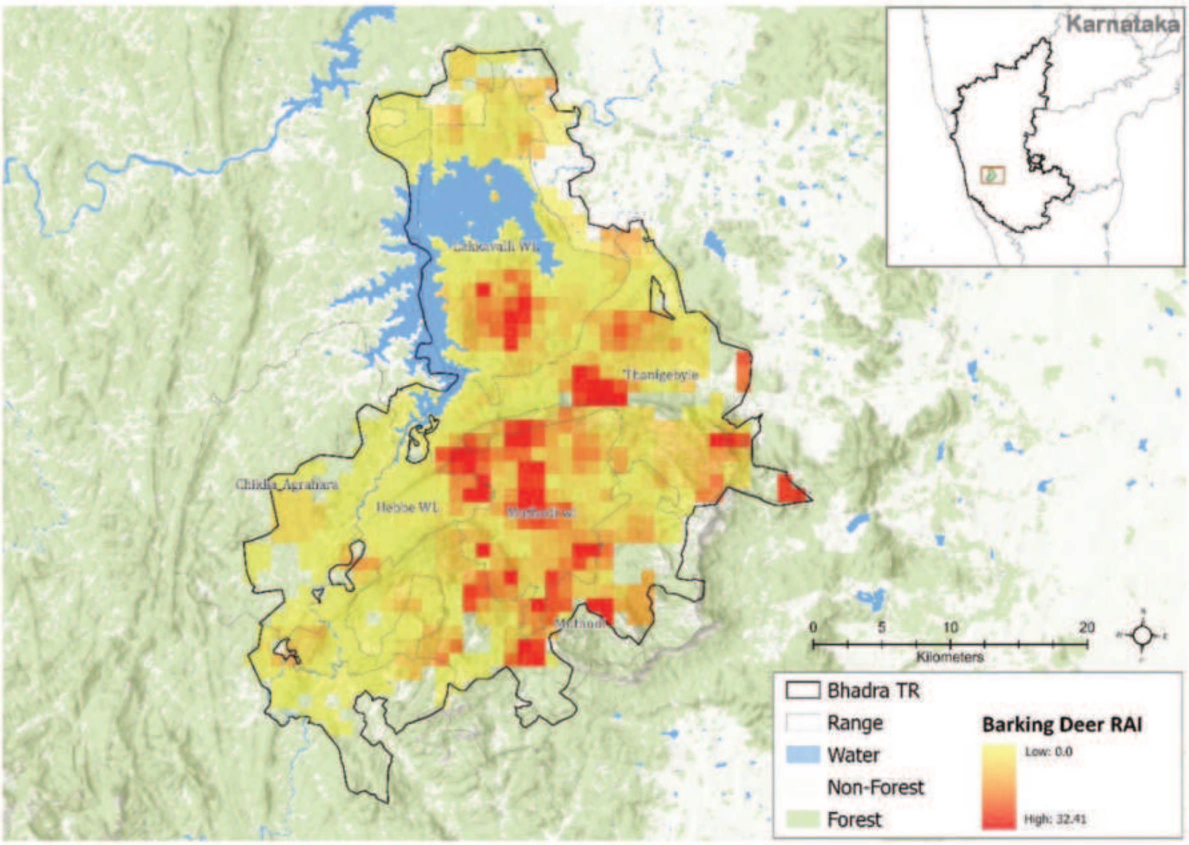


Figure V. 19: Spatial relative abundance of barking deer in Bhadra tiger reserve.

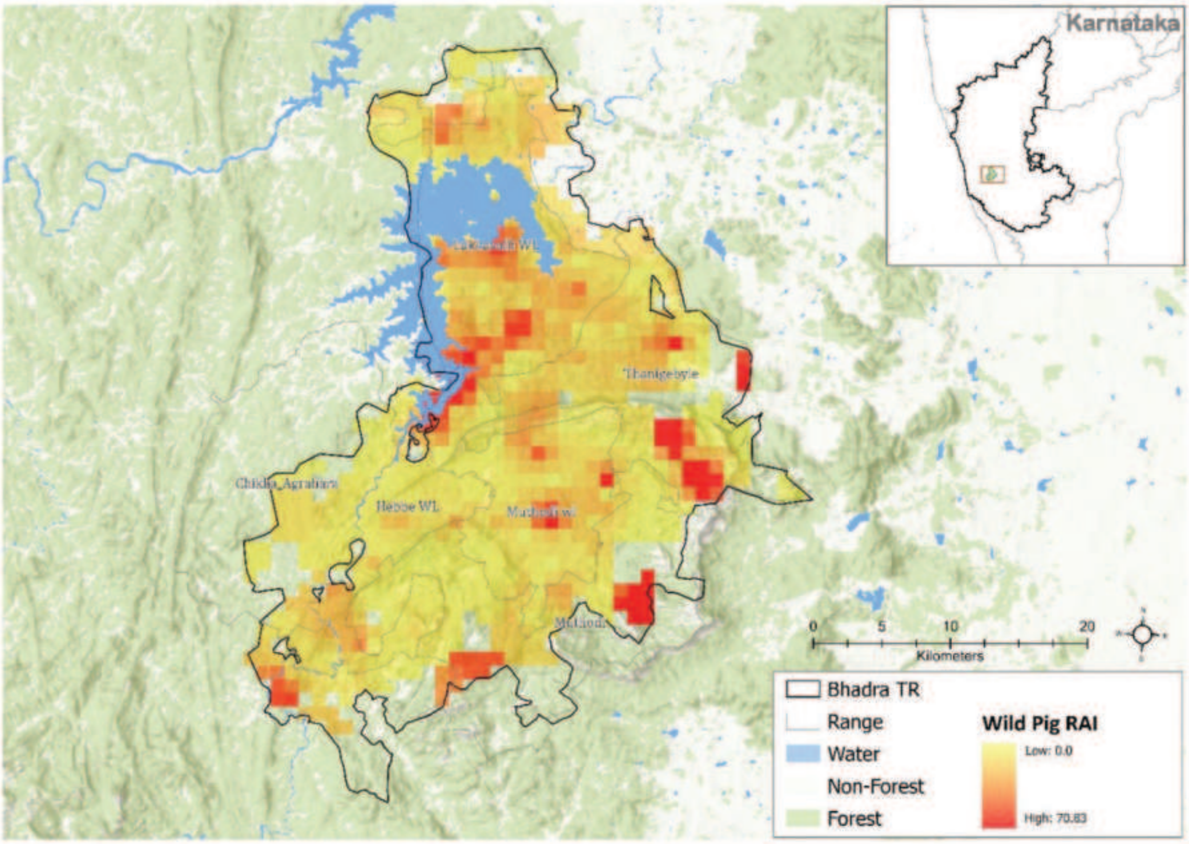


Figure V. 20: Spatial relative abundance of wild pig in Bhadra tiger reserve.

Biligiri Ranganathaswamy Temple (BRT Hills) Tiger Reserve

Biligiri Ranganathaswamy Temple (BRT) tiger reserve, located in the Chamarajanagar district of Karnataka, spans approximately 575 km^2. This tiger reserve acts as a crucial link between the Western Ghats and the Eastern Ghats, creating an important ecological corridor for wildlife (Ganeshaiah & Shankar, 1998). The unique geographic positioning has resulted in a rich blend of flora and fauna from both biogeographical zones. The reserve's habitats range from tropical evergreen forests and moist deciduous forests to dry scrublands and high-altitude shola-grassland ecosystems (Kumara *et al.*, 2014). BRT is home to tiger, elephant, gaur, leopard, and numerous ungulate species like sambar, chital, chousingha, barking deer as well as Nilgiri marten.

Chital is abundant in BRT Tiger reserve (Table V. 3). However, its density is not even throughout the reserve. South-western part of BRT has more chital density than other areas. The species densely occupies K Gudi Wildlife range and Punjur Wildlife range as (Figure V. 21). Sambar density is more in the northern part of the reserve especially in Kollegal range followed by Yelandur, with a sparse distribution in the southern ranges (Figure V. 22). Gaur, barking deer, and wild pig relative abundance is mapped using camera trap data as their observation is very limited in line transect. Gaur abundance is patchy in BRT with high abundance recorded from Punjur Wildlife range (Figure V. 24). Barking deer and wild pig also have clustered distribution in all the ranges of BRT (Figure V. 23 & Figure V. 25).

Table V. 3: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in BRT Tiger Reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	47	0.143 (0.022)	0.4 (0.05)	3.91 (0.49)	2.74 (0.55)	10.47 (1.58)
Sambar	49	0.159 (0.022)	0.3 (0.03)	2.53 (0.3)	3.26 (0.57)	7.83 (1.09)

B)

Species	Chital	Sambar
Detection model	Half-normal (Cosine)	Half-normal (Null)
s(x,y)	23.822	3.758
s(Aridity)	3.678	-
s(Elevation)	1.669	-

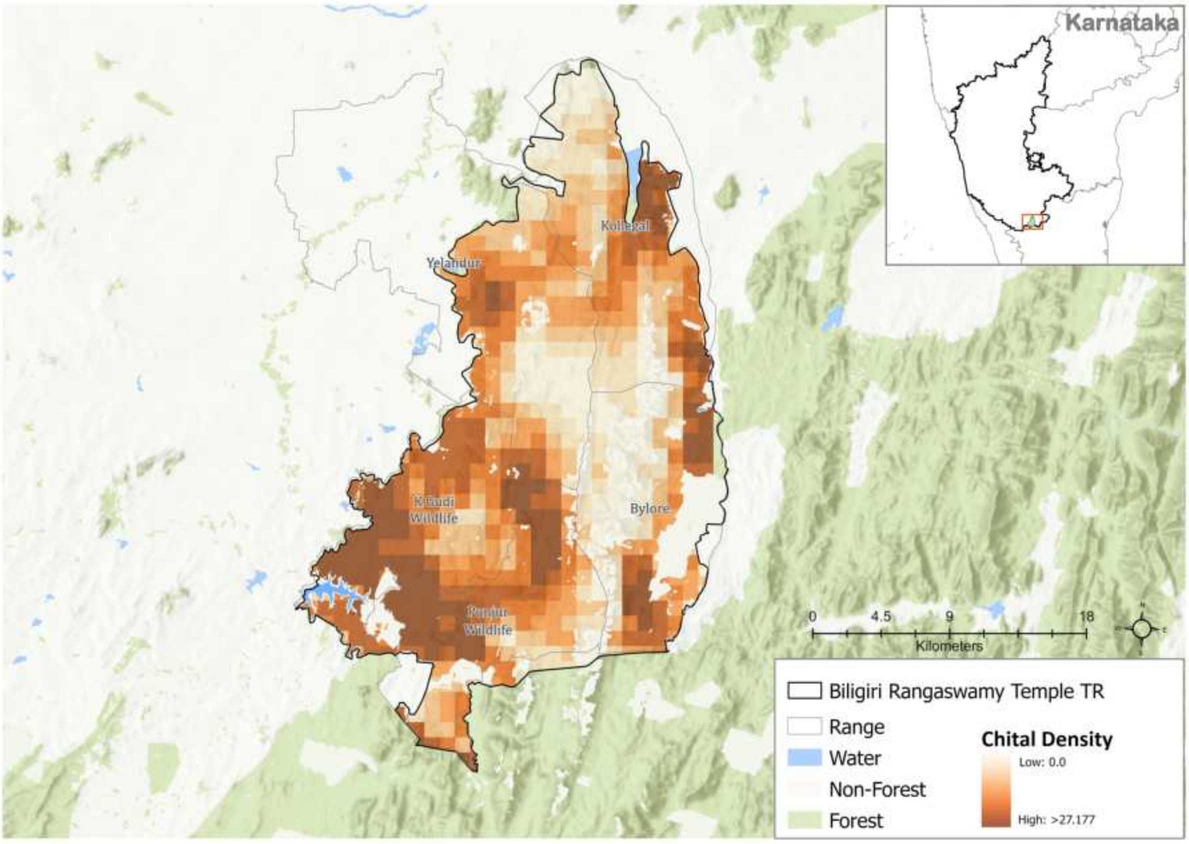


Figure V. 21: Density of chital (per km²) in BRT: Site-level DSM

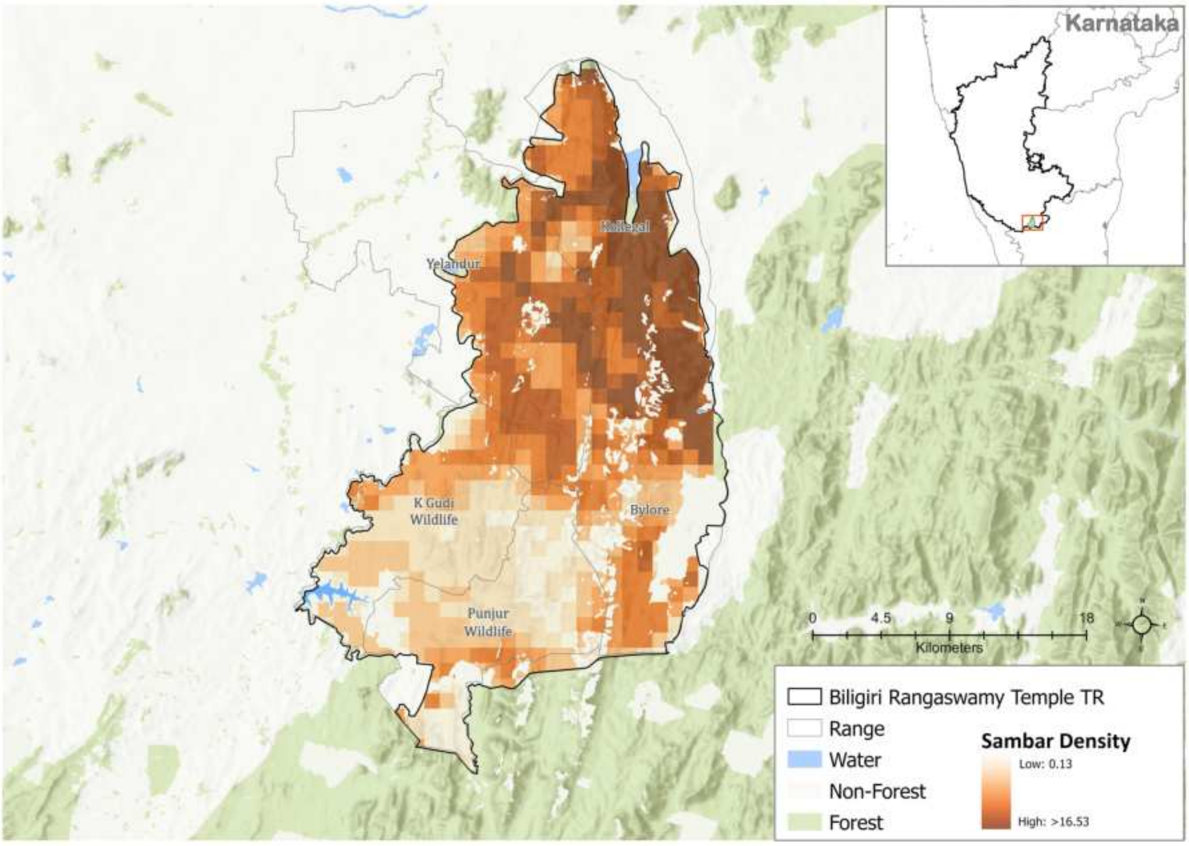


Figure V. 22: Density of sambar (per km²) in BRT: Site-level DSM

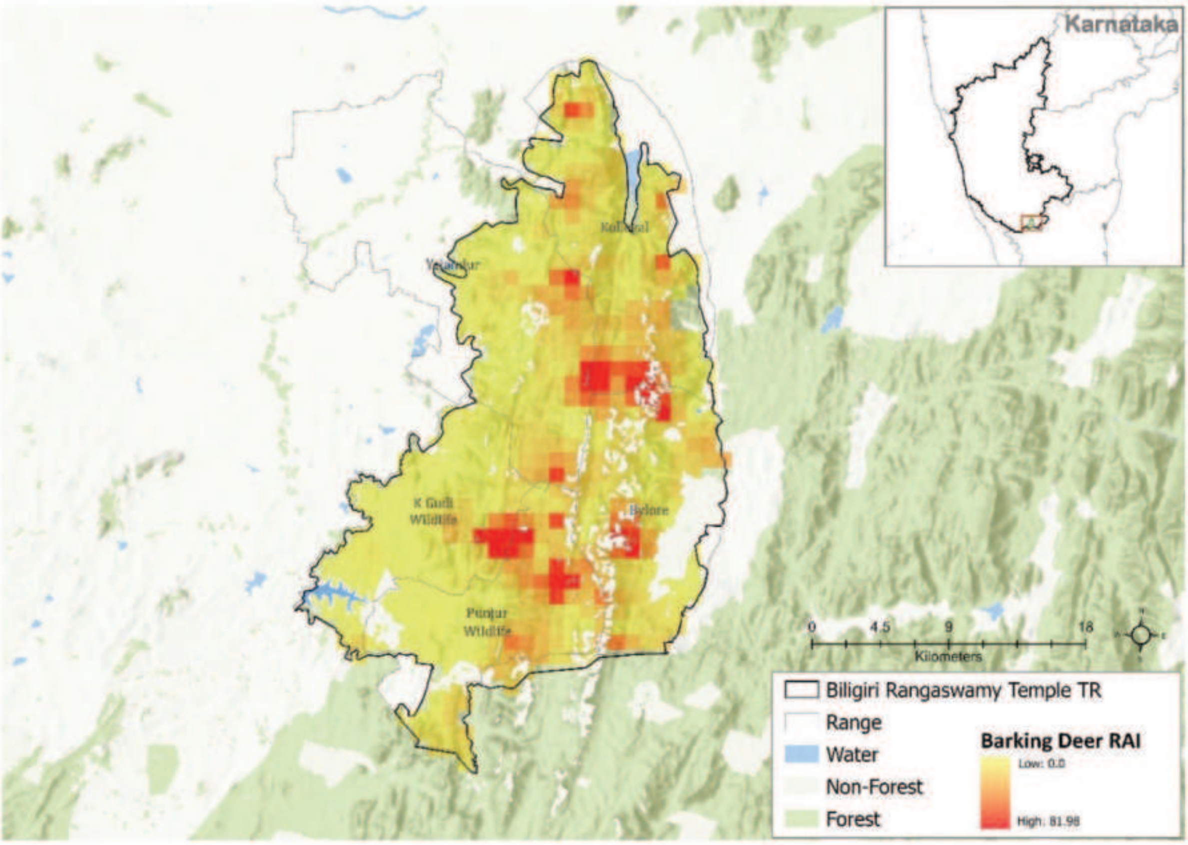


Figure V. 23: Spatial relative abundance of barking deer in BRT.

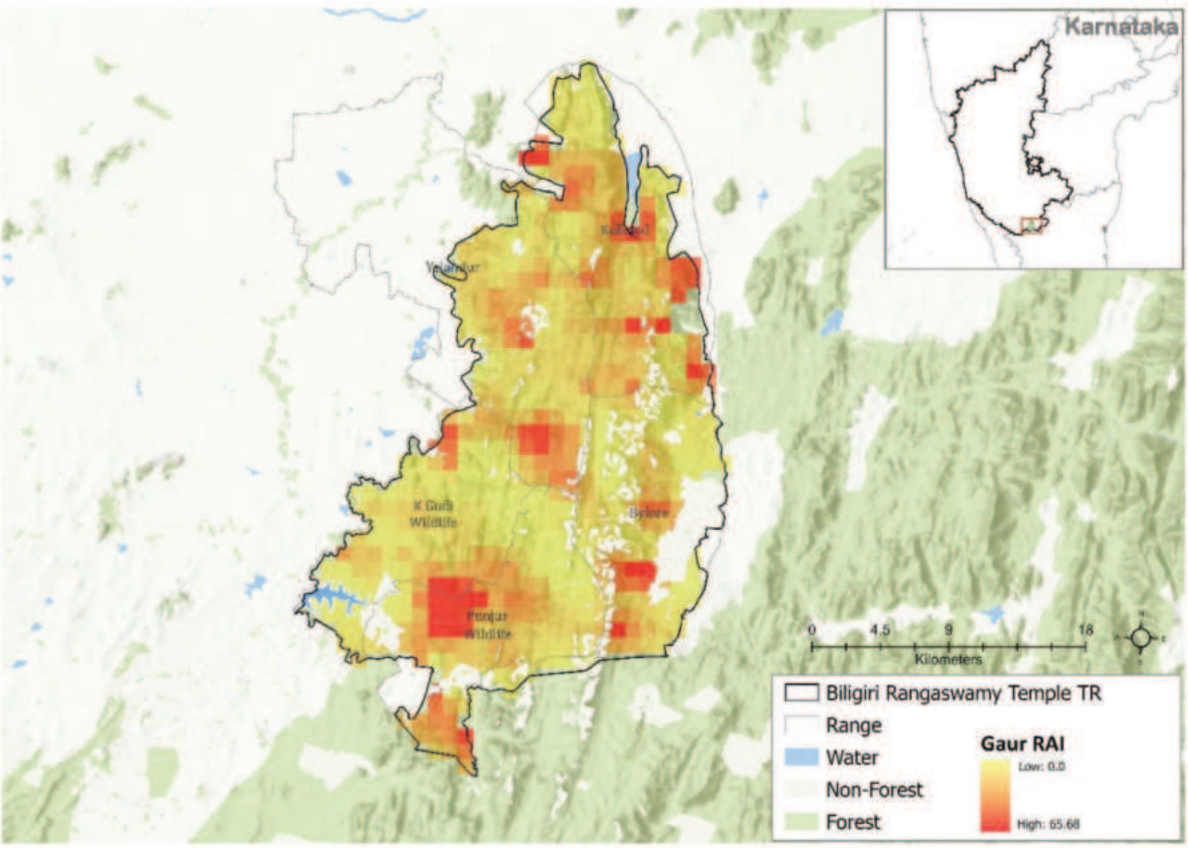


Figure V. 24: Spatial relative abundance of gaur in BRT.

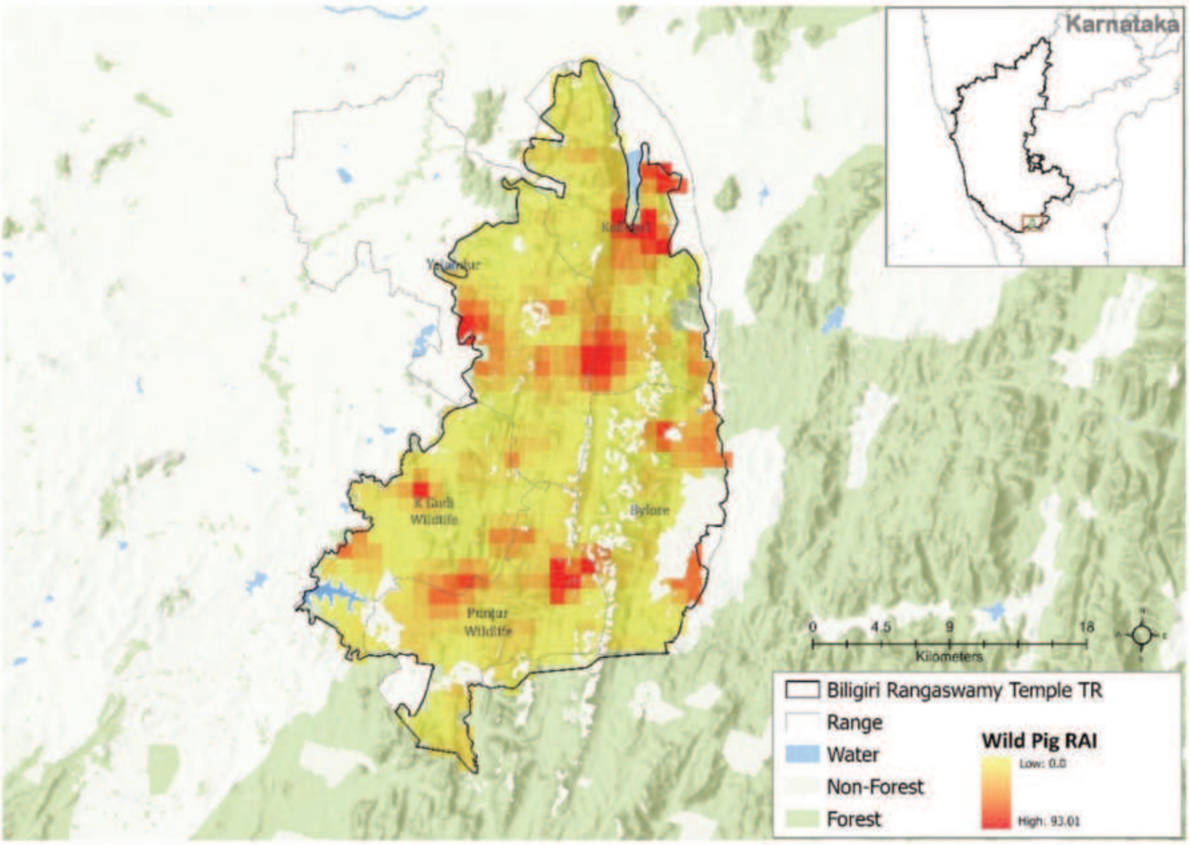


Figure V. 25: Spatial relative abundance of wild pig in BRT.

Nagarahole Tiger Reserve

Nagarhole tiger reserve, is located in the Kodagu and Mysore districts of Karnataka. Extending from the foothills of the Bramhagiri range in the west to the Deccan Plateau on the east, the tiger reserve covers an area of approximately 1,205 km^2 (Mahanty, 2003). The reserve forms a critical part of the Nilgiri Biosphere Reserve. The predominant vegetation types comprise tropical moist & dry deciduous forests, and sub-tropical hill forests, dominated by species like teak, rosewood, and sandalwood, interspersed with grasslands and swamps (Habib and Saxena, 2020). Nagarhole is famous for its Kabini water body which along with Taraka reservoir is vital for the reserve. The faunal diversity of tiger reserve includes tigers, elephants, leopards, gaur, chital, and sambar, baring deer alongside a vibrant avifauna. Being contiguous with Wayanad WLS and Bandipur TR, Nagarhole plays a major role in habitat connectivity.

Nagarhole has a high abundance of chital, sambar, and barking deer, and their spatial density is mapped using line transect data. The relative abundance of gaur and wild pig was mapped using photo-capture data from camera traps due to low observation during line transect. All major prey species in Nagarhole show clustered distributions, with each range having both high-abundance pockets and low-abundance patches. Chital is highly abundant in the Kalahalla Wildlife Range and the D.B. Kuppe Wildlife Range (Figure V. 26). In contrast, the Nagarhole Wildlife Range and the Hunsur Wildlife Range have the lowest chital abundance.

Similarly, sambar abundance varies across Nagarhole, with some areas having high abundance and adjacent areas showing low abundance (Figure V. 27). The Veeranahosalli Wildlife Range has the lowest sambar abundance. Barking deer are abundant throughout Nagarhole Tiger Reserve (Figure V. 28). All ranges support healthy populations of barking deer, with the D.B. Kuppe Wildlife Range having the highest abundance. Gaur is present in specific areas of Nagarhole. The D.B. Kuppe Wildlife Range has the highest gaur abundance compared to other ranges (Figure V. 29). However, all ranges exhibit medium to high gaur abundance. Wild pig abundance, based on camera trap data, is highest in the D.B. Kuppe Wildlife Range, followed by the Veeranahosalli Wildlife Range (Figure V. 30). Wild pigs are also present in other areas of Nagarhole.

Table V. 4.: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Nagarahole tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Barking deer	79	0.12 (0.014)	0.31 (0.03)	1.09 (0.05)	2.77 (0.45)	3.28 (0.54)
Chital	252	0.394 (0.026)	0.29 (0.02)	4.71 (0.3)	8.45 (0.8)	35.38 (2.67)
Gaur	29	0.044 (0.009)	0.39 (0.08)	2.04 (0.35)	0.56 (0.15)	1.24 (0.3)
Sambar	91	0.142 (0.015)	0.28 (0.02)	1.53 (0.08)	2.57 (0.34)	4.11 (0.49)

B)

Species	Chital	Sambar	Gaur	Barking deer
Detection model	Hazard rate (Null)	Half-normal (Cosine)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	26.741	12.16	9.851	3.003
s(Aridity)	-	-	-	2.288
s(NDVI Pre-Monsoon)	1.867	-	-	-
s(Ruggedness)	-	-	3.35	-

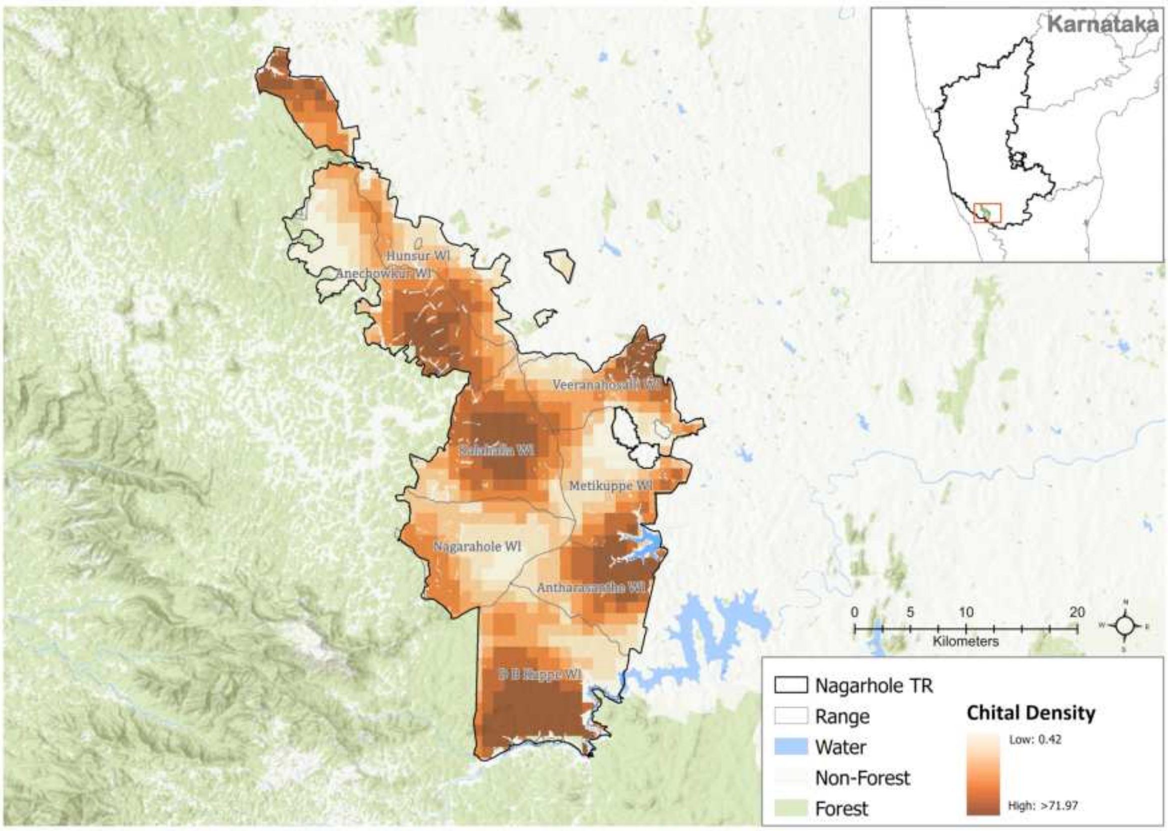


Figure V. 26: Density of chital (per km²) in Nagarahole tiger reserve: Site-level DSM

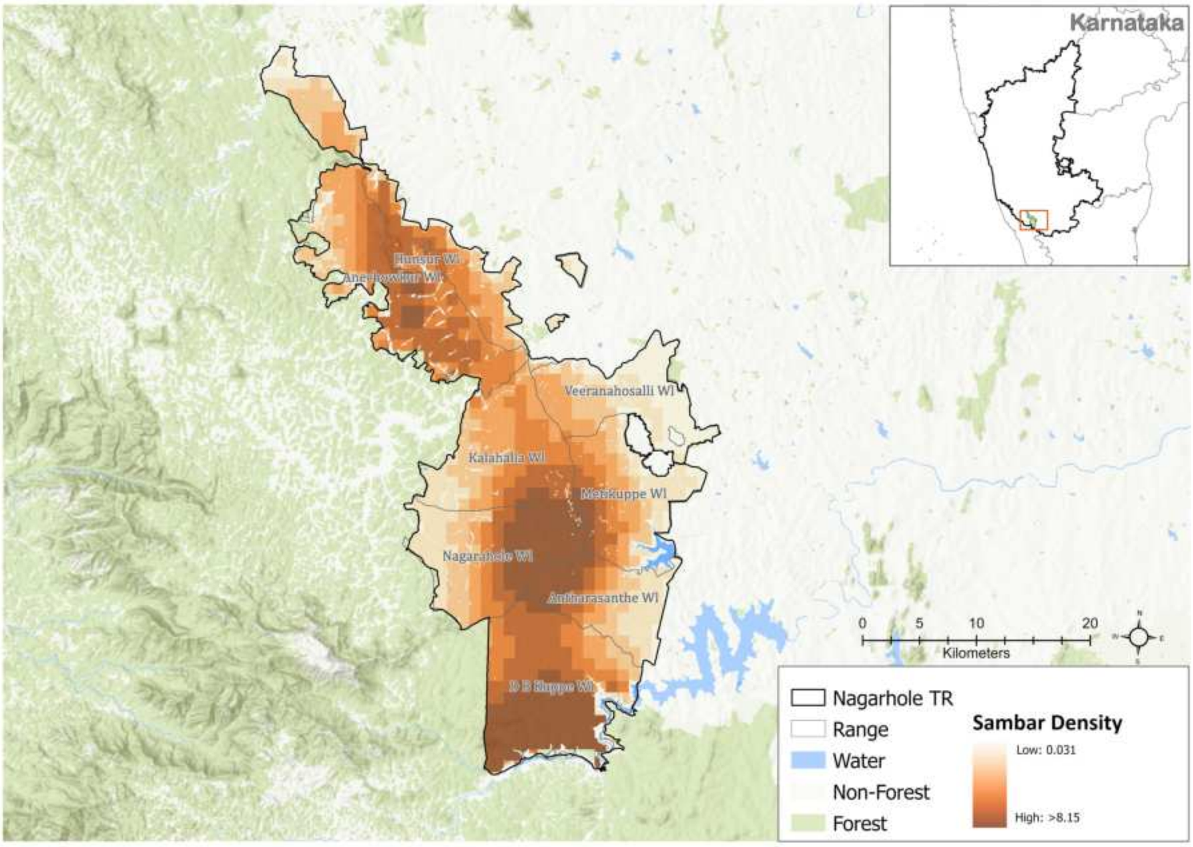


Figure V. 27: Density of sambar (per km^2) in Nagarhole tiger reserve: Site-level DSM

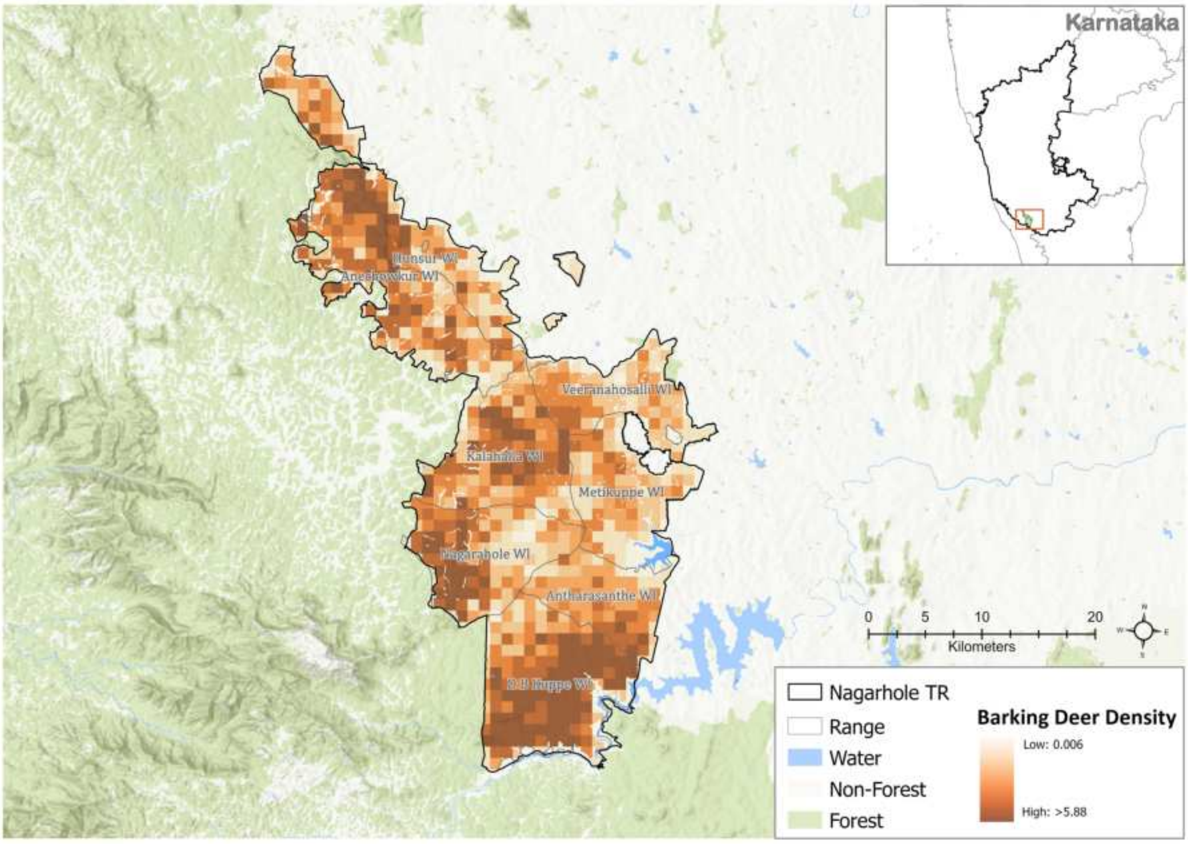


Figure V. 28: Density of barking deer (per km^2) in Nagarhole tiger reserve: Site-level DSM

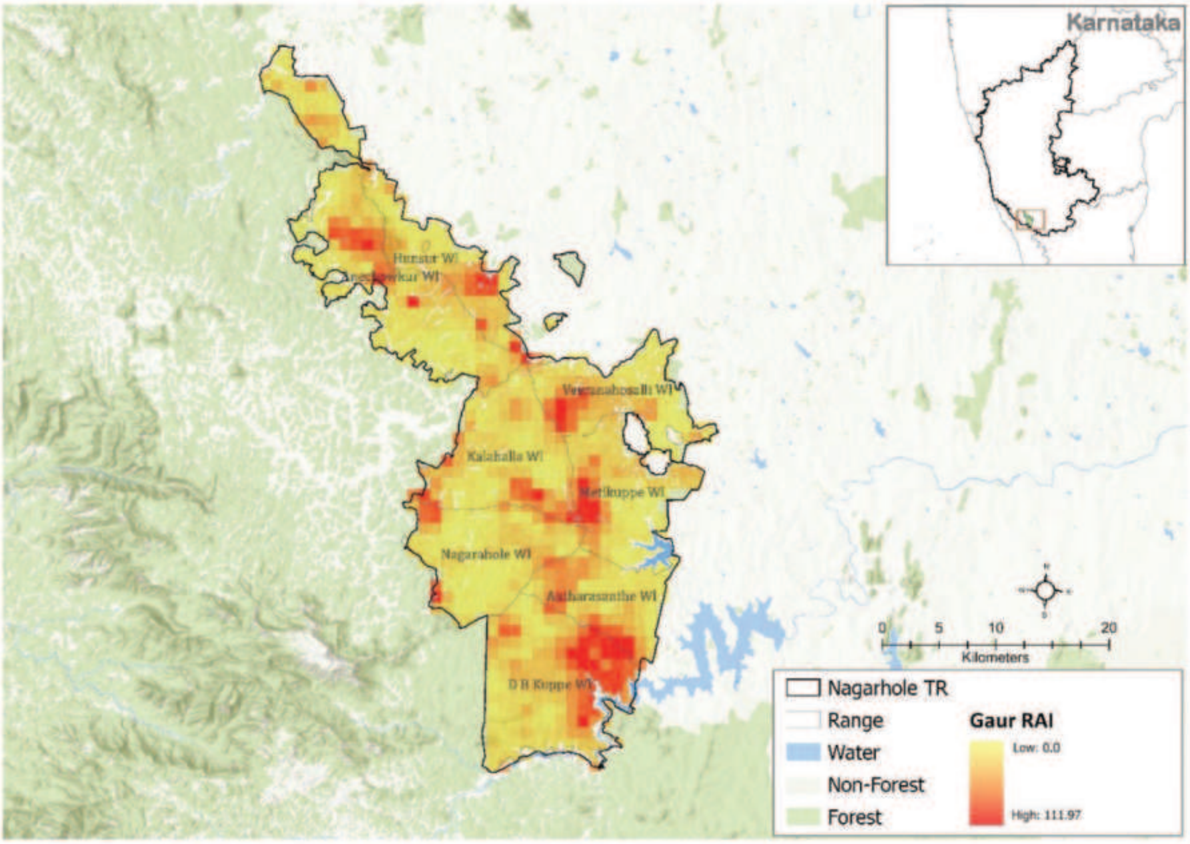


Figure V. 29: Spatial relative abundance of gaur in Nagarhole tiger reserve.

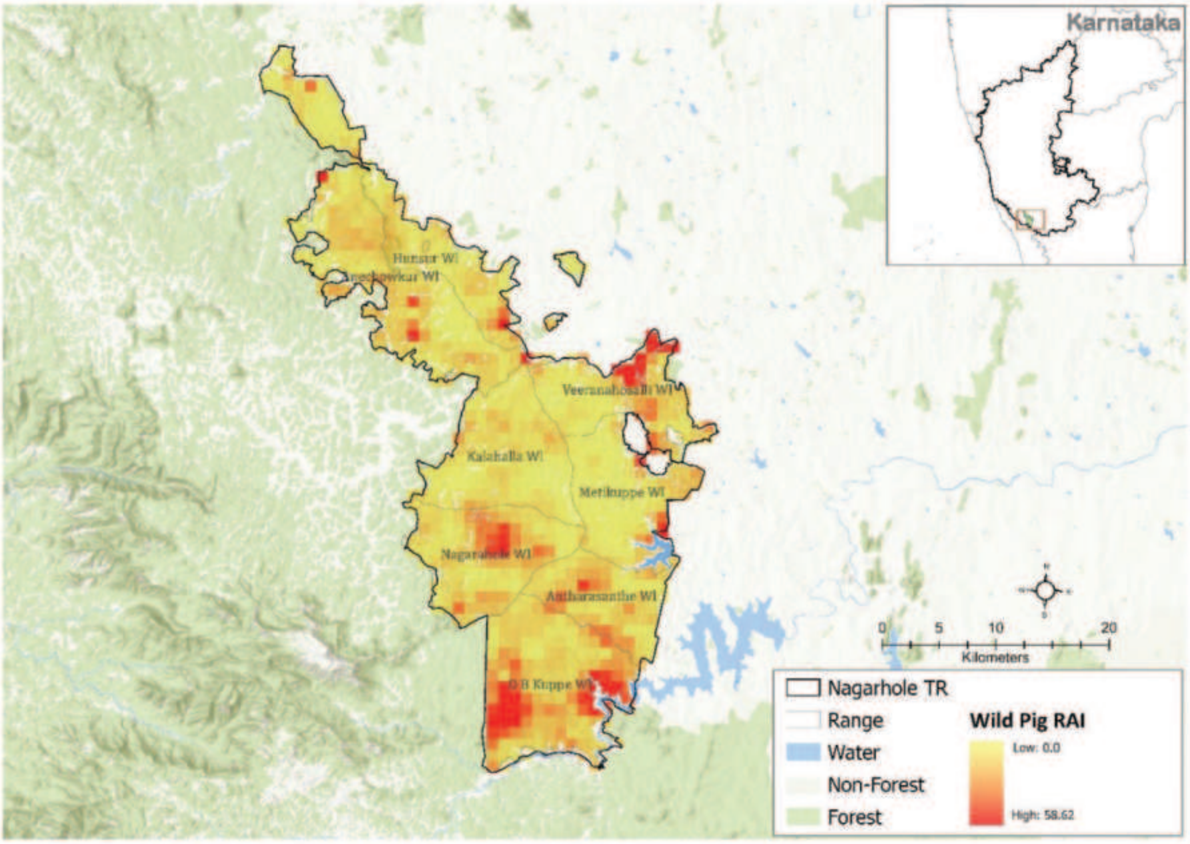


Figure V. 30: Spatial relative abundance of wild pig in Nagarhole tiger reserve.

TAMIL NADU

Anamalai Tiger Reserve

Anamalai tiger reserve, located in the Idukki and Coimbatore districts of Tamil Nadu, spans approximately 1,479 km^2. It forms a contiguous landscape cluster with Parambikulam tiger reserve, Malayatoor and Vazhachal Forest Divisions (Kerala) and Kodaikanal WLS (Tamil Nadu). The reserve is characterized by tropical evergreen forests, tropical semi-evergreen forests, moist deciduous forests, teak plantation forests, patches of dry-deciduous forests, scrub forests, interspersed with grasslands and shola ecosystems at higher elevations (Kumaraguru, 2011). Anamalai is home to the tiger, leopard, sloth bear, stripe-necked mongoose, gaur, elephant, as well as endangered species like the Nilgiri tahr and lion-tailed macaque.

Data from Anamalai tiger reserve is insufficient for spatial density analysis. The encounter rate for chital is 0.0562 (±0.0217) and for sambar is 0.2171 (±0.0254). Therefore, the spatial densities of chital and sambar were predicted using landscape model, while the relative abundance of gaur, barking deer, and wild pig was mapped based on photo-capture rates from camera traps. The landscape model predicts the presence of chital in the Amaravathi and Ulandy ranges (Figure V. 31), while sambar is predicted to occur across all ranges of the Anamalai Tiger Reserve (Figure V. 32). Gaur, barking deer, and wild pigs were photo-captured in all ranges except Udumalpet. The highest abundance of gaur in camera traps was recorded in Amaravathi, followed by Koluman and Ulandy (Figure V. 34). Barking deer were most abundant in the Ulandy and Manambolly ranges, followed by Valparai and Koluman (Figure V. 33). Wild pigs were more abundant in the northern part of the Anamalai Tiger Reserve (Figure V. 35).

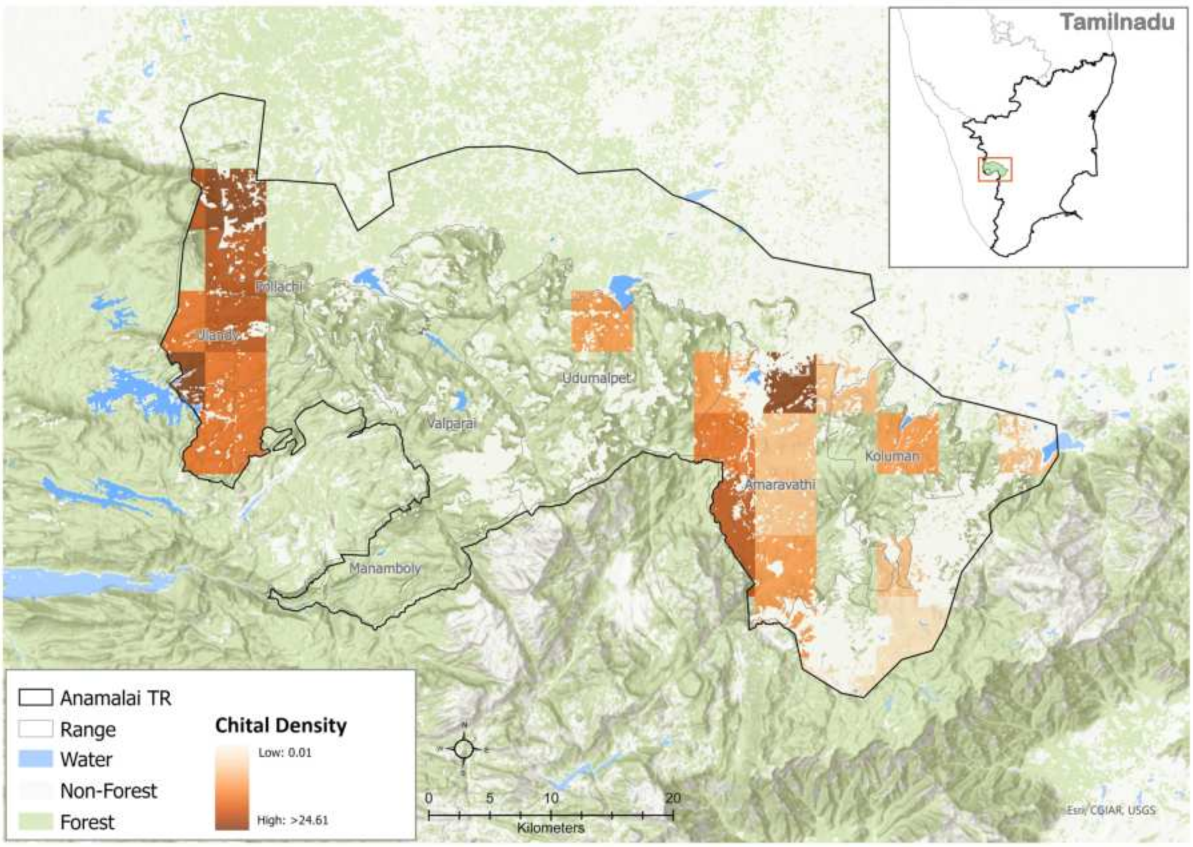


Figure V. 31: Density of chital (per 25 km^2) in Anamalai tiger reserve: Landscape-level DSM

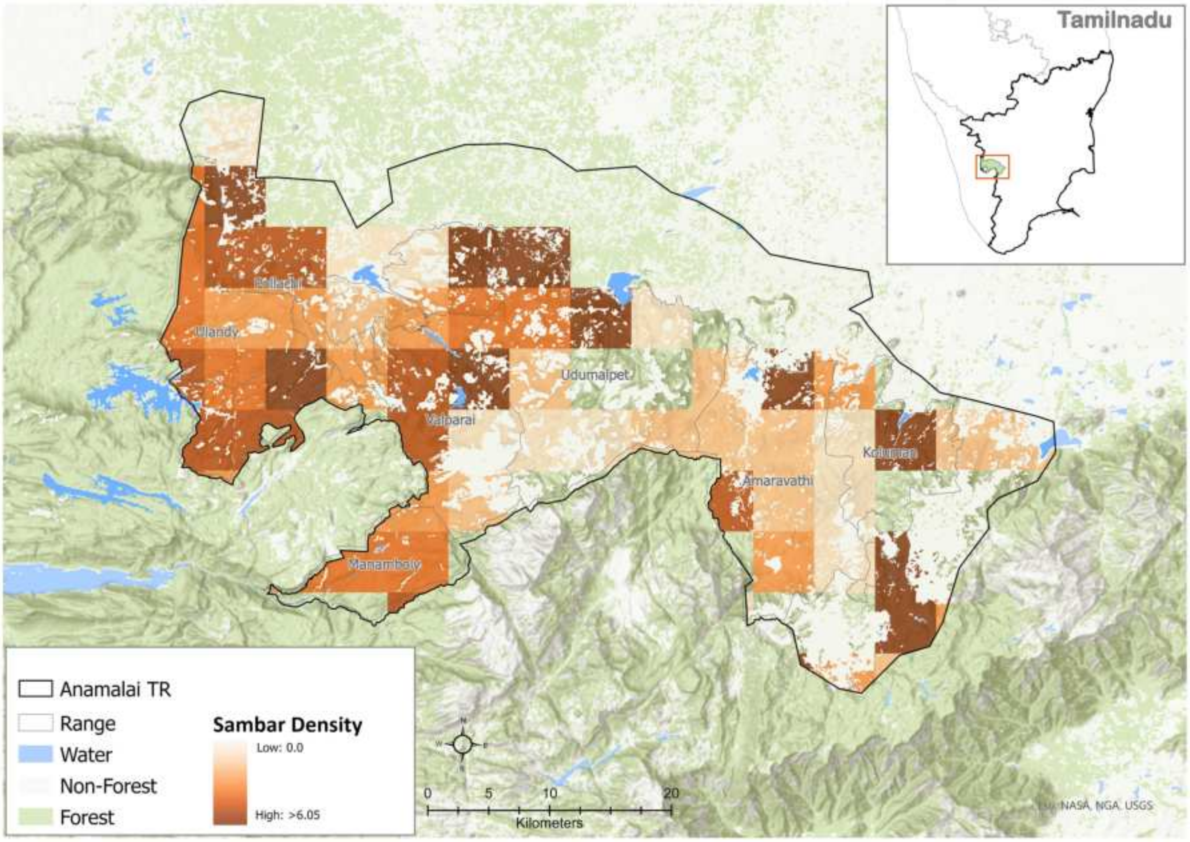


Figure V. 32: Density of sambar (per 25 km²) in Anamalai tiger reserve: Landscape-level DSM

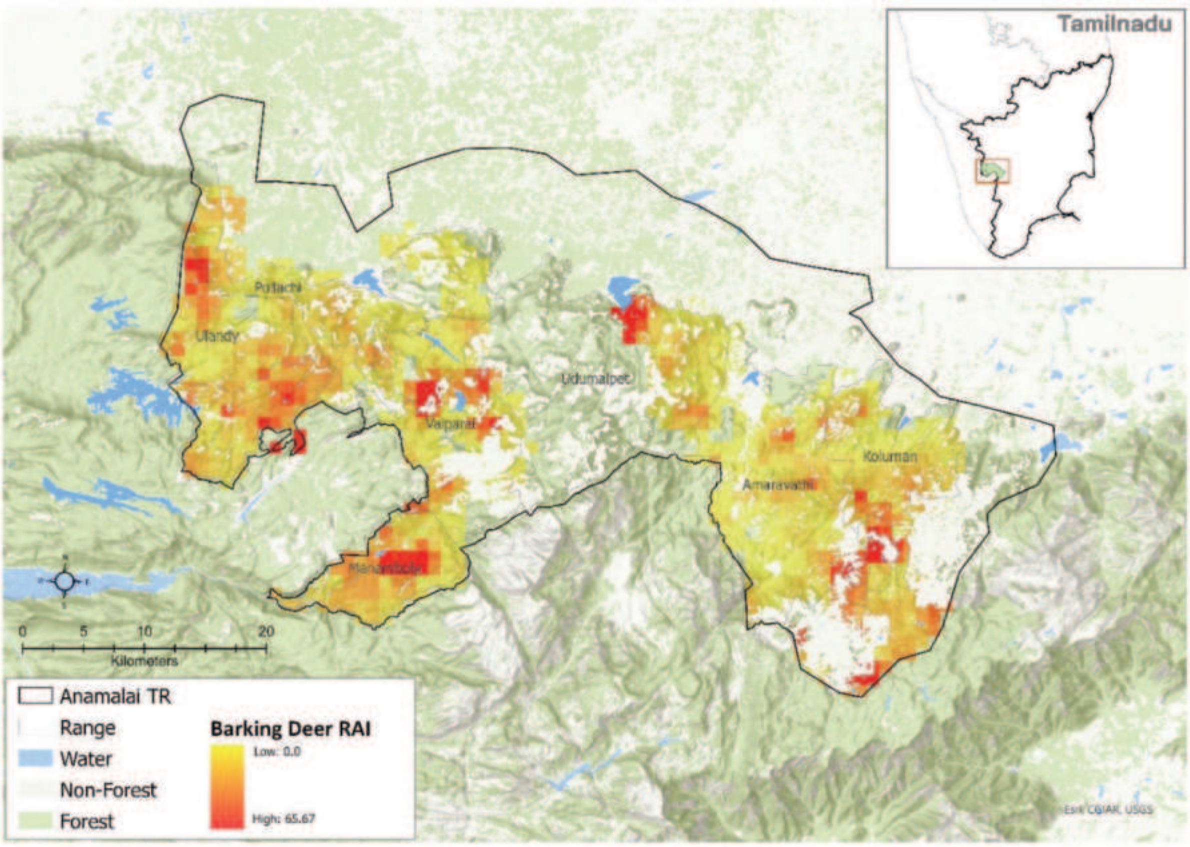


Figure V. 33: Spatial relative abundance of barking deer in Anamalai tiger reserve.

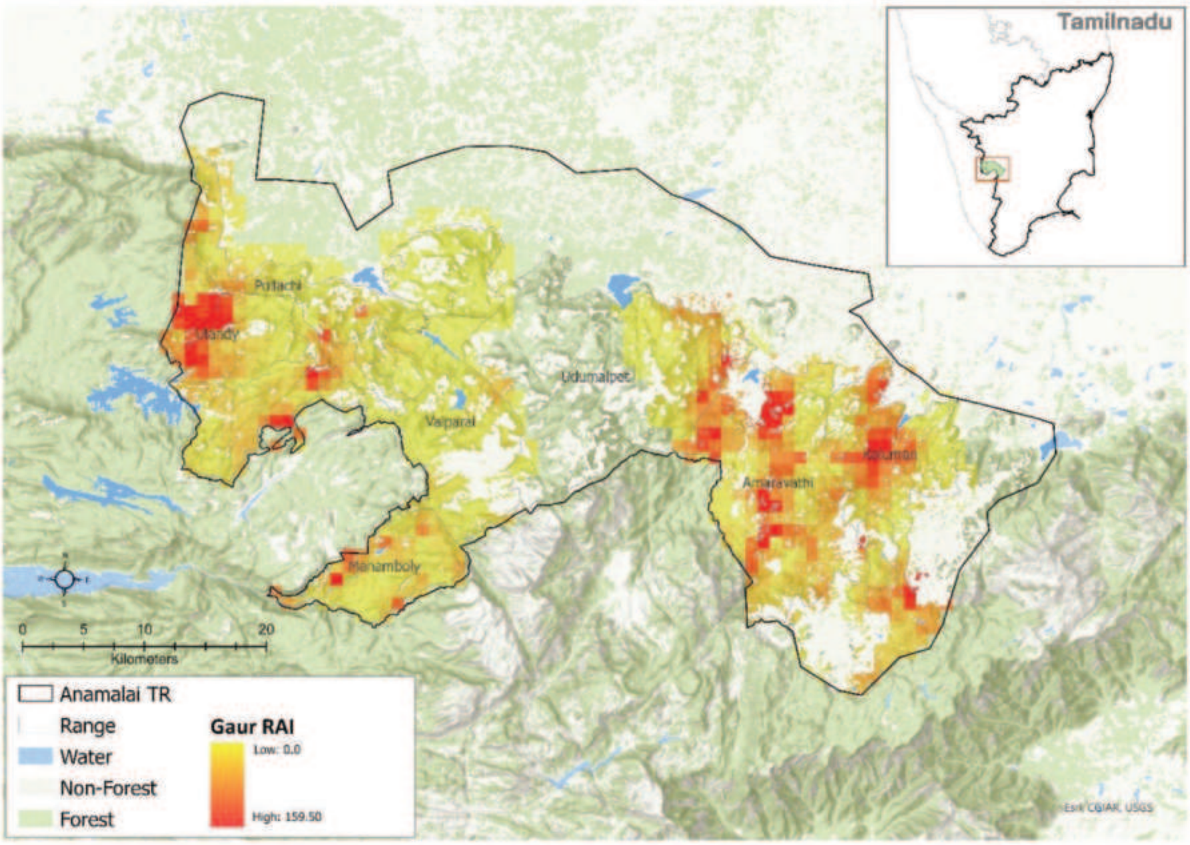


Figure V. 34: Spatial relative abundance of gaur in Anamalai tiger reserve.

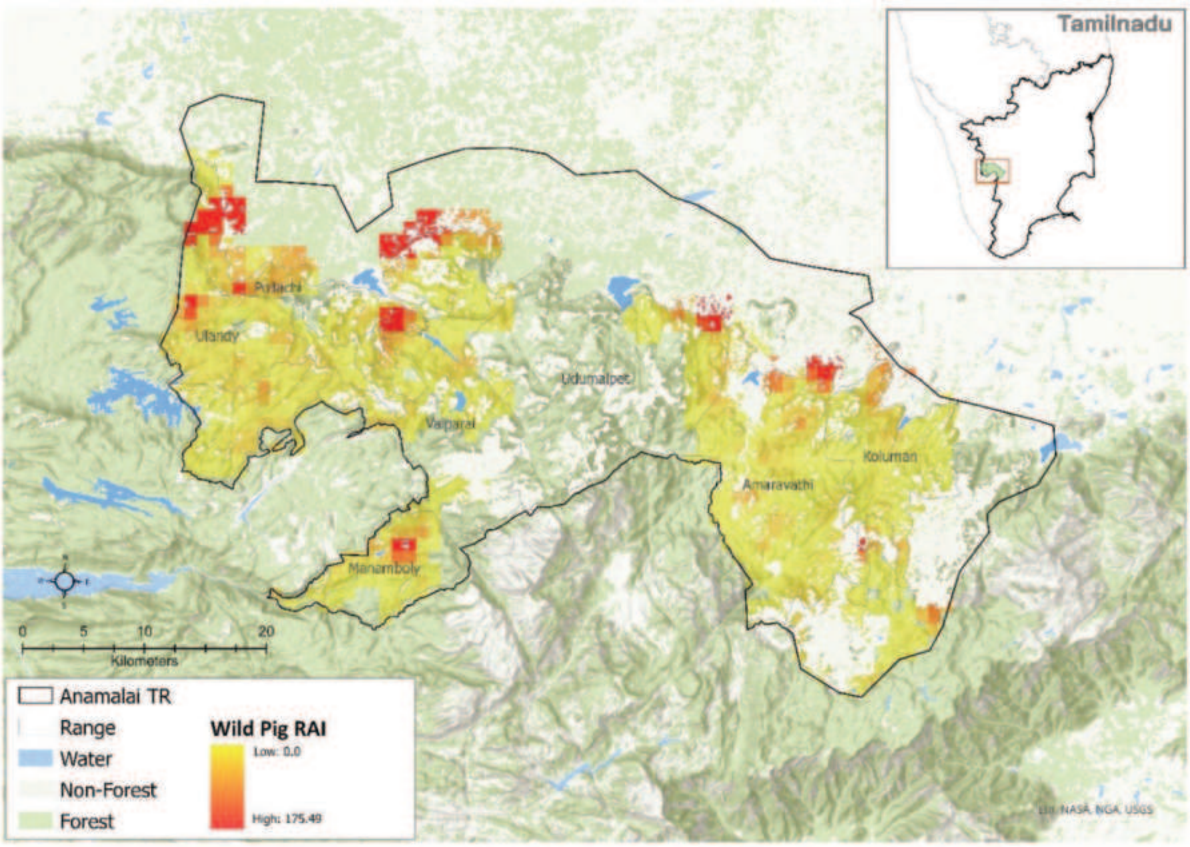


Figure V. 35: Spatial relative abundance of wild pig in Anamalai tiger reserve.

Kalakad-Mundanthurai Tiger Reserve

Kalakad Mundanthurai tiger reserve (KMTR), the southern-most tiger reserve of India, is located in the Tirunelveli and Kanyakumari districts of Tamil Nadu, spans approximately 1,601 km^2. KMTR is a part of the Agasthyamalai Biosphere Reserve. The elevation of the reserve ranges from 100 – 1880m. This elevation gradient generates a wide array of vegetation including tropical evergreen forests and semi-evergreen forests to deciduous forests and high-altitude shola-grasslands (Ganesh *et al*., 1996). KMTR has one of the largest contiguous tracts of tropical rainforests remaining in the Western Ghats (Ramesh *et al*., 1997). Animal diversity of KMTR includes tiger, elephant, leopard, gaur, and a variety of smaller carnivores, herbivores, and amphibians.

Sambar is the most abundant prey species in KMTR (Table V. 5). Sambar populations are concentrated in the eastern and southern forested boundary of the reserve while northern and western regions show sparse distribution. Chital observation during line transect is very low hence their spatial density is predicted using landscape model. The encounter rate for chital is 0.0105 (±0.0053). The prediction indicates chital presence in restricted small patch of areas bordering Mundathurai and papanasam range (Figure V. 36). Gaur, barking deer, and wild pig spatial densities were not estimated due to insufficient data. Their relative abundance through camera trap based photo-captures were mapped for informed decision. Gaur is abundant in small pockets across almost all ranges except Courtallam and Pappanasam (Figure V. 39). Barking deer is most abundant in Mundanthurai and Kadayam ranges (Figure V. 38) while wild pig abundance is high in Mundanthurai, Kadayam and Kalakkad range (Figure V. 40).

Table V. 5: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Kalakad-Mundanthurai tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Sambar	38	0.2 (0.032)	0.64 (0.06)	1.61 (0.17)	4.88 (0.85)	5.37 (0.96)

B)

Species	Sambar
Detection model	Hazard rate (Null)
s(x,y)	9.15
s(NDVI Pre-Monsoon)	3.128

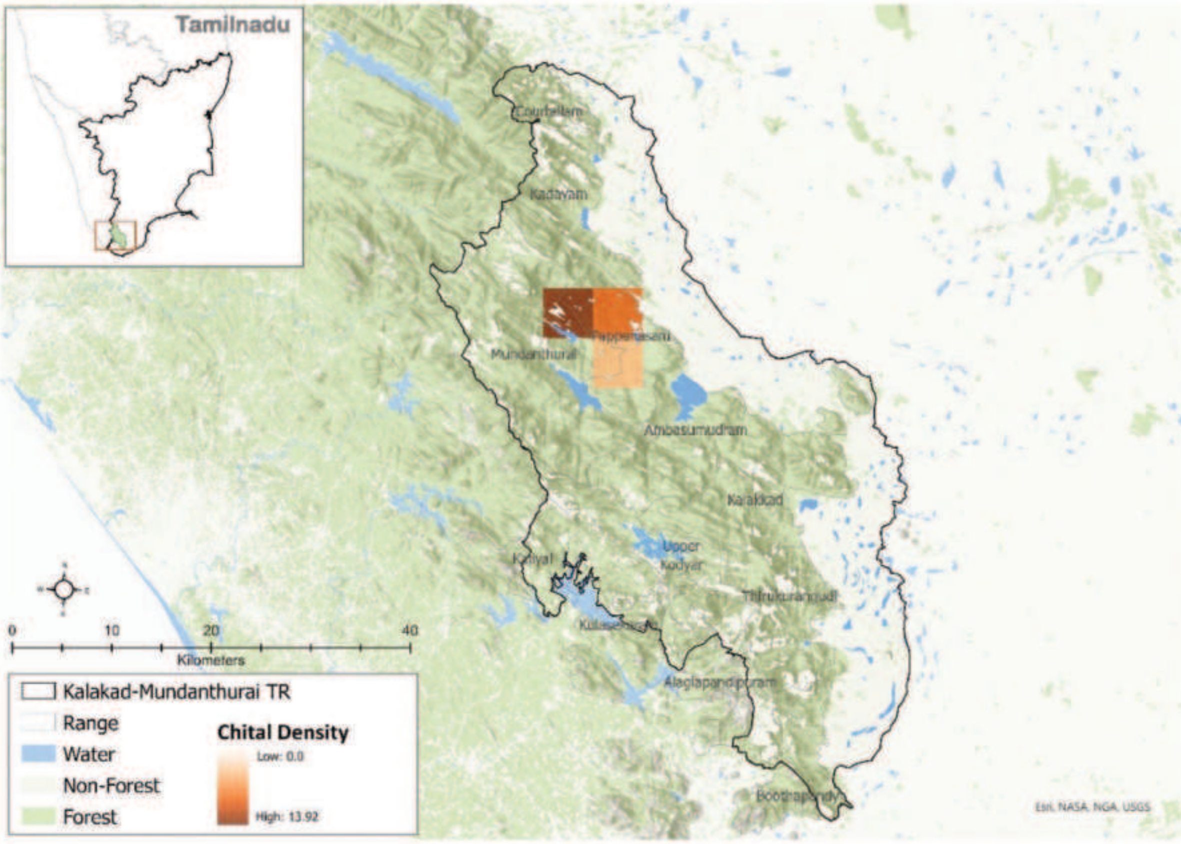


Figure V. 36: Density of chital (per 25 km²) in KMTR: Landscape-level DSM

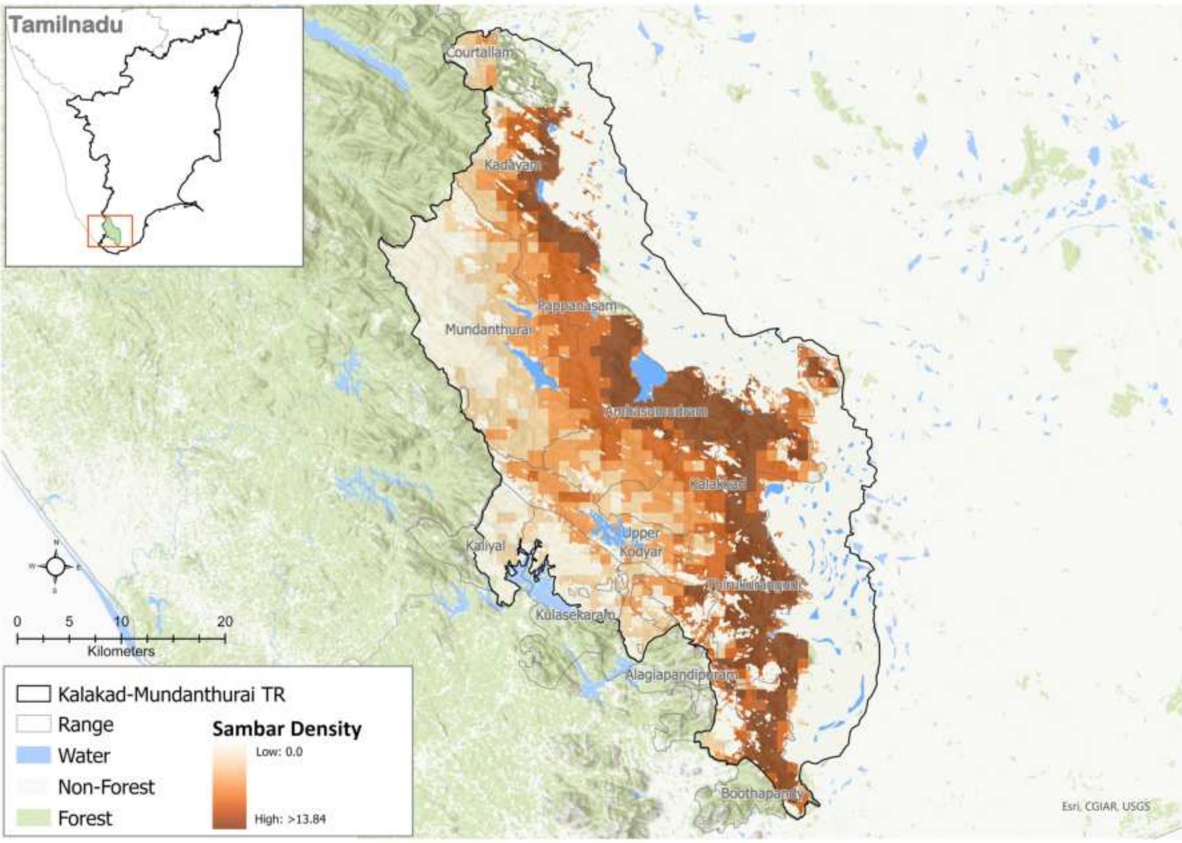


Figure V. 37: Density of sambar (per km²) in KMTR: Site-level DSM

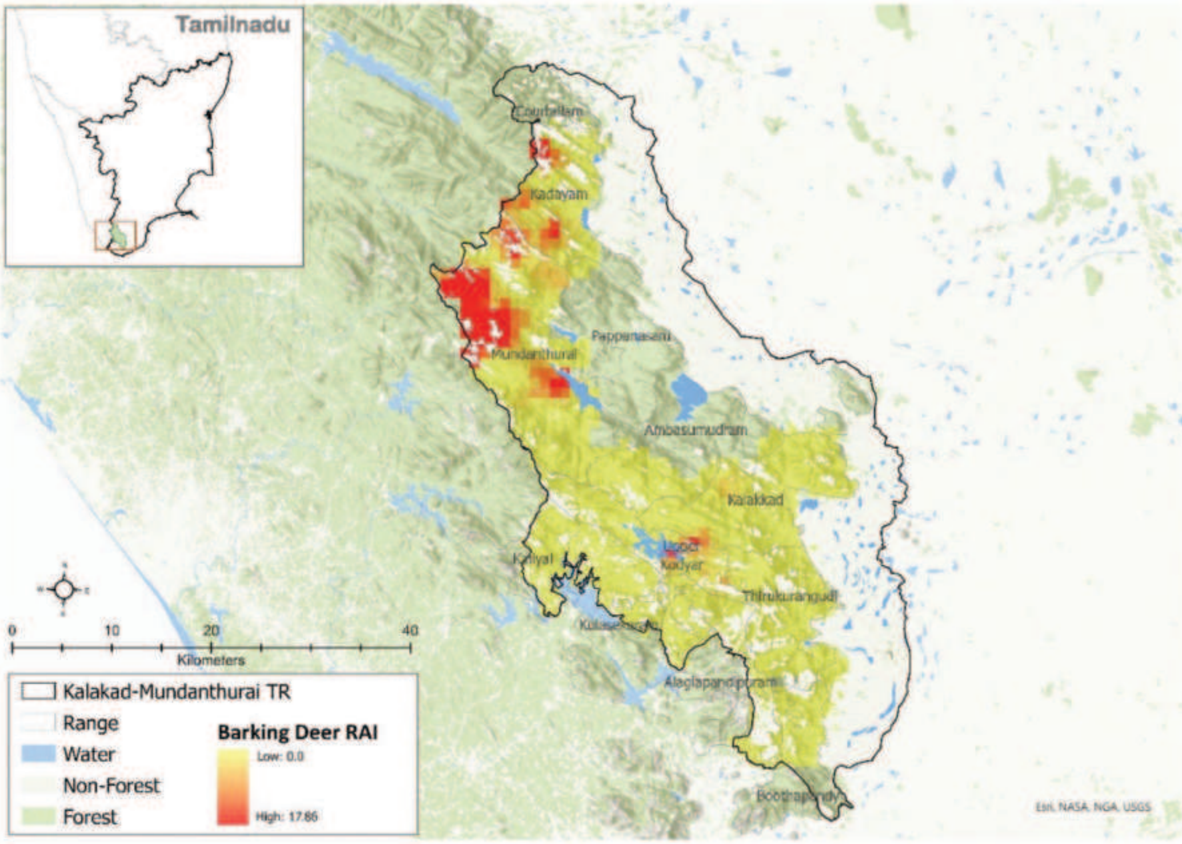


Figure V. 38: Spatial relative abundance of barking deer in KMTR

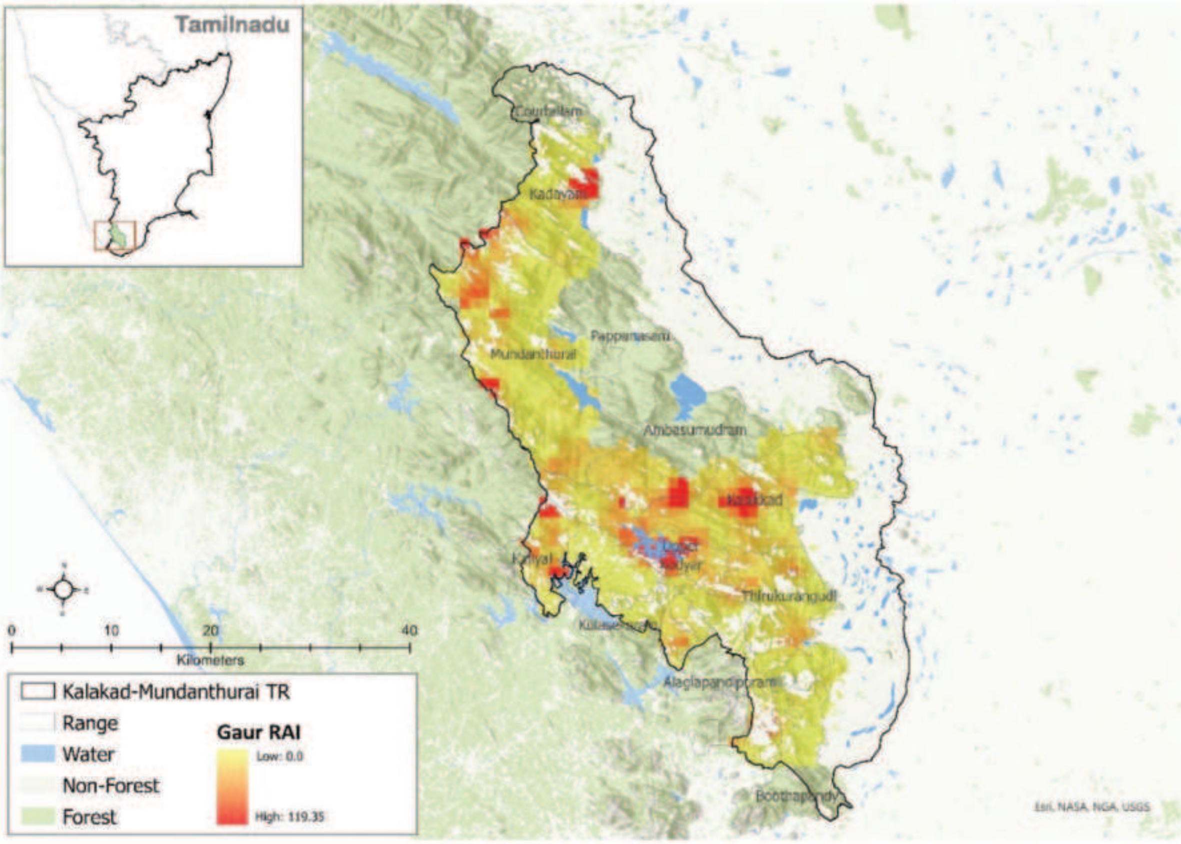


Figure V. 39: Spatial relative abundance of gaur in KMTR

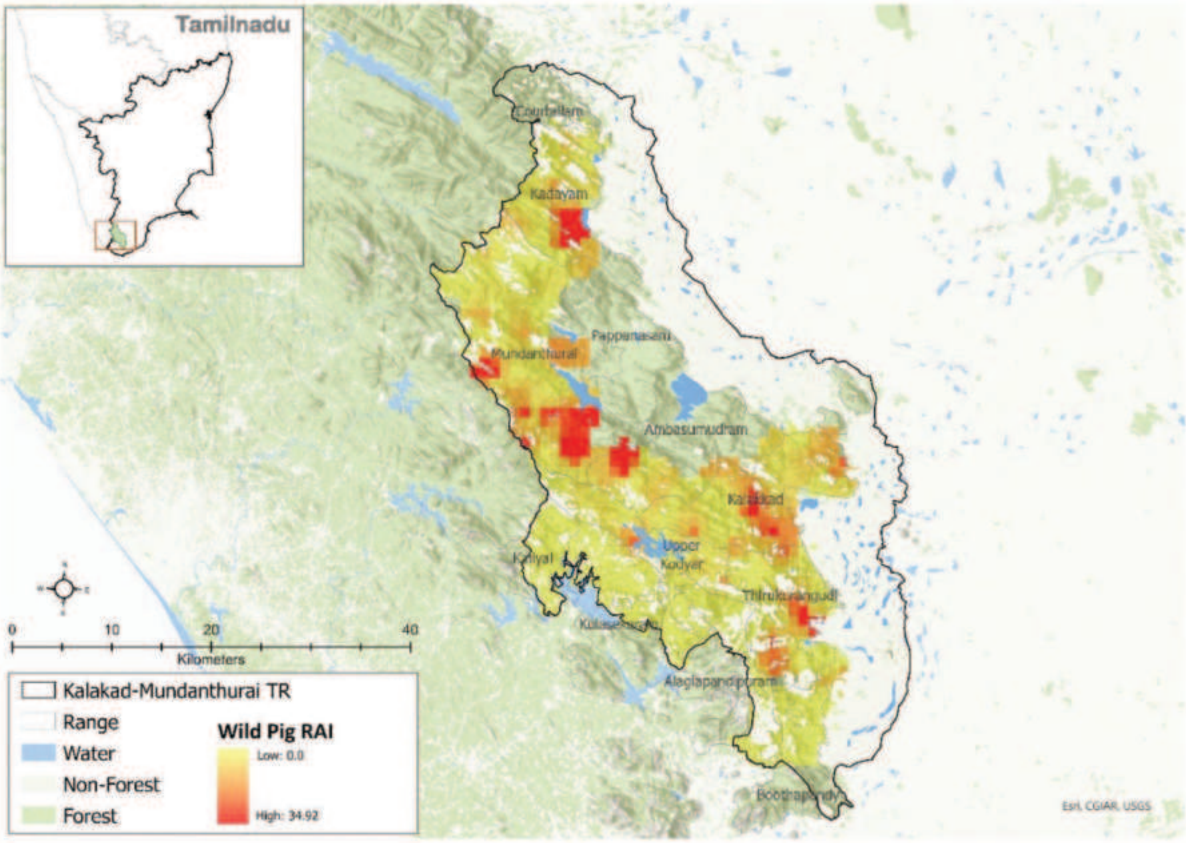
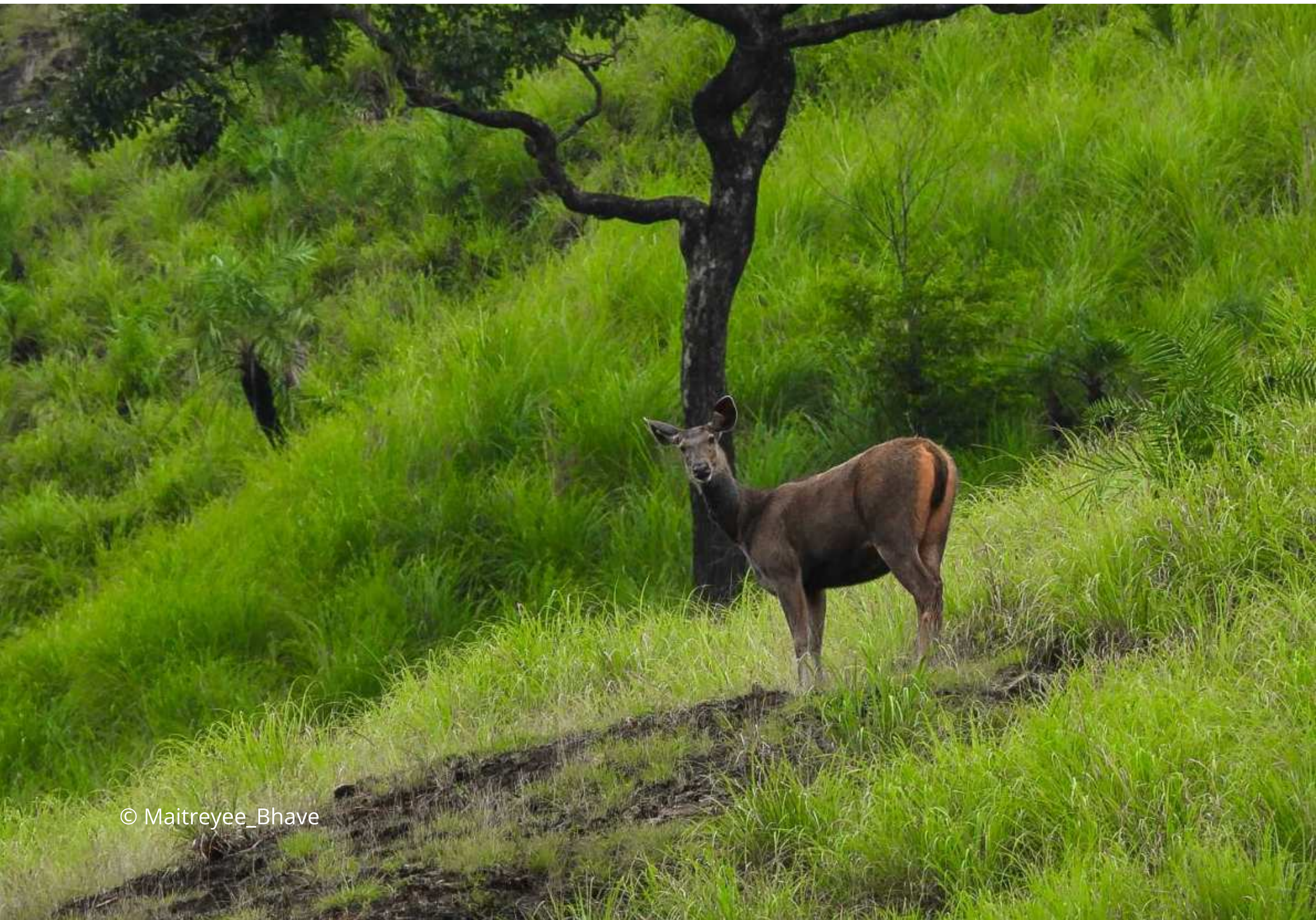


Figure V. 40: Spatial relative abundance of wild pig in KMTR



Mudumalai Tiger Reserve

Mudumalai tiger reserve, spans approximately 688 km^2, is part of Nilgiri Biosphere Reserve of Tamilnadu and situated at the tri-junction of Tamil Nadu, Karnataka and Kerala. The habitat of the tiger reserve includes southern tropical moist deciduous forests, southern tropical dry deciduous forests, evergreen forests, grasslands, thorn scrub forests, bamboo brakes (Champion and Seth, 1968) and riverine ecosystems nourished by the Moyar river. The tiger reserve is home to animals like elephant, tiger, leopard, gaur, dhole, sloth bear, leopard cat, rusty spotted cat, mouse deer, chousingha, chital, sambar, blackbuck *etc*. Mudumalai TR is contiguous with Bandipur TR, Wayanad WLS, and Nilgiri North Division.

Among prey chital has highest density followed by sambar and then gaur (Table V. 6). Highest spatial densities of chital are concentrated in the ranges of Segur and NES (Figure V. 41). However, the density goes down drastically in western ranges. Sambar densities higher numbers focused in range of Segur, NES and Nelakottai ranges (Figure V. 42) while Singara range has very low density. Gaur densities are highest in Segur and NES range (Figure V. 43). Eastern part of mudumalai has high chital, sambar, and gaur density compared to western side. The Mysore-Ooty highway passes through western part of Mudumalai which may affect the animal presence of the area.

Observation of wild pig and barking deer in line transect are not sufficient for spatial density analysis hence their relative abundance is calculated through camera trap data. Barking deer were more abundant towards southern part of the tiger reserve (Figure V. 44). Wild pig is distribution is sparse in Mudumalai. Higher abundance is from Masinagudi, Segur range (Figure V. 45).

Table V. 6: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Mudumalai tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	214	0.287 (0.02)	0.21 (0.02)	12.54 (1.02)	4.51 (0.48)	56.41 (4.75)
Gaur	65	0.083 (0.011)	0.41 (0.05)	4.66 (0.65)	1.29 (0.23)	7.45 (1)
Sambar	72	0.095 (0.011)	0.34 (0.04)	2.61 (0.25)	1.75 (0.29)	4.44 (0.6)

B)

Species	Chital	Sambar	Gaur
Detection model	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)
s(x,y)	3.977	16.657	8.406
s(NDVI Post-Monsoon)	-	1.934	2.459
s(Ruggedness)	1.002	-	-

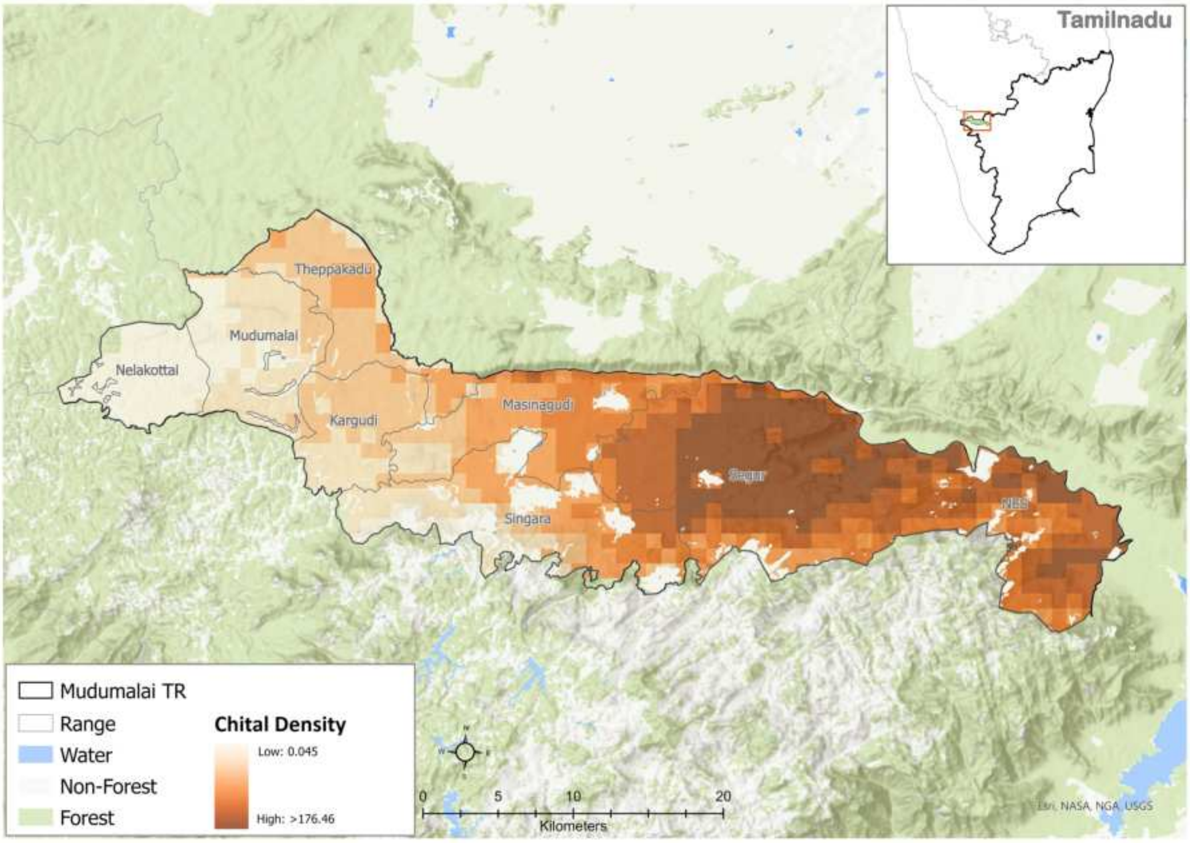


Figure V. 41: Density of chital (per km²) in Mudumalai tiger reserve: Site-level DSM

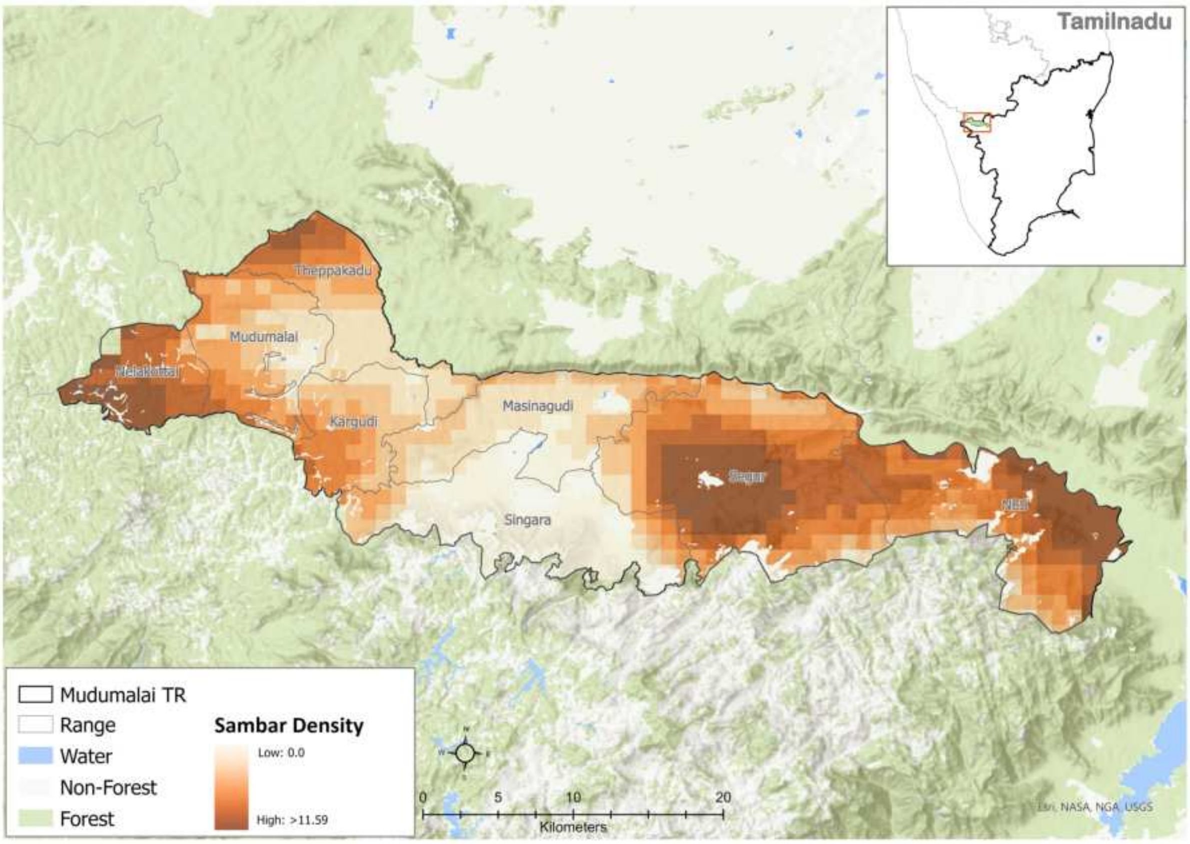


Figure V. 42: Density of sambar (per km²) in Mudumalai tiger reserve: Site-level DSM

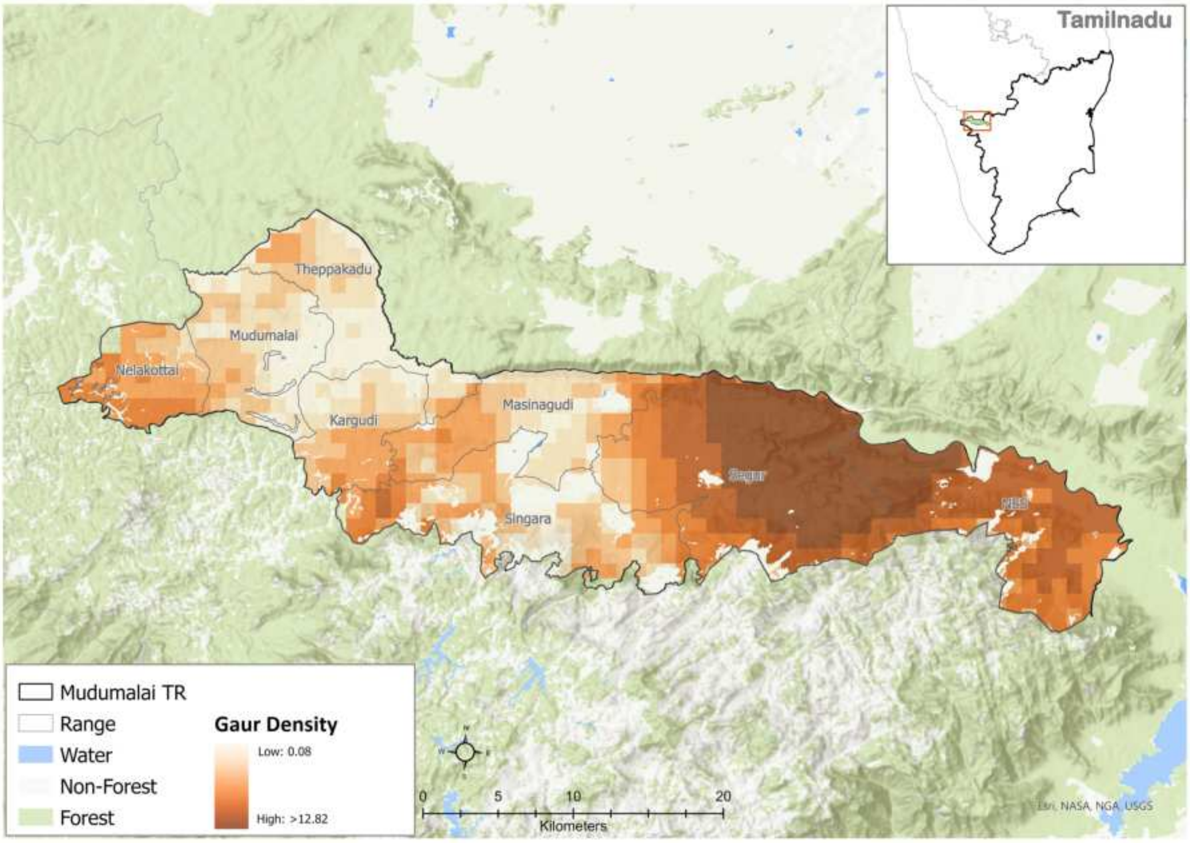


Figure V. 43: Density of gaur (per km²) in Mudumalai tiger reserve: Site-level DSM

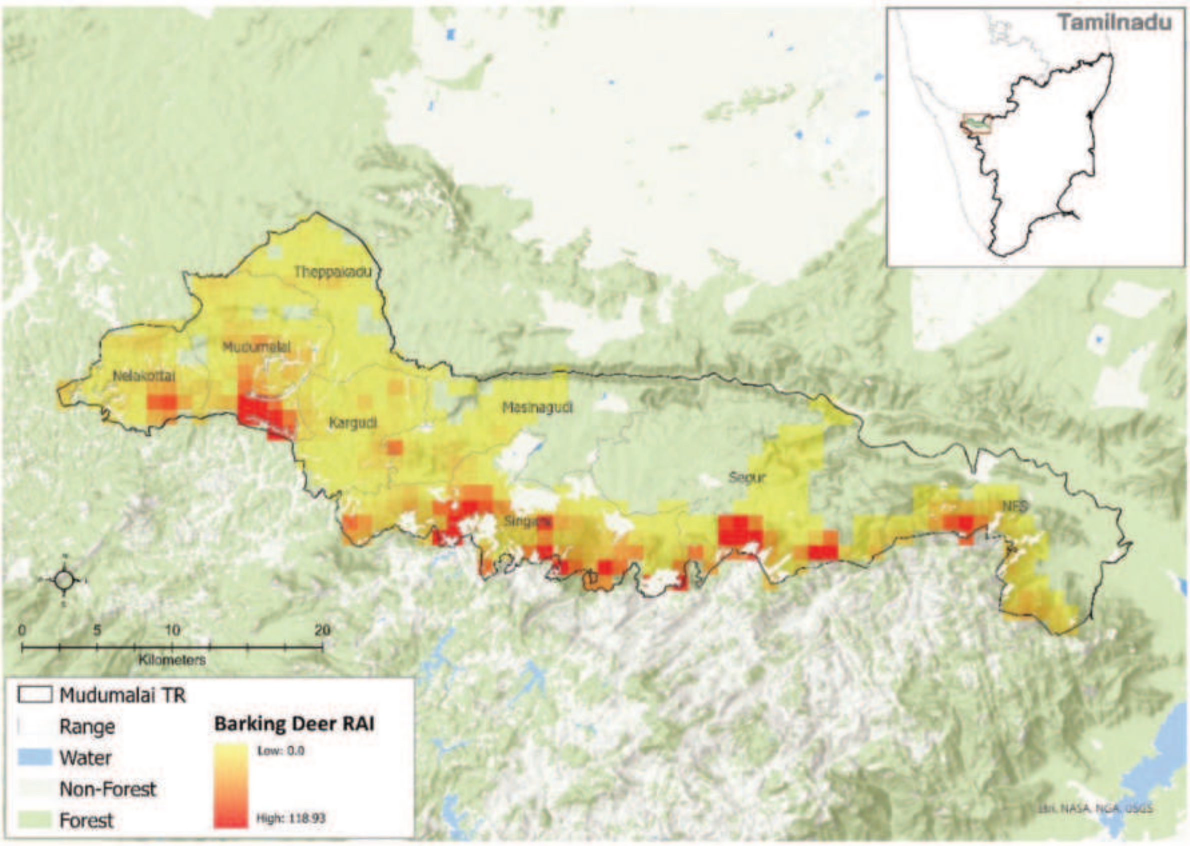


Figure V. 44: Spatial relative abundance of barking deer in Mudumalai tiger reserve

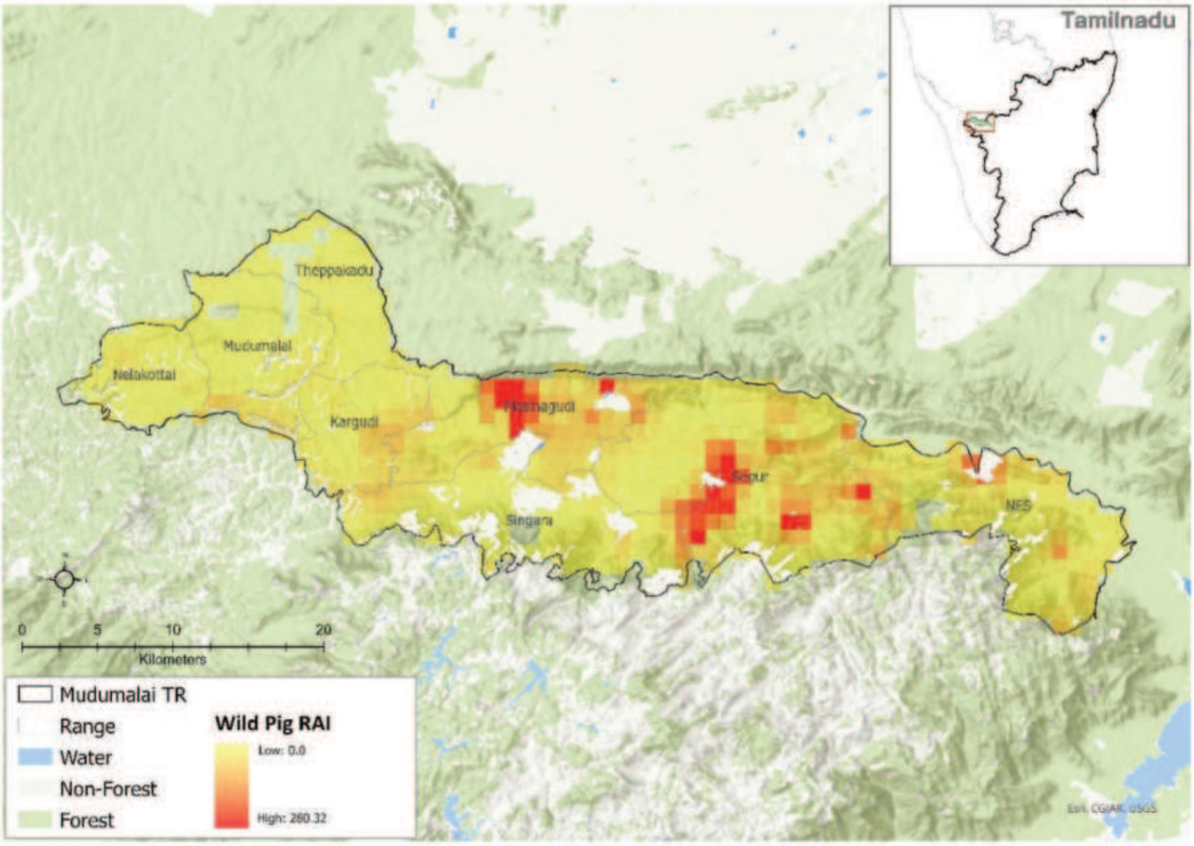


Figure V. 45: Spatial relative abundance of wild pig in Mudumalai tiger reserve.

Sathyamangalam Tiger Reserve

Sathyamangalam tiger reserve, located in the Erode districts of Tamil Nadu, spans approximately 1,408 km^2. It is also a part of the Nilgiri Biosphere Reserve and situated at the strategic confluence of the Western Ghats and Eastern Ghats. Habitat types of the tiger reserve are dry deciduous forests, tropical moist forests, tropical evergreen (shola), and semi-evergreen and thorn forest (Sathya, 2017). Bhavani and Moyar are the two perennial rivers that run through the reserve area. The faunal diversity includes tiger, leopard, gaur, sloth bear, elephant, lion-tailed macaque, herbivores like chital sambar, guar, blackbuck, barking deer, chousingha, and a variety of birds, reptiles.

Chital is most abundant ungulate species in Sathyamangalam (Table V. 7). Density is high in western part of the reserve with a relatively sparse distribution on the Eastern part. Vilamundy range has highest spatial density of chital, followed by Talavadi and Hassanur (Figure V. 46). Sambar density is also concentrated on the western part of Sathyamangalam, particularly in Talavadi, Jeerahalli, Talamalai, Bhavanisagar and Vilamandi ranges (Figure V. 47). Gaur density is more along the periphery of western ranges of Jeerahally, and Bhavanisagar which shares contiguous forests with Mudumalai and Bandipur Tiger reserves as well kadambur, and Thukkanaicken Palayam ranges on the East which shares boundary with MM hills WLS, and Erode WLD respectively (Figure V. 48). The species occupies the central portion of the reserve sparsely and requires management intervention in the central region. Similarly, wild pig density is also low in central area and high towards eastern and western periphery (Figure V. 49). Due to low number of observations in line transect, spatial densities of barking deer was not estimated. Rather, relative abundance is calculated from camera trap data. Barking deer is abundance is highest in Germalam, Talamalai followed by Hassanur (Figure V. 50).

Given the reserve's proximity to pastoral communities, strengthening community-based grazing management programs is crucial to minimize competition with livestock to increase the ungulate population in the tiger reserve.

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Table V. 7: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Sathyamangalam tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Barking deer	52	0.032 (0.005)	0.39 (0.05)	1.09 (0.05)	0.68 (0.13)	1.11 (0.22)
Chital	436	0.278 (0.014)	0.39 (0.02)	6.11 (0.28)	4.42 (0.3)	24.04 (1.41)
Gaur	157	0.112 (0.009)	0.45 (0.03)	2.8 (0.21)	1.8 (0.19)	4.46 (0.35)
Sambar	156	0.101 (0.008)	0.18 (0.01)	2.18 (0.15)	1.58 (0.18)	3.51 (0.36)
Wild pig	49	0.034 (0.005)	0.54 (0.06)	7.35 (0.61)	0.64 (0.12)	5.2 (0.54)

B)

Species	Chital	Sambar	Gaur	Barking deer	Wild pig
Detection model	Hazard rate (Null)	Hazard rate (Null)	Hazard rate (Null)	Half-normal (Null)	Hazard rate (Null)
s(x,y)	27.951	12.422	8.514	2	3.968
s(Aridity)	1.9	-	-	-	-
s(Ruggedness)	-	-	-	2.456	1
s(Elevation)	3.554	-	3.31	-	1.863

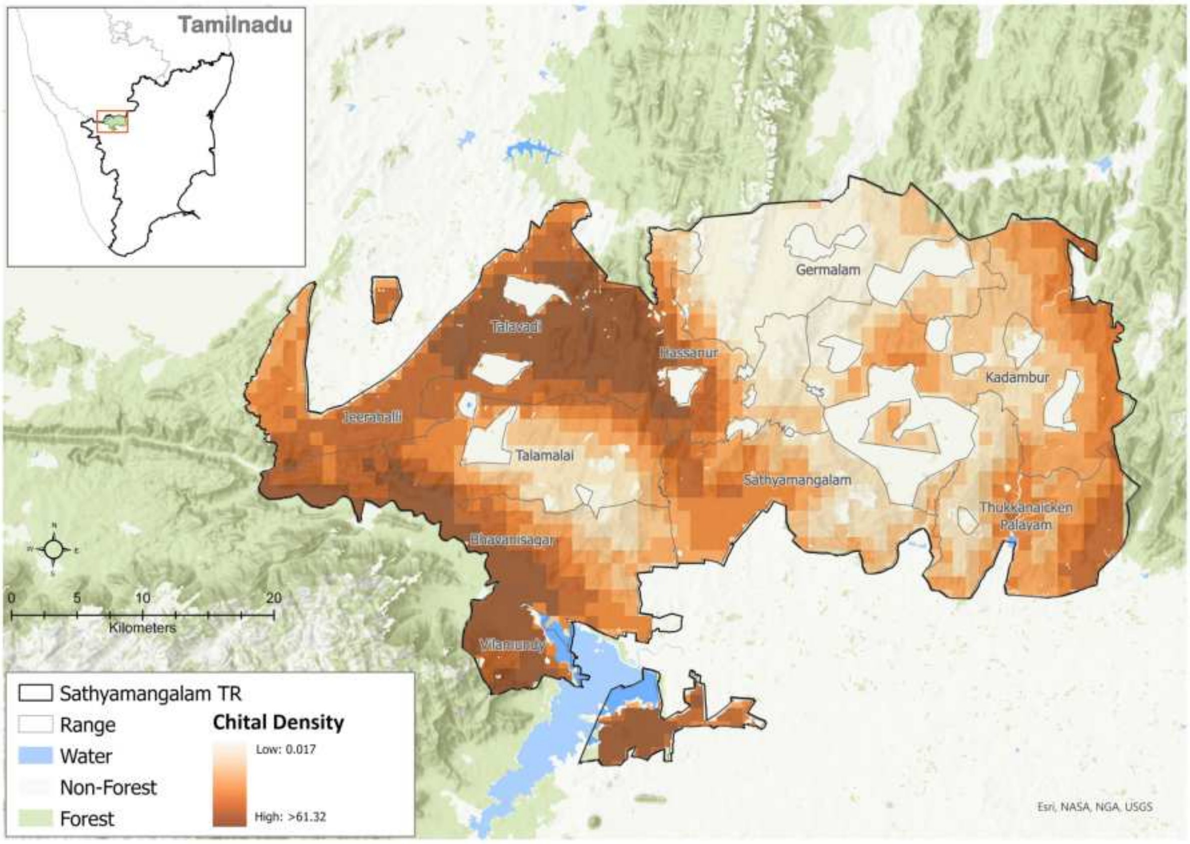

Figure V. 46: Density of chital (per km^2) in Sathyamangalam tiger reserve: Site-level DSM

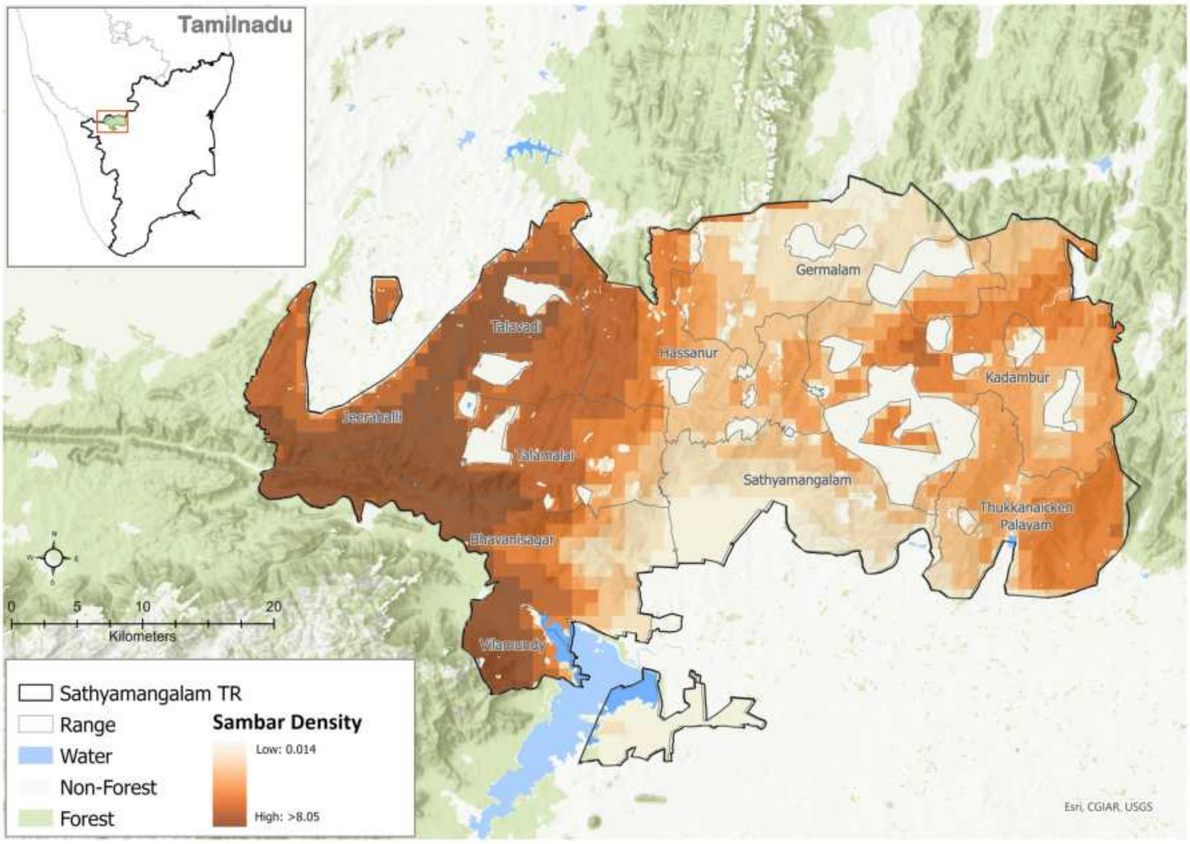

Figure V. 47: Density of sambar (per km²) in Sathyamangalam tiger reserve: Site-level DSM

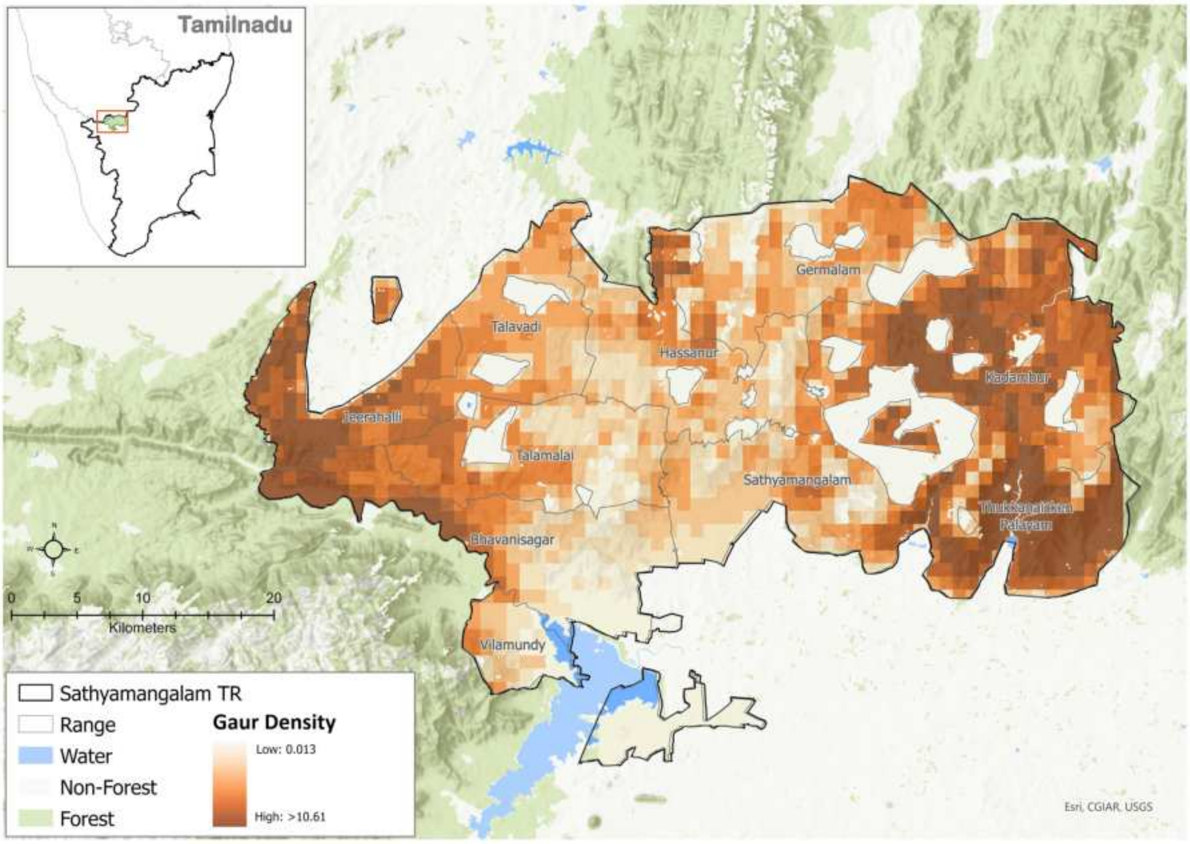

Figure V. 48: Density of gaur (per km²) in Sathyamangalam tiger reserve: Site-level DSM

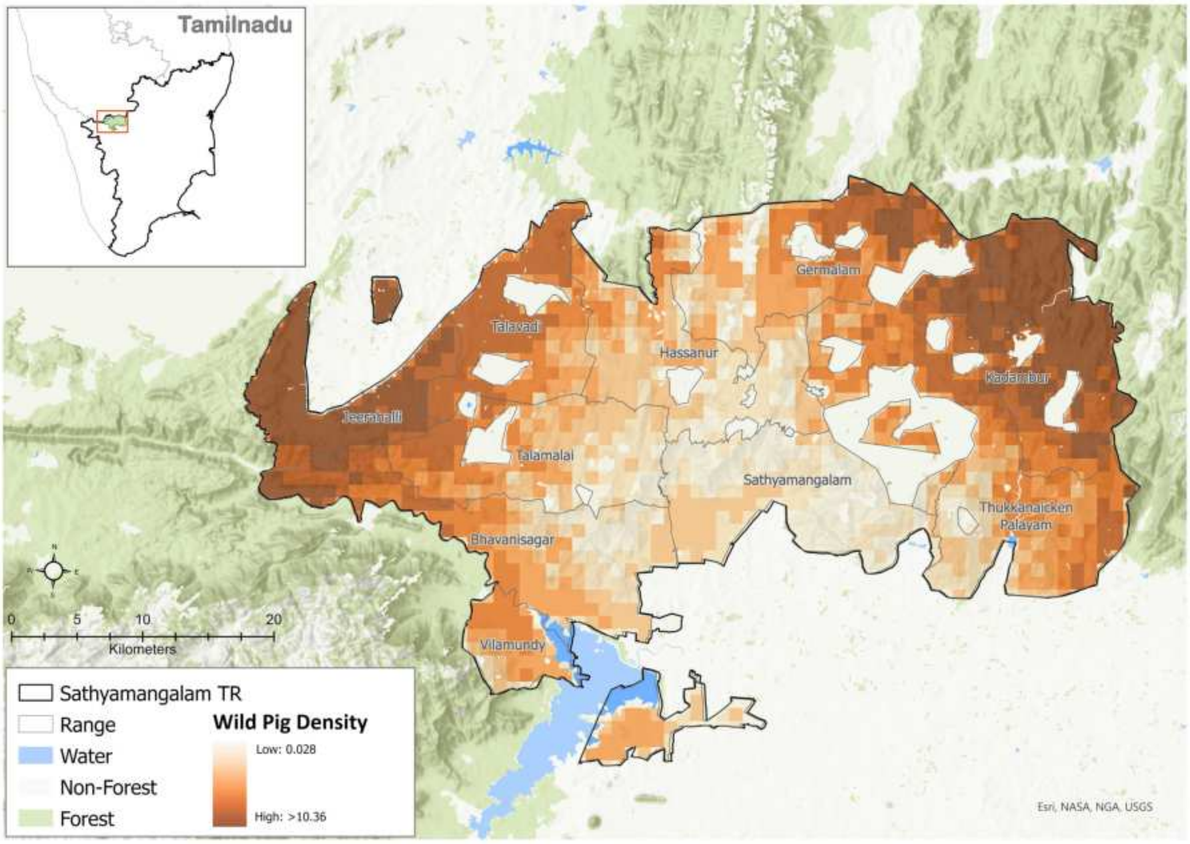

Figure V. 49: Density of wild pig (per km^2) in Sathyamangalam tiger reserve: Site-level DSM

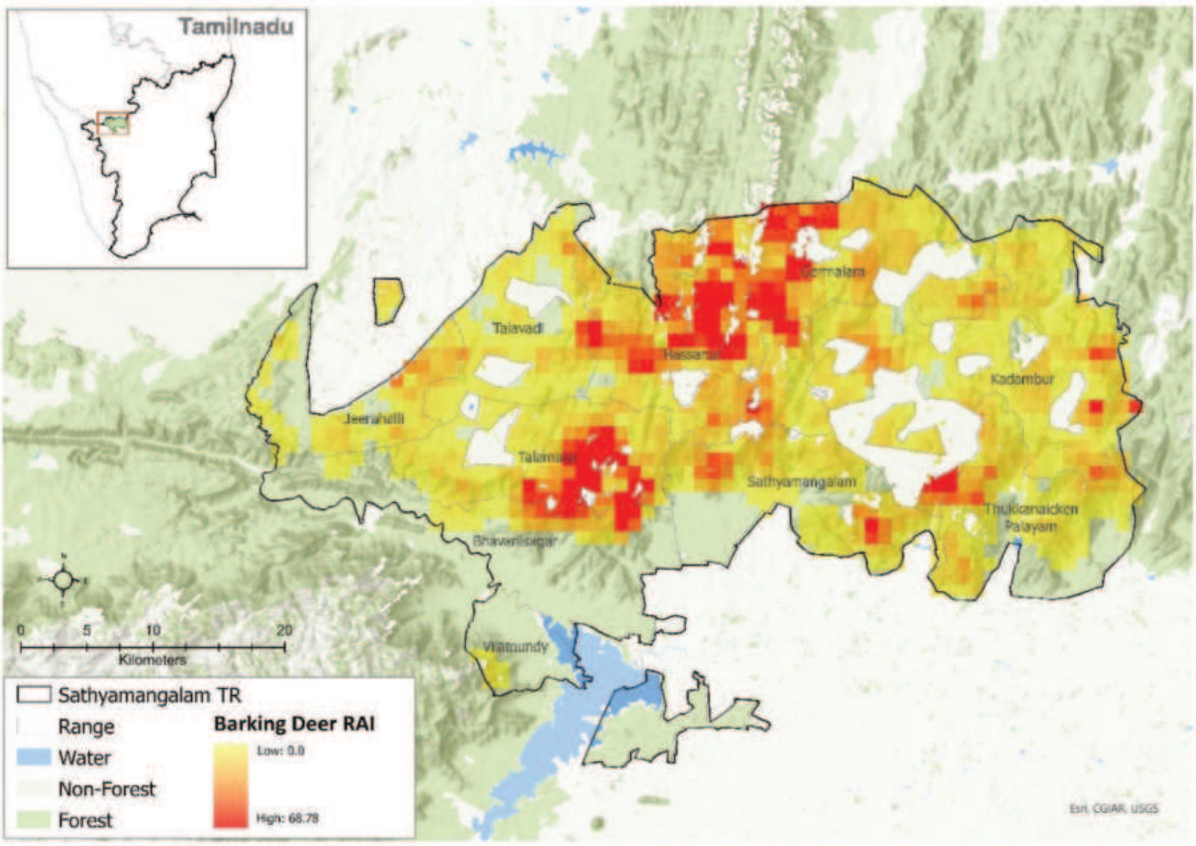

Figure V. 50: Spatial relative abundance of barking deer in Sathyamangalam tiger reserve.

Srivilliputhur-Meghamalai Tiger Reserve (SMTR)

Srivilliputhur Megamalai tiger reserve, located in the Virudhunagar and Theni districts of Tamil Nadu, spans approximately 1,016 km^2. The reserve's vegetation transitions from scrub forests at the foothills, dry and moist deciduous, semi-evergreen, riverine forest, and grassland to extensive tea and coffee estates, spice plantations (including pepper, cardamom, and cinnamon), and dense evergreen forests at higher elevations (Panner *et al.*, 2017). The Vaigai river originates in the Megamalai Hills and flows eastward through the reserve. The animal diversity includes tiger, leopard, elephant, gaur, nilgiri langur, nilgiri tahr, sambar, chital, barking deer, lion-tailed macaque, bonnet macaque as well as numerous birds, reptiles and amphibians. The reserve is contiguous with Periyar TR and Meghamalai WLS facilitating habitat connectivity and gene flow.

Gaur is found to be most abundant ungulate species of SMTR (Table V. 8). Gaur found in high densities in Gudalur, Megamalai, Srivilliputhur, and Watrap ranges (Figure V. 53). Chital density is higher towards eastern side of the tiger reserve, particularly Watrap, Srivilliputhur, and Rajapalayam ranges, while the western ranges like Gandamanur, Chinnamanur have low chital density (Figure V. 51). These areas need management input for habitat management for ungulate population increase. Spatial density of Sambar were high towards southern boundary of SMTR (Figure V. 52). Gudalur, Cumbum East, Megamalai, and Rajapalayam have higher sambar density than other areas.

For species with low number of observations in line transect, relative abundance index derived from camera trap data was used to supplement abundance information. Wild pig abundance is restricted to certain pockets of all ranges of the tiger reserve with highest abundance in Capture range (Figure V. 55). Barking deer abundance is in the ranges towards western boundary with highest abundance in Gandamanur (Figure V. 54).

Table V. 8: A) Parameter estimates and B) Model statistics of line transect based on distance sampling and DSM for ungulates in Srivilliputhur Megamalai tiger reserve.

A)

Species	Groups Detected	Encounter rate (SE)	Detection probability (SE)	Mean group size (SE)	Group density (SE)	Individual density (SE)
Chital	63	0.137 (0.018)	0.59 (0.06)	3.24 (0.27)	2.32 (0.37)	7.97 (0.95)
Gaur	136	0.274 (0.025)	0.38 (0.03)	2.19 (0.18)	5.7 (0.73)	11.67 (1.3)
Sambar	88	0.181 (0.02)	0.48 (0.07)	2.13 (0.2)	3.76 (0.69)	7.91 (1.42)

B)

Species	Chital	Sambar	Gaur
Detection model	Hazard rate (Null)	Hazard rate (Null)	Half-normal (Null)
s(x,y)	8.428	21.497	4.395
s(NDVI Pre-Monsoon)	1.931	2.84	-

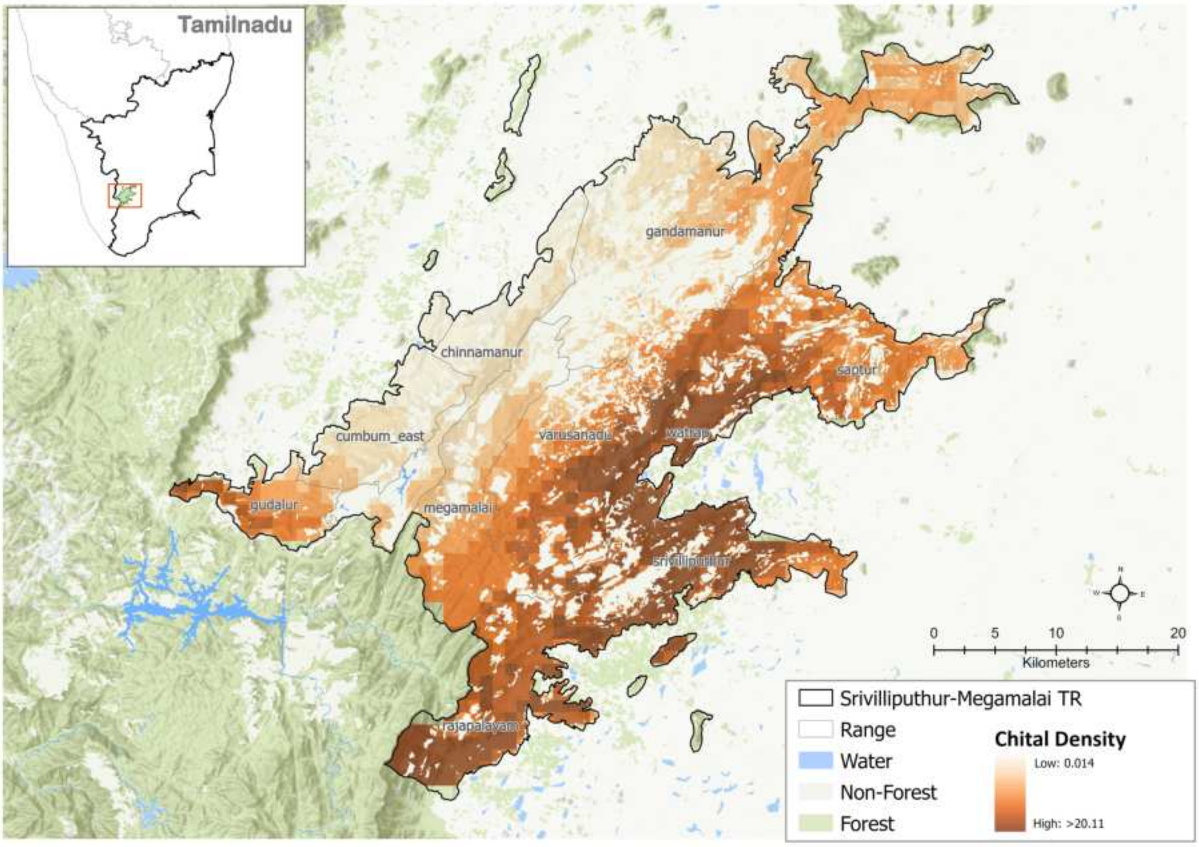

Figure V. 51: Density of chital (per km²) in SMTR: Site-level DSM

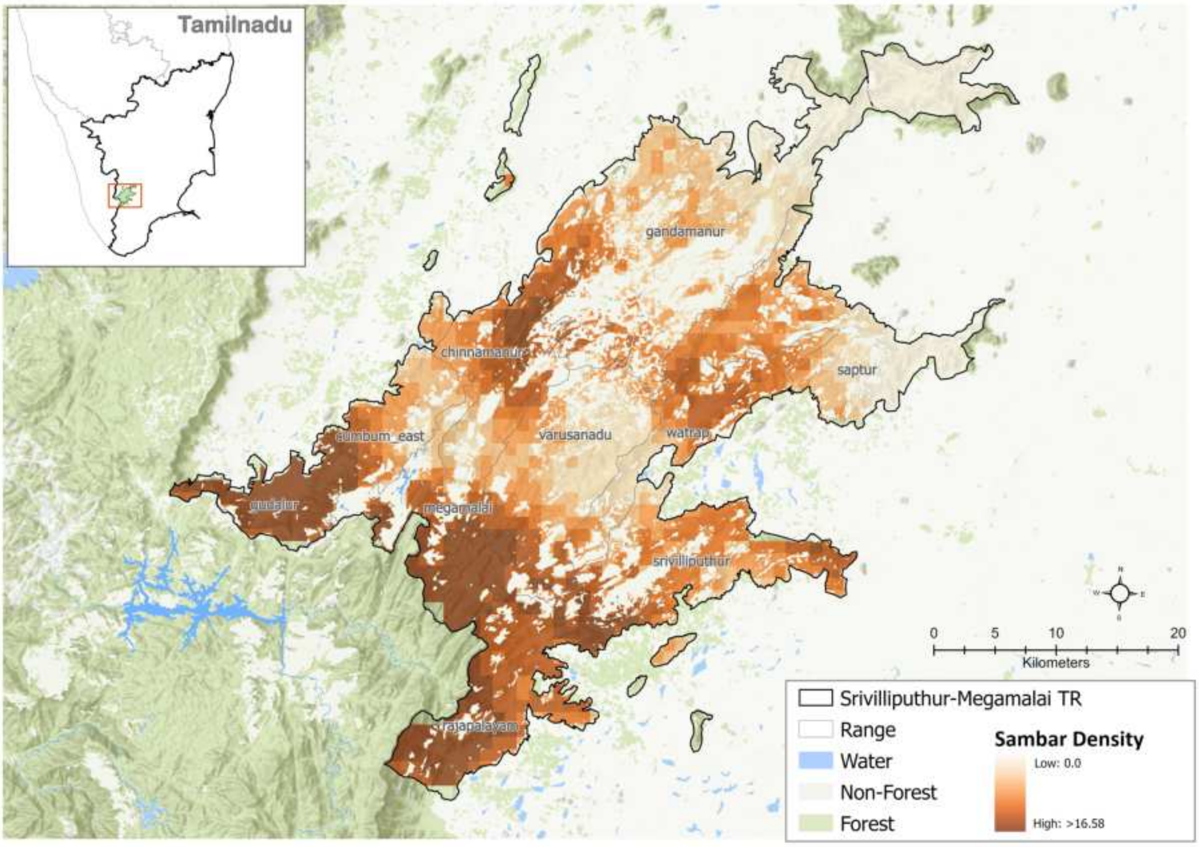

Figure V. 52: Density of sambar (per km²) in SMTR: Site-level DSM

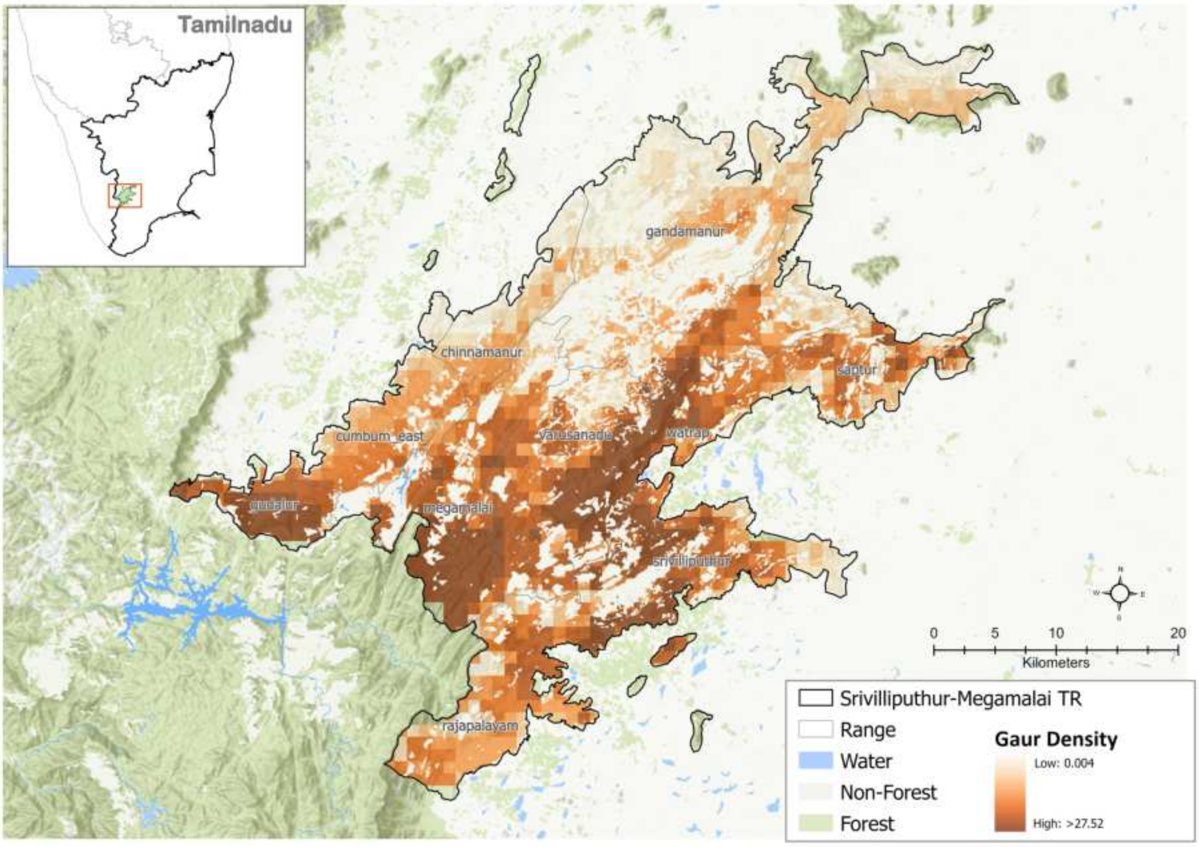

Figure V. 53: Density of gaur (per km^2) in SMTR: Site-level DSM

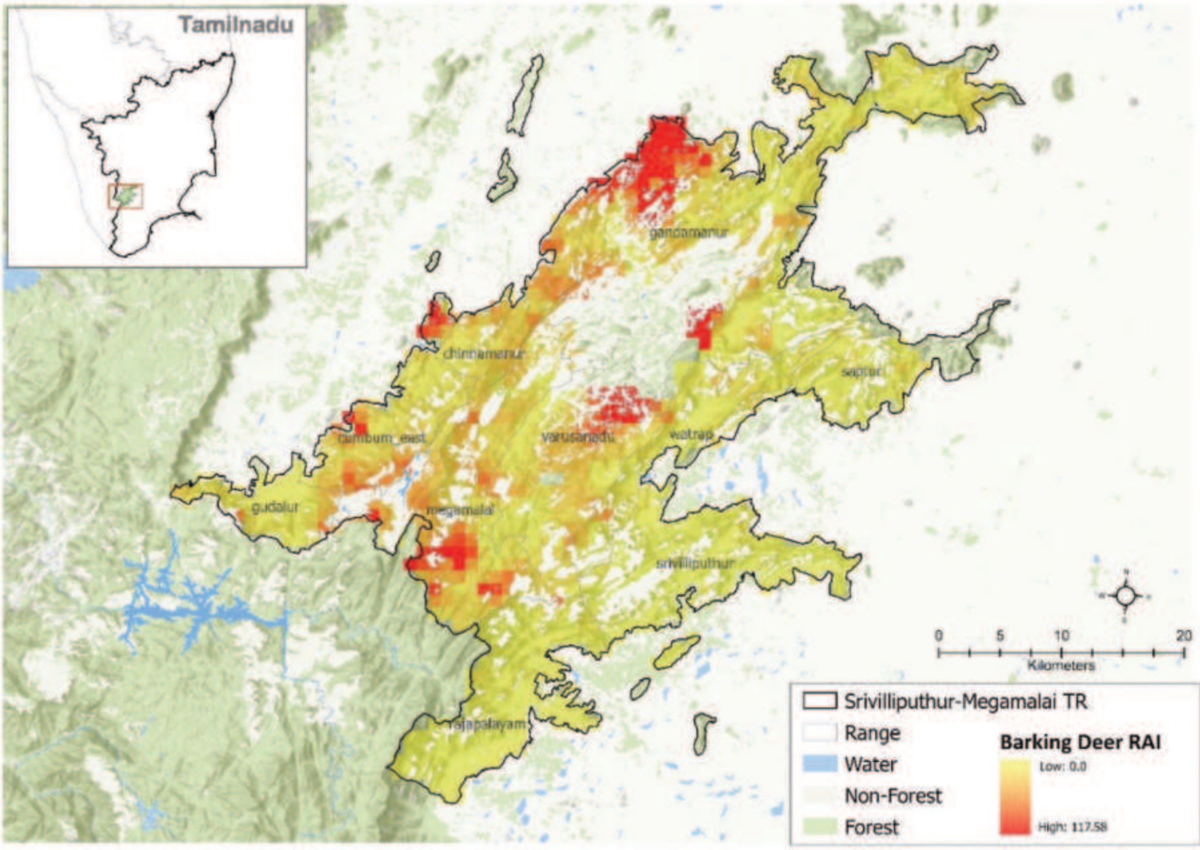

Figure V. 54: Spatial relative abundance of barking deer in SMTR.

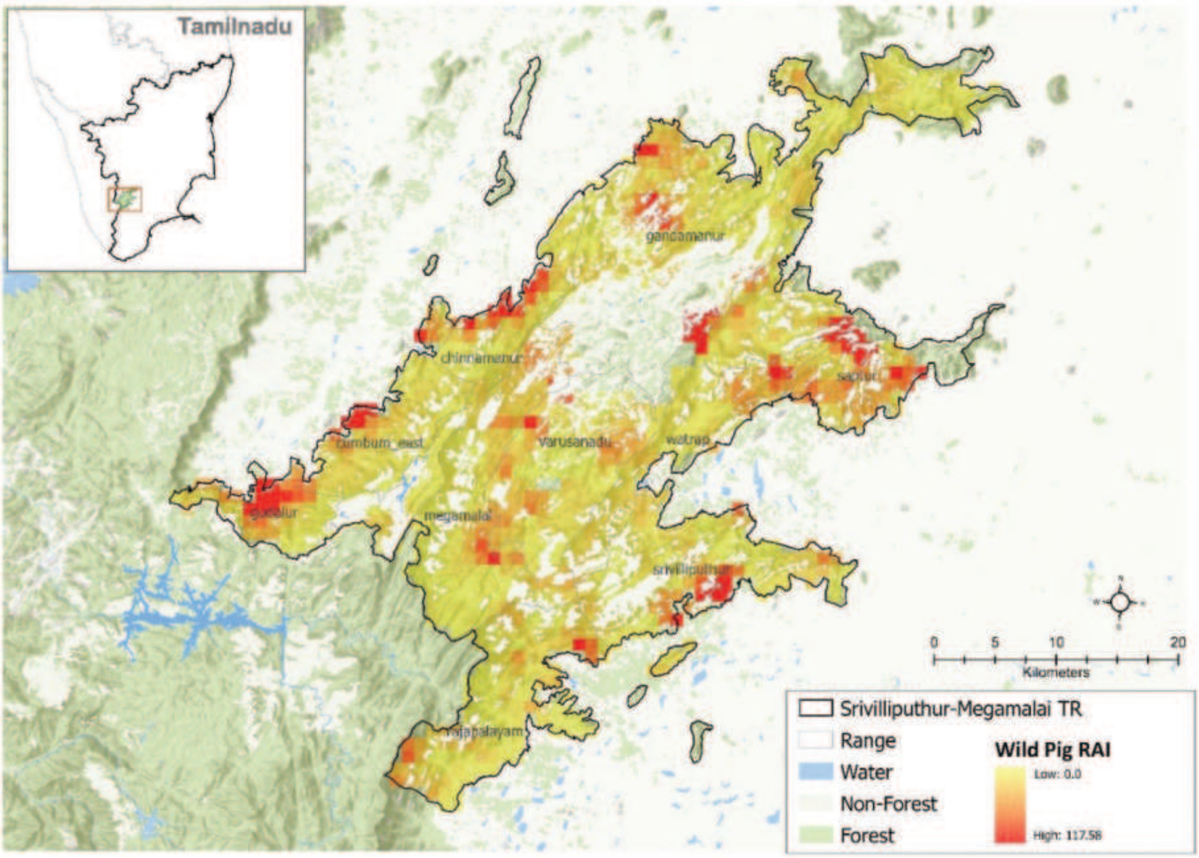

Figure V. 55: Spatial relative abundance of wild pig in SMTR.

KERALA

Parambikulam Tiger Reserve

Parambikulam tiger reserve, situated in the Palakkad district of Kerala, encompasses approximately 643 km^2. The predominant vegetation is a mosaic of west coast tropical evergreen forests, west coast tropical semi evergreen forests, southern moist mixed deciduous forests, southern dry mixed deciduous forests, teak plantation and shola-grassland ecosystems (Sreehari and Nameer, 2016). The reserve is home to a wide variety of species like tiger, leopard, elephant, gaur, sloth bears, dhole, and numerous ungulate species along with a rich avian diversity and rare species such as the Nilgiri langur and lion-tailed macaque. The reserve has interconnected streams and reservoirs, including the Parambikulam reservoir that sustain both terrestrial and aquatic biodiversity.

Observation of ungulates in line transect is not sufficient for spatial density analysis hence, chital and sambar density are predicted using landscape model, and relative abundance of gaur, barking deer, and wild pig are calculated using camera trap photo capture data. The encounter rate for chital is 0.0174 (±0.0128) and for sambar is 0.1104 (±0.0336). Landscape model predict low chital density in parambikulam. Within the reserve the area near parambikulum reservoir havs highest density of chital (Figure V. 56). Sambar is well distributed in parambikulam. It is found in all ranges of the tiger reserve with highest density predicted from Karimala range (Figure V. 57). Nelliyampathy range least sambar density.

Gaur is present in all ranges but abundance is highest in Sungam gange followed by Parambikulam range (Figure V. 59). Barking deer is present in all ranges but abundant towards boundar areas of Vazachal, Sholayar, Orukomban and Nelliyampathy ranges (Figure V. 58). Wild pig is more abundant in Orukamban and Karimala ranges (Figure V. 60).

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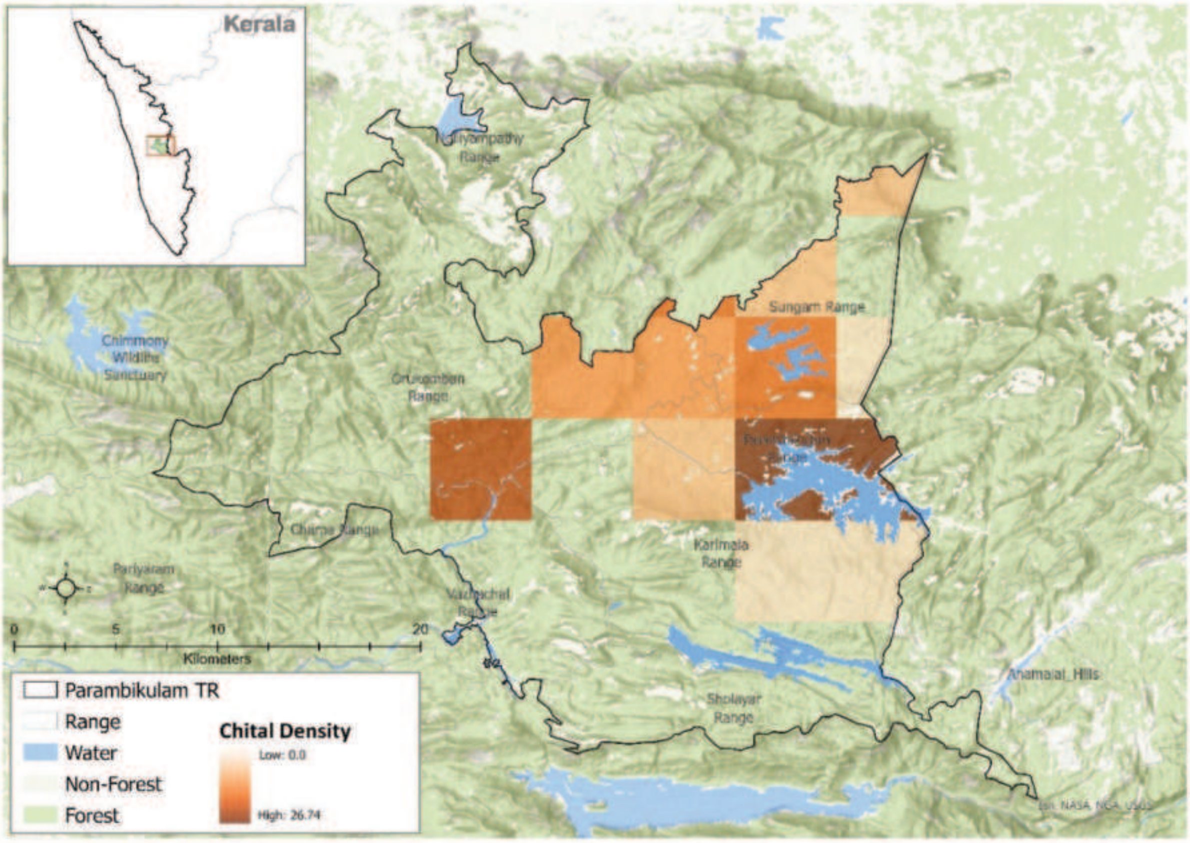

Figure V. 56: Density of chital (per 25 km²) in Parambikulam tiger reserve: Landscape-level DSM

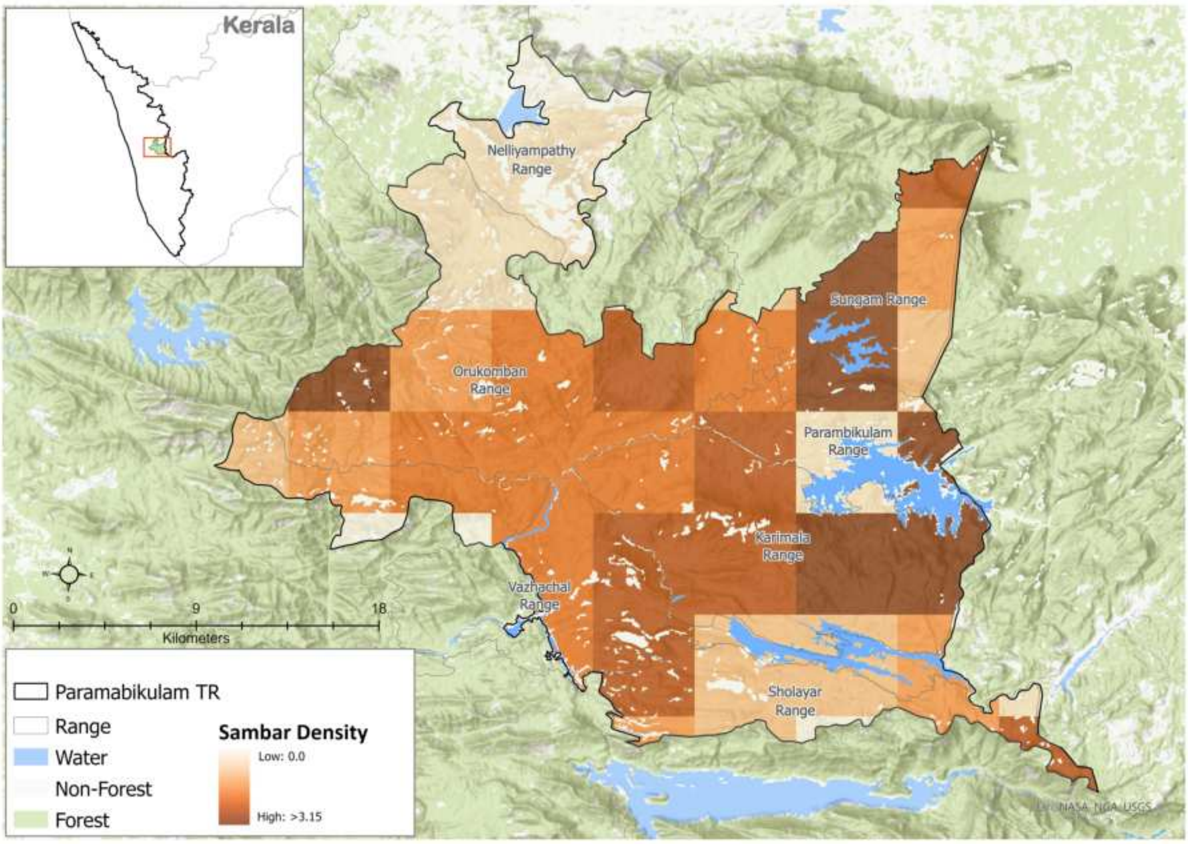

Figure V. 57: Density of sambar (per 25 km²) in Parambikulam tiger reserve: Landscape-level DSM

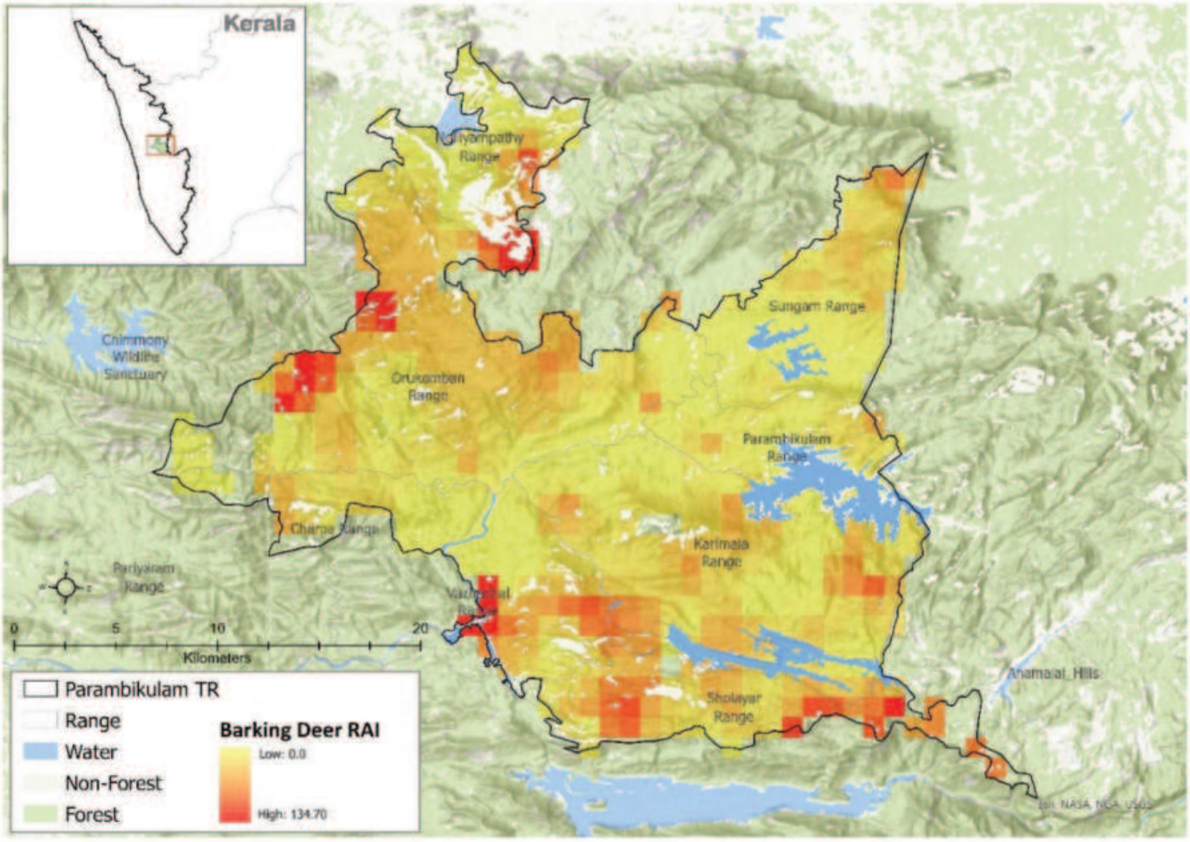

Figure V. 58: Spatial relative abundance of barking deer in Parambikulam tiger reserve.

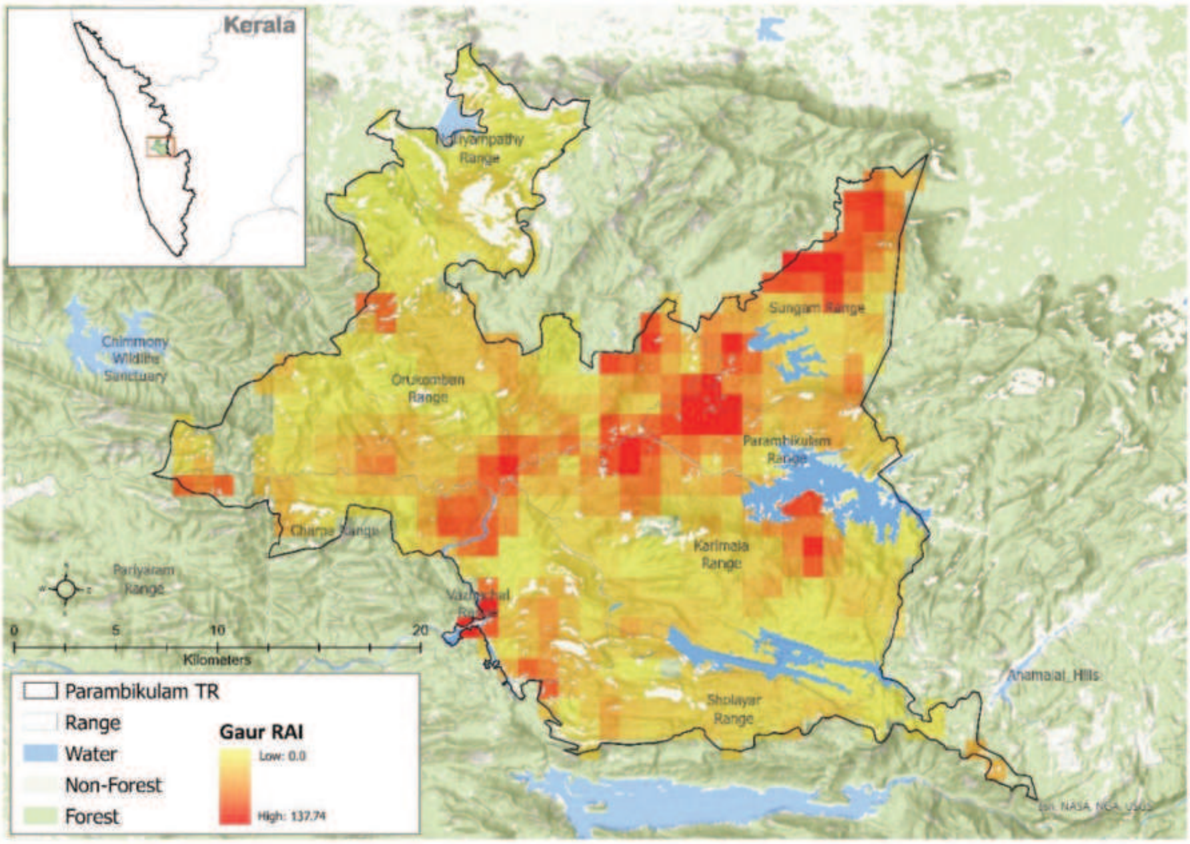

Figure V. 59: Spatial relative abundance of gaur in Parambikulam tiger reserve.

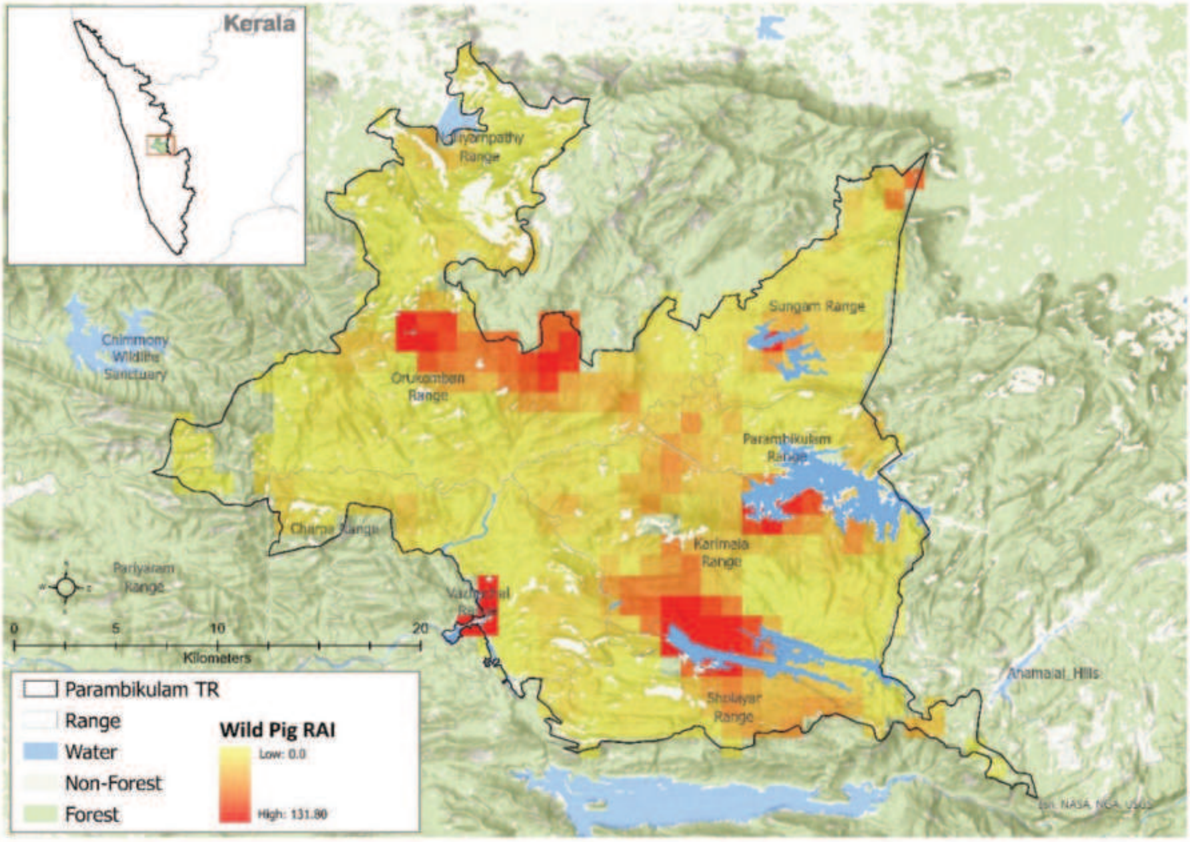

Figure V. 60: Spatial relative abundance of wild pig in Parambikulam tiger reserve.

Periyar Tiger Reserve

Periyar tiger reserve, located in the Idukki, Kottayam, and Pathanamthitta districts of Kerala, spans approximately 925 km². The reserve features a diverse mosaic of ecosystems, including tropical evergreen, tropical semi-evergreen, and moist deciduous forests, grasslands, aquatic habitats, and eucalyptus groves (Gubbi, 2006). The Periyar Lake, a manmade reservoir built in 1895, forms 3.5% of the tiger reserve. It is home to a wide array of wildlife, including tigers, elephants, leopards, dhole, sloth bears, stripe-necked mongooses, gaurs, Nilgiri martens, Nilgiri tahrs, Nilgiri langurs, lion-tailed macaques, Malabar giant squirrels, as well as numerous amphibians and reptiles. Periyar is rich in endemism with three unique species of flora and seven species of fish. Periyar TR forms part of a contiguous and compact forest block of 3,000 km^2 in the southern Western Ghats (Sanderson *et al*., 2006).

Due to low observation rates in line transects, the density of sambars in Periyar was predicted using a landscape model. The encounter rate for sambar is 0.0826 (±0.0466). The relative abundance of gaurs, barking deer, and wild pigs was mapped using photo-capture data from camera traps. Though chital presence is very rare in Periyar, yet landscape model pricts presence in adjoining grids to SMTR and other forest divisions (Figure V.61). The landscape model predicts the presence of sambars across all ranges of the reserve, with the highest densities observed in Thekkady, followed by the Periyar range (Figure V. 62). The relative abundance of gaurs is also highest in Thekkady, followed by Vallakadavu (Figure V. 64). Barking deer abundance is patchy, with Vallakadavu exhibiting the highest abundance (Figure V. 63). Wild pig abundance is greatest in the Pamba range (Figure V. 65).

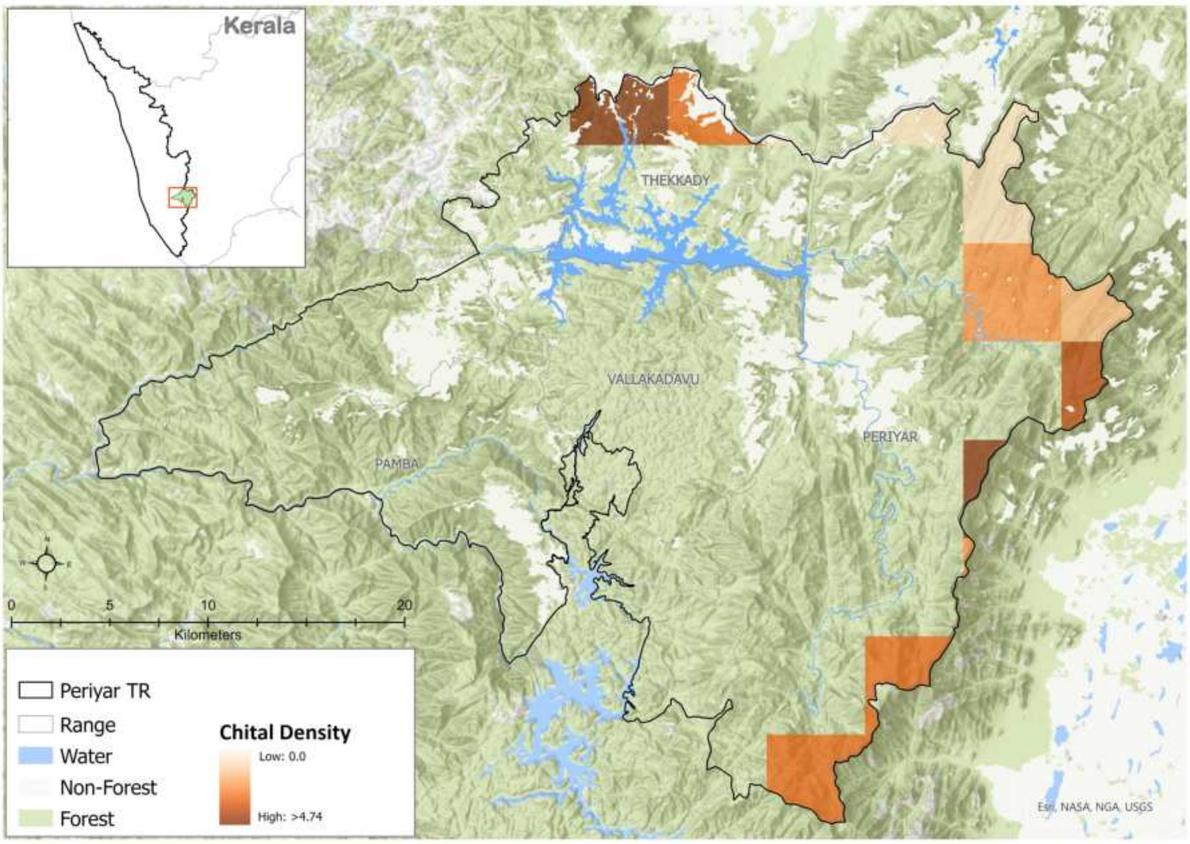

Figure V. 61: Density of chital (per 25 km^2) in Periyar tiger reserve: Landscape-level DSM

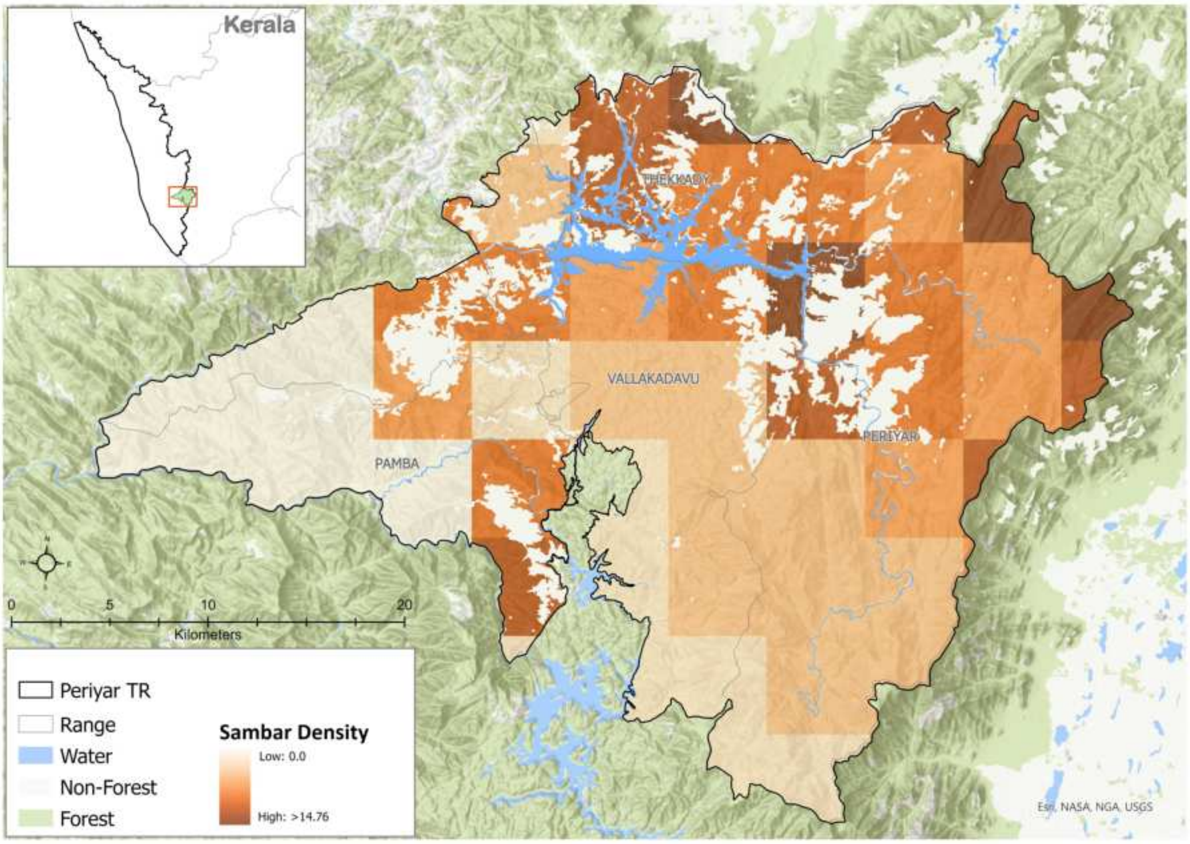

Figure V. 62: Density of sambar (per 25 km^2) in Periyar tiger reserve: Landscape-level DSM

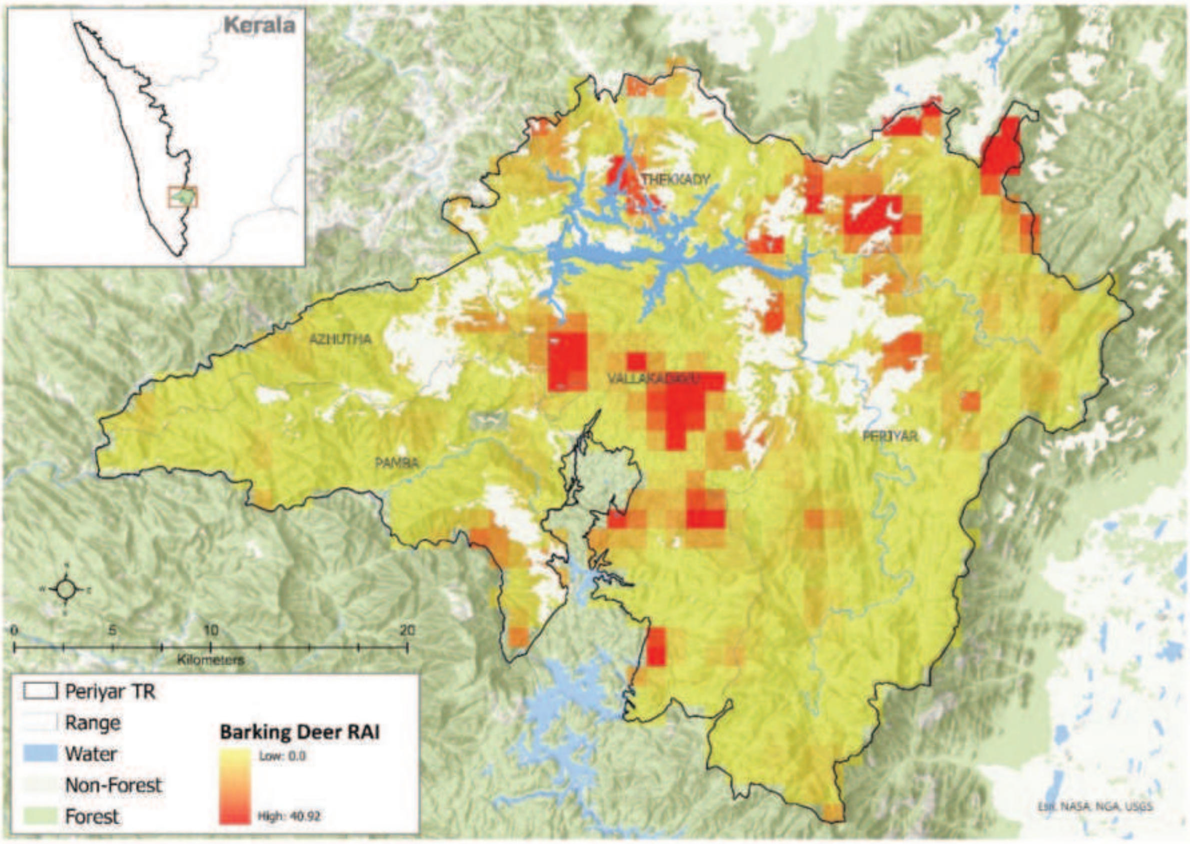

Figure V. 63: Spatial relative abundance of barking deer in Periyar tiger reserve.

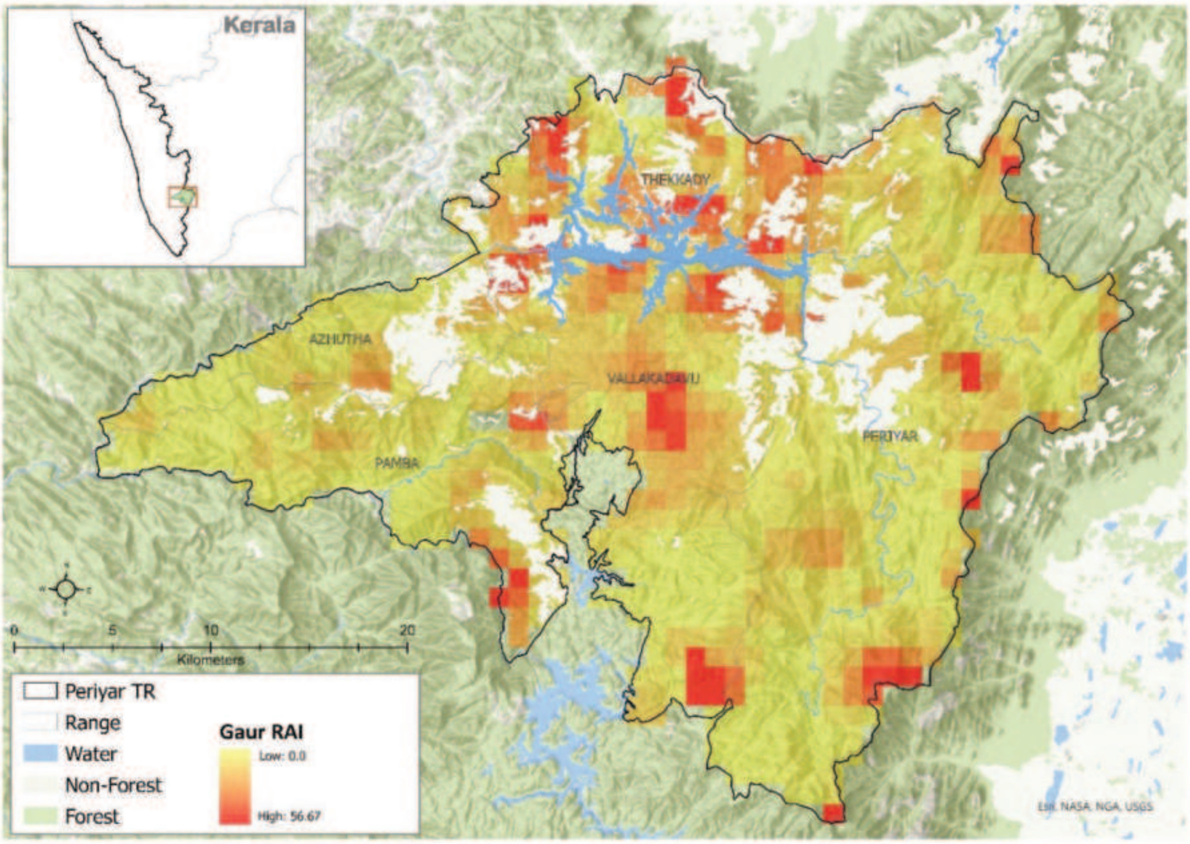

Figure V. 64: Spatial relative abundance of gaur in Periyar tiger reserve.

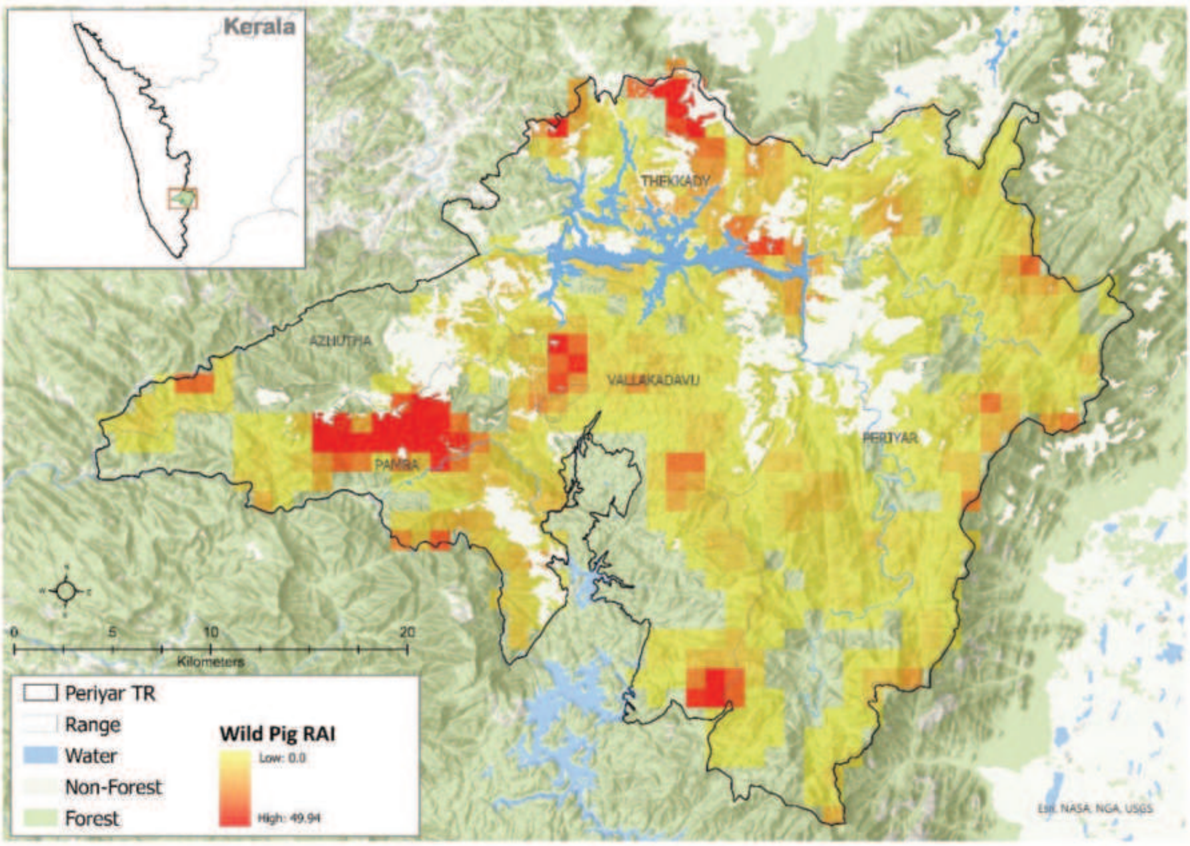

Figure V. 65: Spatial relative abundance of wild pig in Periyar tiger reserve.

SECTION VI

North East Hills and Brahmaputra Flood Plains Landscape

Ujjwal Kumar, Shravana Goswami, Vaishnavi Gusain, Omkar Nar, Deb Ranjan Laha, Rajendra Garawad, Vaibhav C. Mathur, Vishnupriya Kolipakam, Yadvendradev Jhala, Qamar Qureshi

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The North East Hills and Brahmaputra Flood Plains landscape encompasses the northeastern states of Arunachal Pradesh, Assam, Manipur, Mizoram, Nagaland, Sikkim, Tripura, and the hilly districts of northern West Bengal. Located at the intersection of three biogeographic realms *i.e.* Indian, Indo-Malayan, and Indo-Chinese. The region harbours a unique biodiversity assemblage and a high degree of endemism. The varied habitats support tropical, temperate, and alpine ecosystems, in snow-capped mountains, plateaus, foothills, and expansive alluvial floodplains, making it one of India's most biodiverse landscapes. The landscape is traversed by major river systems such as the Brahmaputra, Barak, and Teesta, along with their numerous tributaries. The geographic complexity and elevation variations significantly influence the region's climate, creating stark contrasts between the warm, tropical valleys and the cooler, mountainous areas. Annual rainfall across the region exceeds 1,000 mm, with eastern areas receiving heavier precipitation due to the southwest monsoon. The forest types include tropical evergreen, semi-evergreen, moist deciduous, and dry deciduous forests in the lower altitudes, transitioning to temperate forests and alpine meadows at higher elevations. Though historical land-use changes, including the expansion of tea plantations and cultivation, have led to extensive deforestation, the region retains some of the country's richest floral diversity.

Flora

The North East Hills and Brahmaputra Flood Plains landscape is home to approximately 7,500 species of angiosperms, 700 orchids, 63 bamboo species, 28 conifers, 728 lichens, and numerous ferns and palms. The tropical forests dominate the Assam valley, Himalayan foothills, and parts of the Naga and Manipur hills, with key species such as *Dipterocarpus turbinatus, Artocarpus chaplasha,* and *Terminalia chebula*.

Deciduous forests, dominated by *Shorea robusta*, are prevalent in areas with less rainfall, such as the districts of Goalpara and Kamrup. Temperate vegetation thrives between 1,300 and 2,500 meters in regions like the Shillong Plateau and Arunachal Pradesh, featuring associations of *Quercus, Rhododendron*, and *Magnolia*. Above 4,500 meters, alpine vegetation and *Rhododendron* meadows dominate. The region's grasslands, particularly in riparian belts, are characterized by species such as *Saccharum* and *Phragmites communis*.

Fauna

The North East Hills and Brahmaputra Flood Plains are rich in fauna, especially ungulates, due to diverse topography and habitats. Iconic species include the one-horned rhinoceros (*Rhinoceros unicornis*) in grasslands and Asian elephants (*Elephas maximus*). The floodplains host barasingha (*Rucervus duvaucelii*), hog deer (*Axis porcinus*), and wild water buffalo (*Bubalus arnee*), while forested hills are home to barking deer (*Muntiacus muntjak*), sambar (*Rusa unicolor*), and gaur (*Bos gaurus*). High-altitude areas feature Himalayan goral (*Naemorhedus goral*), serow (*Capricornis thar*), takin (*Budorcas taxicolor*), and blue sheep (*Pseudois nayaur*). The critically endangered pygmy hog (*Porcula salvania*) also inhabits dense grasslands. These ungulates are crucial for ecosystem balance, serving as prey for predators like tigers (*Panthera tigris*) and clouded leopards (*Neofelis nebulosa*).

Ungulate Distribution and Abundance in the landscape

This landscape boasts a diverse array of habitats, supporting diverse ungulate assemblage. Compared to other landscapes, chital is least prevalent here, found only as far as West Bengal (sunderbans and buxa) and with a very small population in Manas tiger reserve (Figure VI. 1). Sambar deer, however, has a relatively larger distribution and abundance, with small populations present in Dampa (Figure VI. 2).

Barking deer are widespread across this landscape, from Mananda Wildlife Sanctuary (WLS) to Dibang WLS in the east and Mizoram in the south (Figure VI. 3). Hog deer are also confined to the northern part of this landscape, favouring flat areas, grasslands, and alluvial floodplains. Kaziranga and Orang boast the highest abundance of hog deer in this landscape (Figure VI. 4). Gaur is restricted to the northern part of this landscape, with their population decreasing from west to east (Figure VI. 5). They have relatively higher populations in Buxa and Manas. The one-horned rhinoceros and wild buffalo are the two megaherbivores predominantly found in Kaziranga and Manas tiger reserves, with relatively higher abundance in Kaziranga (Figure VI. 6 & Figure VI. 7). Barasingha (swamp deer) are also present in Kaziranga and Manas, but with very small populations. The wild pig population is notably high in Kaziranga and the Sundarbans, compared to other areas of the landscape (Figure VI. 8).

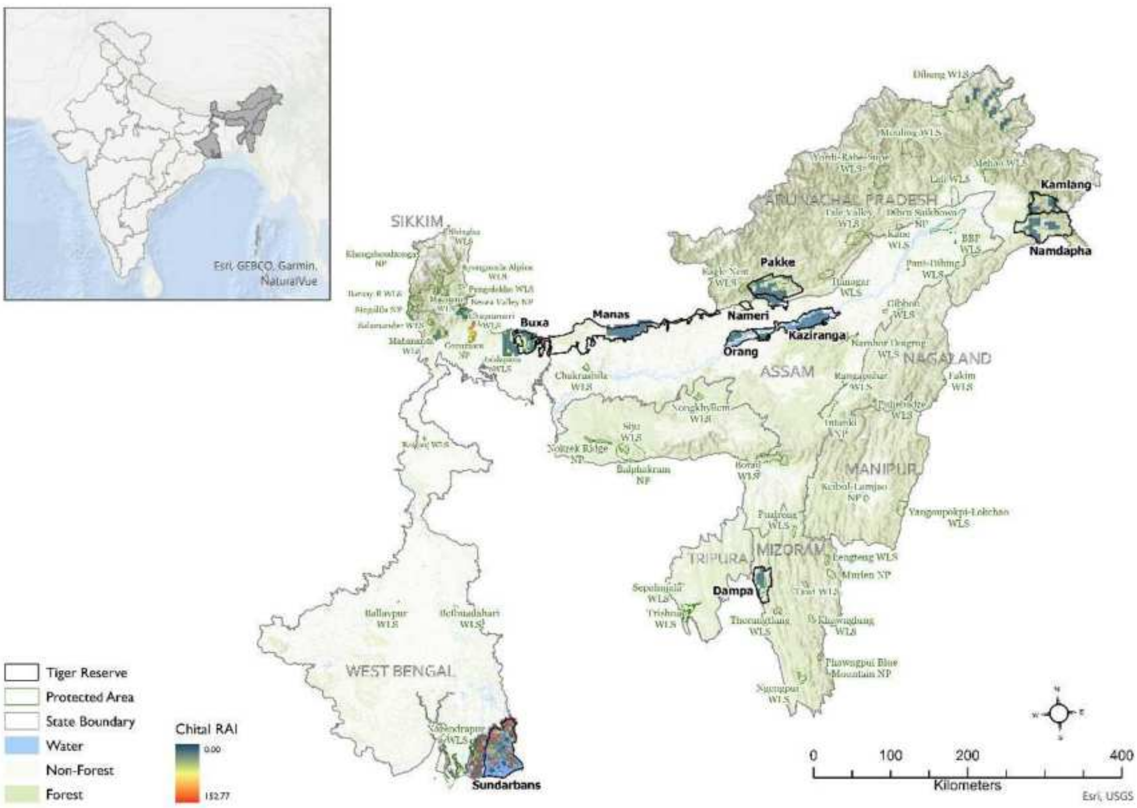

Figure VI. 1: Spatial relative abundance of chital (per 25 km²) in North East hills and Brahmaputra flood plains landscape.

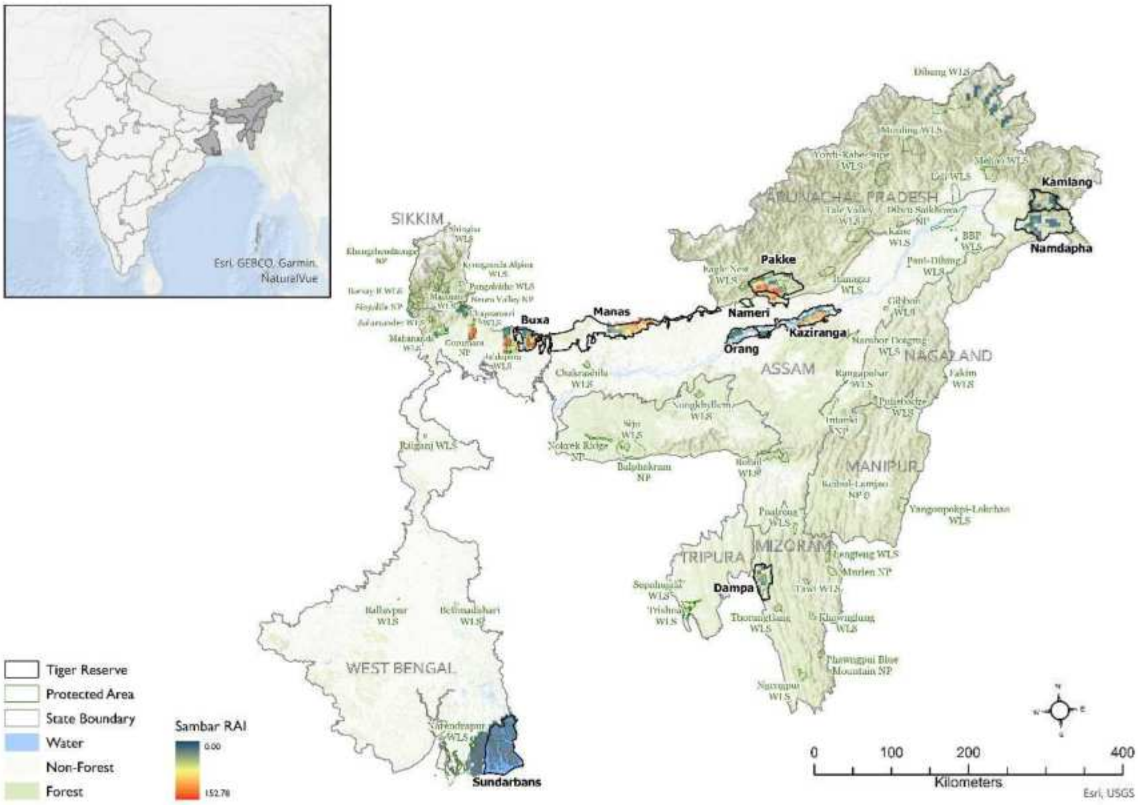

Figure VI. 2: Spatial relative abundance of sambar (per 25 km^2) in North East hills and Brahmaputra flood plains landscape.

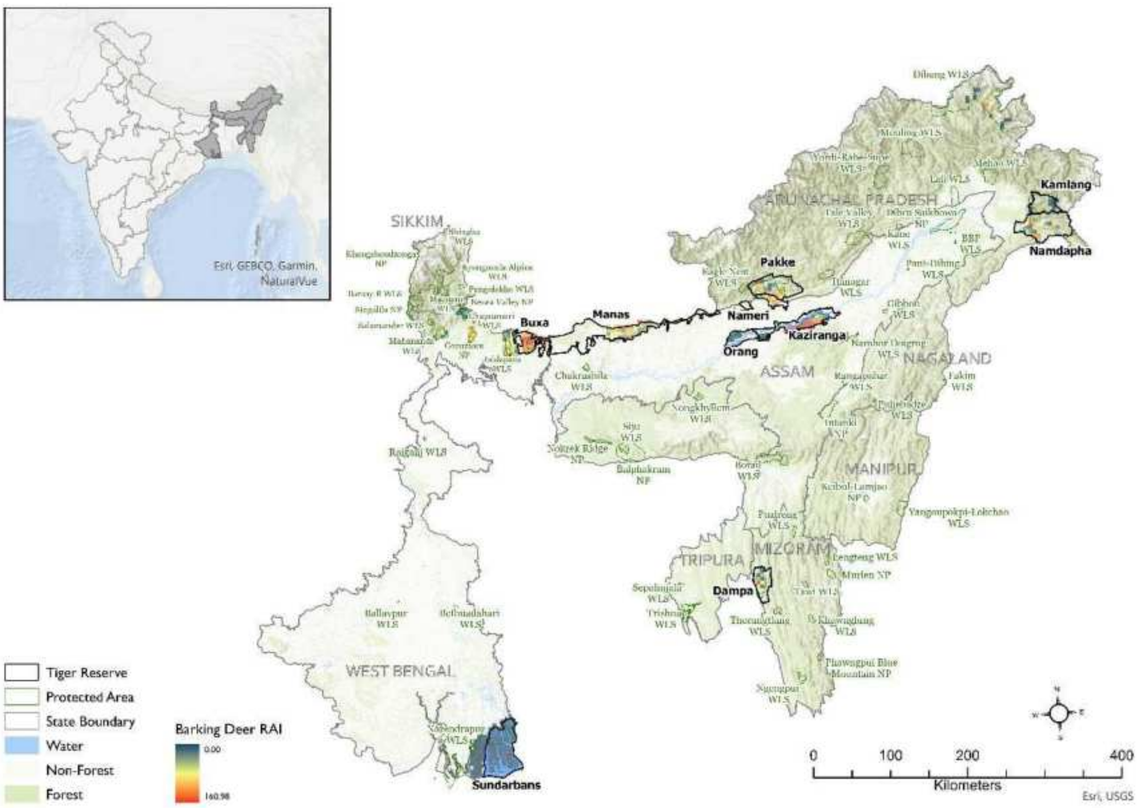

Figure VI. 3: Spatial relative abundance of barking deer (per 25 km^2) in North East hills and Brahmaputra flood plains landscape.

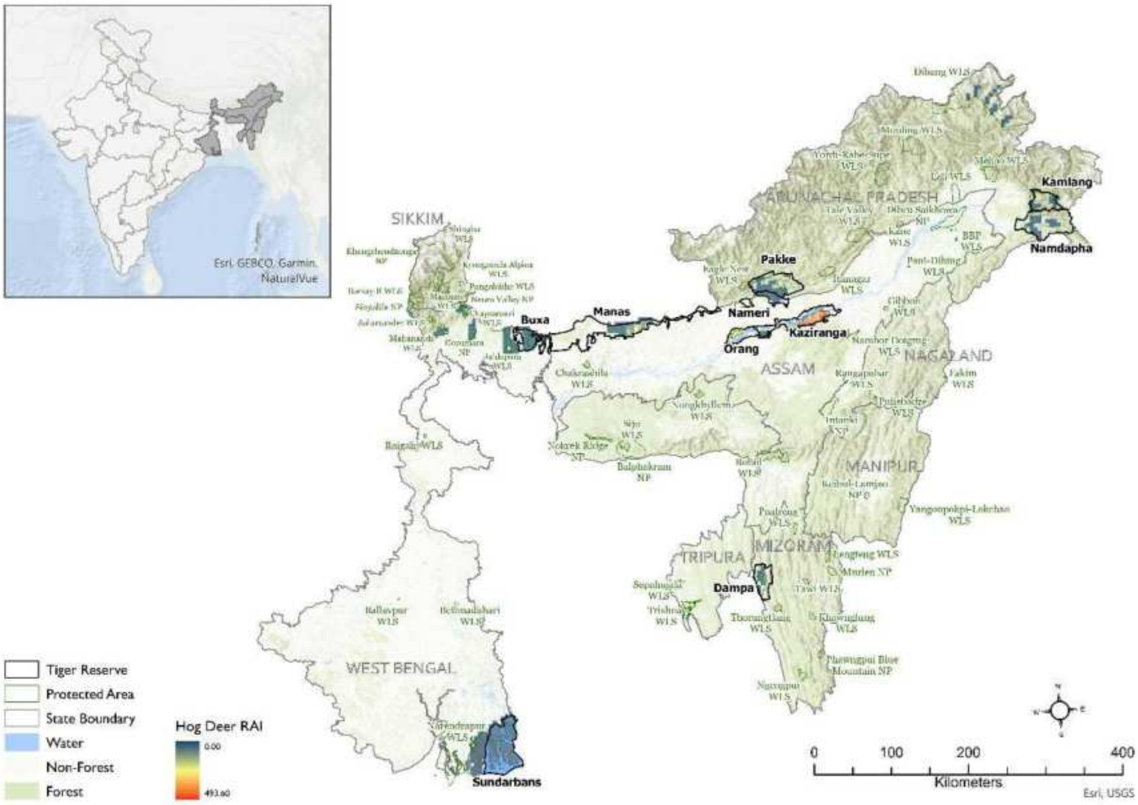

Figure VI. 4: Spatial relative abundance of hog deer (per 25 km²) in North East hills and Brahmaputra flood plains landscape.

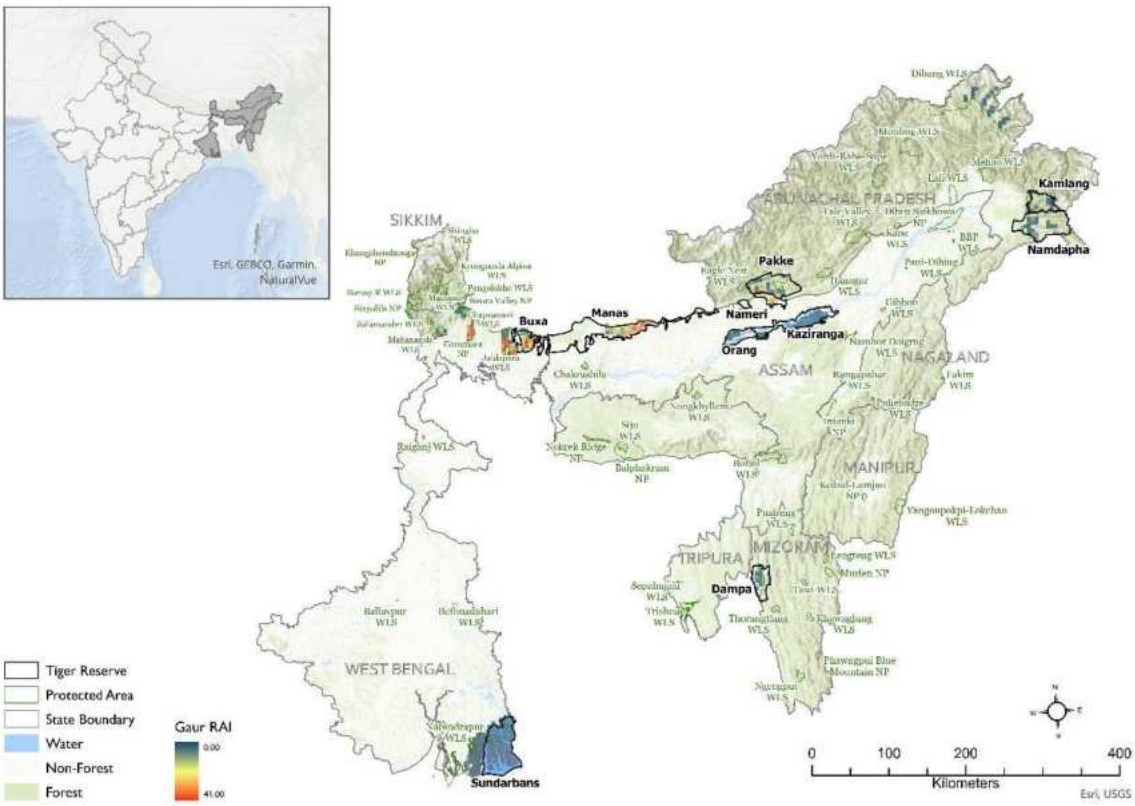

Figure VI. 5: Spatial relative abundance of gaur (per 25 km²) in North East hills and Brahmaputra flood plains landscape.

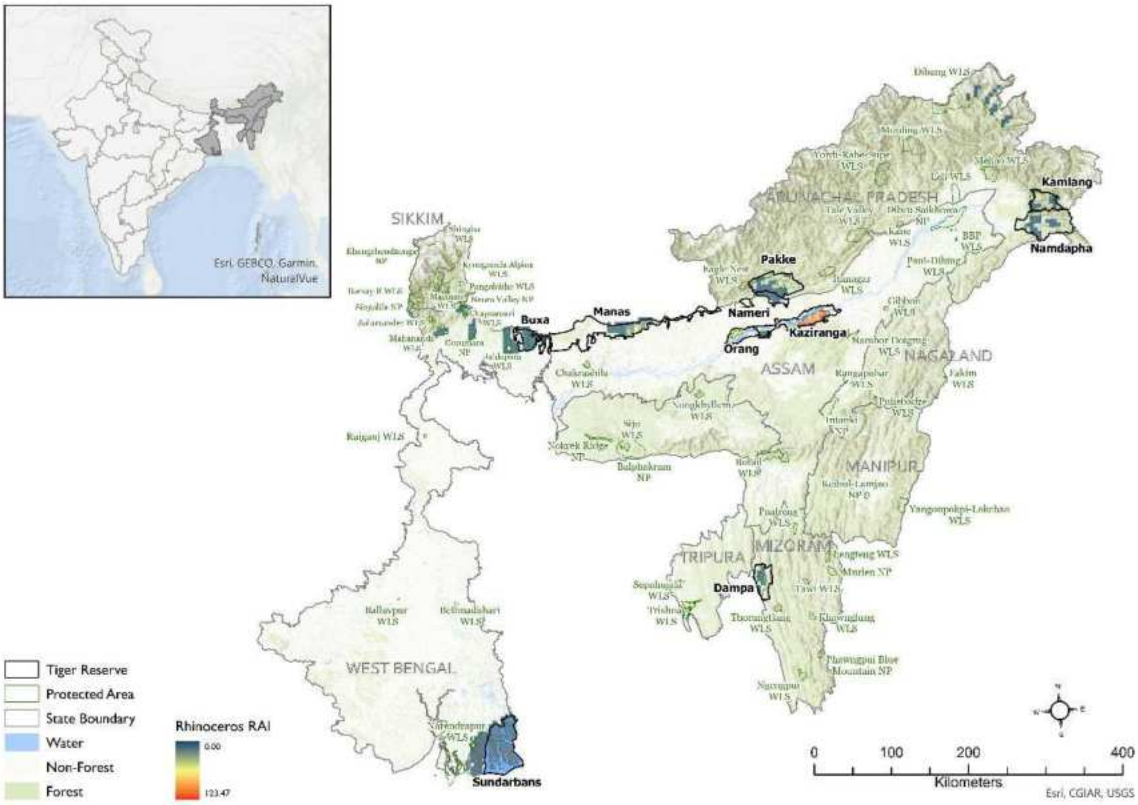

Figure VI. 6: Spatial relative abundance of rhinoceros (per 25 km^2) in North East hills and Brahmaputra flood plains landscape.

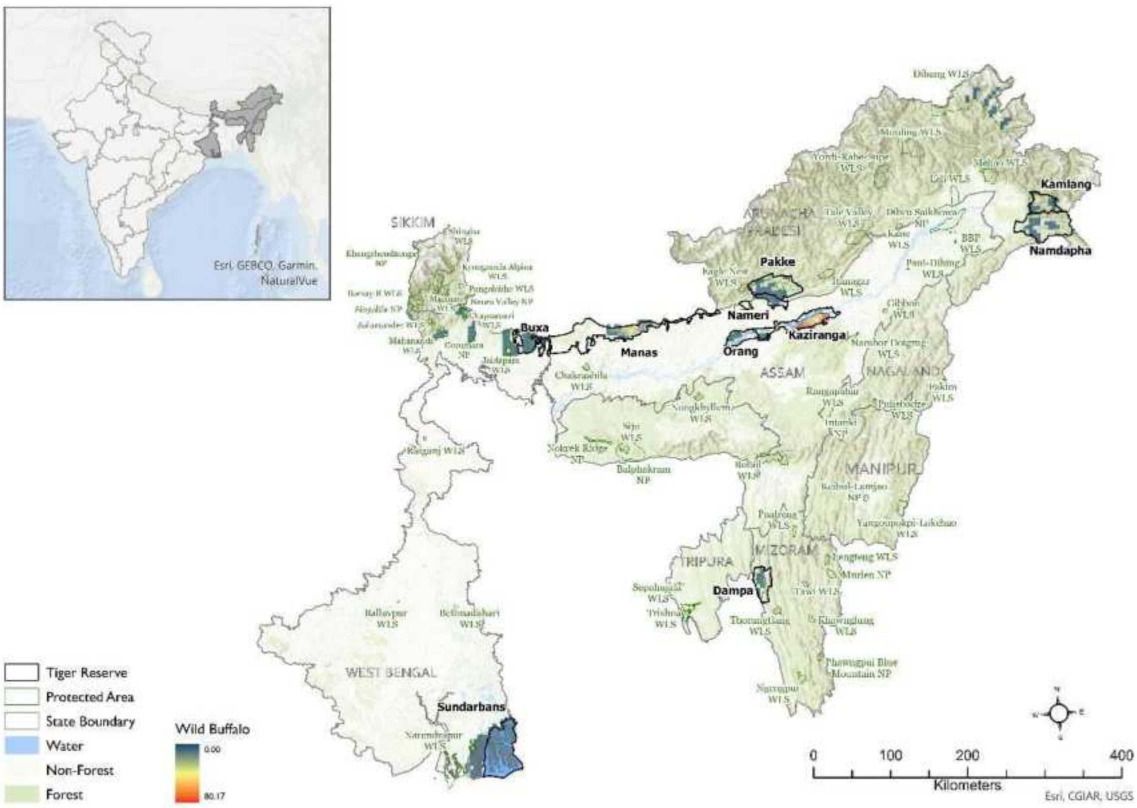

Figure VI. 7: Spatial relative abundance of wild buffalo (per 25 km^2) in North East hills and Brahmaputra flood plains landscape.

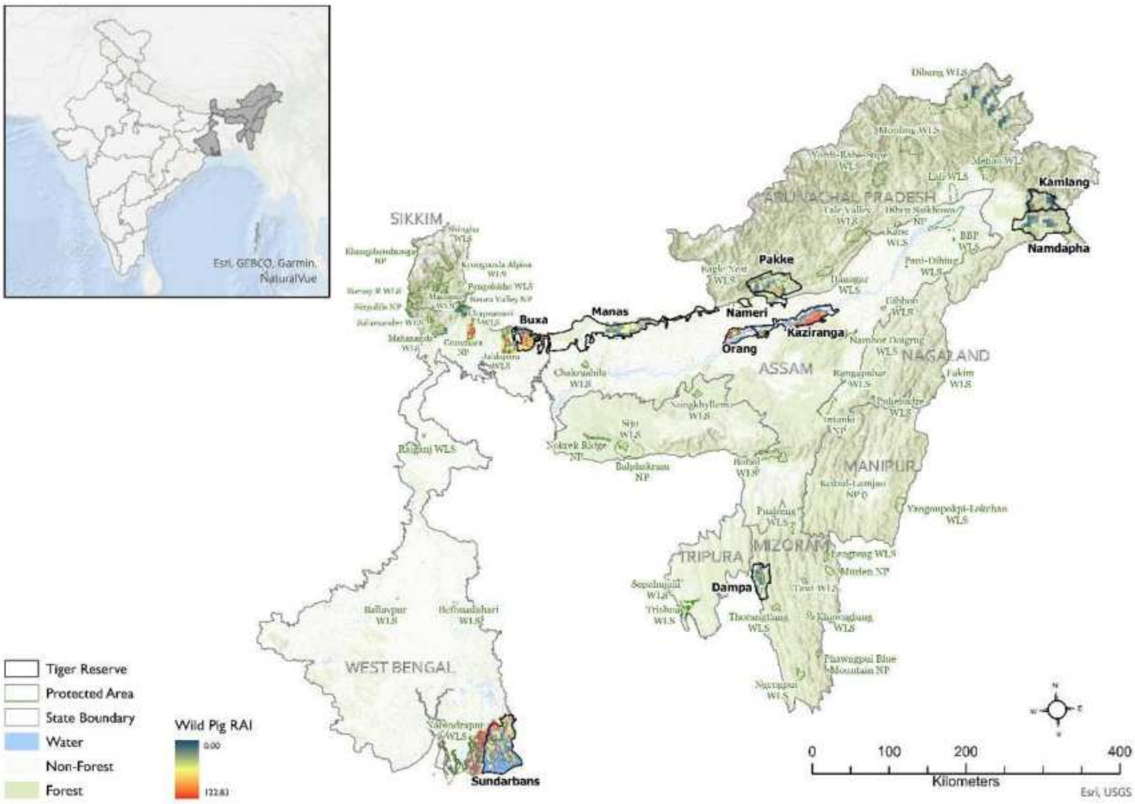

Figure VI. 8: Spatial relative abundance of wild pig (per 25 km^2) in North East hills and Brahmaputra flood plains landscape.

ARUNACHAL PRADESH

Pakke Tiger Reserve

Pakke tiger reserve, located in the East Kameng district of Arunachal Pradesh, spans approximately 1,198 km^2 and is contiguous in the south with the Nameri tiger reserve of Assam. The reserve is characterized by Assam Valley tropical semi evergreen forests (Champion & Seth 1968) rich in epiphytic flora, woody lianas and Subtropical broadleaved forests in the higher hilltops (Chauhan *et al*., 2006). Drainage is provided by Kameng and Pakke Rivers which are tributaries of Brahmaputra. The diverse habitat and terrain complexities support a rich ungulate diversity, providing a crucial prey base for its predator species. Pakke is home to tigers, leopard, clouded leopard, Asian elephants, gaur, and a variety of primates, including the Hoolock gibbon and Assamese macaque. The reserve also hosts a wealth of bird species, including the white-winged wood duck, and various pheasants.

The sampling was also limited to conducive southern west area Tippi and Seijosa ranges. Distance-based analysis to estimate ungulate density has not been conducted due to limited data availability. However, the relative abundance index derived from photo-capture events provides insights into the spatial distribution of ungulates within the reserve.

Sambar appears to be the most abundant ungulate species in Pakke tiger reserve (Figure VI. 9), followed by barking deer (Figure VI. 10), wild pig (Figure VI. 13), and gaur (Figure VI. 11). Hog deer is confined to the boundary along with Nameri tiger reserve (Figure VI. 12). Illegal hunting for bushmeat remains a critical threat to the herbivore population, compounded by illicit cattle grazing and habitat fragmentation caused by human settlements between the Seijosa Nala and Dibru Nala corridors in the eastern part of Pakke Tiger Reserve, which connect with the Papum Reserve Forests. These pressures not only threaten ungulates but also disrupt the ecological balance essential for sustaining the reserve’s biodiversity.

Ensuring the long-term conservation of Pakke Tiger Reserve requires the implementation of robust protection measures. These include the adoption of the MSTrIPES monitoring system, consistent wildlife monitoring, and habitat management efforts to mitigate threats and promote sustainable wildlife populations.

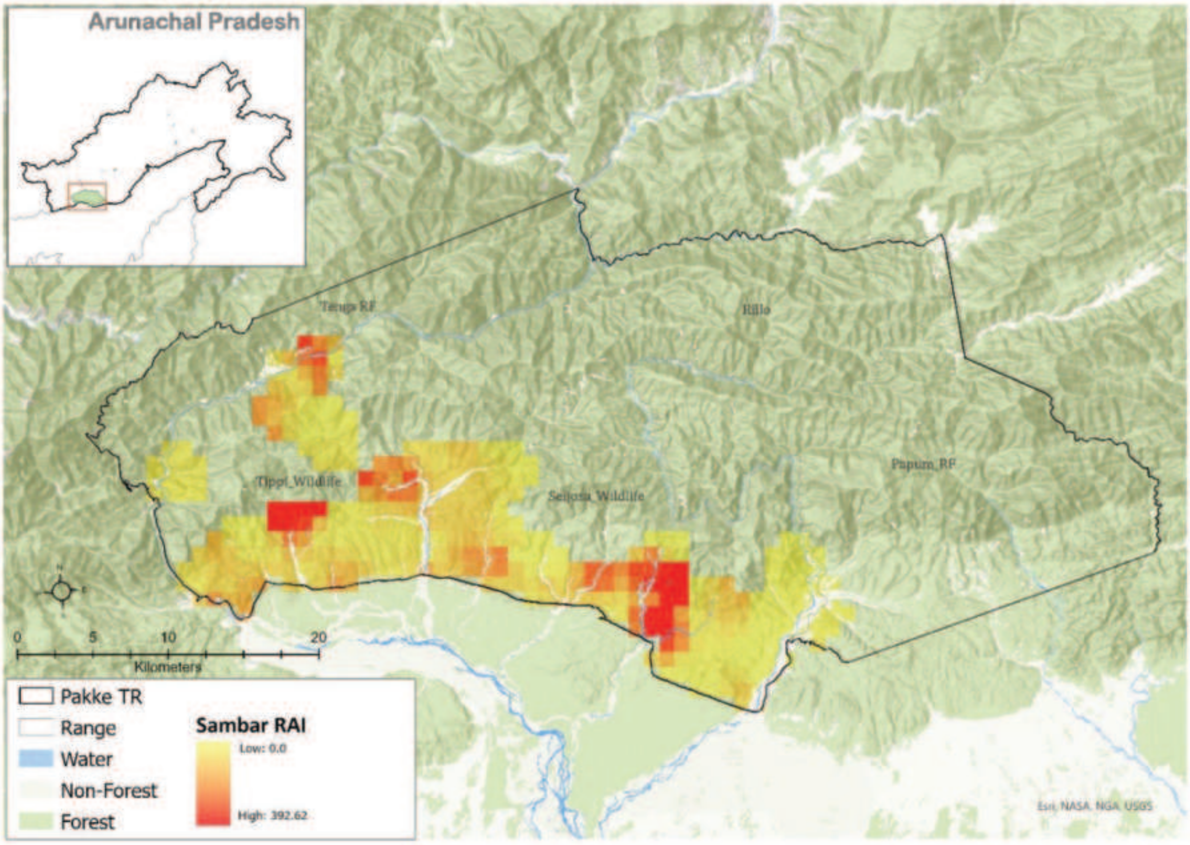

Figure VI. 9: Spatial relative abundance of sambar in Pakke tiger reserve.

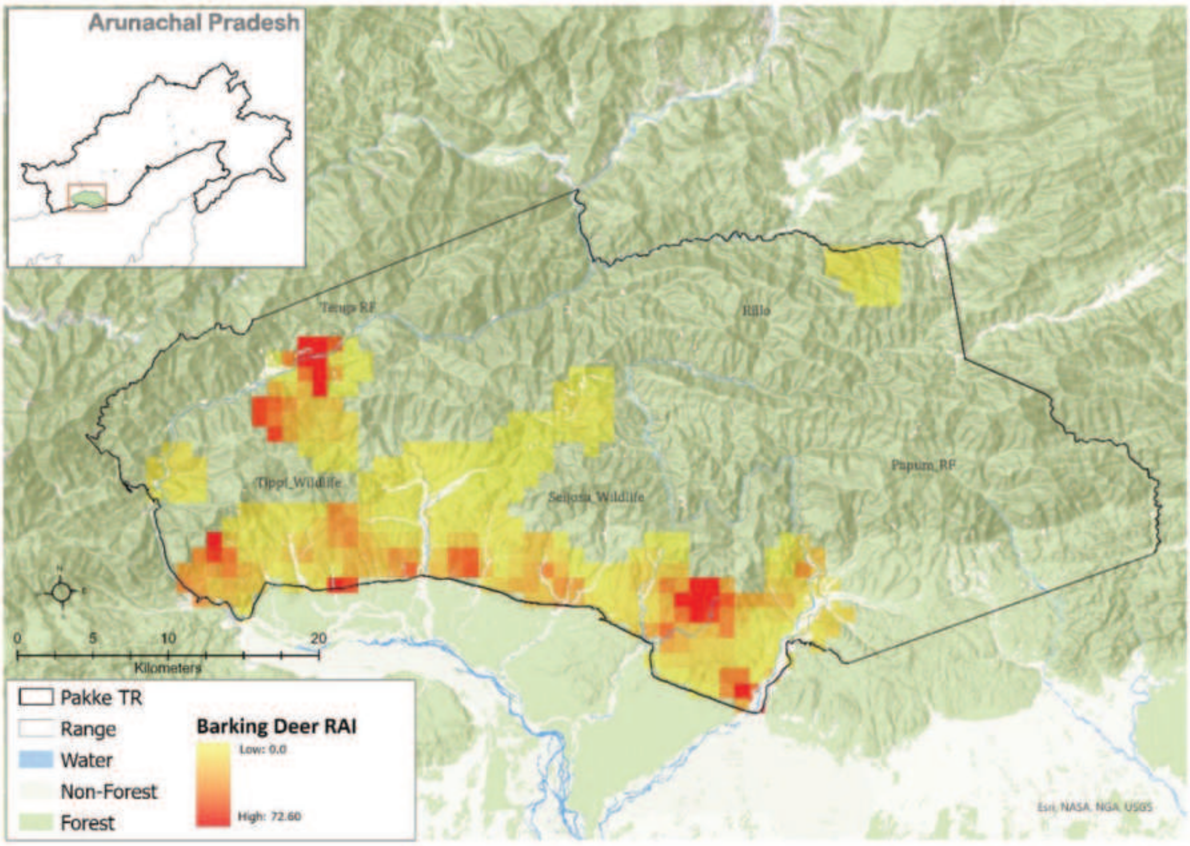

Figure VI. 10: Spatial relative abundance of barking deer in Pakke tiger reserve.

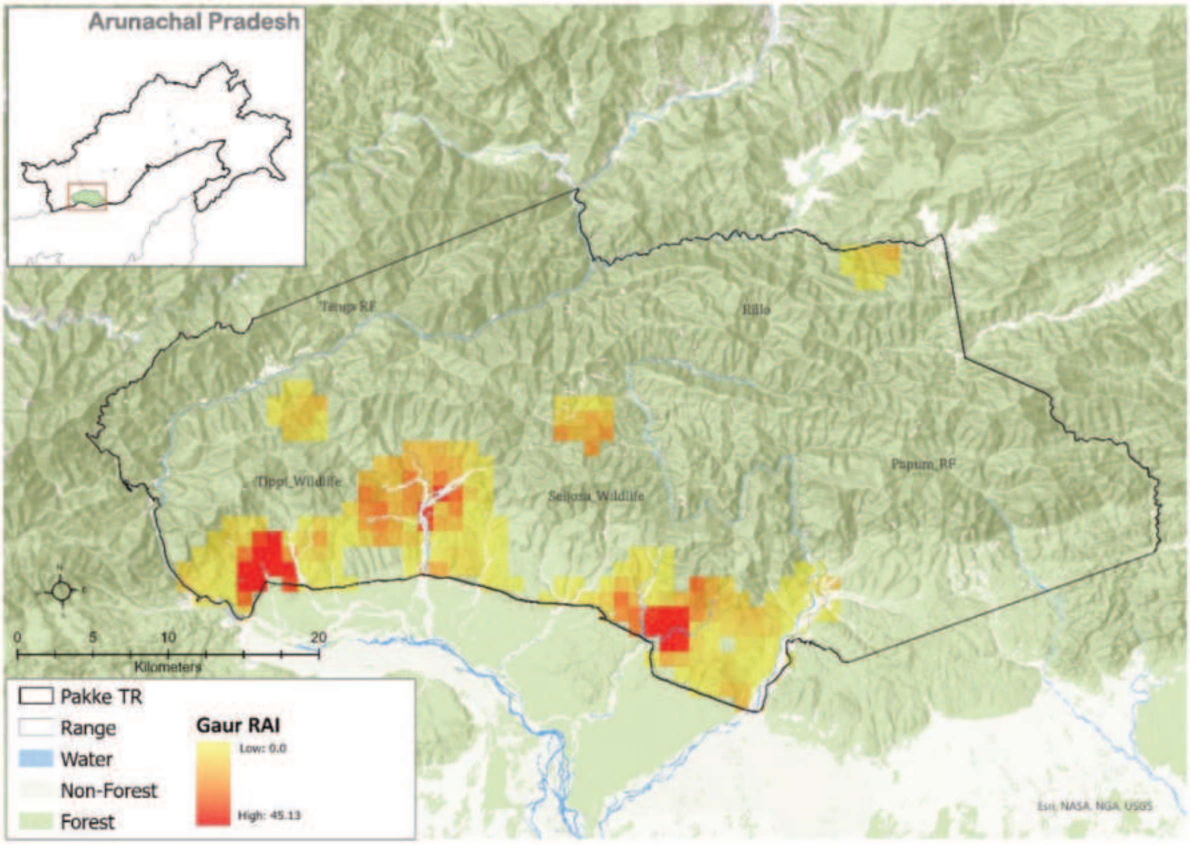

Figure VI. 11: Spatial relative abundance of gaur in Pakke tiger reserve.

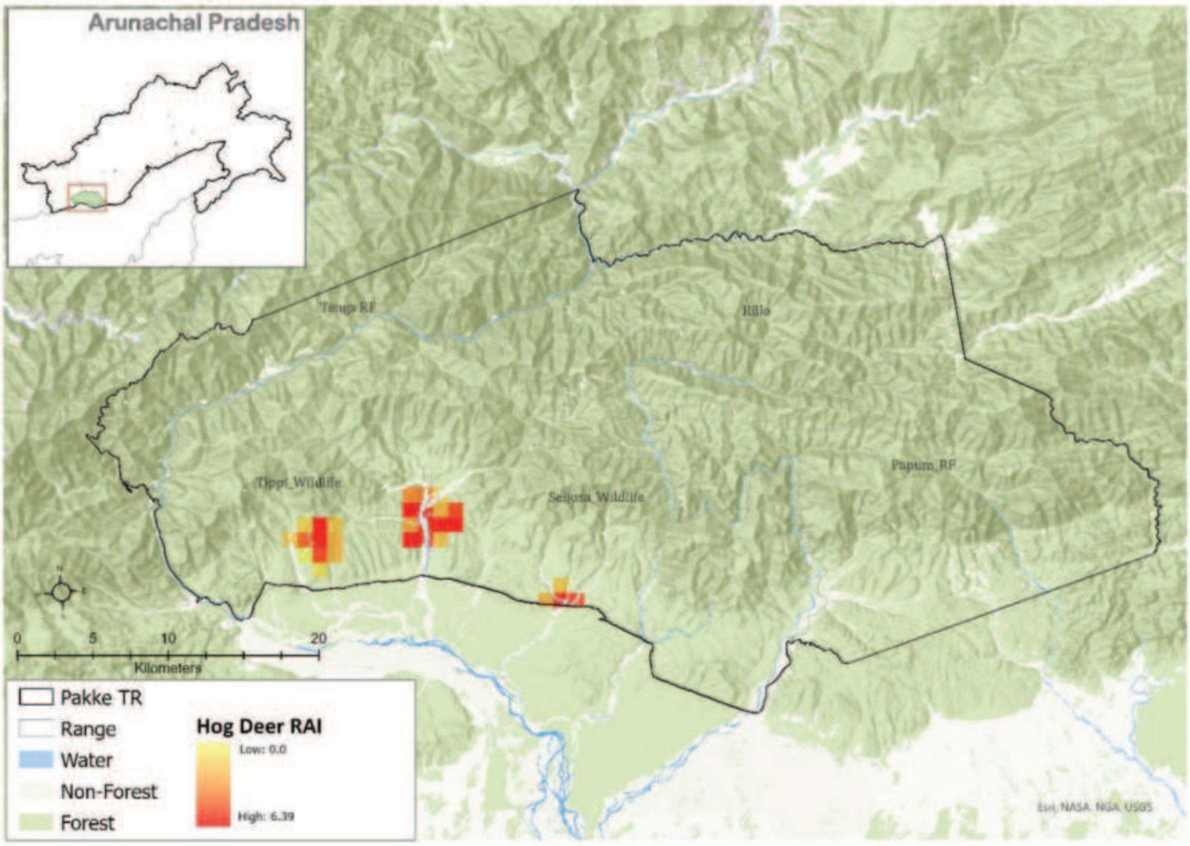

Figure VI. 12: Spatial relative abundance of hog deer in Pakke tiger reserve.

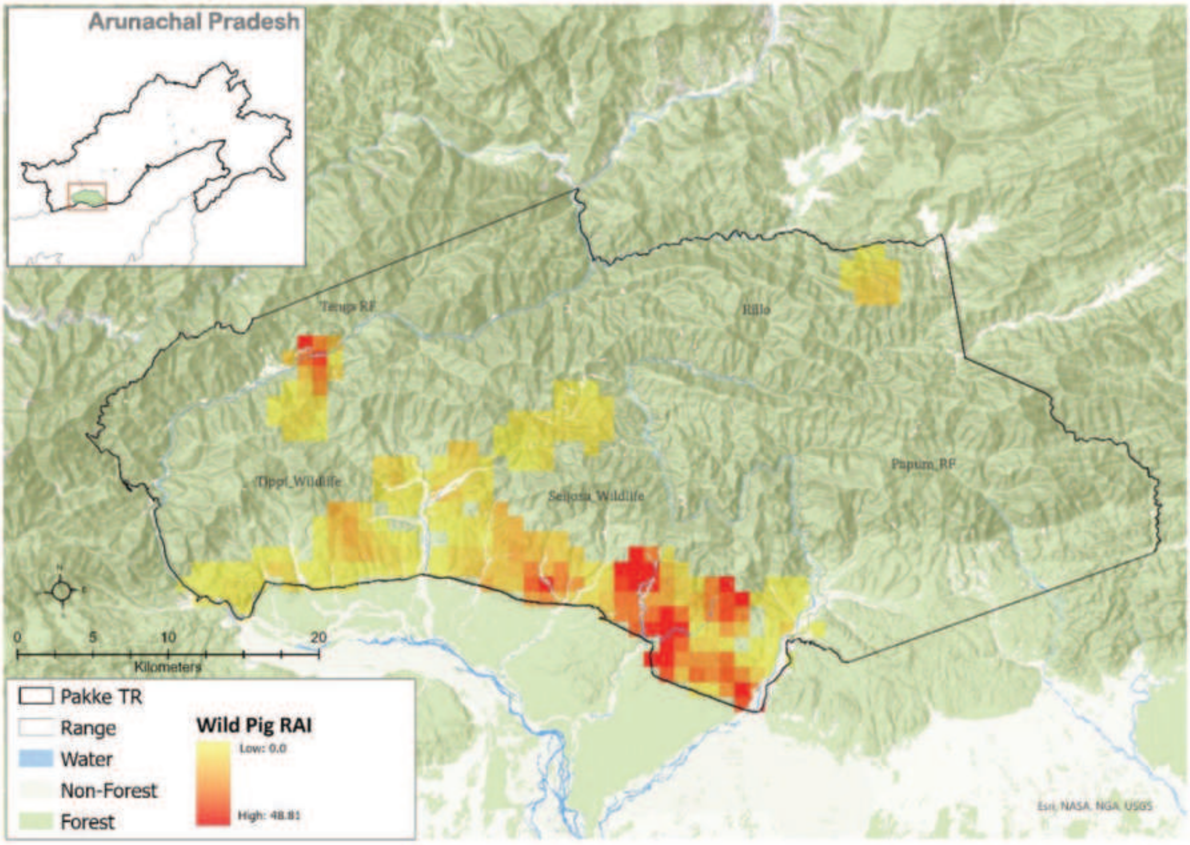

Figure VI. 13: Spatial relative abundance of wild pig in Pakke tiger reserve.

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Namdapha Tiger Reserve

Namdapha tiger reserve, located in the Changlang district of Arunachal Pradesh, covers approximately 2,052 km^2 and is the first protected area of Arunachal Pradesh which was declared as a tiger reserve. Namdapha is the northernmost lowland tropical rainforest (Proctor *et al*., 1998) and has the last large tracts of lowland dipterocarp forests in the Indian Himalayan Region (Deb and Sundriyal, 2015). Terrain of Namdapha is undulating and hilly, ranging from 200m upto 4571m above the msl, creating a unique gradient of ecosystems from tropical rainforests and subtropical forests in the lowlands to temperate and alpine forests at higher elevations (Naniwadekar *et al*., 2013). Namdapha harbours diverse assemblage of species, attributed to its geographic location at the intersection of the Palearctic and Indo-Malayan biogeographic realms. The tiger population of Namdapha is a priority population in terms of their evolutionary significance and holds utmost importance. The reserve is also home to clouded leopard, snow leopard, leopard, Asian elephants, and red pandas. It also supports a variety of primates, such as the Hoolock gibbon and Assamese macaque, alongside a wide range of herbivores like sambar, barking deer, *etc*.

Due to logistical constraints, opportunistic camera trapping was done in Namdapha. However, camera traps were operational in all three ranges *i.e.* Miao, Gandhigram, and Namdapha range. Barking deer, gaur and wild pig were captured in all three ranges whereas sambar was captured only in Gandhigram and Miao range (Figure VI. 14). Among all the species barking deer is the most abundant ungulate found in Namdapha (Figure VI. 15).

However, these maps provide only a snapshot of ungulate species in Namdapha tiger reserve as the camera traps are placed opportunistically and in exploratory mode. There is an urgent need for rigorous scientific monitoring of ungulate species and their abundance. Although several scientific studies have been done in Namdapha, focused study to monitor the status of large carnivores and other co-predators is still lacking. The core of Namdapha tiger reserve is not completely inviolate and few settlements are still present inside. To facilitate the logistics and other humanitarian aid to the remote village, Vijaynagar, a motorable road has been recently established. However, traffic on the road is considerably low, and mostly used for defence and civil purposes. Like Kamlang, Namdapha also shares international boundaries with Myanmar and is very much prone to poaching and hunting of wildlife resources. Given the low prey densities, active management strategies such as consistent law enforcement monitoring, rigorous monitoring of wildlife resources, habitat management, and participatory conservation with local communities would be beneficial in restoring and conserving prey and subsequently tigers in this area.

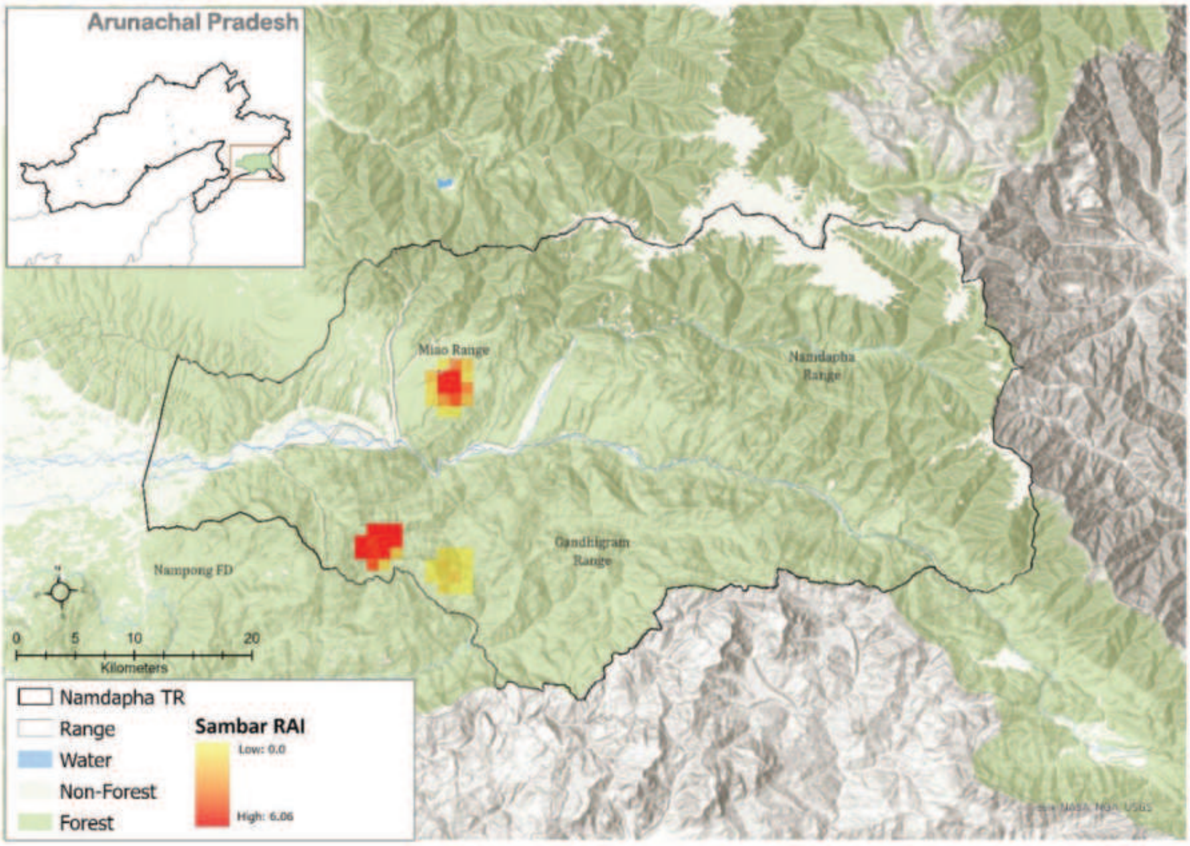

Figure VI. 14: Spatial relative abundance of sambar in Namdapha tiger reserve.

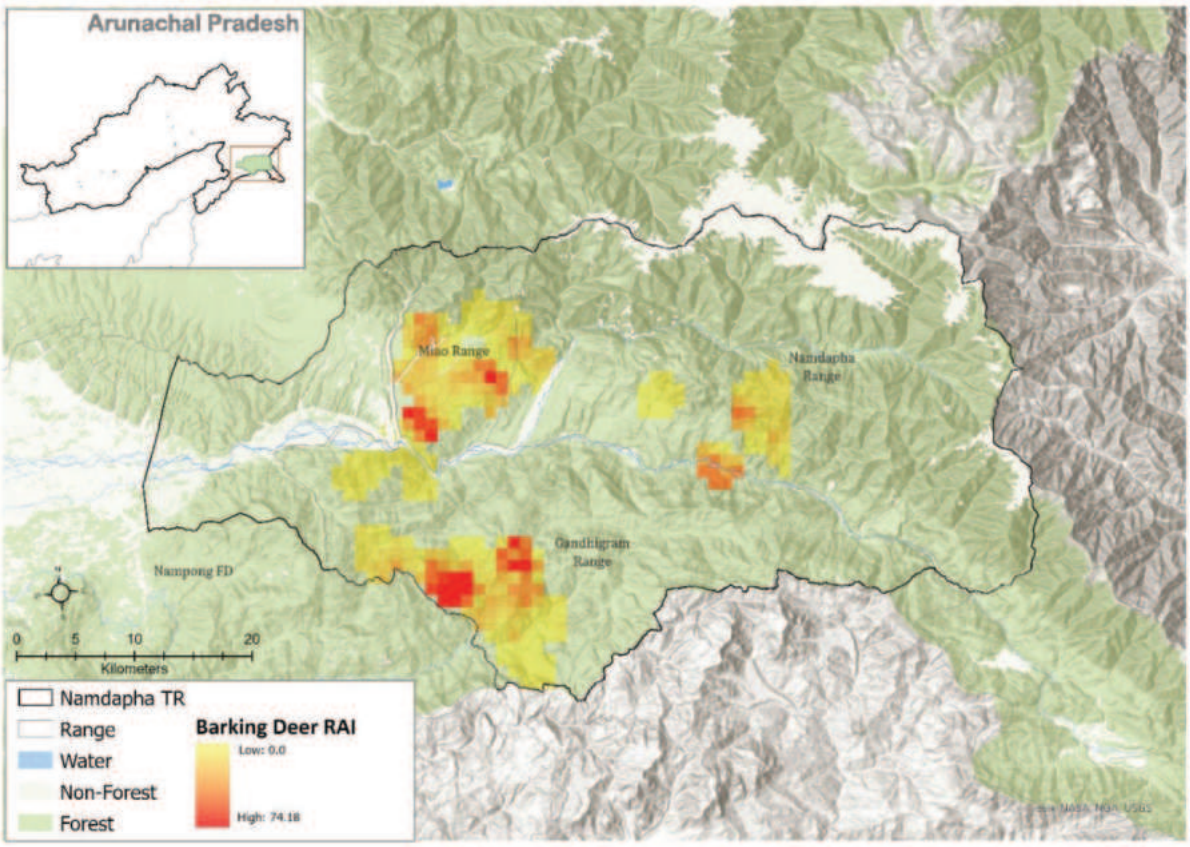

Figure VI. 15: Spatial relative abundance of barking deer in Namdapha tiger reserve.

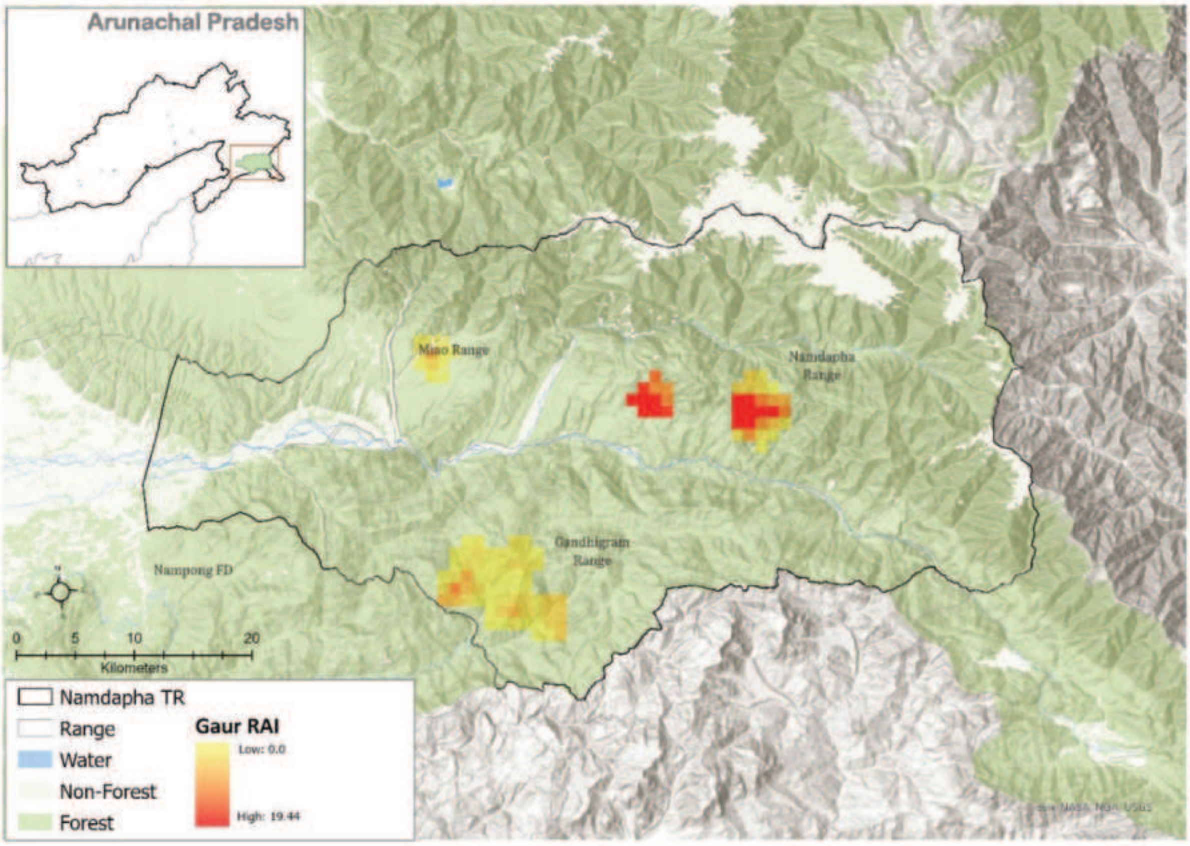

Figure VI. 16: Spatial relative abundance of gaur in Namdapha tiger reserve.

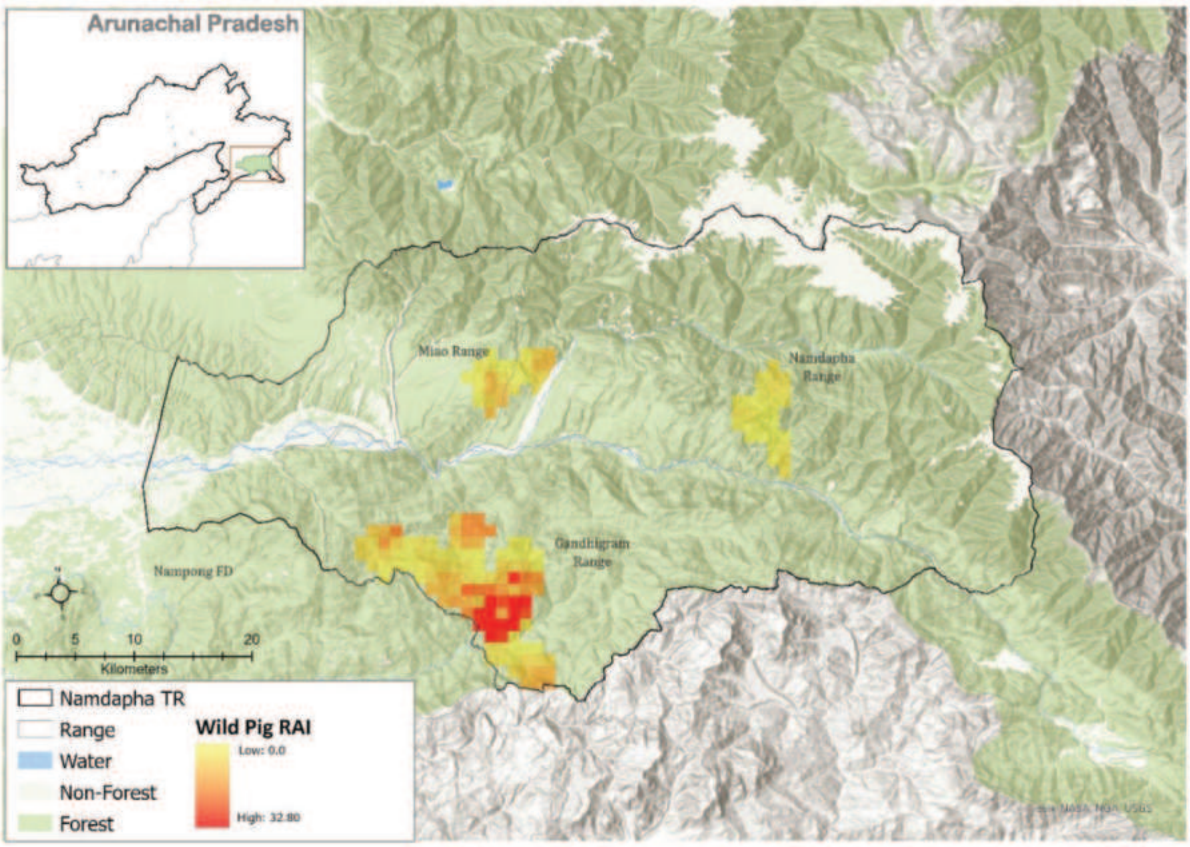

Figure VI. 17: Spatial relative abundance of wild pig in Namdapha tiger reserve.

Kamlang Tiger Reserve

Kamlang tiger reserve, located in the Lohit district of Arunachal Pradesh, covers approximately 783 km^2 within the eastern Himalayas. Southern boundary of Kamlang tiger reserve is continuous with Namdapha tiger reserve. The area falls in a heavy rainfall belt with 2,500 – 3,500 mm of average annual rainfall. Vegetation of Kamlang varies from wet evergreen tropical forests in the foothills and sub-tropical broadleaf, coniferous forest, sub – alpine dry scrub and montane wet temperate in higher elevation (Biju *et al*., 2023). Kamlang river flows through the tiger reserve. Being situated in the Indo- Malayan biogeographic region, its varied topography ranges from lowland valleys to hilly terrain and harbours an excellent faunal assemblage including white bellied heron, malayan sun bear, hoolock gibbon, mishmi takin, red goral. Kamlang is also home to the tiger, leopard, clouded leopard, and herbivores like sambar, gaur, wild pig and barking deer.

Till now a larger part of the Kamlang tiger reserve is unexplored, and opportunistic camera trapping has been done owing to the logistical constraints and highly undulating terrain. Sambar, gaur, barking deer, and wildpig are captured in Kamlang and their high abundance is recorded in south western part of Kamlang (Figure VI. 18-13).

Tiger population in Arunachal hills is low and it is related to prey availability. Nonetheless, Kamlang has recorded several prey species during camera trap sampling; there is a lack of rigorous evidence based abundance estimation of prey species. Protection of existing faunal assemblage would help the prey population to recover in Kamlang. Law enforcement monitoring protocol is still not robust in Kamlang, and much effort needs to be put in patrolling as poaching and hunting of wildlife species pose significant threats due to its proximity to the international border with Myanmar. Other efforts, such as setting up anti-poaching camps at strategic entry points to the tiger reserve. Also, creating awareness among local communities and engaging them in eco-development activities, and eco-tourism would certainly help to reduce the biotic pressure in the reserve.

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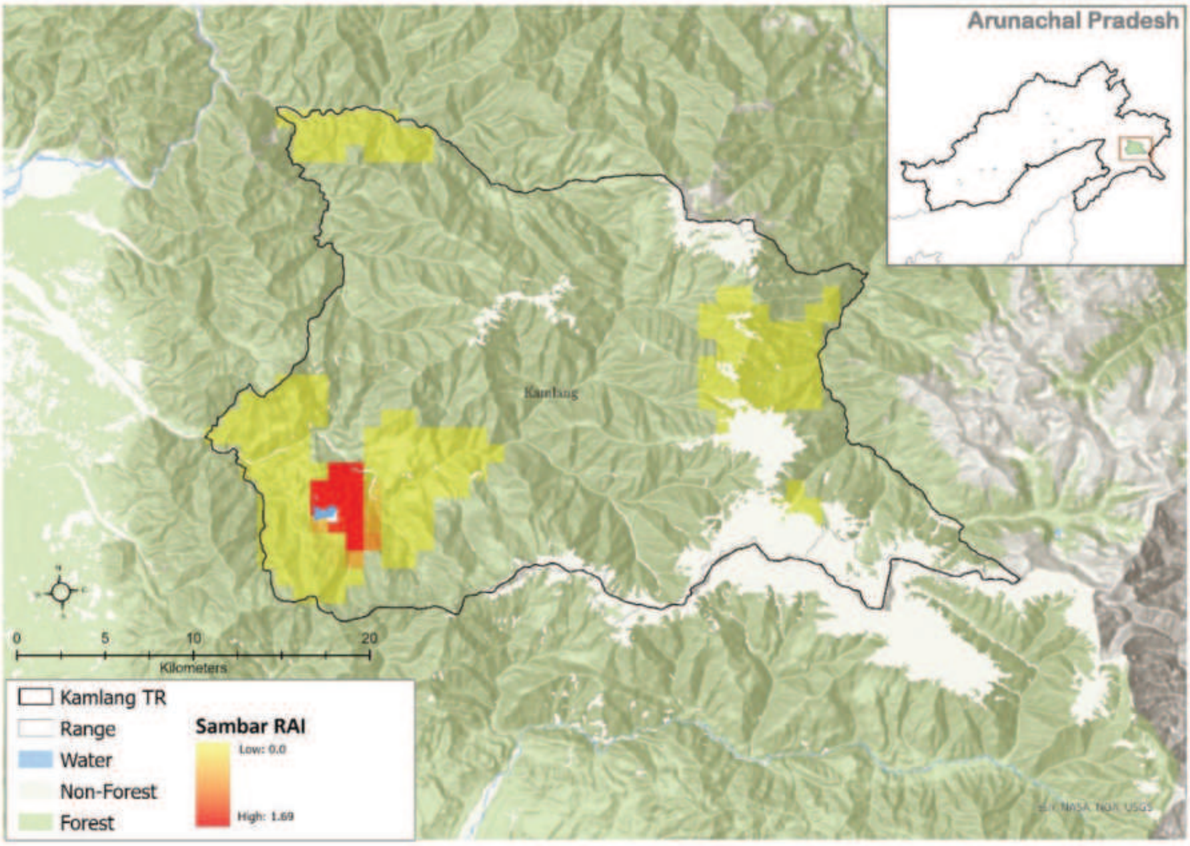


Figure VI. 18: Spatial relative abundance of sambar in Kamlang tiger reserve.

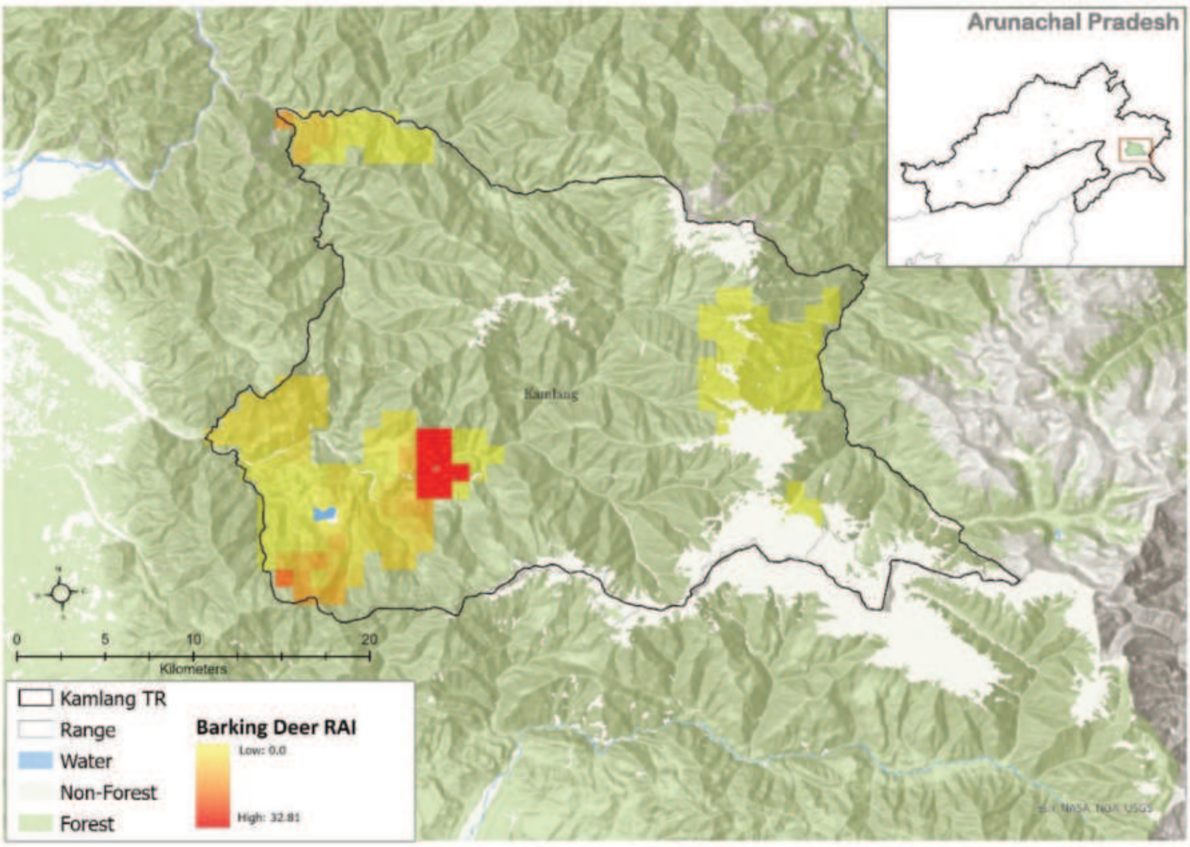


Figure VI. 19: Spatial relative abundance of barking deer in Kamlang tiger reserve.

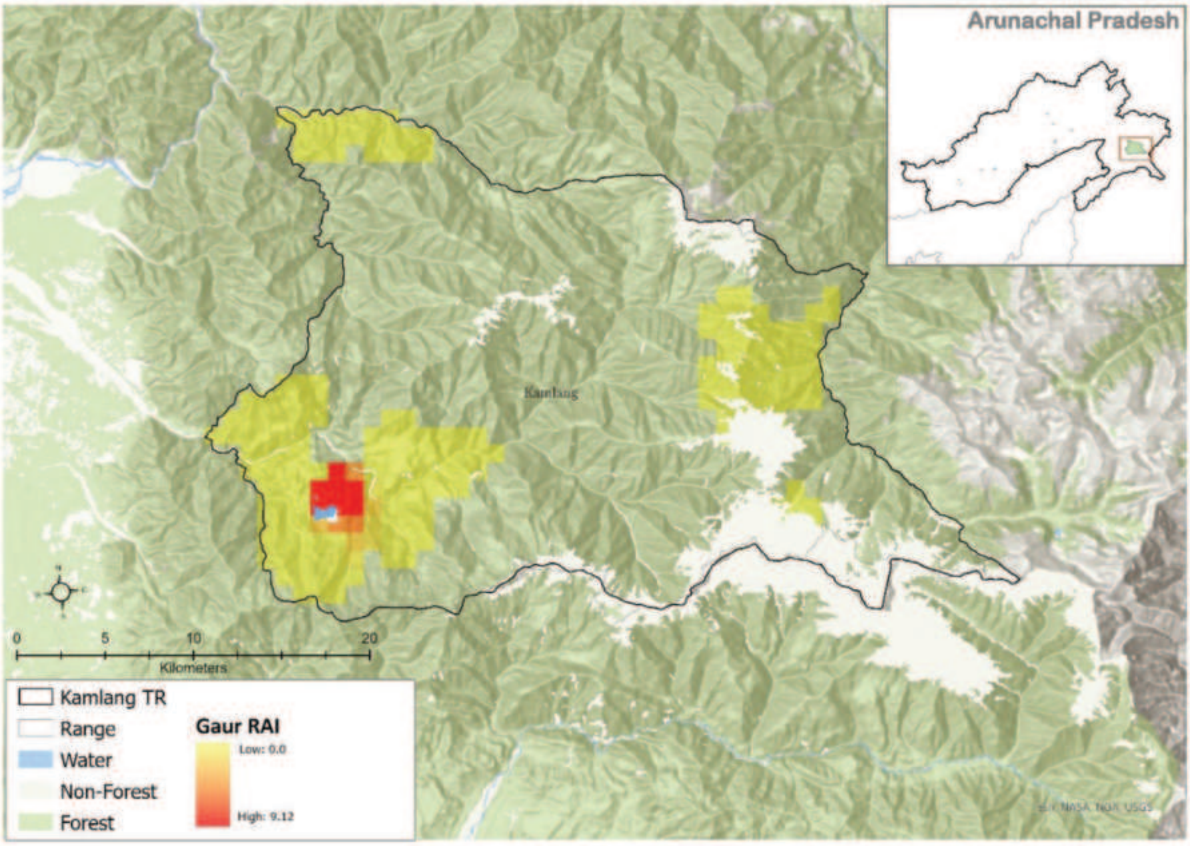


Figure VI. 20: Spatial relative abundance of gaur in Kamlang tiger reserve.

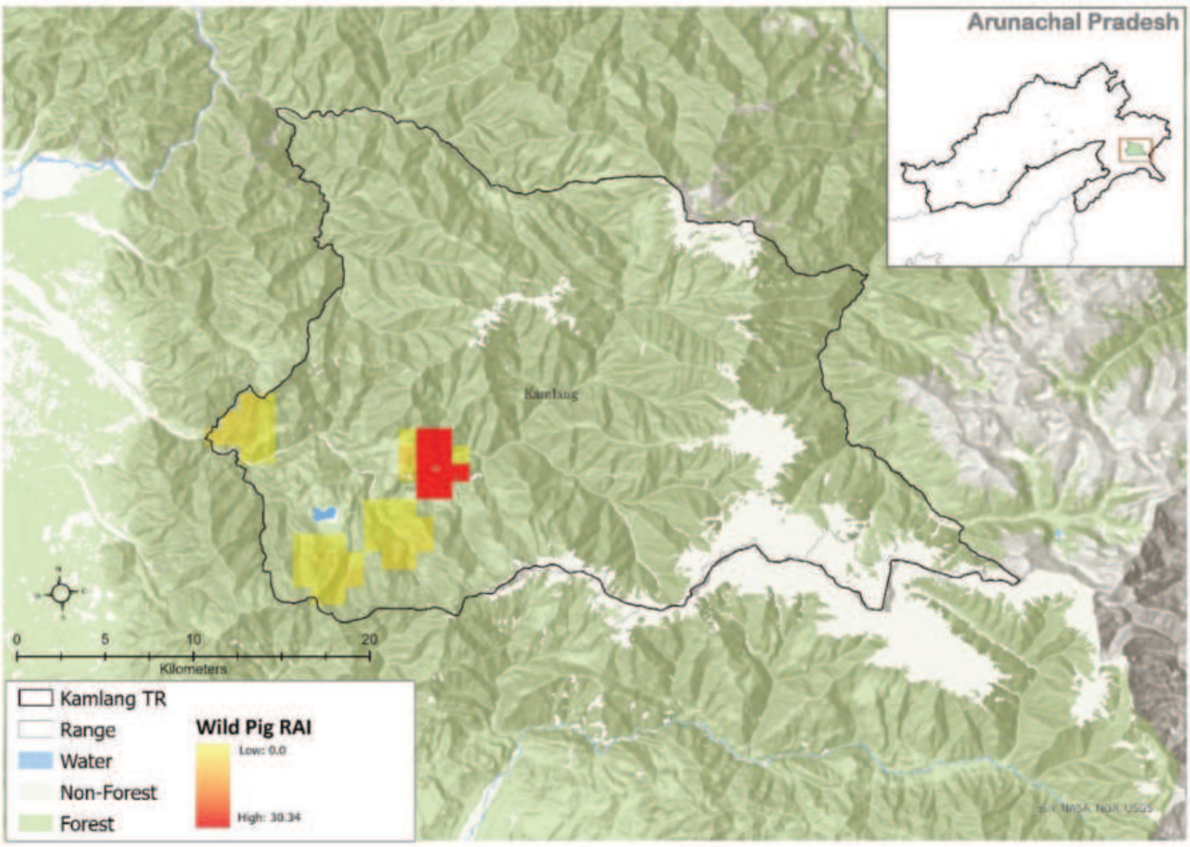


Figure VI. 21: Spatial relative abundance of wild pig in Kamlang tiger reserve.

ASSAM

Kaziranga Tiger Reserve

Kaziranga tiger reserve, located in Assam, spans approximately 1,173 km^2 and is a UNESCO World Heritage Site renowned for its exceptional biodiversity and conservation significance. Situated in the floodplains of the Brahmaputra River, the reserve features a dynamic mosaic of tall elephant grasslands, tropical moist deciduous forests, semi-evergreen forests, and extensive wetlands that support a unique assemblage of flora and fauna (Vasu, 2023). These ecosystems are shaped by annual monsoon floods, which rejuvenate the soil and create a landscape crucial for the survival of its iconic species. Kaziranga is home to two-thirds of the global population of the Indian one-horned rhinoceros (Sharma *et al*., 2016) along with other megaherbivores like elephants, and wild water buffalo. It also has one of the highest tiger density in India (Qureshi *et al*., 2023). Other important species of Kaziranga includes hoolock gibbon, barasingha, capped langur, hog deer, sambar *etc.*

Due to insufficient recordings of ungulates on line transect, spatial densities could not be estimated. However, hog deer is the only species where density is estimated. To show spatial occurance of all the species within the tiger reserve, relative abundance indices based on camera trap photo capture data are calculated. Hog deer is the most abundant prey species in Kaziranga (49 per km^2), and their population is concentrated in the short grasslands with highest abundance in Bagori range. Woodlands have moderate to low concentration of hog deer (Figure VI. 24).

The wild pig abundance is highest towards southern boundary of Kohora range (Figure VI. 28). Barking deer abundance is highest in the Bagori followed by Burapahar range (Figure VI. 30). Sambar is abundant throughout Kaziranga with each range having some area of high abundance (Figure VI. 22). Barasingha (Swamp deer) is grassland obligate species and photo captured only in grasslands of kaziranga. Highest abundance is recorded in bagori range (Figure VI. 26). Wild Buffalos are distributed throughout with major concentration in Baghori range (Figure VI. 27).

Except for the total or block counts of a few species, rigorous scientific abundance estimation of ungulate species in Kaziranga is still lacking. Tall grasslands with highly abundant megaherbivores in Kaziranga pose a major hindrance to execute line transect exercise on foot. Line transects on elephant back after the annual grassland burning session should be carried out to estimate absolute abundance of ungulate species followed by other methods such as camera trap based distance sampling. Cattle grazing from the villages in the fringe areas pose significant threats to the ungulate species in terms of competition for resources, disease outbreak *etc.* Effective management practices such as employing rigorous scientific methods to estimate the absolute abundance of ungulate species, evidence based monitoring of wildlife resources and law enforcement is solicited.

Table VI. 1: Model statistics and parameter estimates of line transect based on distance sampling for ungulates in Kaziranga tiger reserve.

Species	Detection probability (SE)	Groups Detected	Mean Group size (SE)	Group density [SE]	Density [SE]
Hog Deer	0.28 (0.03)	175	4.76 (1.14)	16.08 (3.64)	49 (11.82)

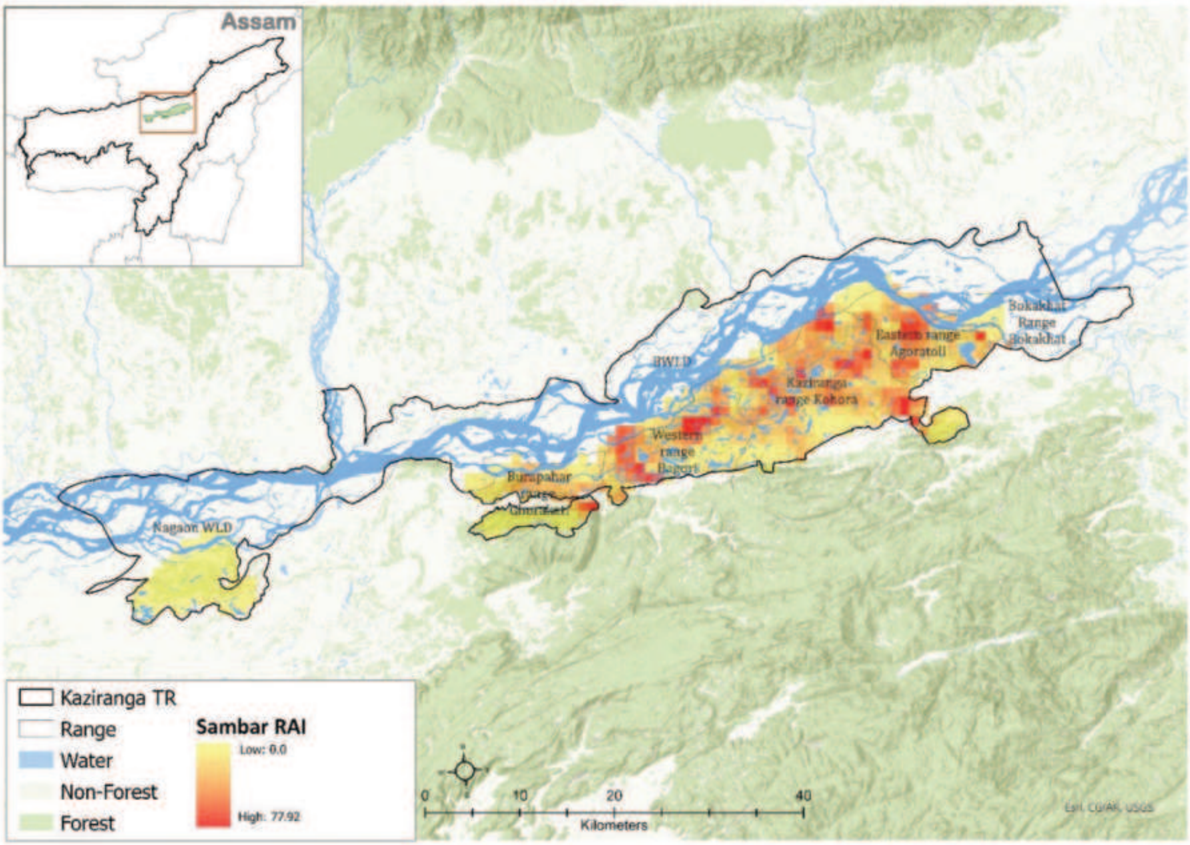


Figure VI. 22: Spatial relative abundance of sambar in Kaziranga tiger reserve.

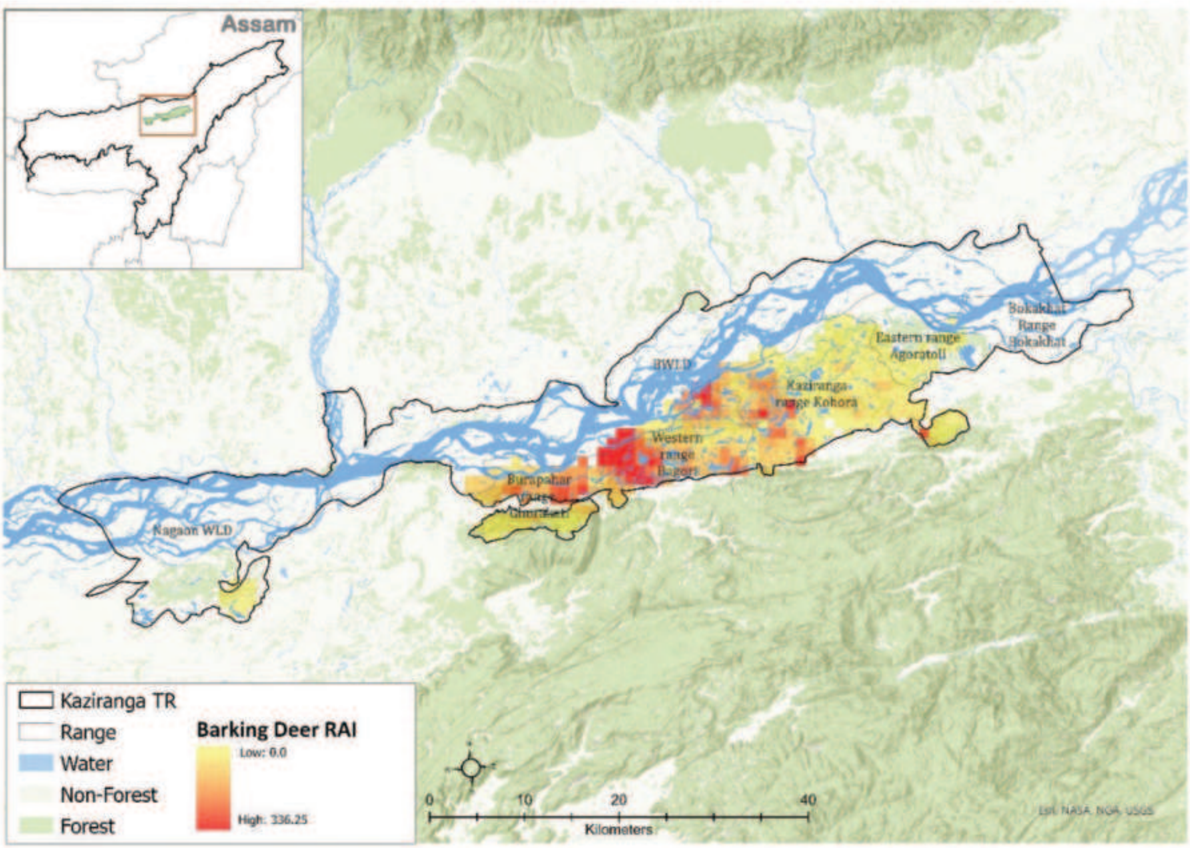


Figure VI. 23: Spatial relative abundance of barking deer in Kaziranga tiger reserve.

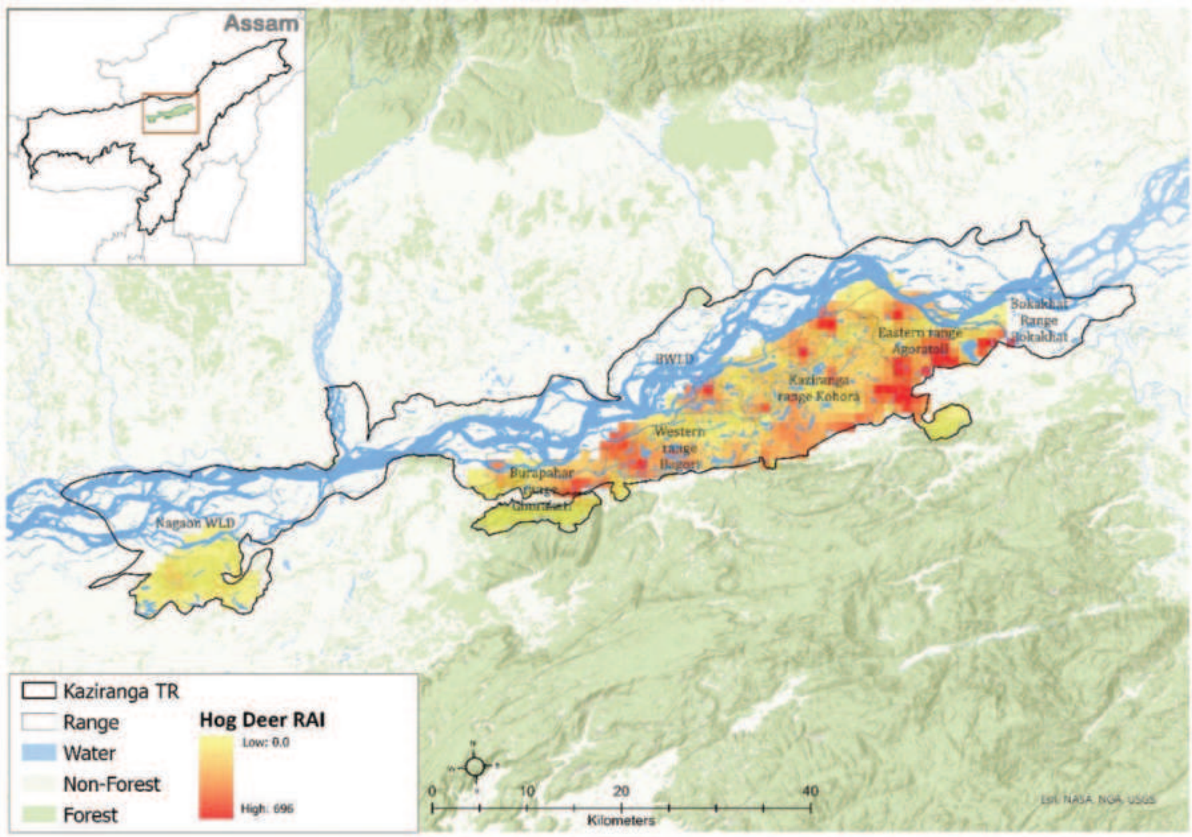


Figure VI. 24: Spatial relative abundance of hog deer (per km²) in Kaziranga tiger reserve.

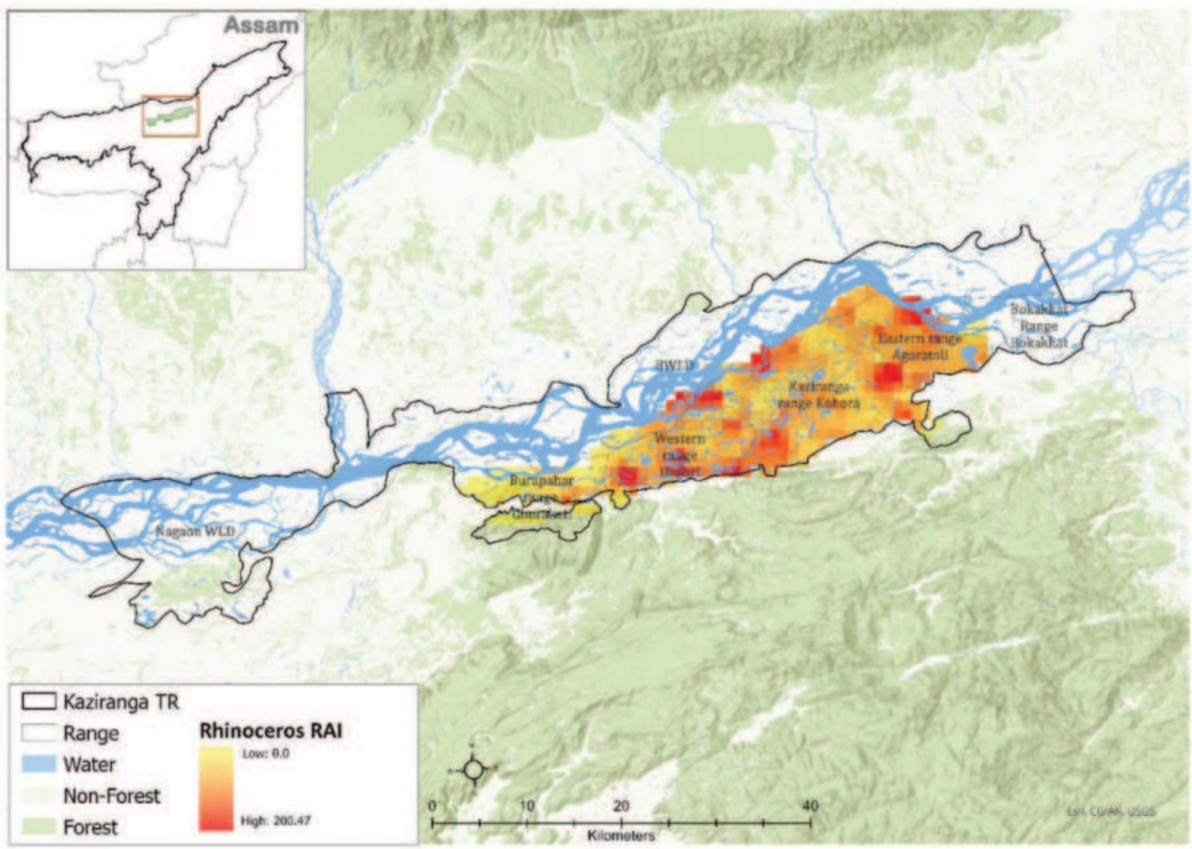


Figure VI. 25: Spatial relative abundance of rhinoceros in Kaziranga tiger reserve.

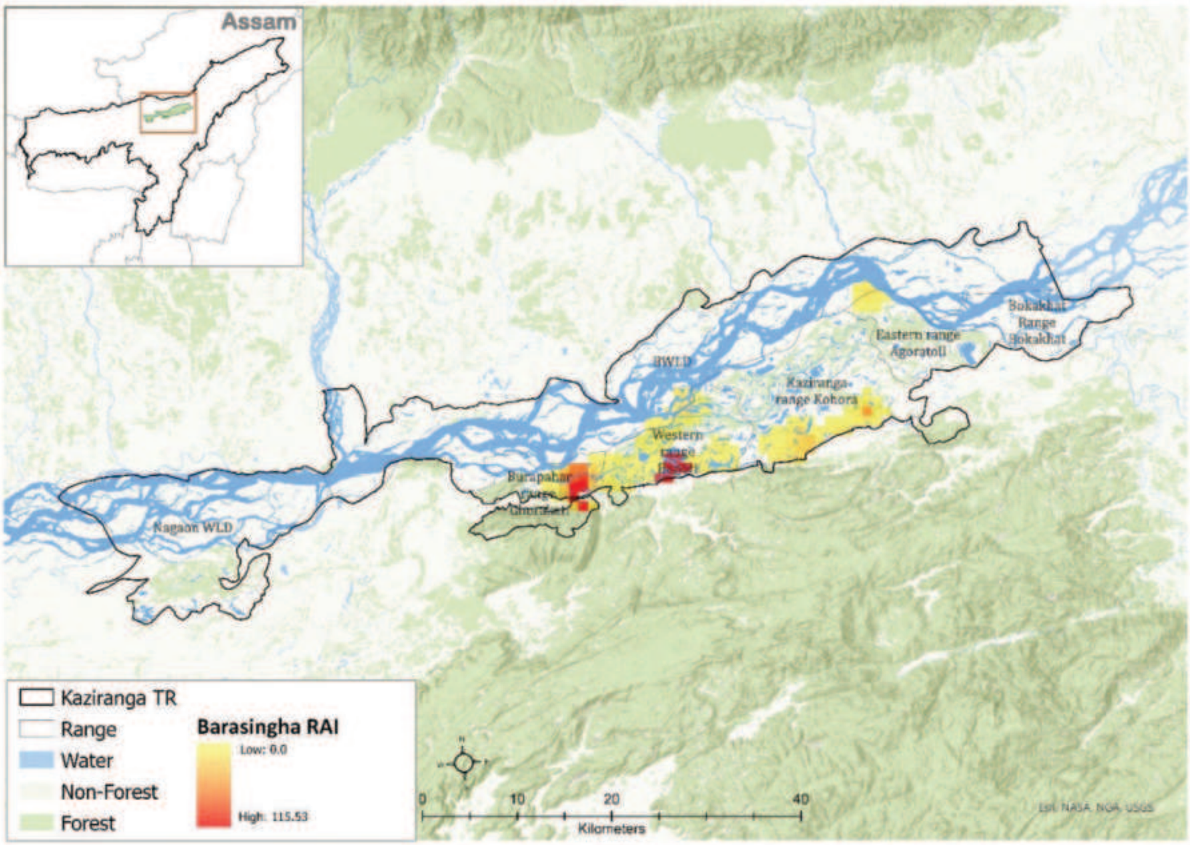


Figure VI. 26: Spatial relative abundance of barasingha in Kaziranga tiger reserve.

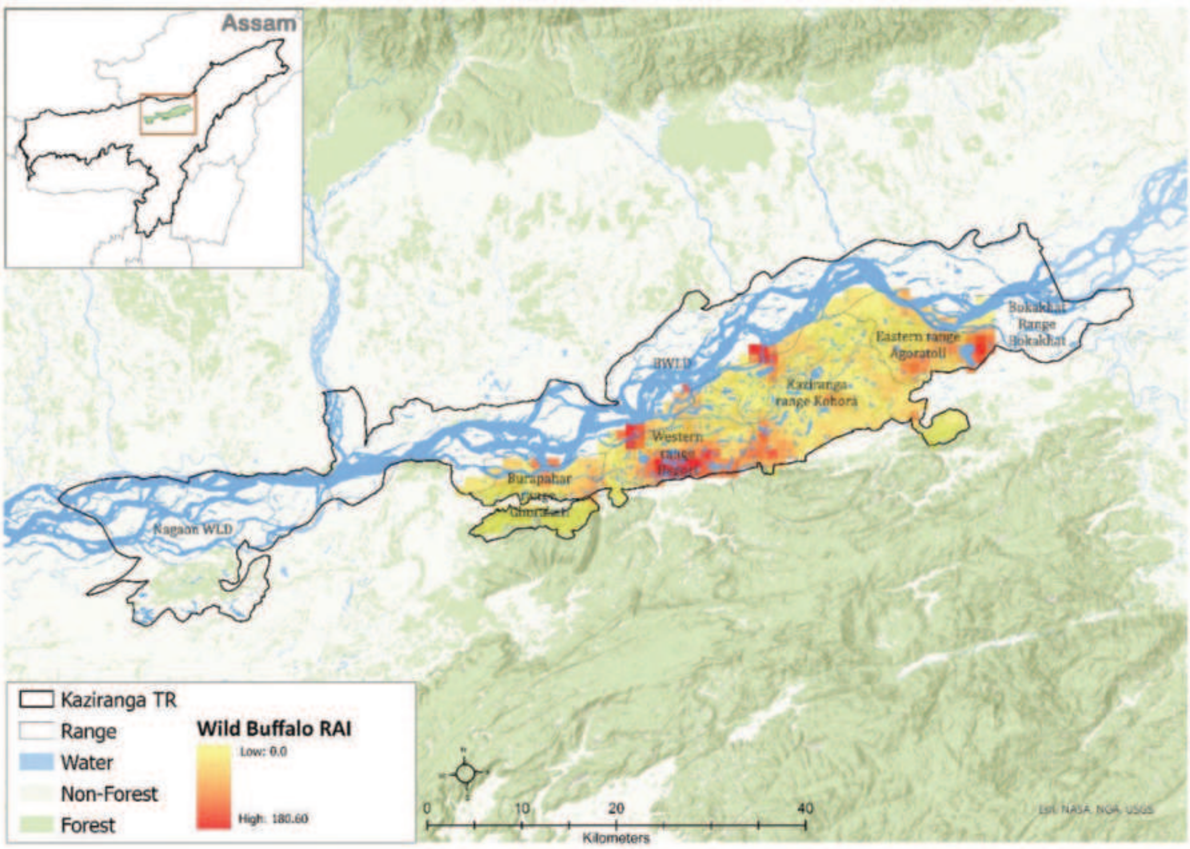


Figure VI. 27: Spatial relative abundance of wild buffalo in Kaziranga tiger reserve.

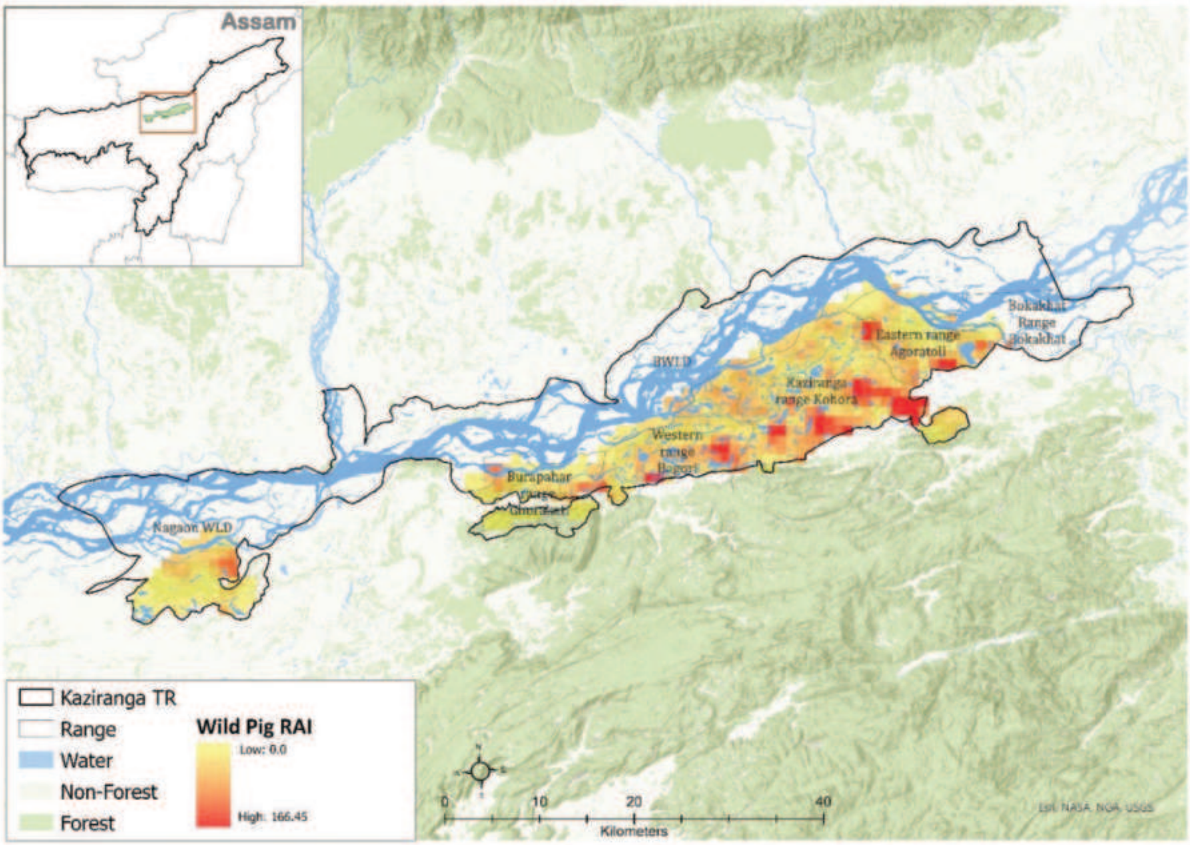


Figure VI. 28: Spatial relative abundance of wild pig in Kaziranga tiger reserve.

Manas Tiger Reserve

Manas tiger reserve, located in the foothills of the Himalayas in Assam, is a UNESCO World Heritage Site, a Biosphere Reserve, and an essential component of the Indo-Burma Biodiversity Hotspot. Spanning over 2,837 km^2, it encompasses a blend of sub-Himalayan alluvial semi-evergreen forests, east-Himalayan mixed moist and dry deciduous forests, grasslands, riparian zones, and swampy marshes (Goswami and Ganesh, 2014). The Manas and Beki rivers run through the tiger reserve. This landscape supports an extraordinary diversity of flora and fauna, including rare and endemic species. The reserve is a critical habitat for the tiger, Asian elephants, greater one horned rhinoceros, clouded leopard, golden cat, marbled cat, leopard cat, hog deer, sambar, wild buffalo, gaur as well as endangered species like the pygmy hog, golden langur, and hispid hare. The grasslands of manas are vital for the survival of species like the barasingha and Bengal florican.

Prey densities of these ungulates were found to be relatively similar across the reserve (Table VI. 2). Observations of ungulates were limited, so data from two years were pooled together using a global detection function and post-stratified density estimates were obtained. However, spatial densities were not modeled due to the limited number of observations in each year.

Hog deer are most abundant in the Bansbari range, followed by the Panbari and Bhuyanpara ranges (Figure VI. 32). Gaur is distributed throughout the reserve and were recorded at similar abundance levels across all ranges (Figure VI. 31). Wild buffalo are most abundant in Bansbari, with lower densities in the Panbari and Bhuyanpara ranges. Sambar is primarily concentrated in the Bansbari and Bhuyanpara ranges (Figure VI. 35), while wild pig occurs across all camera-trapped areas (Figure VI. 36). Barking deer are found at high densities in forested habitats within the reserve (Figure VI. 30), and Barasingha (swamp deer) are confined to the major grassland areas of the Bansbari and Bhuyanpara ranges (Figure VI. 34). Manas tiger reserve has faced significant challenges in the past, particularly during periods of armed conflict. However, the reserve is currently on a path to recovery. Effective protection measures and consistent wildlife monitoring, are essential for sustaining this progress. The grassland habitats of Manas are under threat from invasive plant species, which pose a serious challenge to the ecosystem. Therefore, habitat management and invasive species control, including weed removal, should be prioritized to ensure the long-term health of the reserve's biodiversity.

Table VI. 2: Model statistics and parameter estimates of line transect based on distance sampling for ungulates in Manas tiger reserve.

Species	Detection probability (SE)	Groups Detected	Mean Group size (SE)	Group density [SE]	Density [SE]
Hog Deer	0.29 (0.08)	58	2.38(0.21)	2.49 (0.89)	6 (2.19)
Sambar	0.59 (0.06)	25	9.98 (1.99)	0.33 (0.99	3 (0.95)
Gaur	0.44 (0.068)	31	10.13 (2.29)	0.34 (0.10)	3 (1.29)
Wild Buffalo	0.32 (0.029)	44	7.34 (0.99)	0.66 (0.20)	5 (1.62)
Barking deer	0.31 (0.061)	27	1.46 (0.97)	0.66 (0.24)	1 (0.37)
Wild Pig	0.52 (0.05)	70	13.28(3.31)	0.32 (0.09)	4 (1.59)

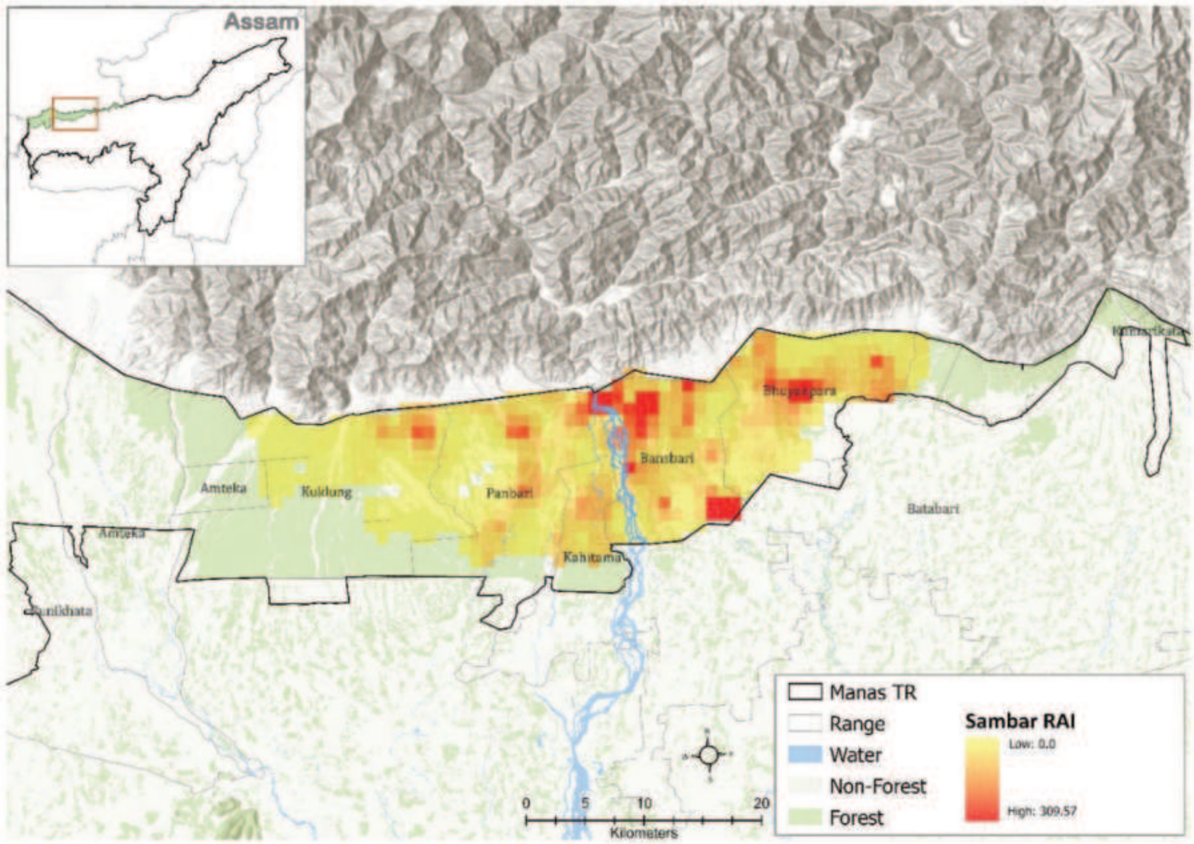


Figure VI. 29: Spatial relative abundance of sambar in Manas tiger reserve.

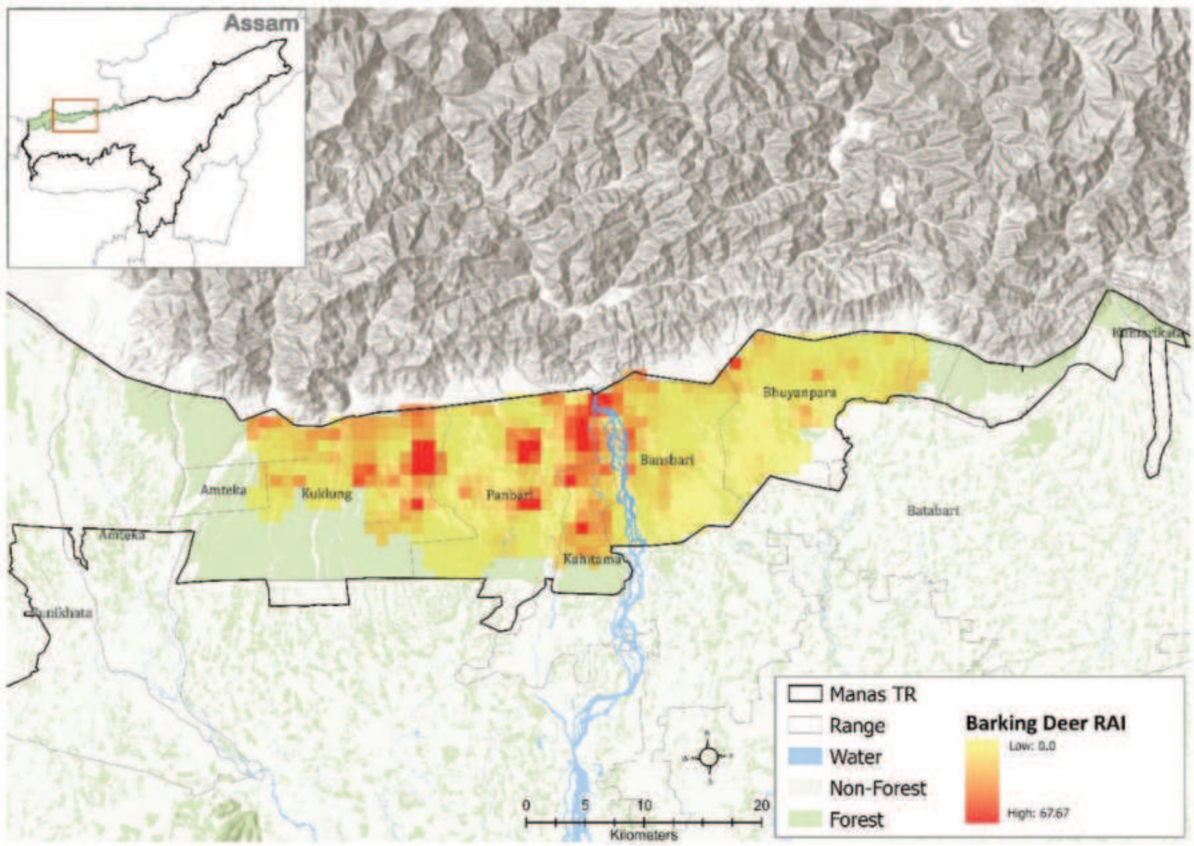


Figure VI. 30: Spatial relative abundance of barking deer in Manas tiger reserve.

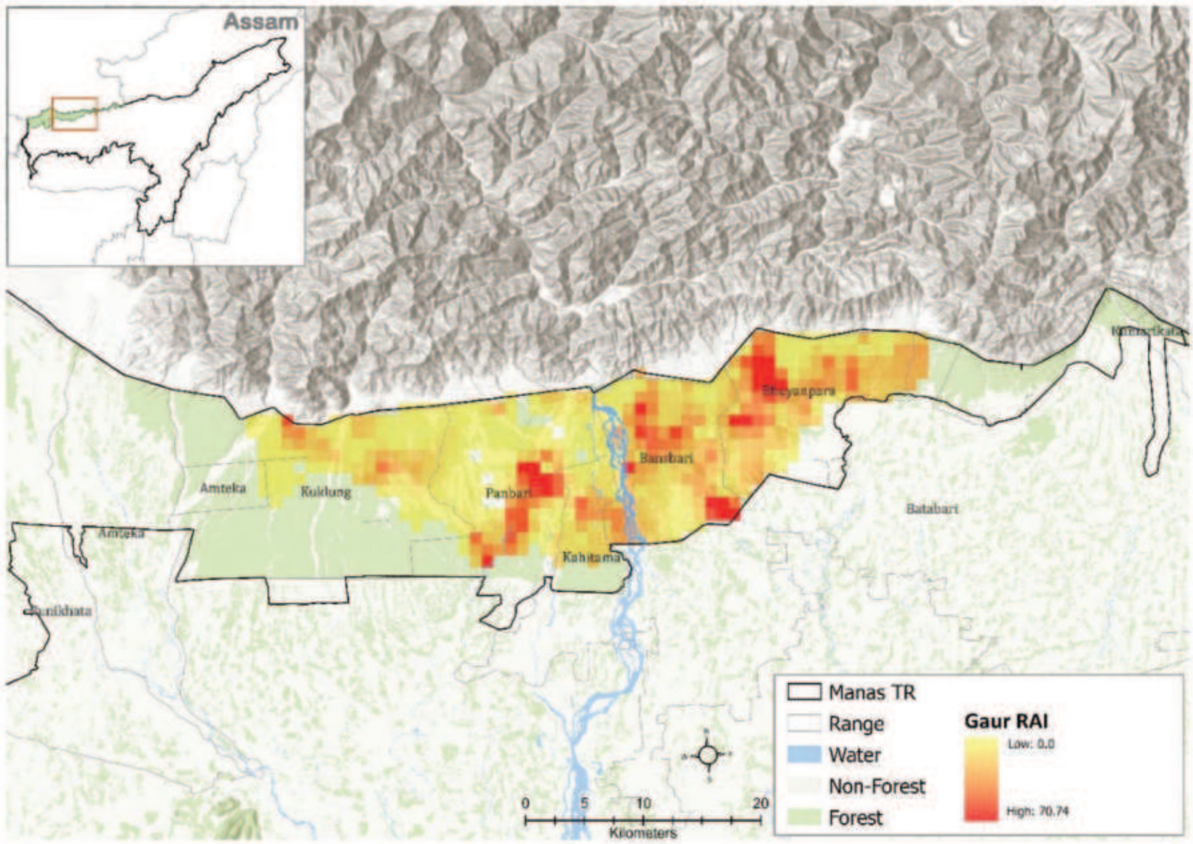


Figure VI. 31: Spatial relative abundance of gaur in Manas tiger reserve.

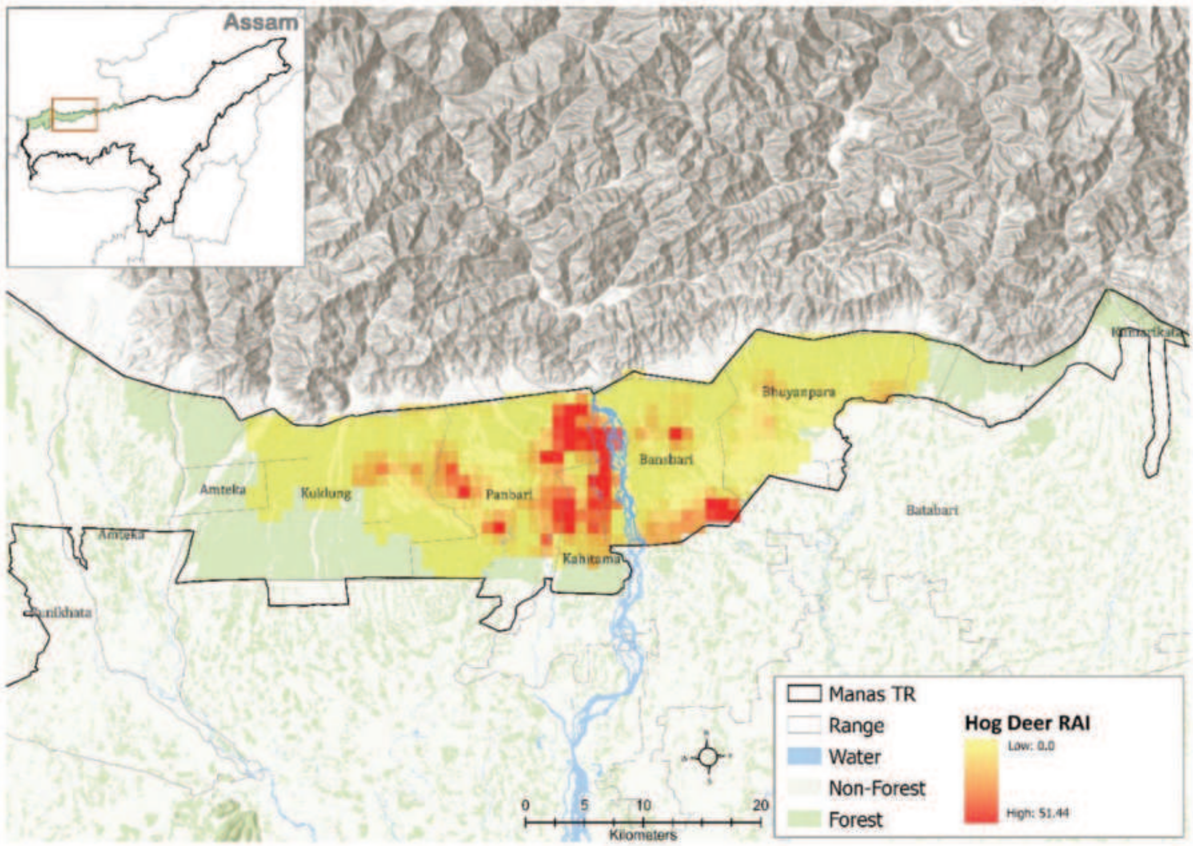


Figure VI. 32: Spatial relative abundance of hog deer in Manas tiger reserve.

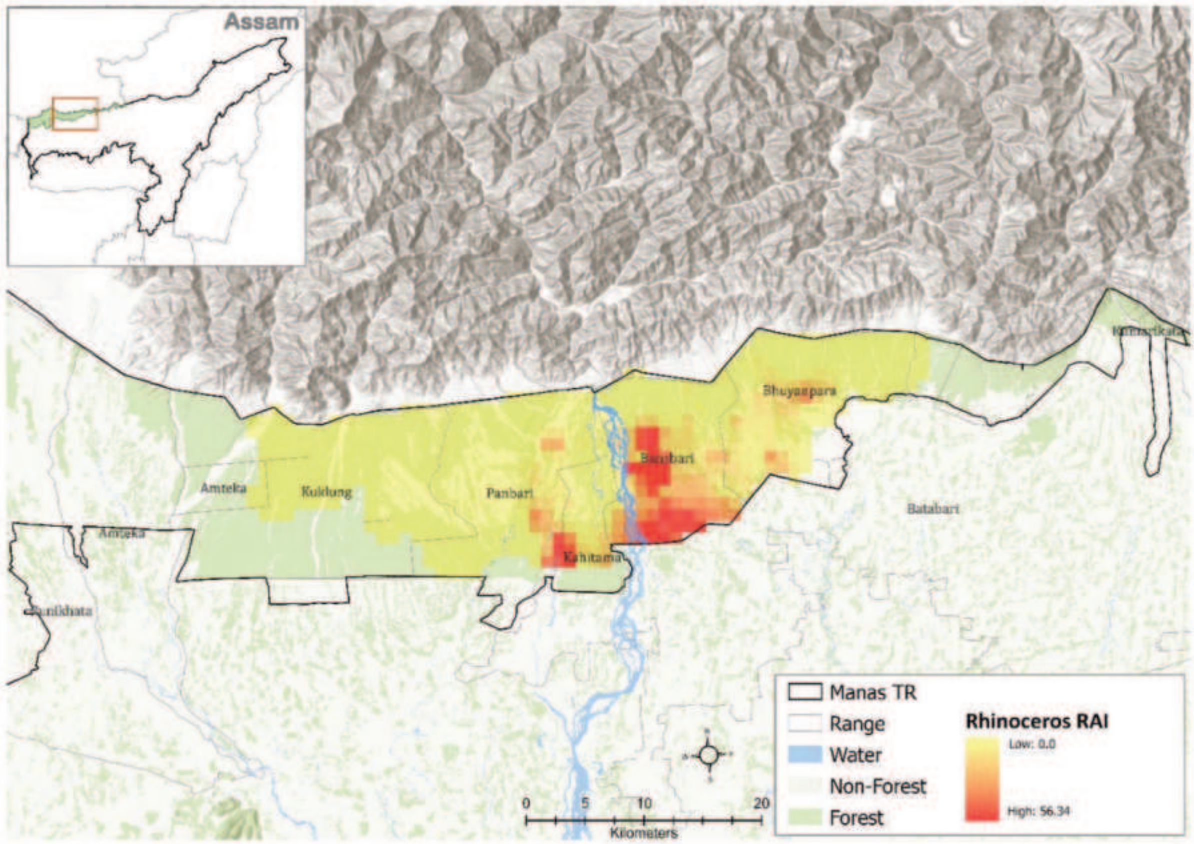


Figure VI. 33: Spatial relative abundance of rhinoceros in Manas tiger reserve.

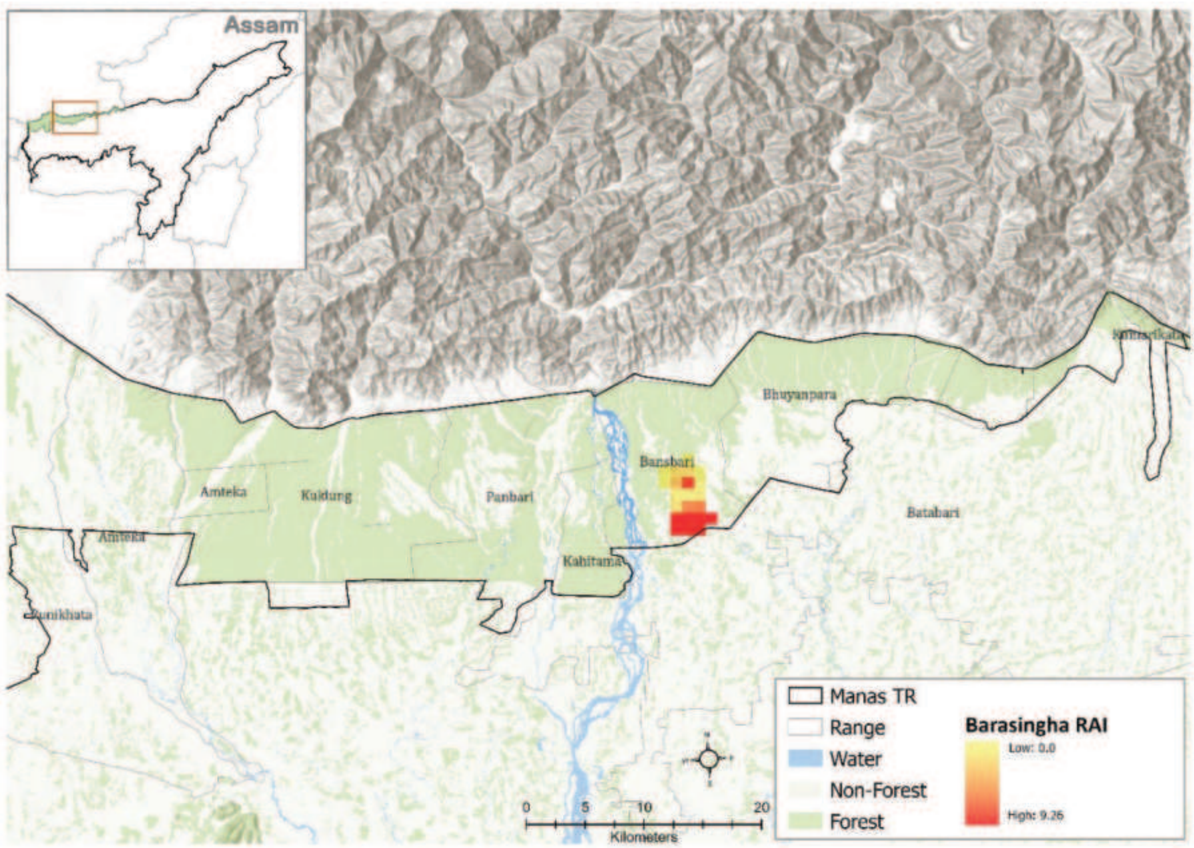


Figure VI. 34: Spatial relative abundance of barasingha in Manas tiger reserve.

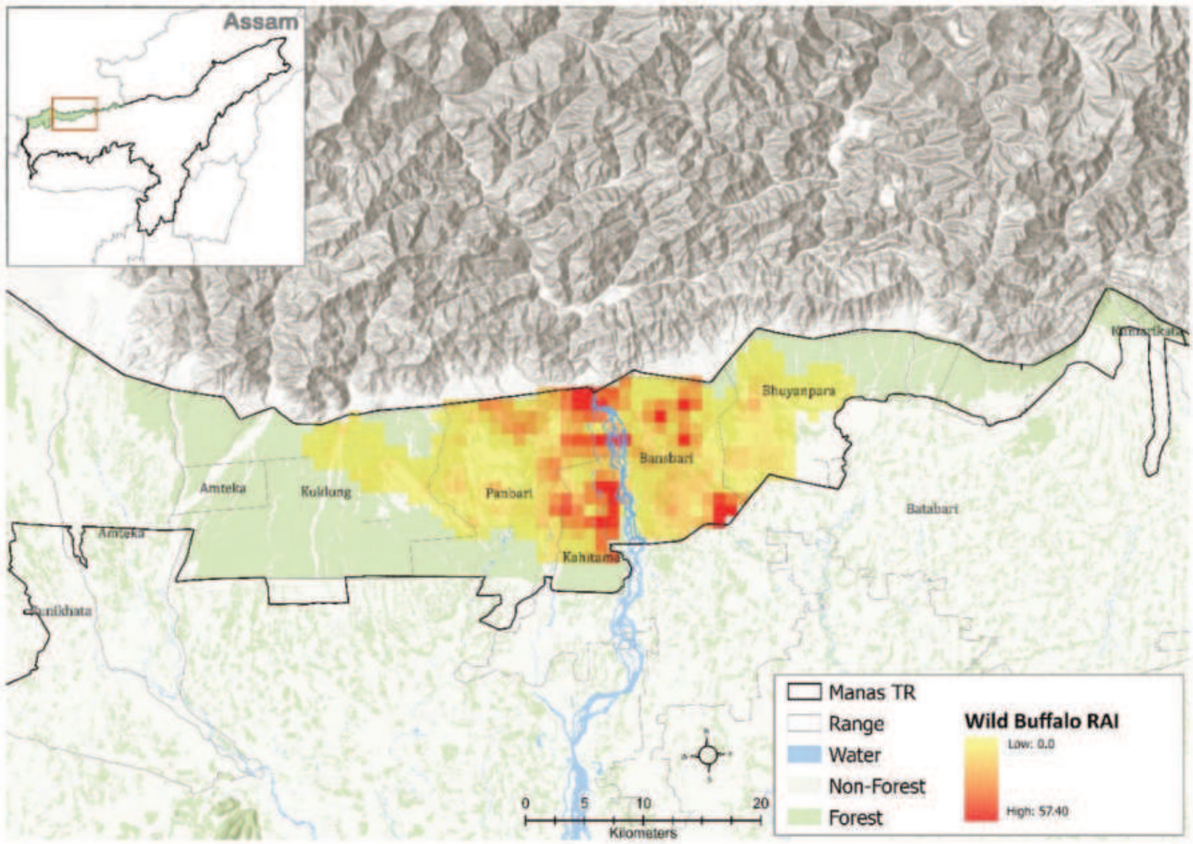


Figure VI. 35: Spatial relative abundance of wild buffalo in Manas tiger reserve.

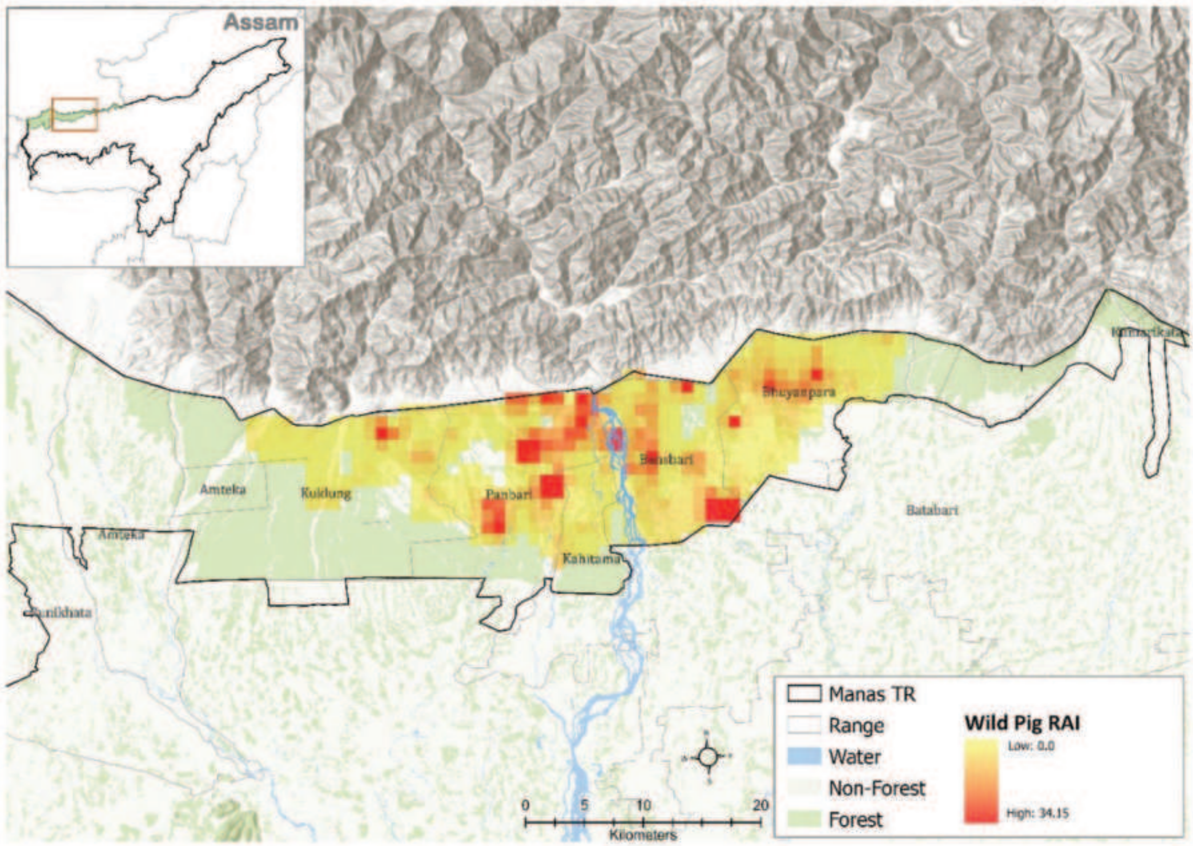


Figure VI. 36: Spatial relative abundance of wild pig in Manas tiger reserve.

Orang Tiger Reserve

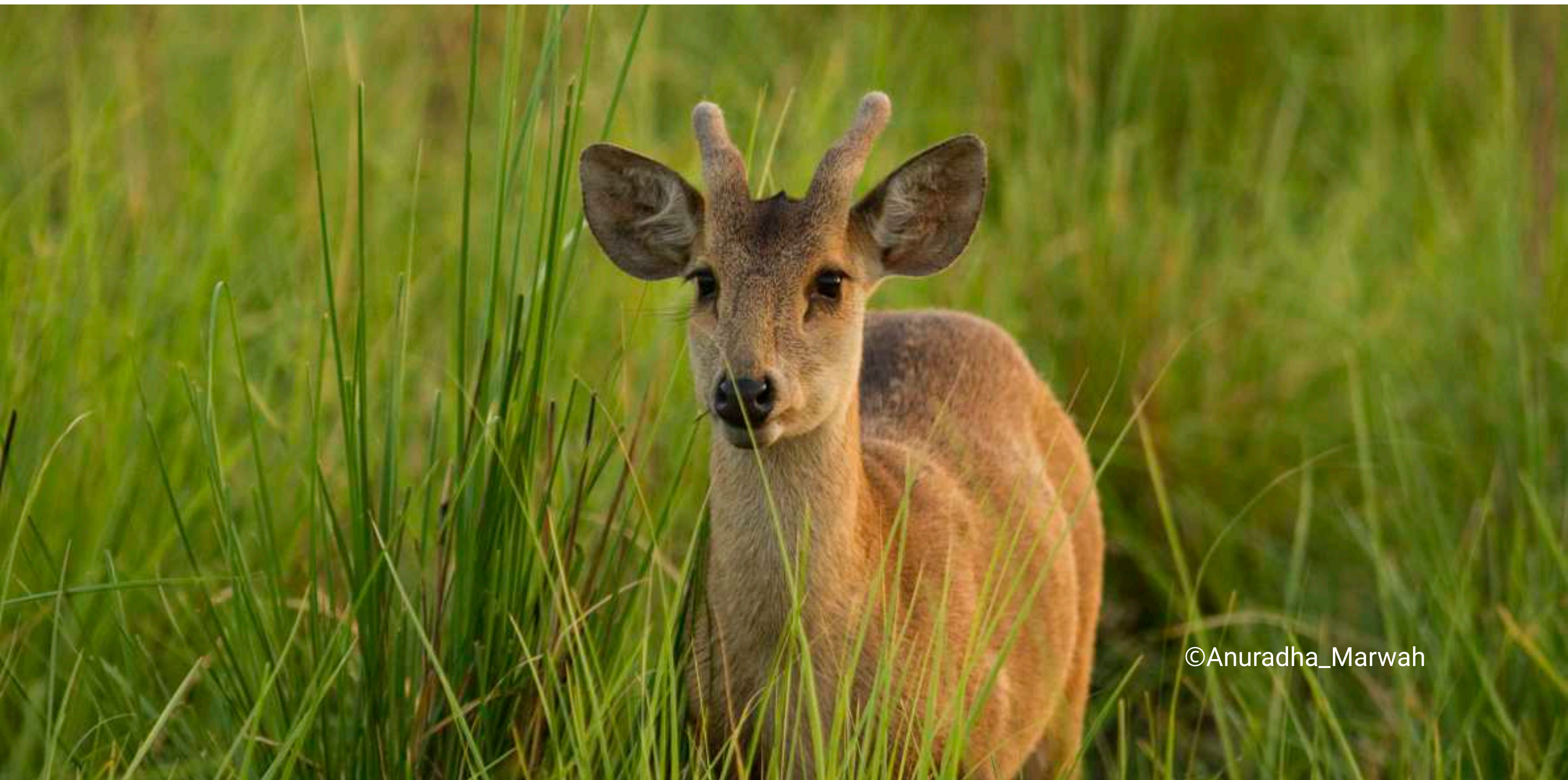
Orang tiger reserve, located in the Darrang and Sonitpur districts of Assam, covers approximately 492 km^2 and is situated on the northern bank of the Brahmaputra River. The reserve is characterized by its Himalayan mixed deciduous forests, wetlands, and eastern wet alluvial grasslands (Talukdar and Sarma, 2007). The landscape is influenced by annual flooding from the Brahmaputra, which replenishes the soil and creates rich, fertile grounds that support a vibrant ecosystem. Orang is home to the tiger, greater one horned rhinoceros, elephant, pygmy hog, and other notable species like swamp francolin and Bengal florican. The reserve's wetlands provide important feeding and breeding grounds for migratory waterfowl and aquatic species.

The ungulate diversity at Orang tiger reserve is relatively limited, comprising hog deer, wild pigs, and rhinoceros. Among these, hog deer are the most abundant followed by wild pigs. The rhinoceros population, as reported by the Assam Forest Department in 2022, stands at 125 individuals.

The hog deer and wild pig populations are primarily concentrated in the short grassland areas on the eastern and western sides of the reserve (Figure VI. 37 & Figure VI. 39). Illegal cattle grazing poses a significant threat to wild ungulate populations by creating competition for forage resources. Additionally, poaching for bushmeat remains a critical challenge, further impacting the populations of these species. To ensure the long-term conservation of Orang's wildlife, effective protection measures are imperative. This includes the consistent wildlife monitoring to mitigate threats and promote sustainable population recovery.

Table VI. 3: Model statistics and parameter estimates of line transect based on distance sampling for ungulates in Orang tiger reserve.

Species	Detection probability (SE)	Groups Detected	Mean Group size (SE)	Group density [SE]	Density [SE]
Wild-Pig	0.50 (0.05)	41	2.39 (0.20)	6.14 (1.45)	14.14 (3.57)
Hog Deer	0.26 (0.02)	183	3.71 (0.65)	33.05 (3.44)	80.21 (15.31)



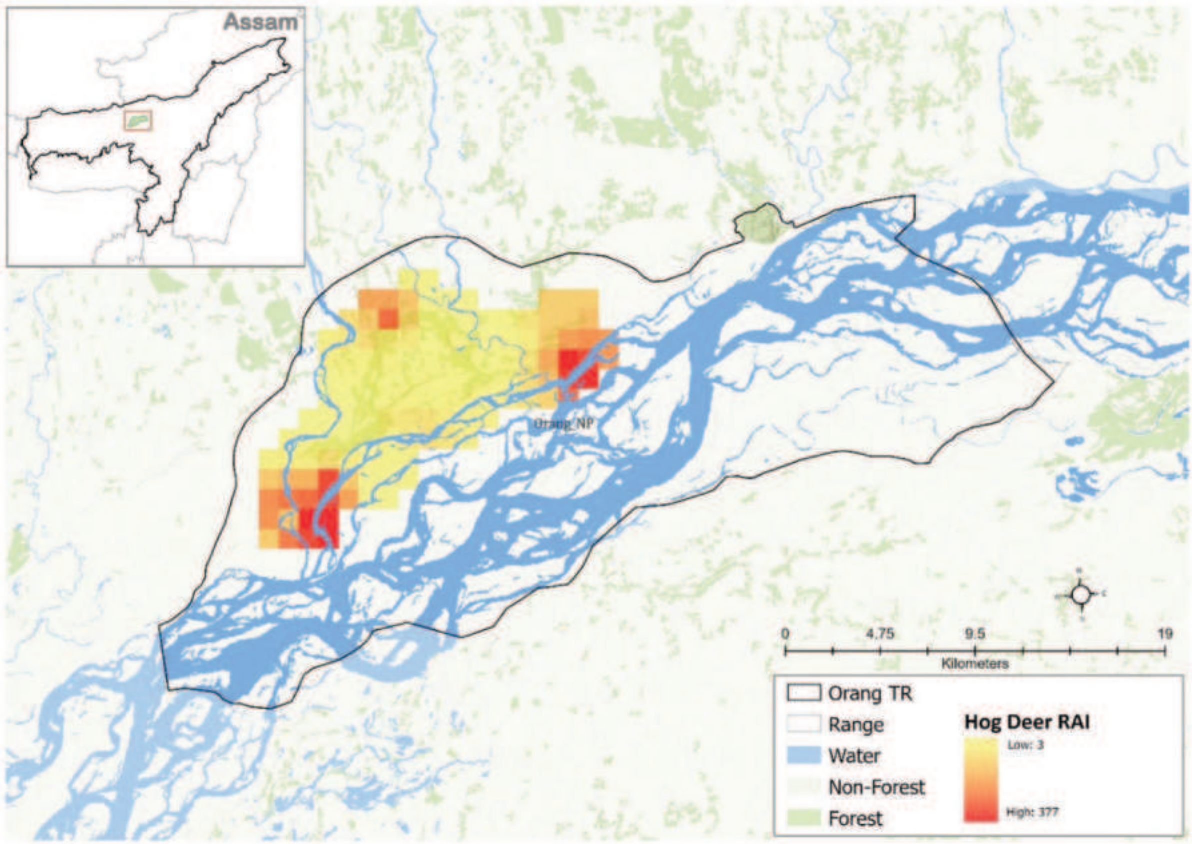


Figure VI. 37: Spatial relative abundance of hog deer in Orang tiger reserve.

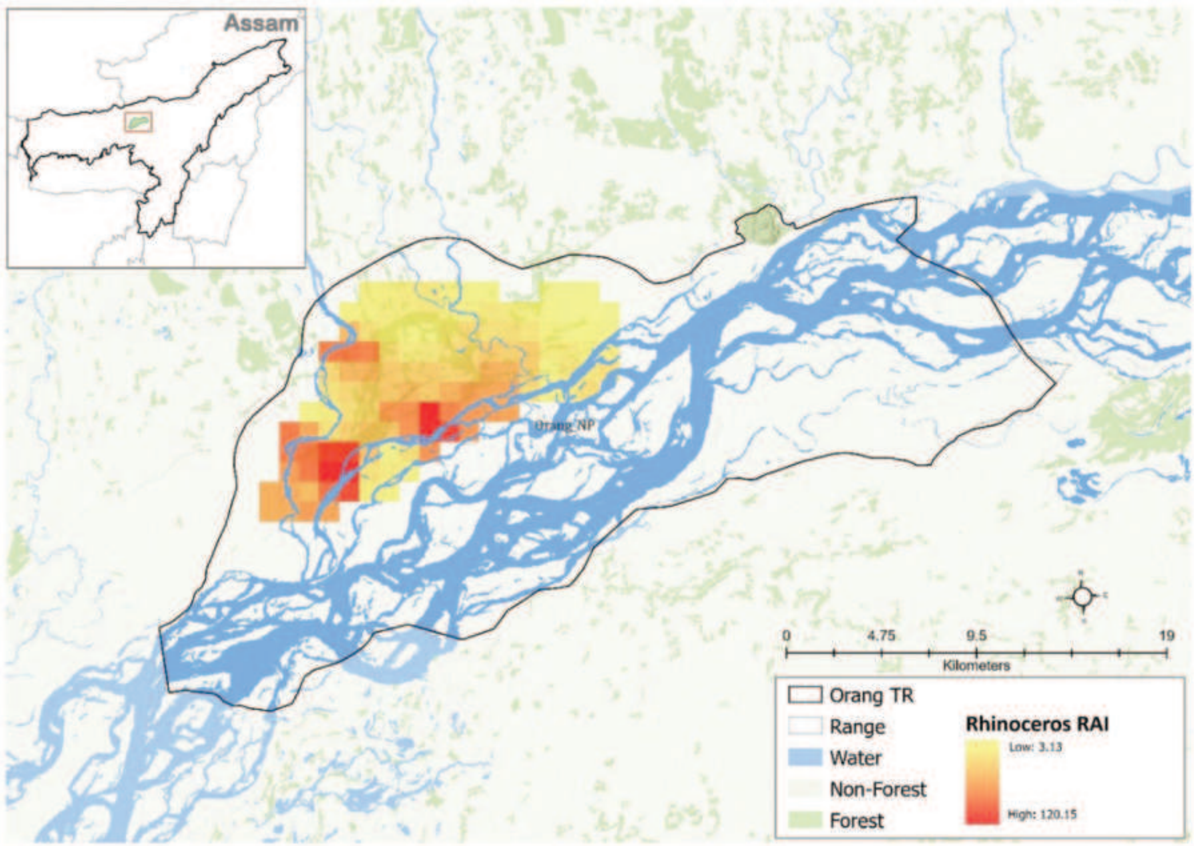


Figure VI. 38: Spatial relative abundance of rhinoceros in Orang tiger reserve.

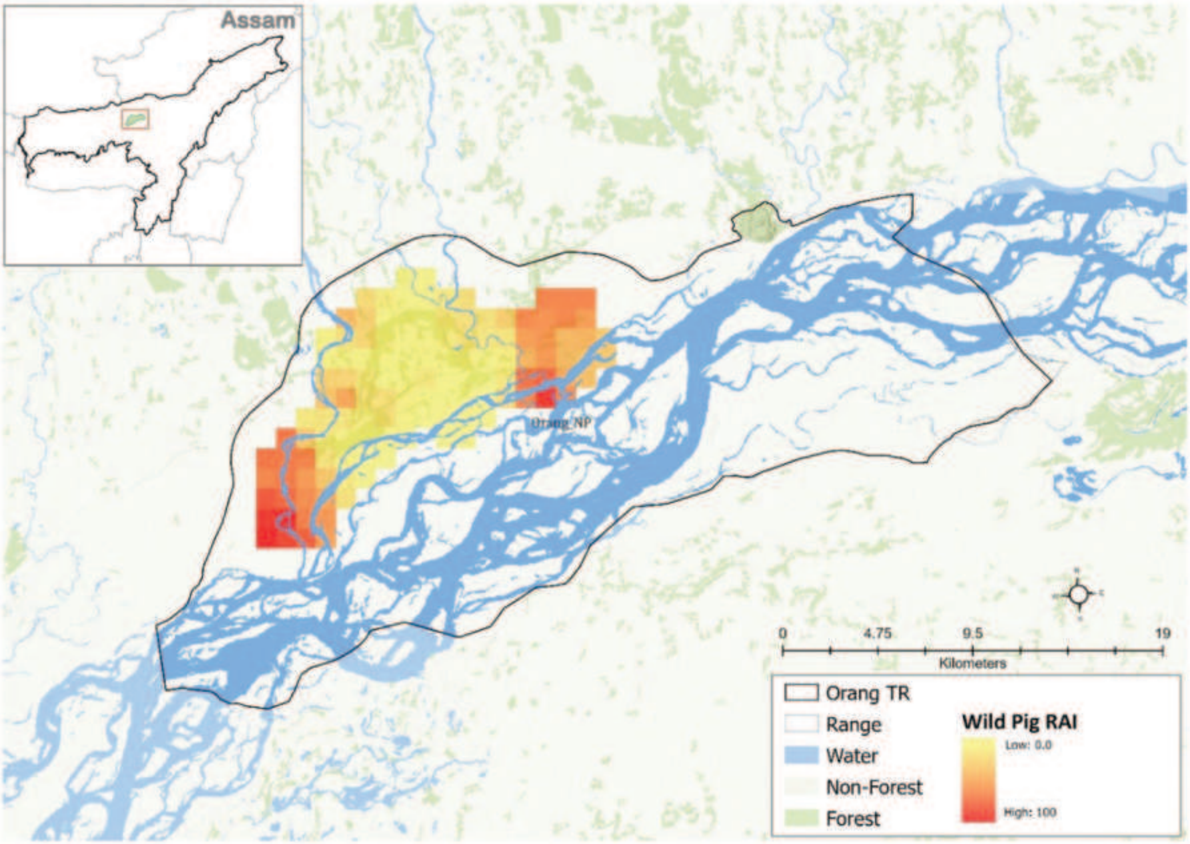


Figure VI. 39: Spatial relative abundance of wild pig in Orang tiger reserve.

Nameri Tiger Reserve

Nameri tiger reserve, located in the Sonitpur district of Assam, covers approximately 464 km^2 and lies at the foothills of the Eastern Himalayas, bordering the Pakke tiger reserve in Arunachal Pradesh. The reserve is characterized by its rich and varied landscapes, including tropical moist deciduous forests, semi-evergreen forests, grasslands, and riparian ecosystems along the jia-bhorali River (Saikia and Saikia, 2012). Nameri is home to key species such as the tiger, elephant, leopard, clouded leopard, wild pig, and gaur, as well as a diverse array of birdlife, including the white-winged wood duck. The mixed habitat of Nameri tiger reserve, coupled with its connectivity to Pakke tiger reserve, provides a diverse forage base to sustain ungulates like sambar and barking deer, Himalayan serow, and several species of primates, reptiles, and amphibians.

Due to limited data, distance-based analysis for estimating ungulate density is calculated only for barking deer and wild pig. However, the relative abundance index derived from photo-capture events offers insights into the spatial distribution of other ungulates within Nameri tiger reserve. Sambar appears to be the most abundant ungulate species (Figure VI. 40), followed by barking deer (Figure VI. 41), wild pig (Figure VI. 44), gaur (Figure VI. 42), and hog deer (Figure VI. 43). Hog deer are primarily confined to the riverine grassy expanses of Nameri, while other ungulate species are distributed throughout the reserve.

Poaching for bushmeat remains a significant threat to herbivore populations, alongside illegal cattle grazing, which exacerbates competition for forage resources. To ensure the long-term conservation of Nameri tiger reserve, stringent protection measures are crucial. This includes consistent wildlife monitoring to address threats and support sustainable population recovery.

Table VI. 4: Model statistics and parameter estimates of line transect based on distance sampling for ungulates in Nameri tiger reserve.

Species	Detection probability (SE)	Groups Detected	Mean Group size (SE)	Group density [SE]	Density [SE]
Barking deer	0.27 (0.04)	46	1.7 (0.15)	10.59 (2.38)	18 (4.33)
Wild Pig	0.33 (0.07)	29	2.59 (0.33)	7.25 (2.18)	19 (6.22)

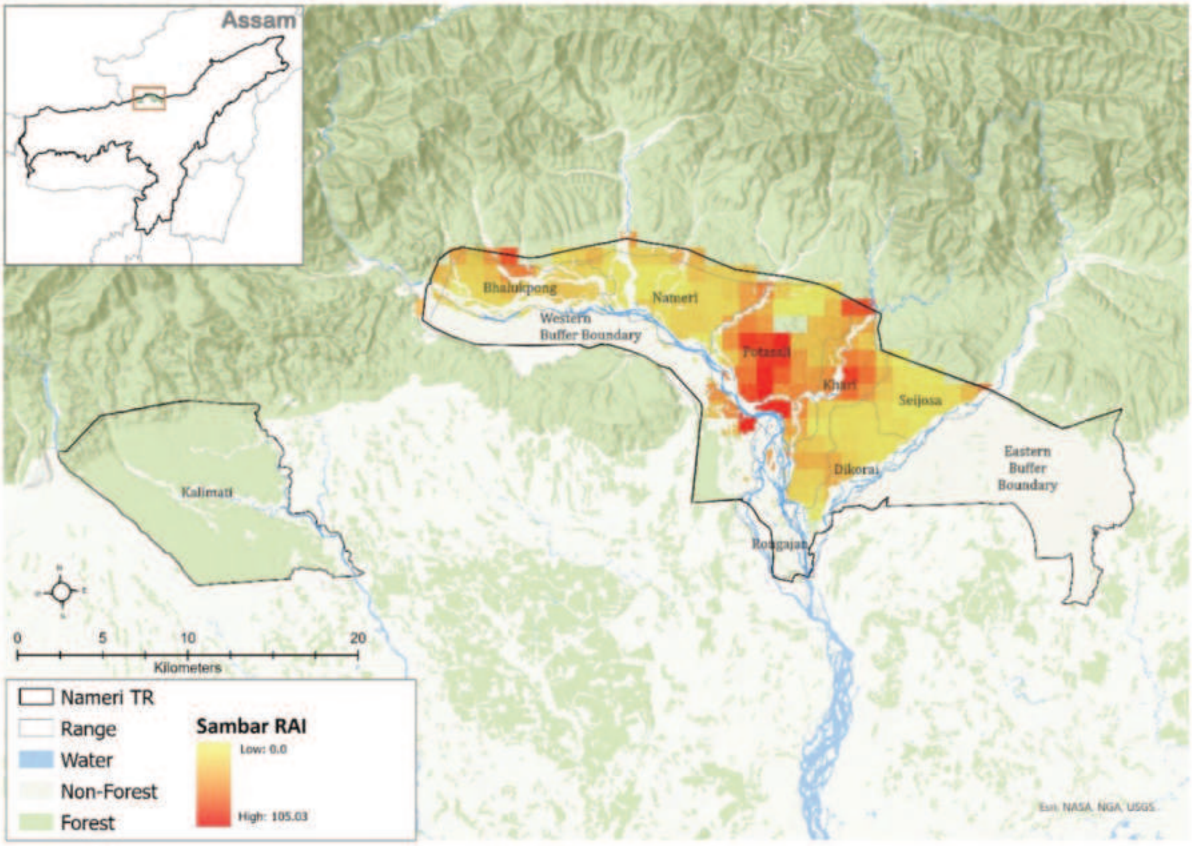


Figure VI. 40: Spatial relative abundance of sambar in Nameri tiger reserve.

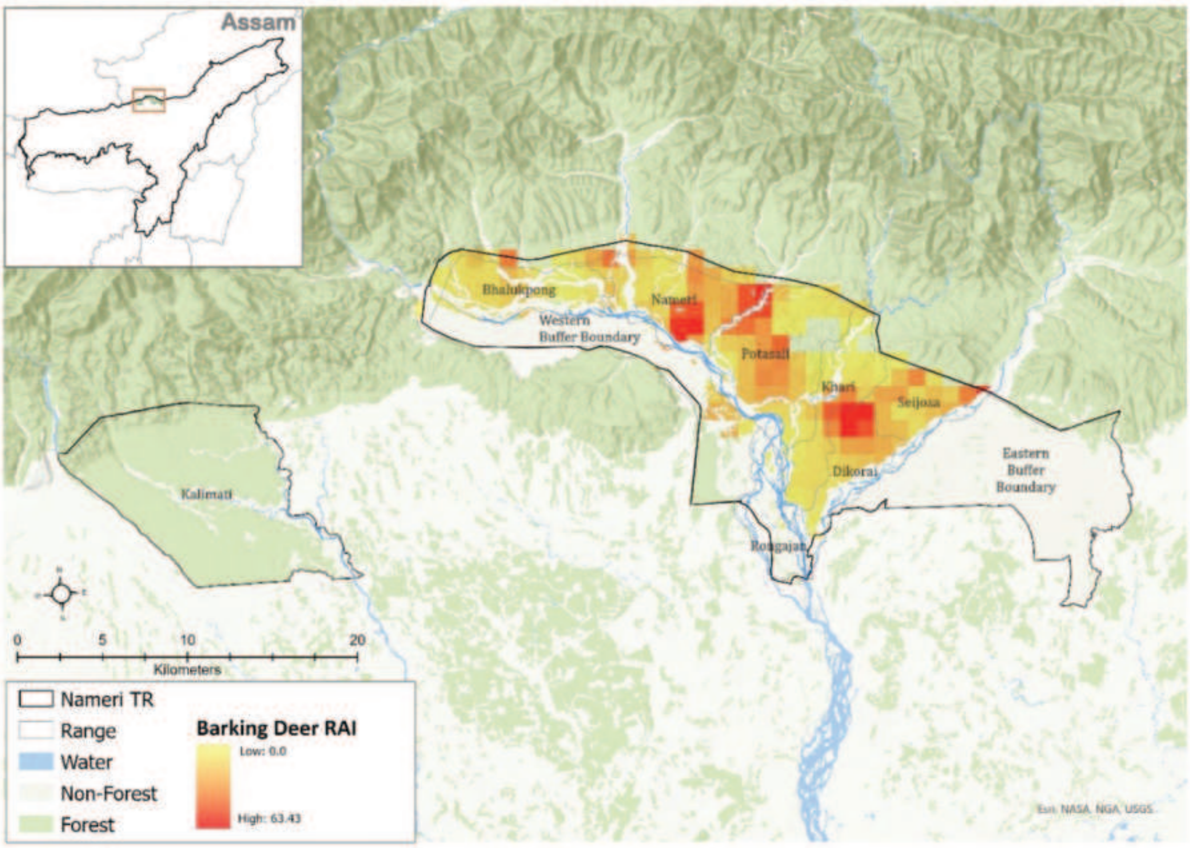


Figure VI. 41: Spatial relative abundance of barking deer in Nameri tiger reserve.

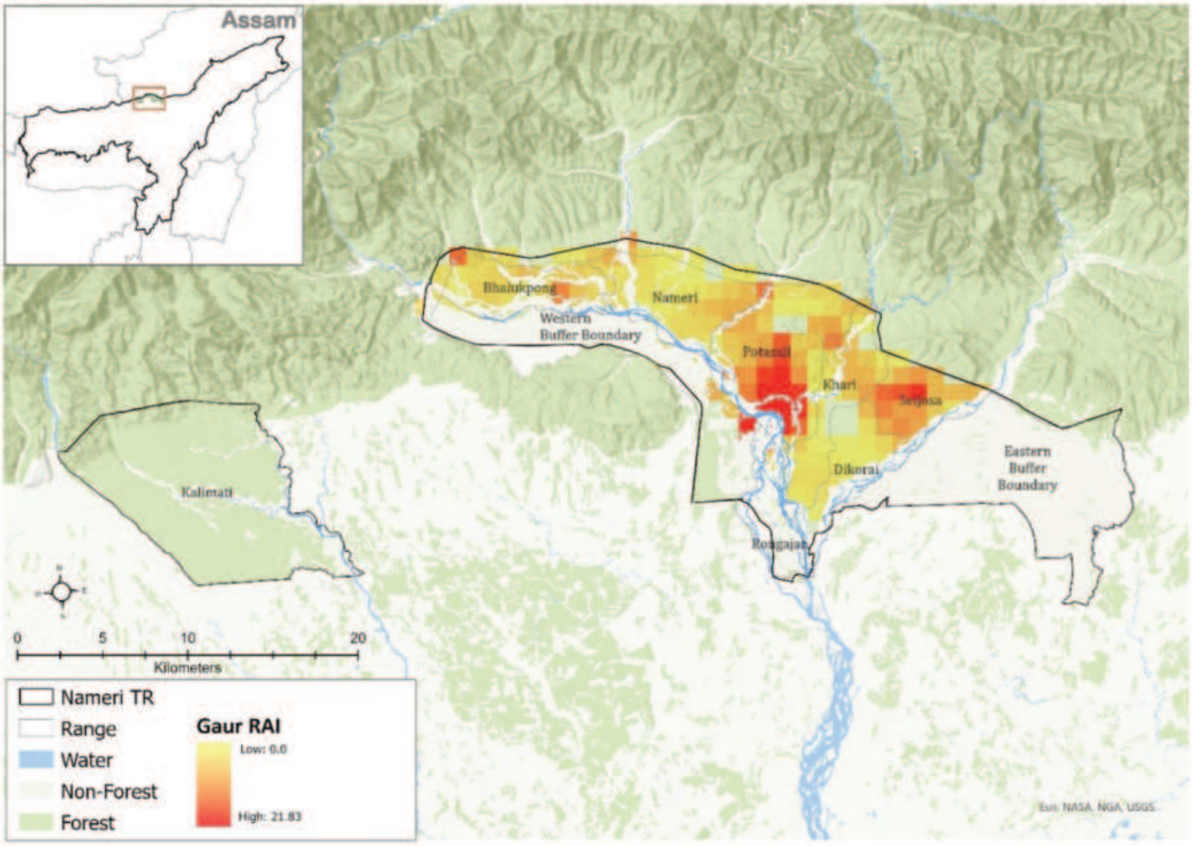


Figure VI. 42: Spatial relative abundance of gaur in Nameri tiger reserve.

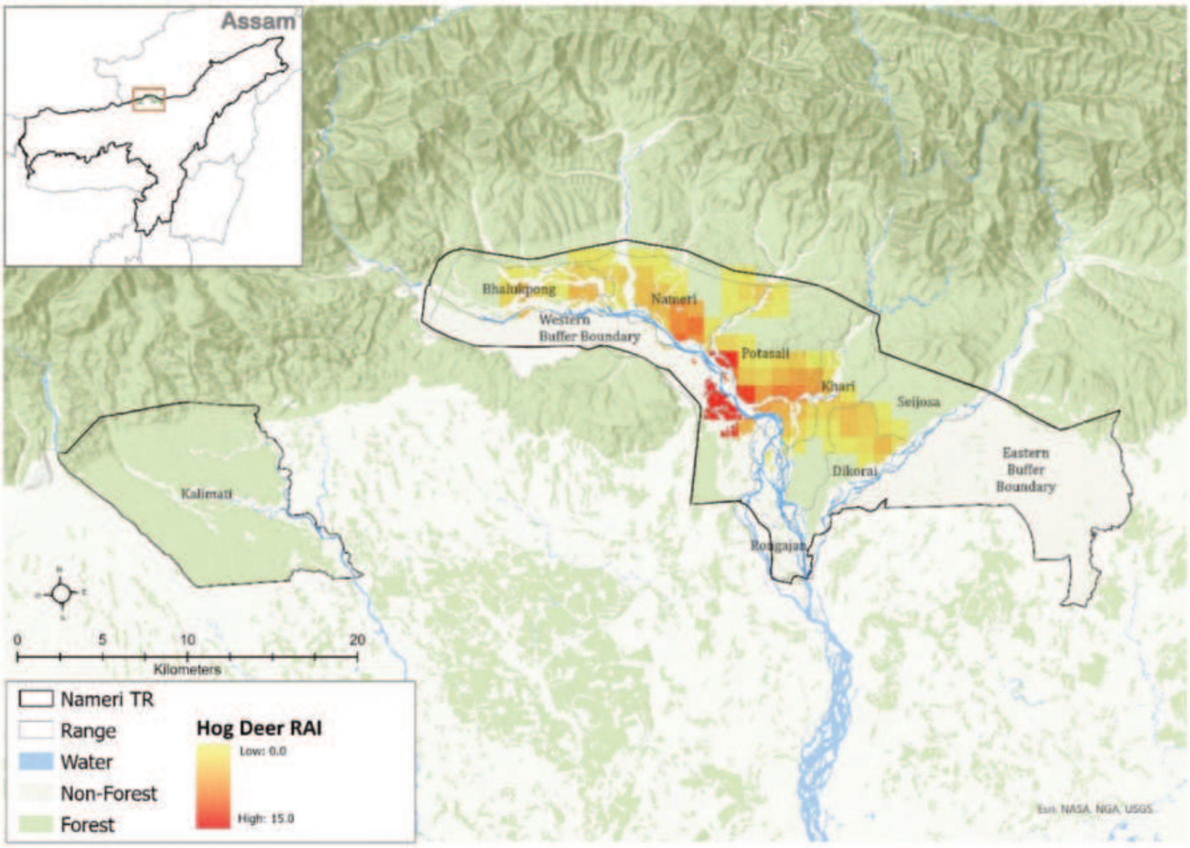


Figure VI. 43: Spatial relative abundance of hog deer in Nameri tiger reserve.

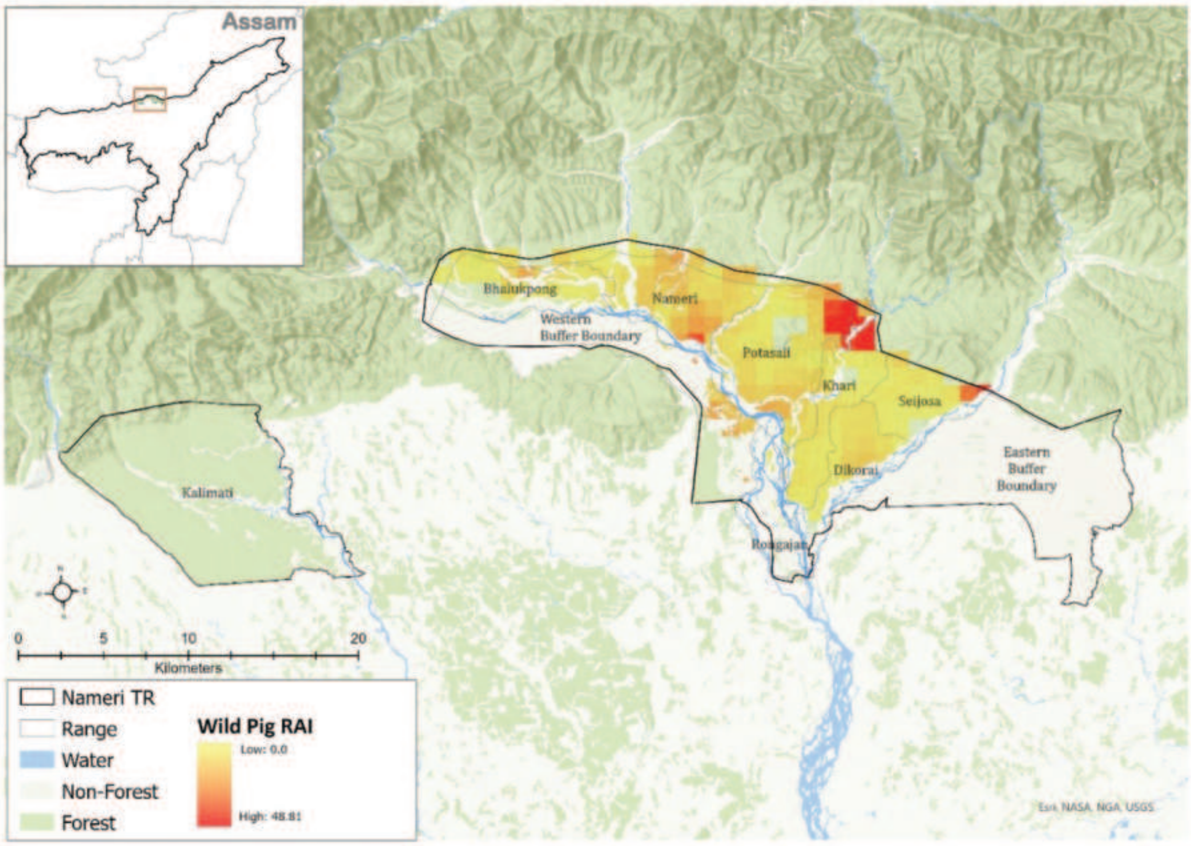


Figure VI. 44: Spatial relative abundance of wild pig in Nameri tiger reserve.

MIZORAM

Dampa Tiger Reserve

Dampa tiger reserve, located in the Mamit district of Mizoram, spans over 988 km^2. It is the only tiger reserve in Mizoram. Geographically this tiger reserve is located in Lushai hills and contiguous with Chittagong hill tracts of Bangladesh. It is also a trans-boundary conservation reserve as the western boundary of the tiger reserve shares international boundaries with Bangladesh. Vegetation of Dampa is characterised by different forest types including wet evergreen in the valleys, moist deciduous and tropical grasslands in the higher elevations. The reserve is home to elusive tigers, clouded leopards, leopard cats, gaur, and serow, as well as a rich diversity of primates such as the Hoolock gibbon, capped langur, and over 150 species of birds.

Since line transect-based distance sampling could not be done in Dampa, relative abundance indices of ungulate species based on camera trap images are calculated. An opportunistic camera trap sampling was done in Dampa, and camera traps were deployed in both the rages. Barking deer relative abundance is higher in Teirei range (Figure VI. 46), while Phuldengsei range has moderate abundance. However, gaur abundance is concentrated in Phuldengsei range and parts of Teirei range (Figure VI. 47). Sambar abundance is mostly concentrated in Teirei range and Phuldengsei range has moderate presence (Figure VI. 45). Wild pig abundance of Dampa is almost similar in both the range, and found in both dense and moderately dense forests (Figure VI. 48).

The tiger reserve is vulnerable in terms of poaching of wildlife resources. To secure the long-term conservation success of Dampa tiger reserve, it is essential to implement strong protection measures, maintain strong and consistent wildlife monitoring, habitat management, and engage concerned communities to address threats and help in recovery of wildlife resources.

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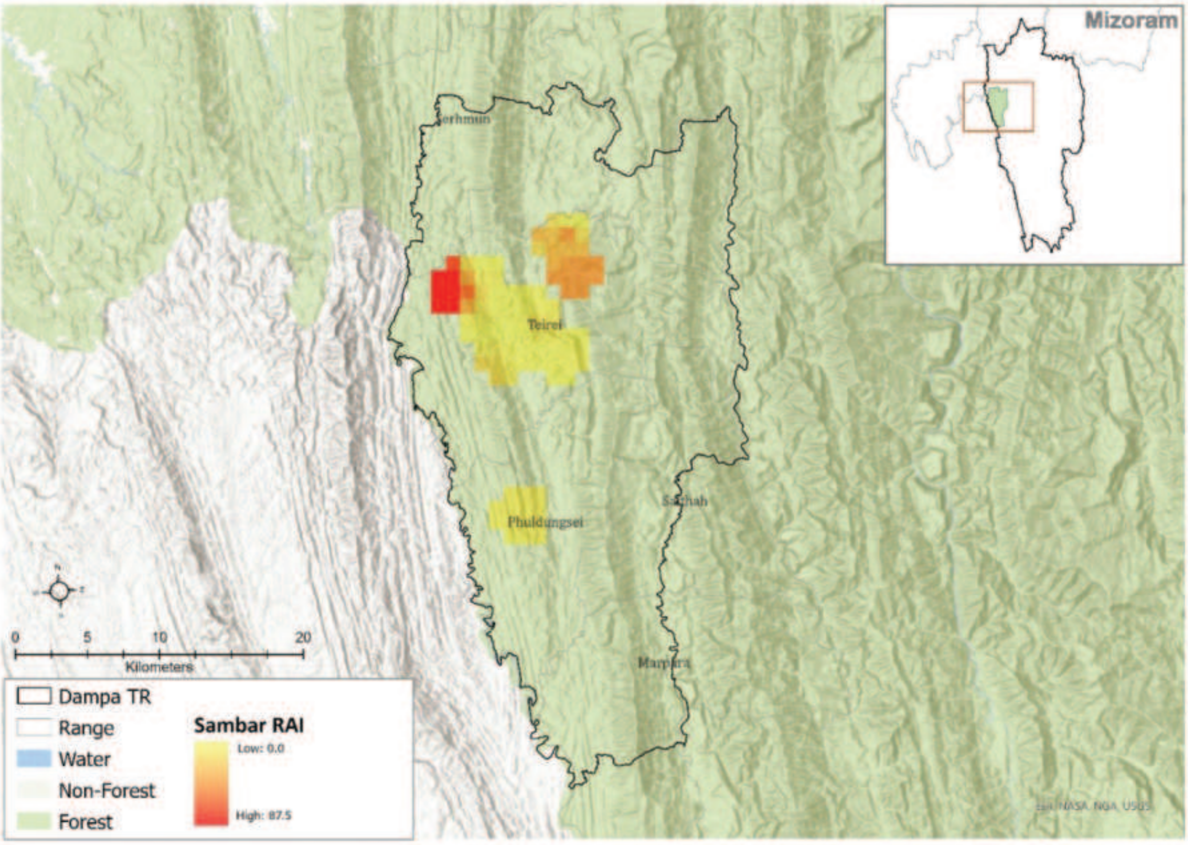

Figure VI. 45: Spatial relative abundance of sambar in Dampa tiger reserve.

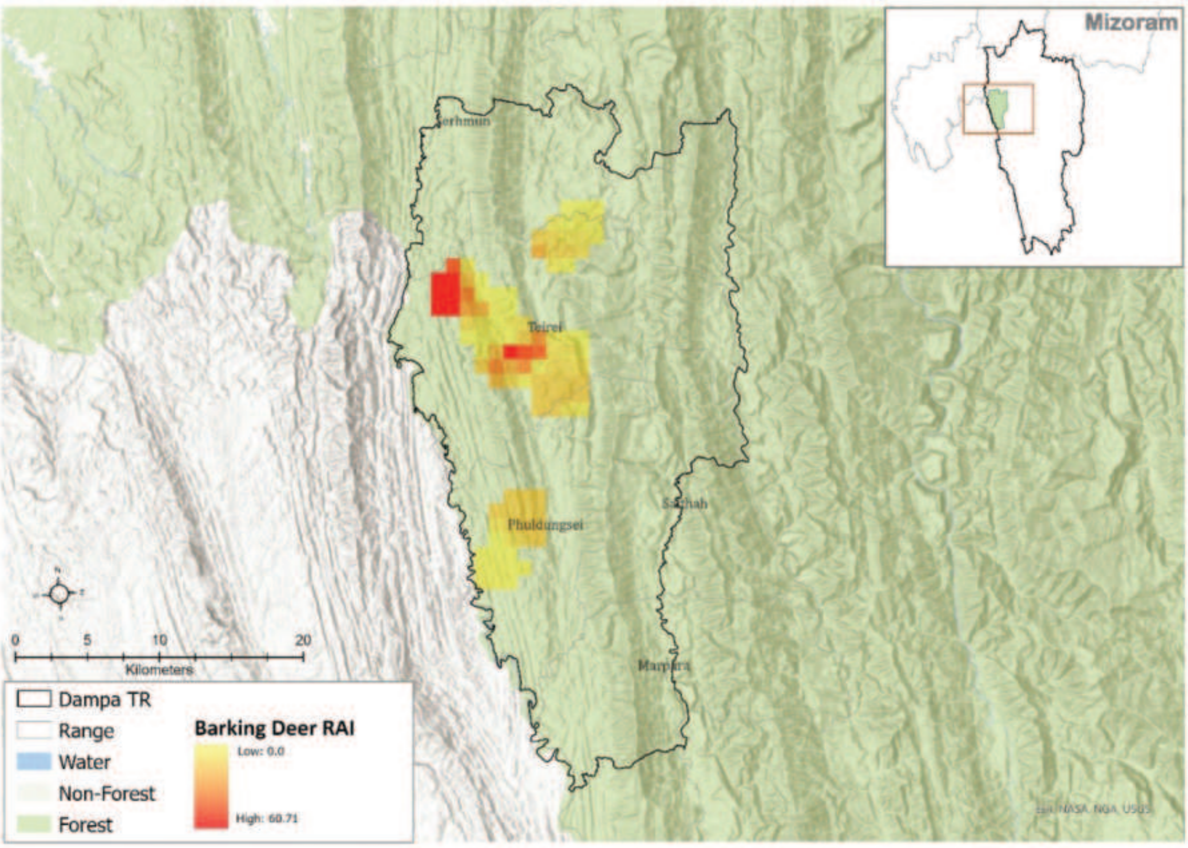

Figure VI. 46: Spatial relative abundance of barking deer in Dampa tiger reserve.

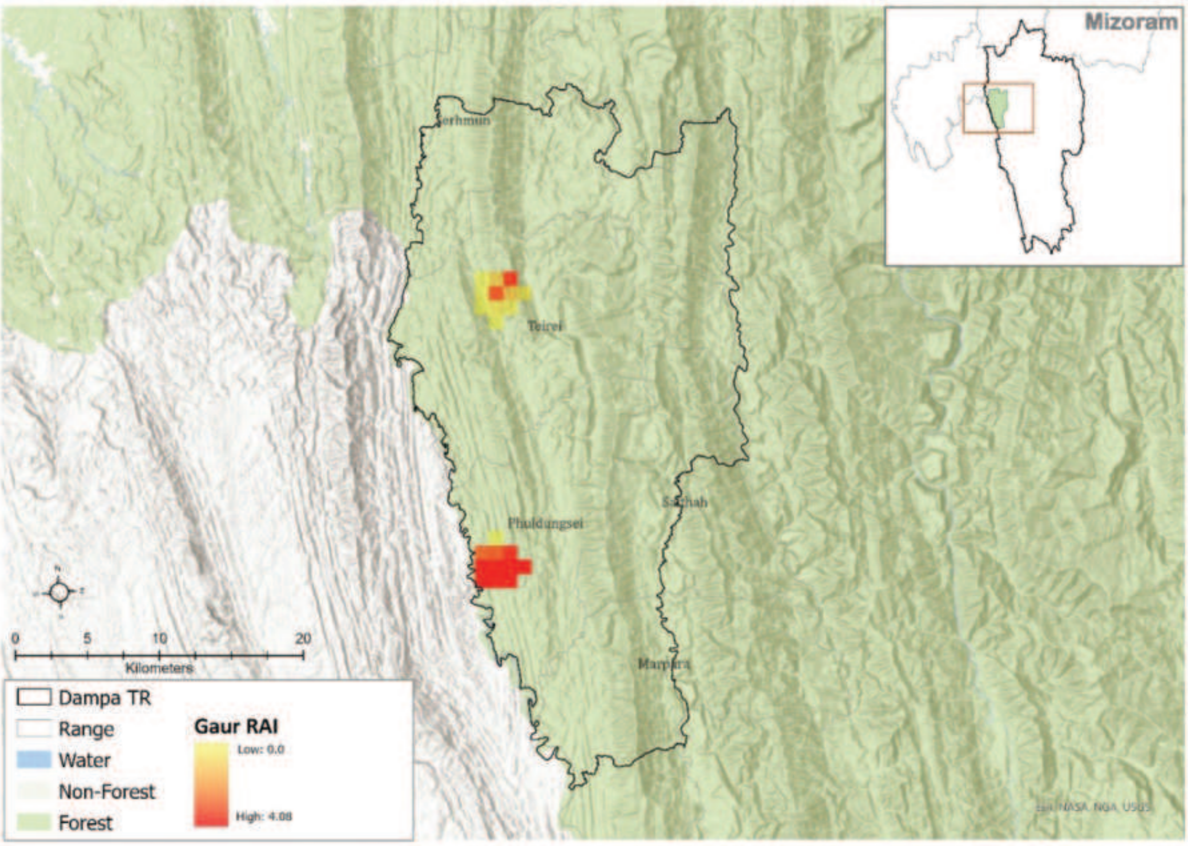

Figure VI. 47: Spatial relative abundance of gaur in Dampa tiger reserve.

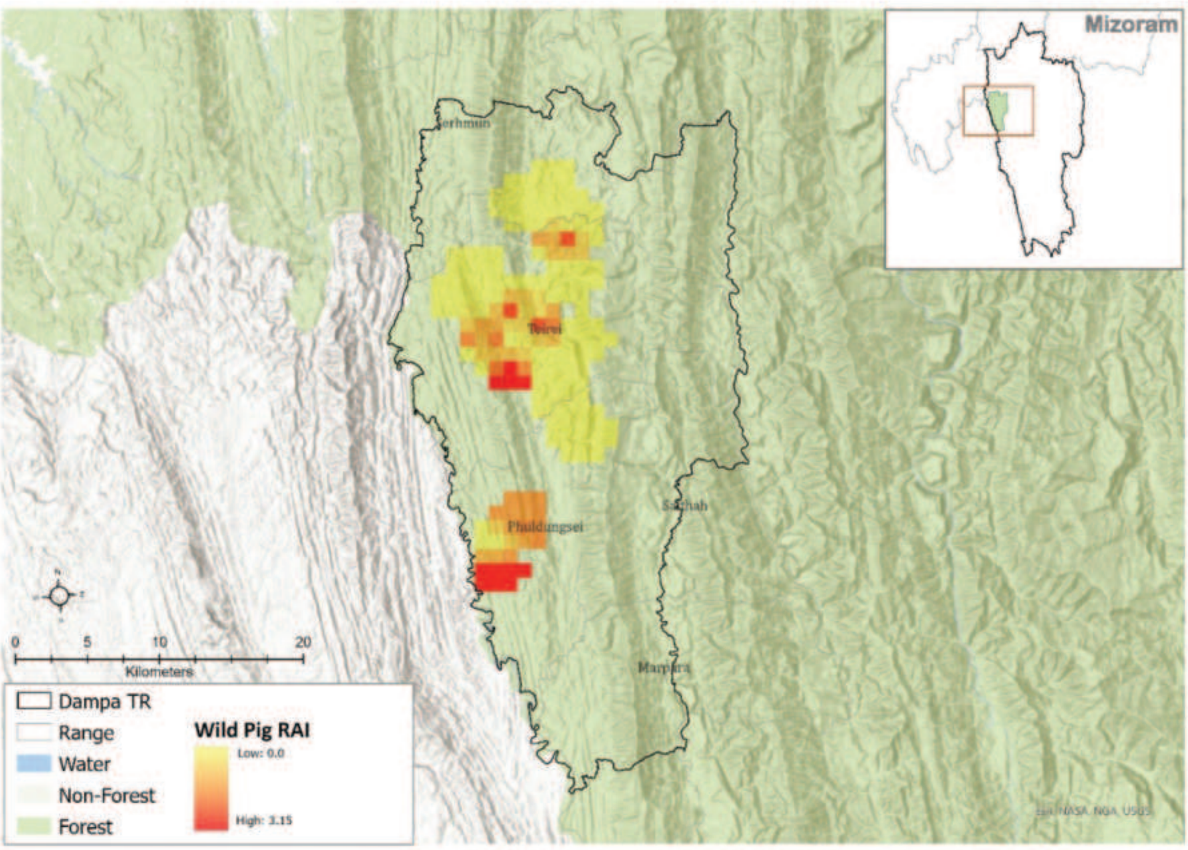

Figure VI. 48: Spatial relative abundance of wild pig in Dampa tiger reserve.

WEST BENGAL

Buxa Tiger Reserve

Buxa tiger reserve, located in the Alipurduar district of West Bengal, spans over 758 km^2 and lies at the confluence of the Himalayas and the Brahmaputra Plains. This reserve encompasses a mix of tropical moist-deciduous forests dominated by sal, semi-evergreen forests, grasslands, and riparian ecosystems, shaped by the dynamic flow of rivers Jayanti and Raidak (Sivakumar *et al*., 2006). Its diverse landscape supports a remarkable range of flora and fauna, including over 680 plant species and numerous endangered species. Buxa is home to tigers, Indian leopards, elephants, and gaur. It also serves as a crucial habitat for several bird species, including the rufous-necked hornbill, alongside an impressive diversity of butterflies and herpetofauna.

Herbivore densities in the Buxa tiger reserve were low, and line transect observation are insufficient for spatial densities estimates, and only distance analysis base densities of barking deer and wild pig were calculated. Hence, relative abundance indices were derived using camera trap photo-capture events. Chital and hog deer abundance is high in North rydak range (Figure VI. 49 & Figure VI. 53). Sambar, gaur, barking deer, and wild pig are present throughout the tiger reserve. Relative abundance of sambar is high in Jainti range followed by West rajabhatkhawa (Figure VI. 50). Gaur abundance is high in East rajabhatkhawa and Kumargram (Figure VI. 52). Barking deer found in high abundance in Jainti range (Figure VI. 51). Higher wild pig abundance is concentrated in some area of each range (Figure VI. 54).

Reducing biotic pressure through ecologically sustainable livelihood options for local communities, addressing human-wildlife conflicts, enhancing protection through consistent monitoring of wildlife are crucial measures for Buxa. Additionally, retrofitting safeguards are essential to prevent train collisions involving ungulates. The tiger reserve management should also prioritize chital breeding using predator-proof enclosures, with subsequent releases in these areas to facilitate tiger recovery.

Table VI. 5: Model statistics and parameter estimates of line transect based on distance sampling for ungulates in Buxa tiger reserve.

Species	Detection probability (SE)	Groups Detected	Mean Group size (SE)	Group density [SE]	Density [SE]
Barking Deer	0.25 (0.03)	114	1.21 (0.04)	4.83 (0.78)	6 (0.97)
Wild Pig	0.56 (0.07)	32	2.47 (0.31)	1.31 (0.27)	3 (0.79)

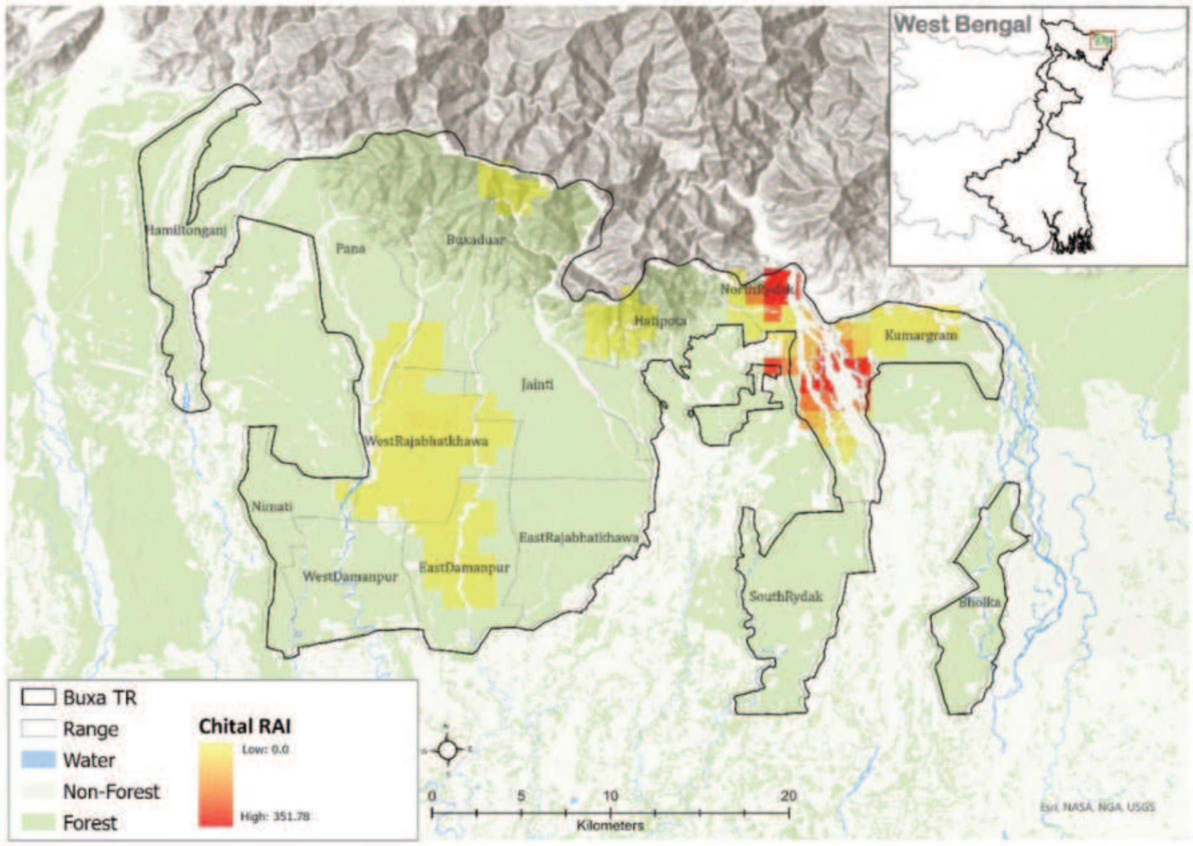

Figure VI. 49: Spatial relative abundance of chital in Buxa tiger reserve.

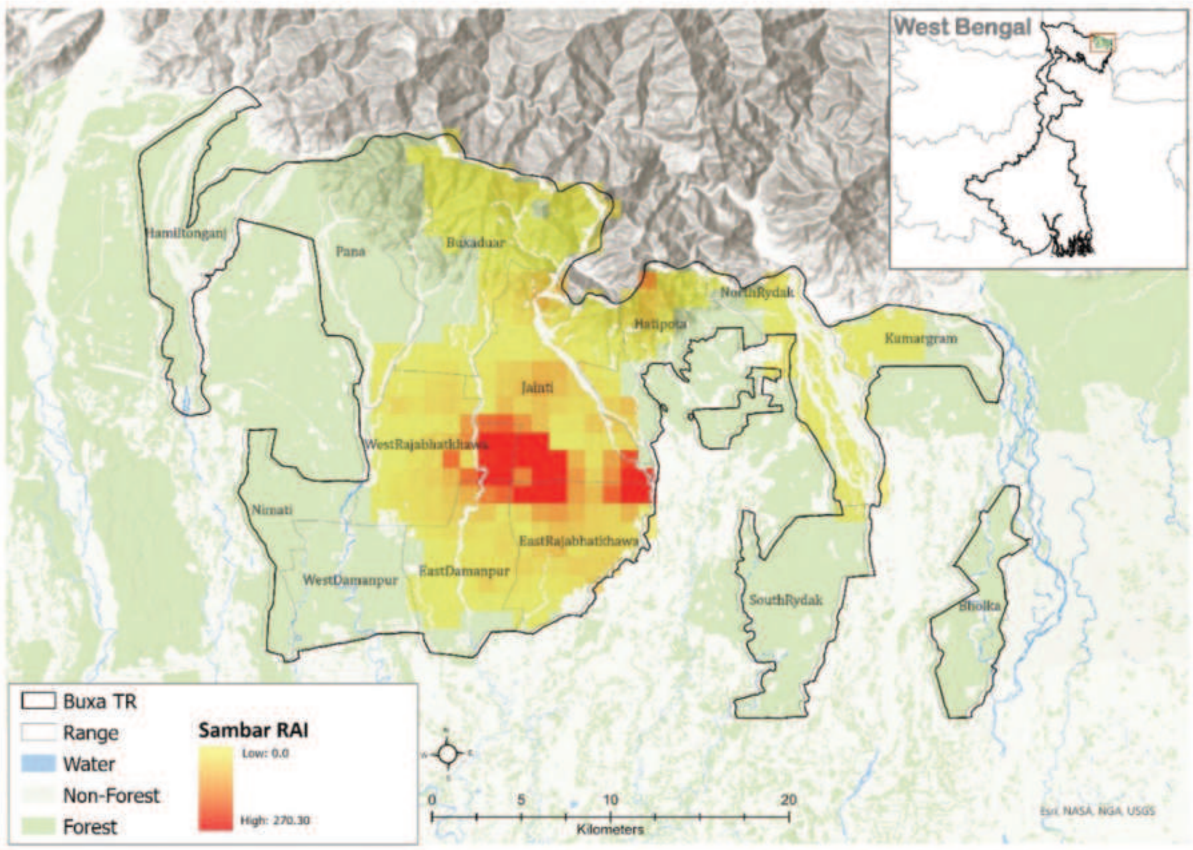

Figure VI. 50: Spatial relative abundance of sambar in Buxa tiger reserve.

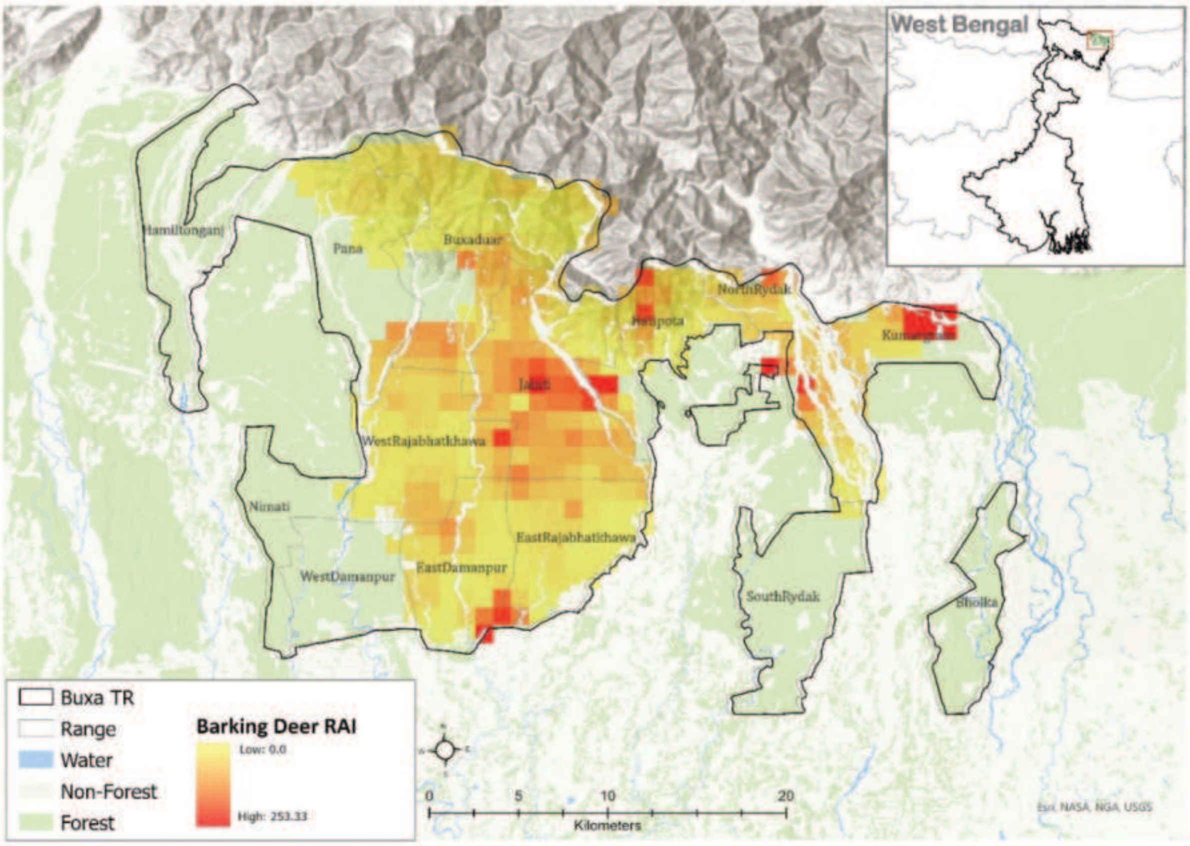

Figure VI. 51: Spatial relative abundance of barking deer in Buxa tiger reserve.

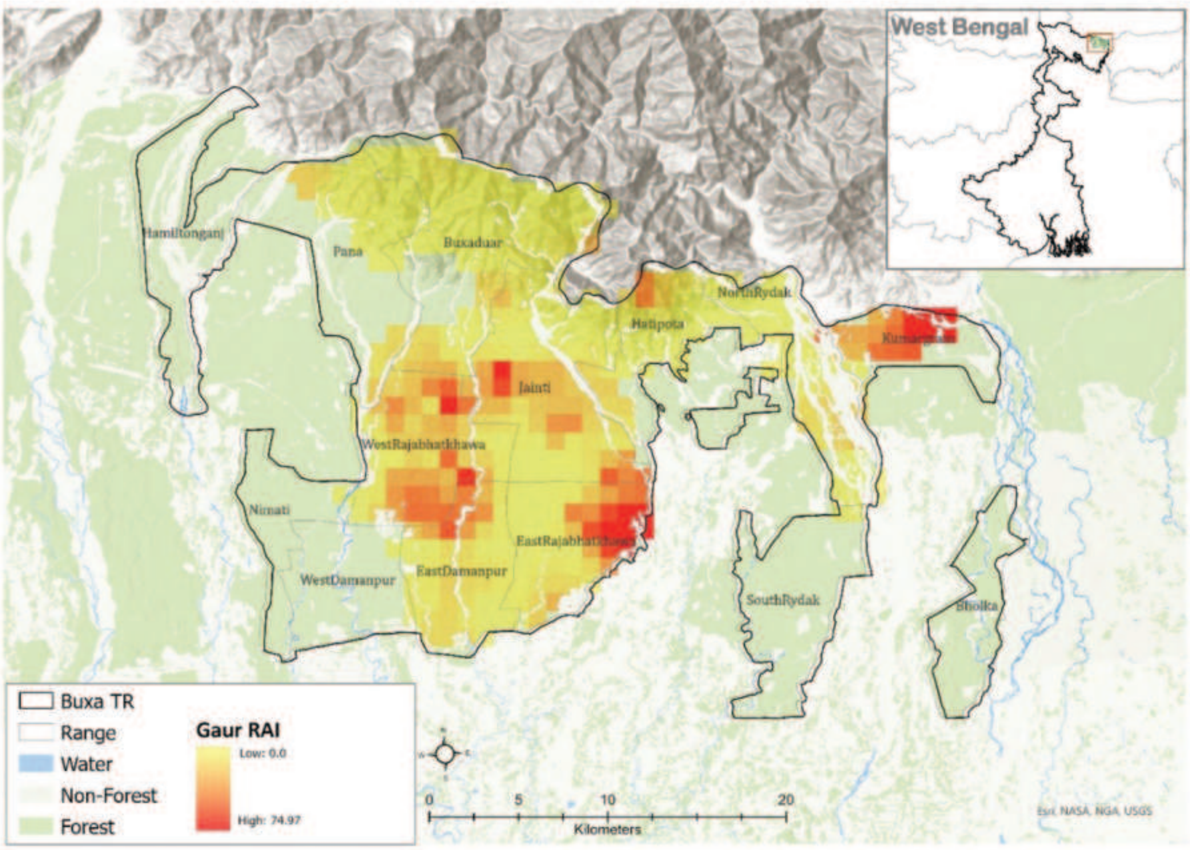

Figure VI. 52: Spatial relative abundance of gaur in Buxa tiger reserve.

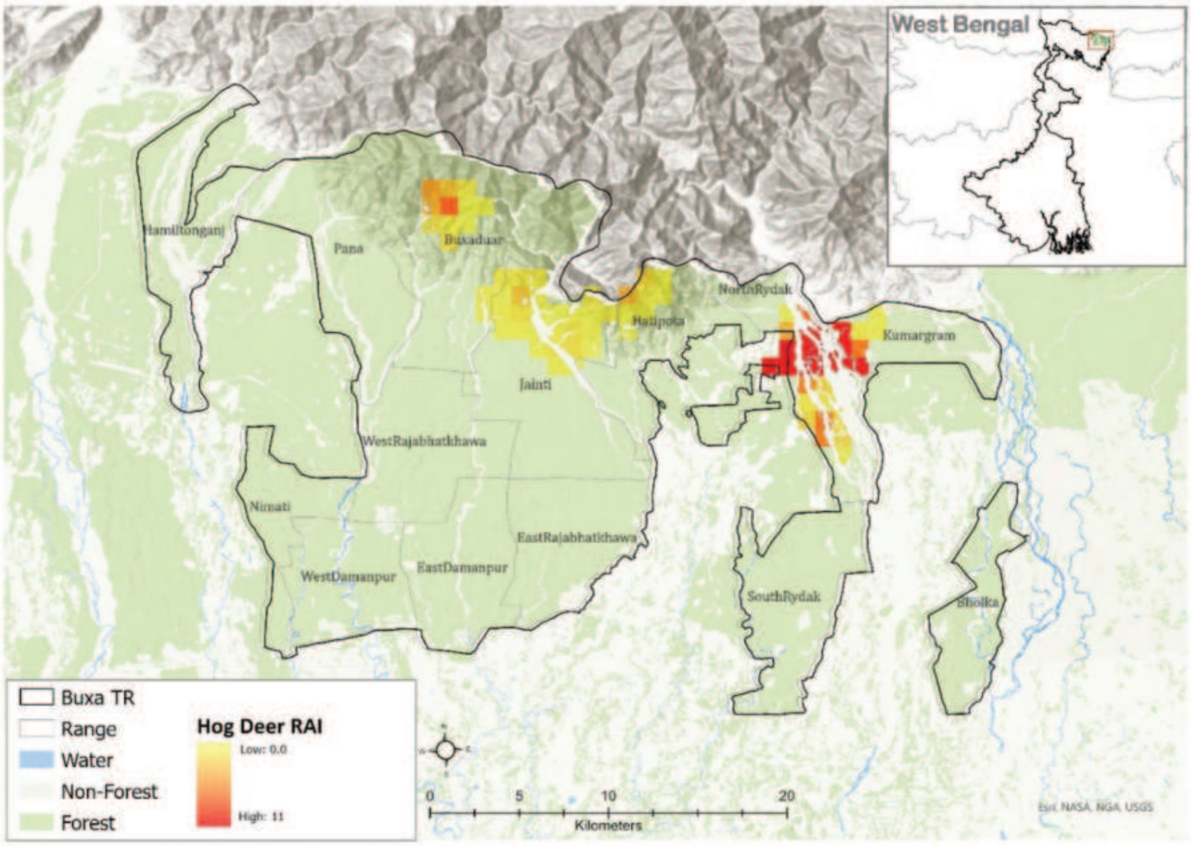

Figure VI. 53: Spatial relative abundance of hog deer in Buxa tiger reserve.

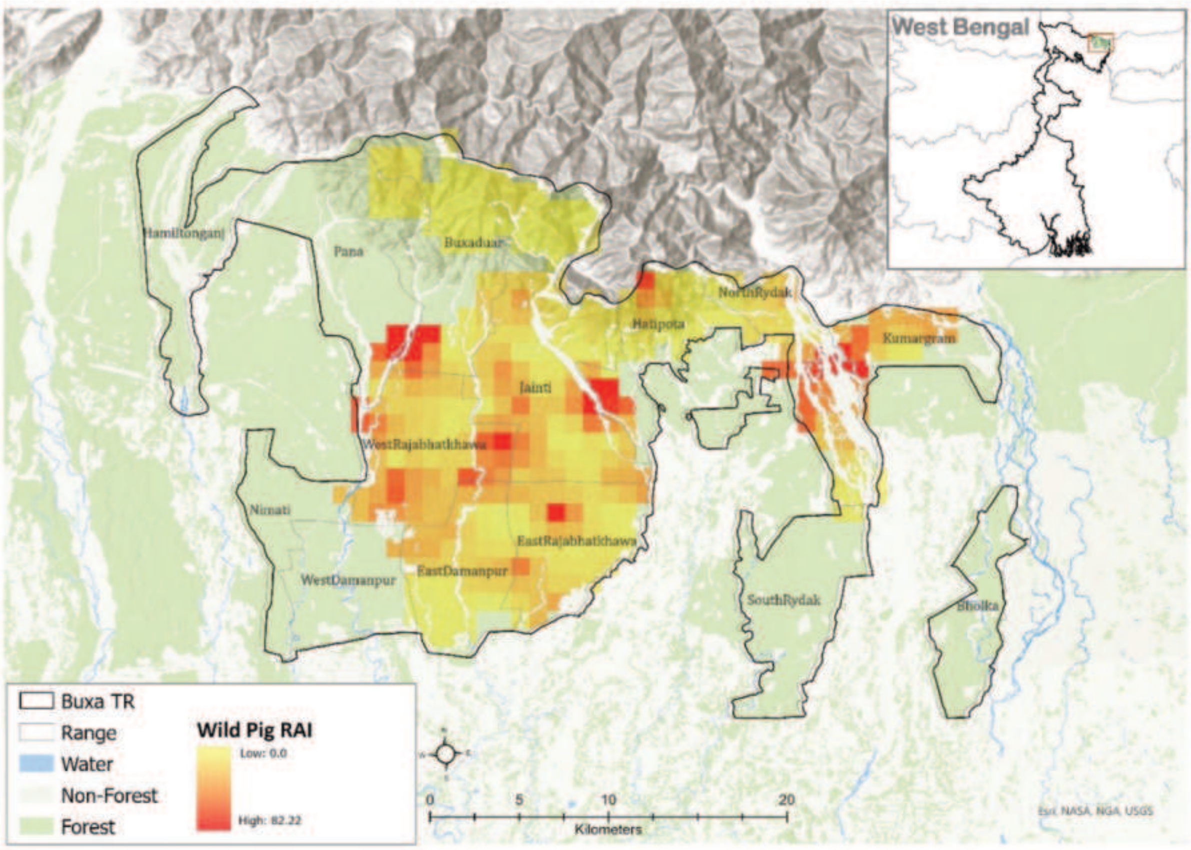

Figure VI. 54: Spatial relative abundance of wild pig in Buxa tiger reserve.

Sundarban Tiger Reserve

Sundarban tiger reserve, located in the southern part of West Bengal, covers around 2,585 km^2 and is the largest mangrove habitat spread over India and Bangladesh, in the delta of Ganges, Brahmaputra, and Meghna rivers. It is the only mangrove habitat in the world to harbour tigers. The Indian part of Sundarbans is known as Sundarban biosphere reserve, and protected areas of Sundarban biosphere reserve comprises Sundarbans tiger reserve and Narendrapur WLS of adjacent South 24 Parganas forest division. Sundarban is characterized by numerous islands formed by sediments deposited by major rivers and a network of tidal rivers, saltwater and brackish water swamps, mudflats, and islands, creating a dynamic habitat that fluctuates with the tides (Qureshi *et al*., 2023). The entire Sundarbans mangrove habitat has a similar kind of successional pattern, where grasses and mangrove species like *Avicennia sp*. are the pioneers in the newly formed landmass (Rahman, 2000). Sundarban is globally significant for the conservation of the tiger, which is uniquely adapted to the mangrove environment and is a key predator in this region. Principal ungulate prey of tigers in Sundarbans are chital and wild pigs. These herbivores are an integral part of the food web, supporting large predators and contributing to vegetation management. The reserve's mangrove forests also provide critical breeding grounds for fish, crustaceans, and other marine life, which sustain the local fishing communities. Sundarbans acts as a vital buffer against coastal erosion, storm surges, and salinity intrusion.

As it is difficult to execute line transects on foot in Sundarbans, boat transects are being done to estimate ungulate abundance. However, due to low detection of ungulate species on transect and absence of reliable distance measurements, ungulate abundance could not be estimated using distance sampling method. Due to logistical constraints, camera traps in Sundarbans are placed strategically in comparatively elevated lands near the creeks to maximize the capture of tiger and other wildlife species.

Chital are photographed in every range of Sundarbans (Figure VI. 55) whereas, wild pig is captured only in tiger reserve areas (Figure VI. 56). Sajnakhali range has higher abundance of both chital and wild pig.

Ungulate densities in Sundarbans are comparatively low compared to peninsular tiger reserves in India (Roy *et al*., 2016). As a result of this along with frequent natural calamities like cyclones, tigers of Sundarbans often venture into human habitation raising the issue of human tiger conflict. As this is a unique and only mangrove tiger habitat, it is important to put special emphasis like seasonal/ annual rigorous scientific abundance estimation of ungulate and available prey base of tiger to ensure long term conservation success of Sundarbans.

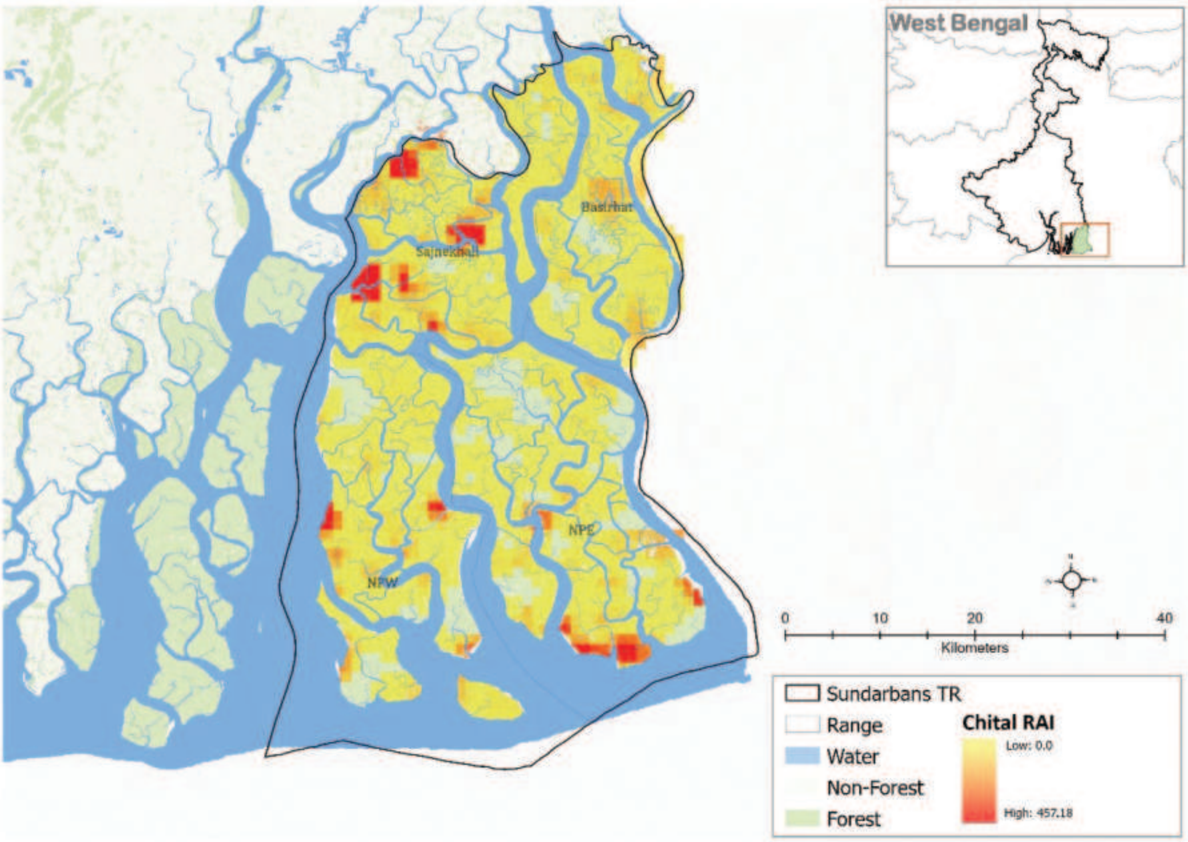

Figure VI. 55: Spatial relative abundance of chital in Sundarbans tiger reserve.

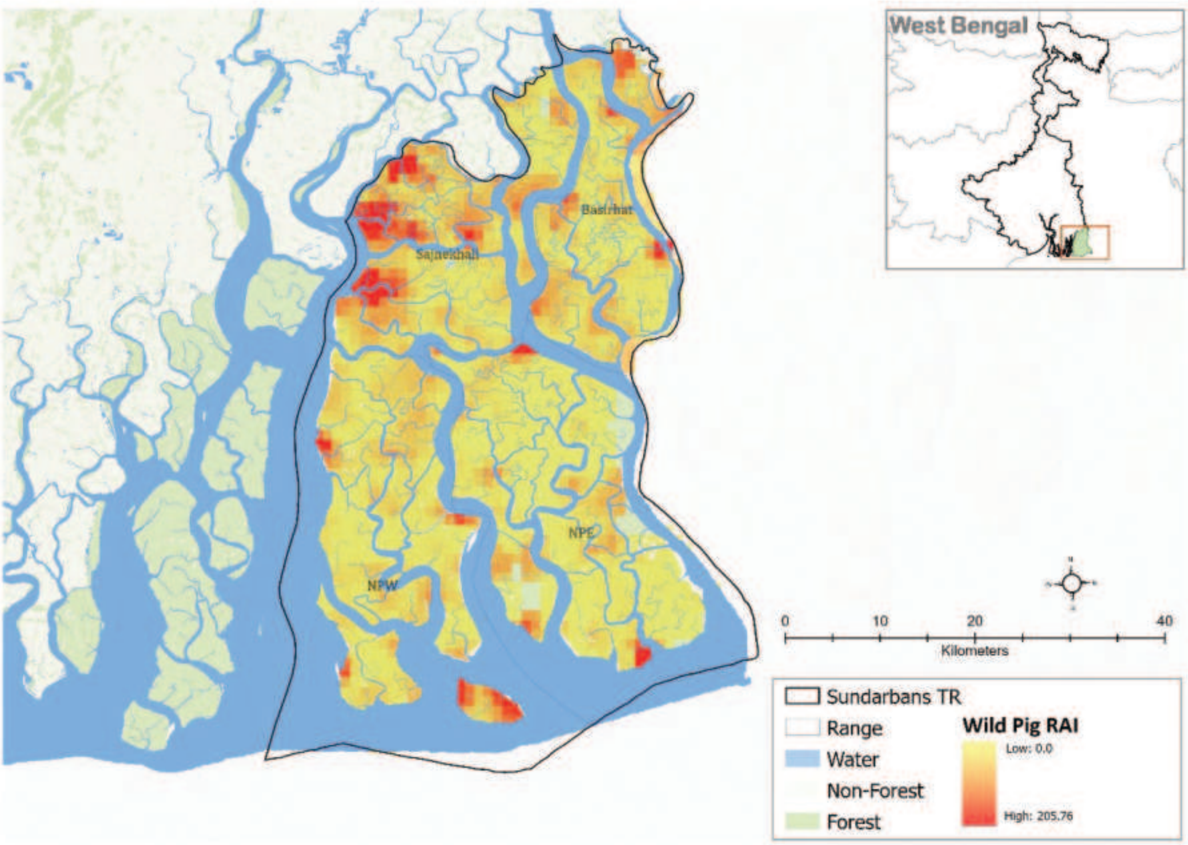

Figure VI. 56: Spatial relative abundance of wild pig in Sundarbans tiger reserve.


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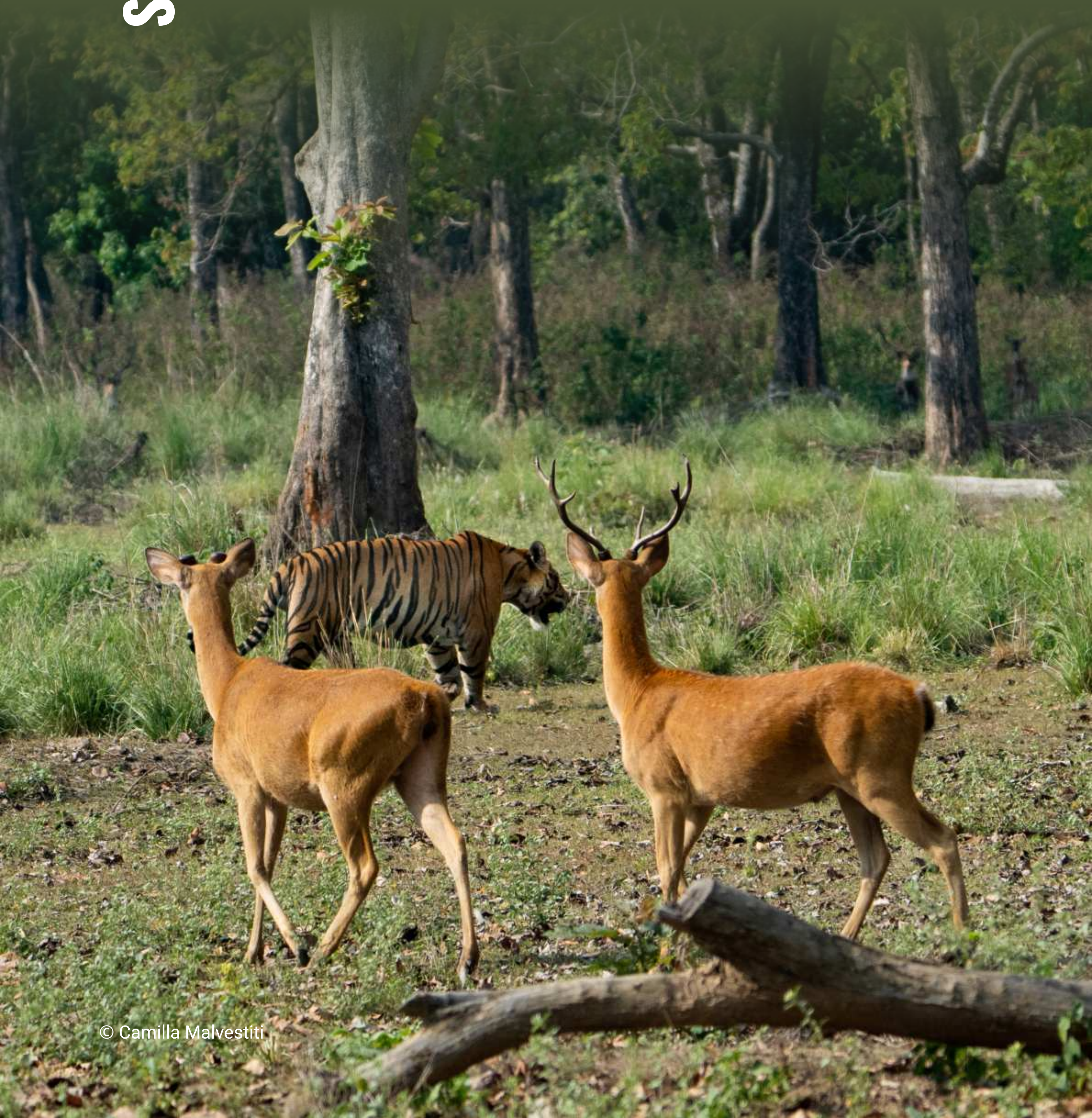
SECTION VII

Conservation of Ungulates in tiger bearing forests

Vishnupriya Kolipakam, Qamar Qureshi, Yadvendradev Jhala, Ujjwal Kumar, Shravana Goswami, Omkar Nar, Dhruv Jain, Vaishnavi Gusain, Bilal Habib, Vaibhav C. Mathur, Rajesh Gopal



India's geographical position, spanning from the tropical south to the temperate north, supports a diverse range of habitats, including 51 ecoregions under 10 biomes. A total of 39 species of ungulates, from 23 genera, 7 families, and 2 orders, are reported in India, each spread across these ecoregions according to their specific habitat requirements. Ungulates which also act as prey for large carnivores helps in maintain a healthy population of large and medium carnivores. The diverse assemblage of ungulates in leads to competition for resources. This competition influences population dynamics, resource partitioning, habitat selection, and community structure, which, in turn, affect predator-prey dynamics and ecosystem stability. Densities of 30 or more individuals per square kilometer can support over 4 tigers per 100 square kilometers, and this tiger density scales with increasing prey availability (Jhala *et al*., 2020). When species occurrence and abundance are modelled, it provides spatial information which helps in policy formation and conservation management. Information from large areas surveyed during All India Tiger Estimation (approximately 395,379 km² of forested habitat), combined with model based inference using ecologically relevant covariates can explain the underlying factors responsible for the observed patterns and predict suitable habitats of a species.

Change in ungulate presence trend

The grids consistently sampled across three monitoring cycles were used for data analysis. Encounter rates recorded along transects within 100 km² grid cells were log-transformed and regressed for each site (Fig. VII.1, 2, 3 & 4). Given the limited number of repeat cycles (three), this analysis provides indicative trends rather than definitive conclusions; however, it still offers valuable insights for conservation decision-making. Chital, sambar, and gaur exhibit similar population trends (Table VII.1), with approximately 27% of sites showing a decline. This correlates to an increased probability of livestock depredation in these areas. Enhancing ungulate populations is crucial for sustaining healthy tiger populations. Conservation strategies should focus on in-situ population recovery by protecting ungulates from excessive predation and augmenting their numbers in areas with critically low densities. Additionally, management practices from regions with high chital-sambar densities can be adapted for similar suitable habitats.

Table VII. 1: Change in percent population trend from 2014 to 2022. The decline is when beta=< -0.05, increase when it is => 0.05 and stable is between -0.05 to 0.05.

	Chital	Sambar	Gaur
Decline	28	27	28
Stable	38	41	34
Increase	34	32	38

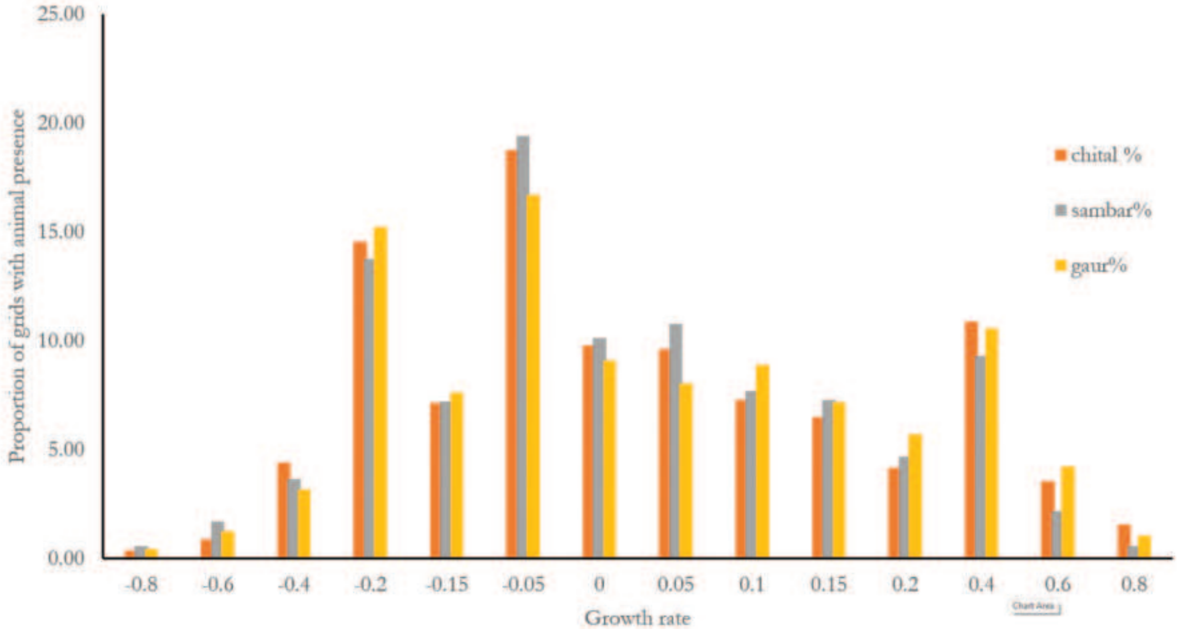


Figure VII. 1: Change in population trend (%) from 2014 to 2022. A population is classified as declining when β ≤ -0.05, increasing when β ≥ 0.05, and stable when β falls between -0.05 and 0.05 for chital, sambar, and gaur.

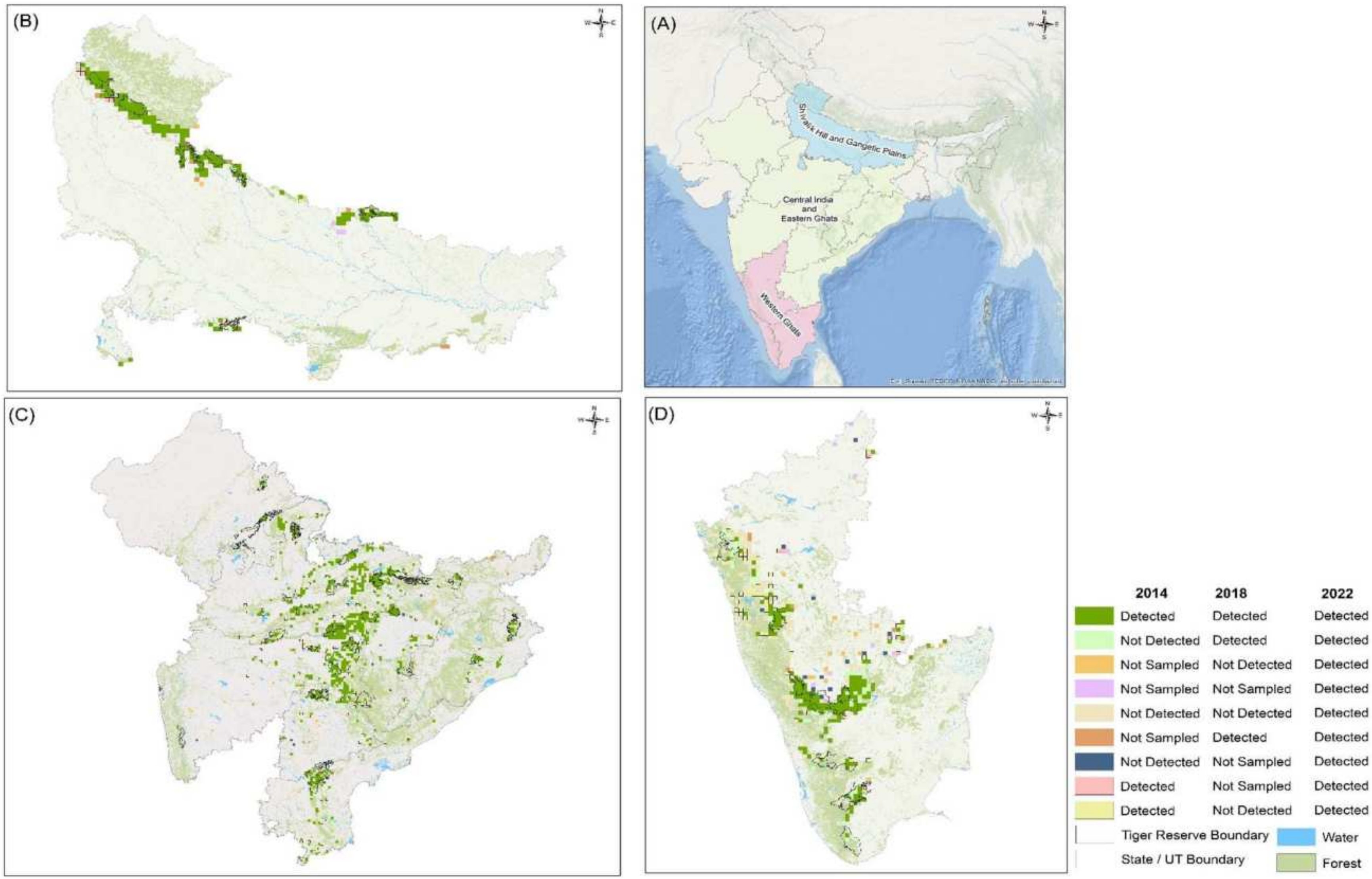


Figure VII..2: Change in occupancy of Chital in the sampled forest of in India during AITE sample at a scale of 25 km² grid

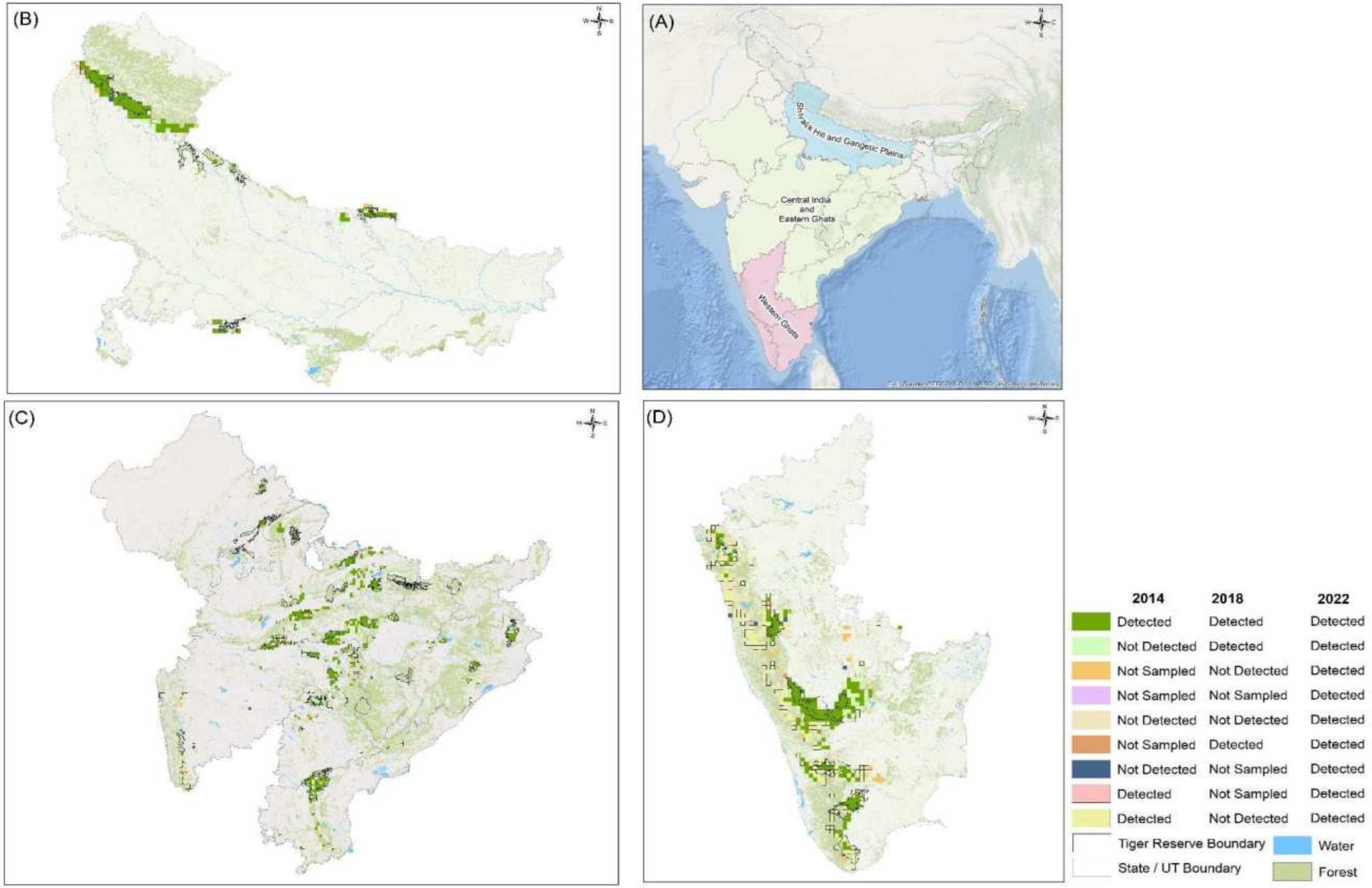


Figure VII..3: Change in occupancy of Sambar in the sampled forest of in India during AITE sample at a scale of 25 km² grid

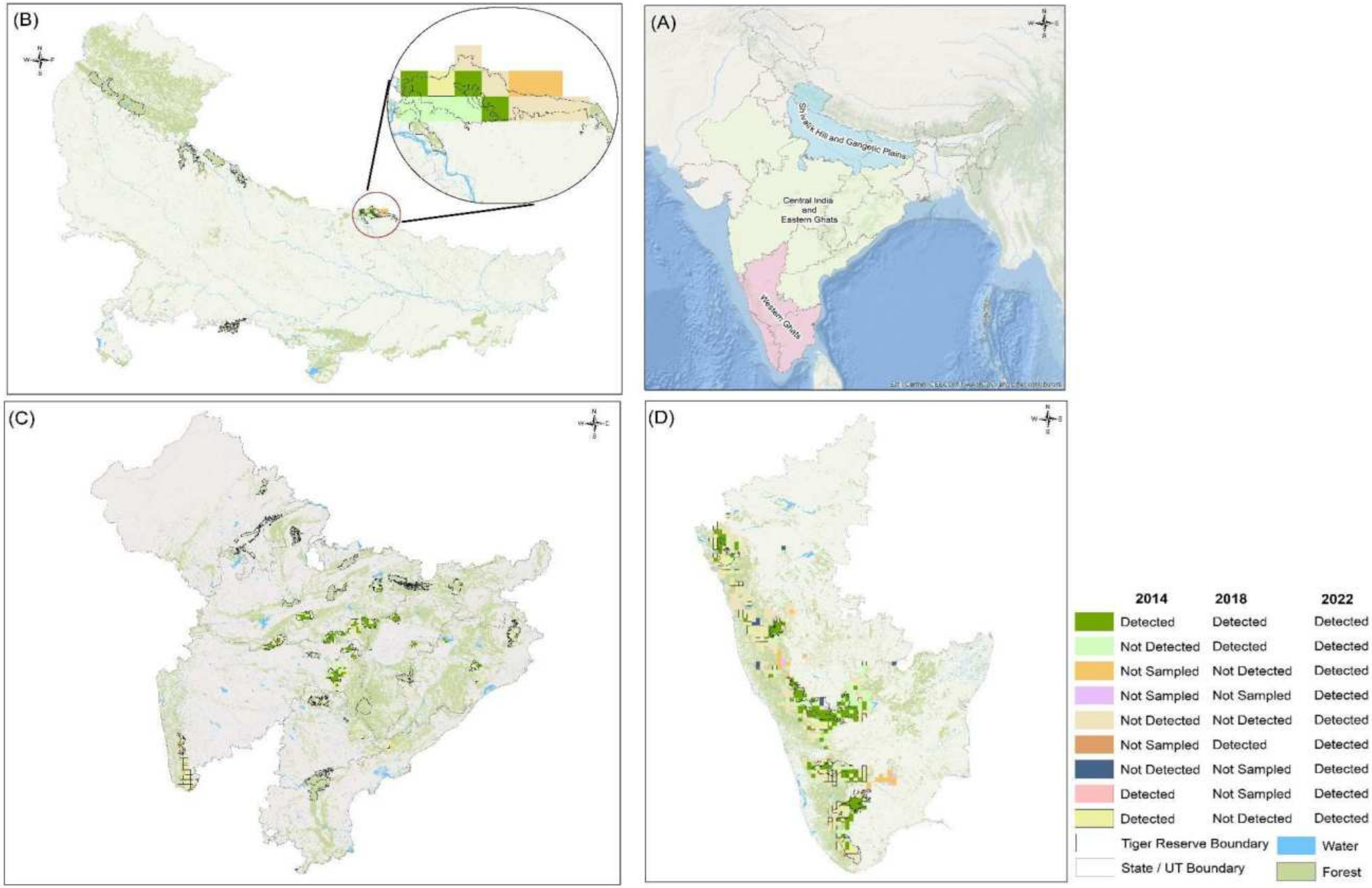


Figure VII..4: Change in occupancy of Gaur in the sampled forest of in India during AITE sample at a scale of 25 km² grid

Human Impact

Human presence is a significant factor influencing the distribution of ungulates (Kurien *et al*., 2007; Awasthi *et al*., 2016; Kumar *et al*., 2023; Khan *et al*., 2024). Although ungulates can inhabit areas outside designated protected areas, their populations tend to reach higher densities within or in proximity to such protected areas. This pattern highlights the critical role that protected areas play in maintaining viable ungulate populations.

The presence of humans in forested landscapes, particularly in the form of extractive activities like wood cutting and lopping, livestock grazing, and direct human disturbance, can negatively impact ungulate distribution and abundance (Fig VII.5). Among these factors, the presence of livestock and human settlements has a more pronounced detrimental effect compared to extractive activities such as wood cutting and lopping. Livestock compete with ungulates for resources such as forage and water, while human settlements and associated activities lead to habitat degradation and increased disturbance, further limiting suitable habitats for ungulates.

Given these pressures, the establishment and maintenance of inviolate core areas—regions with minimal human interference—are crucial for sustaining ungulate populations. These protected spaces provide undisturbed habitats that support higher ungulate densities, which, in turn, serve as a critical prey base for carnivores. Thus, ensuring the integrity of core areas within protected landscapes is not only vital for ungulate conservation but also plays a significant role in the persistence and growth of carnivore populations.

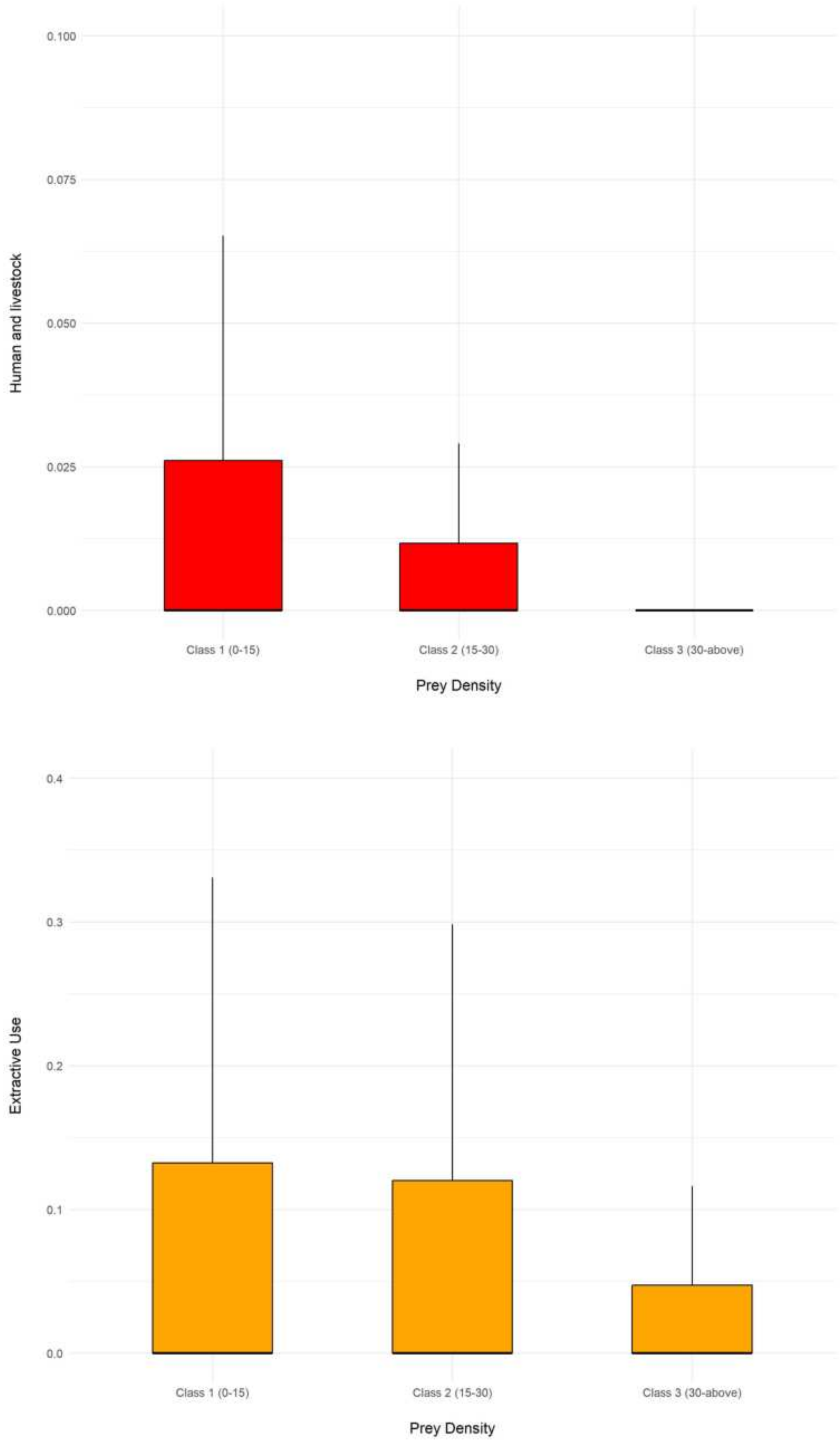


Figure VII.5: Response of ungulate density categories to human impacts A. Human and livestock presence B. extractive uses (wood cutting and lopping)

Ungulates and habitat

Ungulate affects vegetation dynamics and nutrient cycling. They play a vital role in shaping ecosystems through their grazing and browsing activities, which influence plant community structure, habitat heterogeneity, and biodiversity. By preventing any single plant species from dominating, they promote floristic diversity and create habitats that support a wide range of wildlife. Their feeding behaviours also facilitate resource partitioning, enabling the coexistence of multiple herbivore species and maintaining ecosystem stability (Ahrestani *et al*., 2012). Overgrazing by dominant species, such as chital in Kanha, can lead to resource depletion and alter plant community structure (Bagchi & Ritchie, 2010). Additionally, ungulates contribute to nutrient cycling by depositing dung, which enriches the soil and supports insect populations, reinforcing overall ecosystem functionality (Murray & Illius, 2000; Bagchi & Ritchie, 2010). Competition for resources is a key factor influencing ungulate population dynamics. Intraspecific competition often driven by seasonal fluctuations in forage availability. Social ungulates also optimize group sizes and exhibit spatial segregation to mitigate competition (Chatterjee *et al*.,2022). This balance is essential for maintaining biodiversity and supporting apex predators like tigers.

Chital and sambar have extensive suitable habitats spanning various ecoregions (Figure II.9 & VII.8). For chital, these include East Deccan moist deciduous forests, Terai-Duar savanna and grasslands, upper Gangetic plains moist deciduous forests, North Western Ghats montane rain forests, Central Deccan Plateau dry deciduous forests, and South Western Ghats moist deciduous forests (Figure VII.8). The highest densities of chital are recorded in clusters such as Rajaji-Corbett-Ramnagar-Pilibhit-Dudhwa, Kanha-Pench-Achanakmar, Bandhavgarh-Sanjay Dubri-Veerangana Durgawati, and Nagarhole-Bandipur-BRT-Wayanad-Mudumalai-Sathyamangalam (Figure VII.8). These clusters are located within the East Deccan moist deciduous forests, Terai-Duar savanna and grasslands, and South Western Ghats moist deciduous forests ecoregions (Figure VII.8).

Similarly, sambar has major suitable habitats in the South Western Ghats moist deciduous forests, Terai-Duar savanna and grasslands, South Western Ghats montane rain forests, upper Gangetic plains moist deciduous forests, North Western Ghats montane rain forests, East Deccan moist deciduous forests, and Central Deccan Plateau dry deciduous forests (Figure II.11 & VII.9). The highest densities of sambar are observed in clusters such as SMTR-Periyar-KMTR, Rajaji-Corbett-Ramnagar-Pilibhit-Dudhwa, Nagarhole-Bandipur-BRT-Wayanad-Mudumalai-Sathyamangalam, and Kanha-Pench-Achanakmar (Figure VII.9). These clusters are located within the South Western Ghats moist deciduous forests, South Western Ghats montane rain forests, Terai-Duar savanna and grasslands, upper Gangetic plains moist deciduous forests, and East Deccan moist deciduous forests ecoregions (Figure VII.9).

Competition amongst Ungulates

In tropical ecosystems, ungulates coexist by partitioning resources in space and time. Spatial segregation occurs when species prefer distinct habitats based on food availability and shelter. For example, sambar favours dense forests near water, while chital prefers open grasslands (Karanth & Sunquist, 1995; Sankar & Acharya, 2004). Larger species like gaur occupy rugged terrain, whereas smaller ungulates such as barking deer prefer thick undergrowth (Bagchi *et al*., 2003c). Predator avoidance further influences habitat selection, with species choosing areas that minimize predation risk (Sankar *et al*., 2010). Temporal segregation helps reduce direct competition, as some species adjust activity patterns—sambar and gaur being more crepuscular or nocturnal, while chital is predominantly diurnal (Wegge *et al*., 2006; Steinmetz *et al*., 2013).

Dietary adaptations also drive resource partitioning. In North and Northeast India, species like rhinoceros, buffalo, barasingha, hog deer, and wild pig segregate based on body size, bite size, and food coarseness. Smaller species are more selective feeders, while larger ungulates like gaur modify their diets according to resource availability (Ahrestani *et al*., 2012). Grazers primarily consume grasses, browsers feed on shrubs and understory vegetation, and mixed feeders adjust based on seasonal abundance (Sankar & Acharya, 2004). Studies in Kanha and Bandipur tiger reserves show that these adaptations reduce niche overlap (Bagchi *et al*., 2003; Awasthi *et al*., 2020).

Though chital and sambar share common ecoregions with suitable habitats, their habitat requirements are quite different due to their distinct feeding strategies: chital being prominent grazers and sambar being browser (Karanth & Sunquist, 1995; Sankar & Acharya, 2004; Awasthi *et al*., 2020). Gaur has wide distribution in the Western Ghats forest compared to other parts of India which supports its preference for higher elevations or rugged terrains with dense vegetation cover (Figure III.4, IV.4, V.4, VI.5). As different ungulate species have specific habitat requirements, these requirements should be taken into consideration when planning management practices.

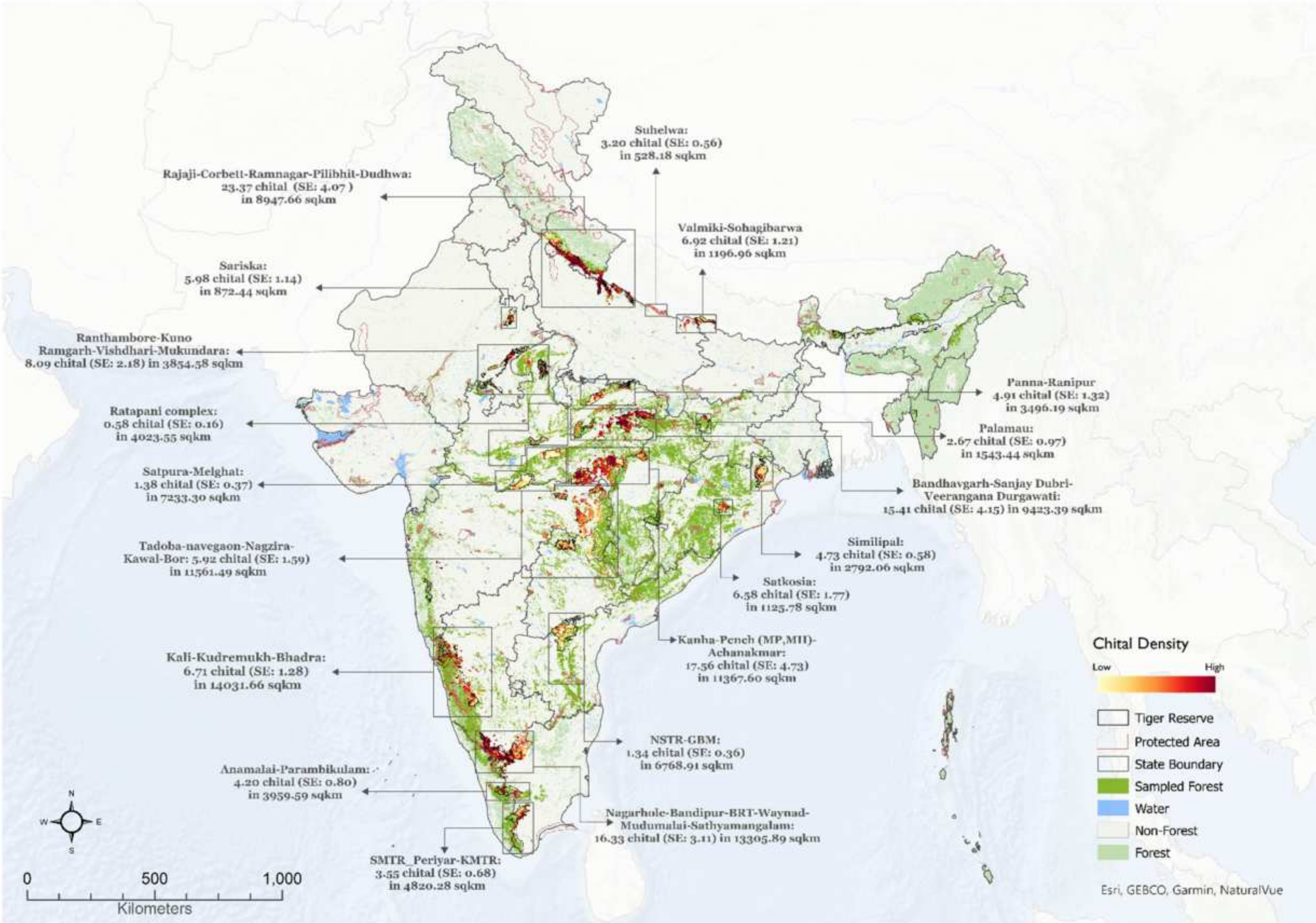


Figure VII..8: Chital Density, population blocks across tiger bearing states in India

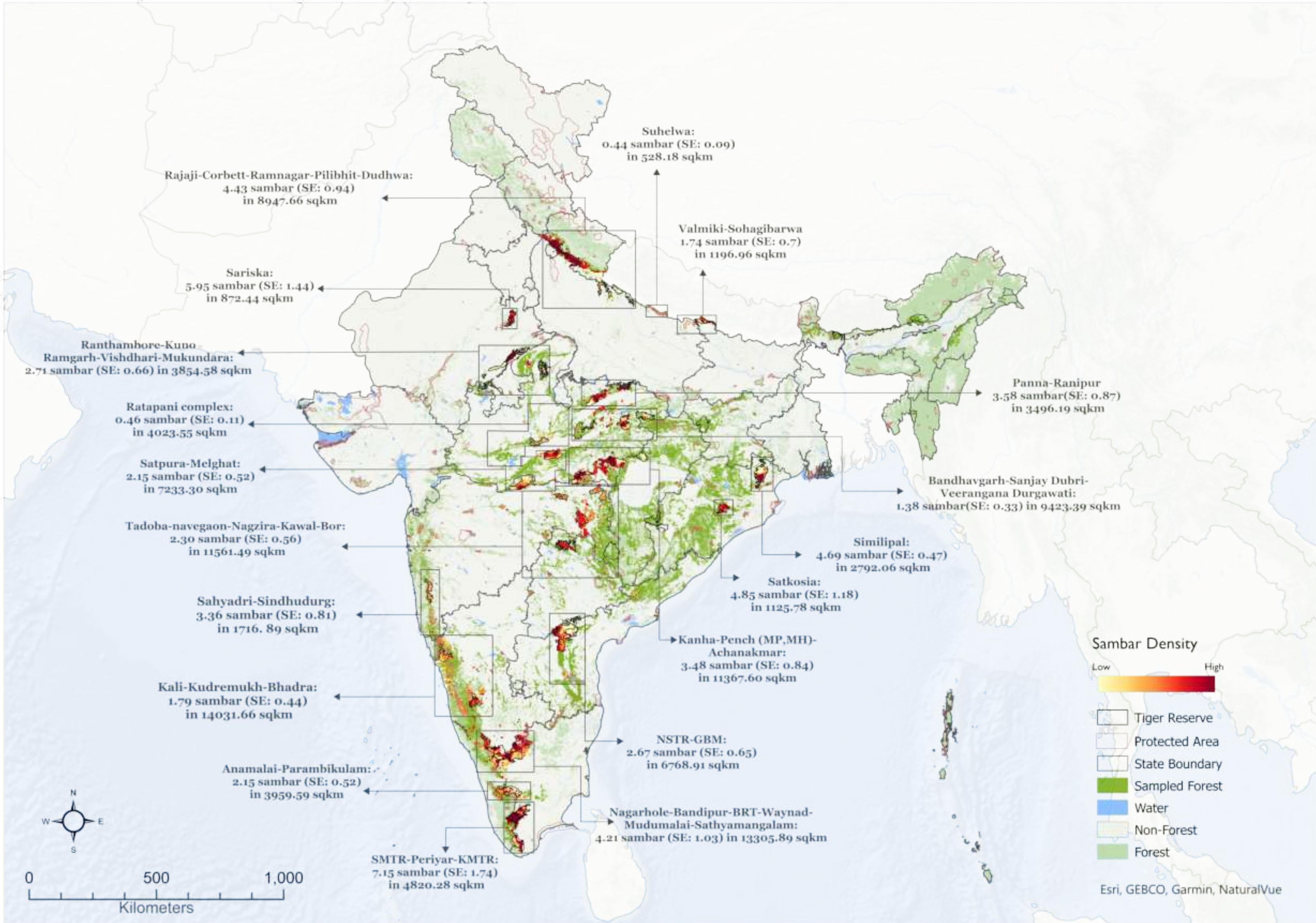


Figure VII.9: Sambar Density, population blocks across tiger bearing states in India.

Predator-Prey Dynamics

Ungulates serve as primary prey for apex predators, influencing the population dynamics of these carnivores. Chital, sambar, and gaur are key prey species in the tiger's diet (Karanth & Sunquist, 1995; Bagchi *et al.*, 2003; Ramesh *et al*., 2012; Biswas *et al*., 2022; Variar *et al*., 2023). Areas with high densities of these ungulates often support higher tiger densities (Figure VII.8 & VII.9., Qureshi *et al*., 2023). However, certain high-tiger-density regions, such as Valmiki-Sohagibarwa, the Ratapani Complex, and the Tadoba-NNTR-Kawal-Bor cluster, exhibit low chital and sambar densities (Figure VII.8). When preferred prey is not available, tigers shift to smaller prey such as wild pigs or barking deer (Karanth & Sunquist, 1995) and livestock (Qureshi *et al*., 2024). However, selective predation by apex predators can significantly influence the populations of ungulates (Schmitz, 2003; Giller, 1984).

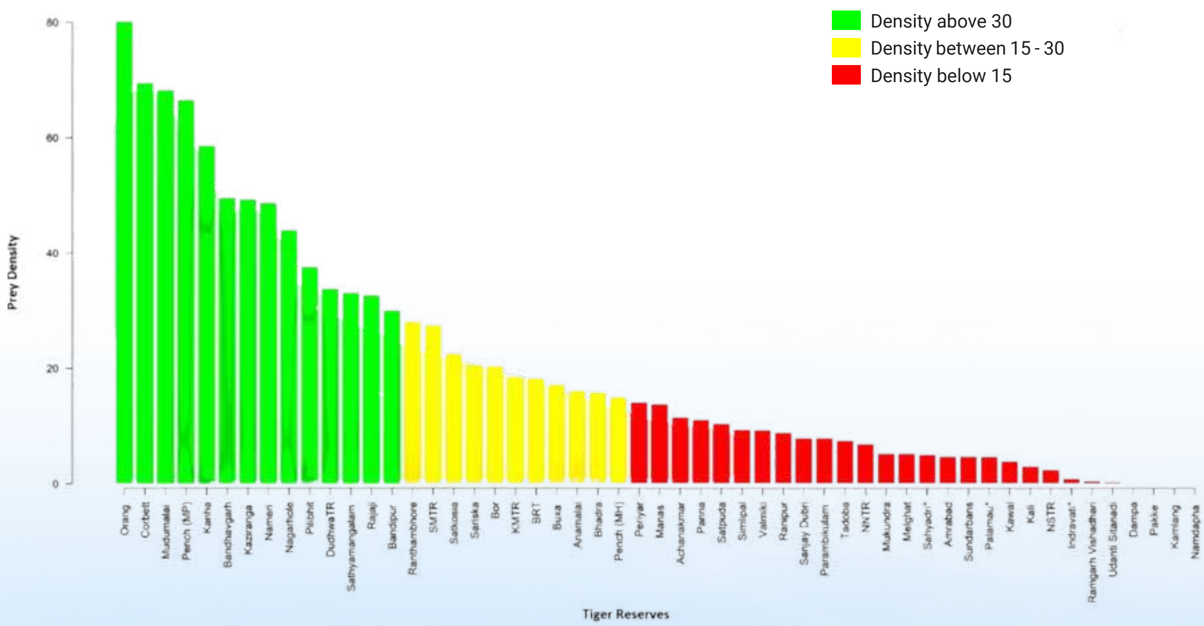


Figure VII.6: Estimated prey densities across various tiger reserves, colour green indicates those reserves which can support a good multi predator system, yellow the moderate, and red means poor support.

As prey densities increase, tiger densities rise sharply, reflecting the critical role of prey abundance in supporting predator populations. However, beyond ~75 prey/km², the curve plateaus, indicating diminishing returns where additional prey no longer correlates with higher tiger densities. This saturation may stem from ecological constraints such as territoriality, limited habitat suitability, or competition, which cap tiger numbers even in prey-rich areas. Ecologically, this highlights the importance of maintaining prey thresholds (e.g., >75/km²) to sustain viable tiger populations, while also addressing secondary factors like habitat connectivity and human encroachment that may limit tigers despite adequate prey. Conservation strategies should prioritize both prey recovery and holistic habitat management to optimize tiger conservation outcomes.

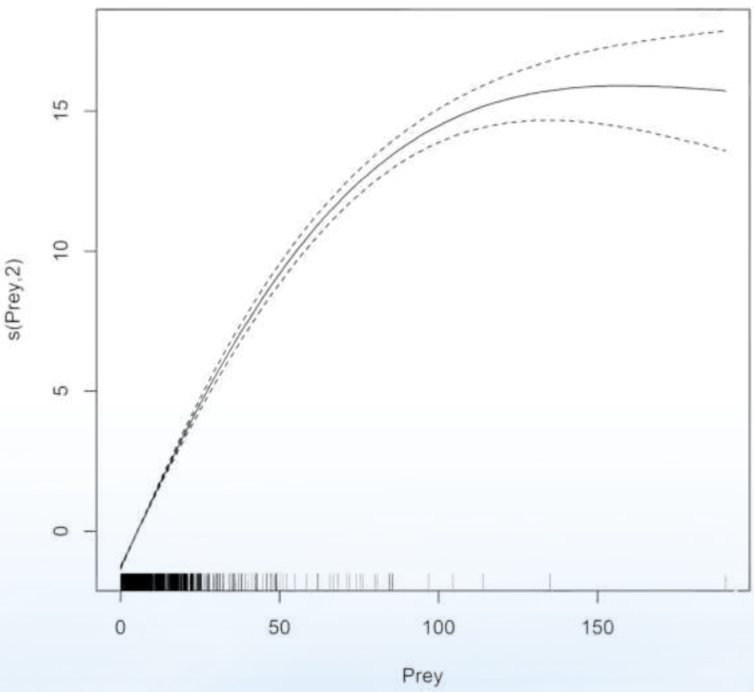


Figure VII. 7: GAM plot between tiger density and prey densities threshold-driven tiger-prey dynamics: Non-linear GAM response of tiger densities (per 100 km²) to prey availability (per km²) reveals a critical prey threshold (~75/km²), beyond which ecological constraints limit population growth.

Ungulate conservation priority area

To address population declines, targeted reintroduction and habitat restoration efforts are essential. Augmenting or reintroducing native ungulate species, which serve as principal prey for larger carnivores, into areas where they have low densities or have been locally extirpated can help restore predator-prey dynamics and improve habitat conditions for apex predators like tigers (Jhala *et al*., 2021). In certain areas, the conservation of ungulates should be prioritized.

In Odisha, both prey and tiger densities are low (Figure VII.8 & VII.9, Qureshi *et al*., 2023). High bushmeat consumption and civil unrest in the region negatively impact wildlife presence, leading to low ungulate densities. To increase tiger and co-predator populations, efforts focused on prey supplementation and population recovery are necessary. Similarly, Palamau, an important part of the Central Indian corridor, faces challenges such as left-wing extremism, which affects wildlife presence. The area has very low ungulate and leopard densities and has not had a resident tiger population for more than a decade. Prey recovery strategies, such as voluntary village relocation to create more grassland habitats for herbivores and targeted population supplementation, are essential in this region.

In tiger reserves of Maharashtra, particularly Tadoba, and in Ratapani, Madhya Pradesh, carnivore presence is high, whereas prey density remains low (Figure VII.8 & VII.9, Qureshi *et al*., 2023). As a result, these areas experience high rates of livestock depredation, leading to increased human-wildlife conflict. Similarly, NSTR-Amarabad-GBM is an isolated block with a rapidly increasing tiger population but low prey density. Without prey recovery and supplementation, human-wildlife conflict in this region is also expected to rise rapidly.
The Valmiki-Sohagibarwa landscape has a high human population density alongside an increasing tiger population. Without a proper ungulate population recovery plan, this landscape may experience heightened conflict between carnivores, livestock, and humans.

In Satpura-Melghat, voluntary village relocations have facilitated grassland regeneration. This landscape holds significant potential for wildlife management, as prey recovery programs—such as augmentation and supplementation—could contribute to carnivore population recovery.

When augmenting or supplementing any animal population, it is crucial to ensure that individuals are sourced from within the landscape (Qureshi *et al*., 2023). While donor sites may not always have surplus populations, they can provide an initial stock for translocation. To enhance survival and facilitate population recovery, translocated individuals should first be housed in predator-proof enclosures before being gradually released in batches (Qureshi *et al*., 2024).

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APPENDIX

A. NATIONAL TIGER CONSERVATION AUTHORITY (NTCA) TEAM

Member Secretary & ADG PT & E :
Dr. S.P. Yadav (Retd.), Dr. G.S. Bhardwaj

Inspector General of Forests:
Dr. Amit Mallick (Retd.), Dr. Sanjayan Kumar

Nodal Officer & Deputy Inspector General of Forests:
Shri Rajendra Garawad (Ex), Dr. Vaibhav C. Mathur

Head Quarter, New Delhi

1. Ms. Banumathi, G., Deputy Inspector General of Forest
2. Md. Sajid Sultan, Assistant Inspector General of Forest
3. Shri Hemant Singh, Assistant Inspector General of Forest
4. Dr. Abhishek Kumar, Assistant Inspector General of Forest

Regional Office, Bengaluru

1. Shri N.S. Murali, Inspector General of Forest (Ex.)
2. Ms. Harini Venugopal, Assistant Inspector General of Forest

Regional Office, Guwahati

1. Shri W. Longvah, Inspector General of Forest (Retd.)
2. Ms. Agatha Momin, Biologist

Regional Office, Nagpur

1. Shri Hemant Bhaskar Kamdi, Assistant Inspector General of Forest (Ex)
2. Shri Nandkishor Kale, Assistant Inspector General of Forest
3. Shri Anil Dashare, Biologist

B. WILDLIFE INSTITUTE OF INDIA TEAM

Director:
Shri Virendra R. Tiwari

Dean:
Dr. Ruchi Badola

Project Investigators:
Prof. Qamar Qureshi, Dr. Y.V. Jhala, Dr. Vishnupriya Kolipakam and Dr. Bilal Habib

NTCA-WII Tiger Cell Scientists:
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Coordinator(Ungulates) & Principal Project Associate:
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Shri G. Muthu Veerappan, Harsh Deep Sethi

Senior Research Biologists:
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Finance:
Shri Surendra Singh Yadav

Administrative Support & Associates:
Ms. Neha Aswal, Shri Harsh Deep Sethi, Ms. Himani Pathak, Ms. Pallavi Sharma,

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Dr. S. Sathyakumar, Dr. J. A Johnson (Registrar), Dr. Bitapi Sinha (Research Coordinator), Dr. V.P Uniyal and Dr. S. K Gupta, Dr. Samrat Mondal (Nodal Officer Externally Aided Projects), Dr. K. Ramesh & Dr. Gautam Talukdar (Nodal Officer IT), Baljeet Kaur (Deputy Registrar), Narendra Singh Chauhan (Finance Officer), Dr. Panna Lal, Shri Dinesh Pundir, Alka Agarwal (Technical Officer IT Cell), Akash Aggarwal (Office Coordinator) are acknowledged for their support and facilitation. Dr. Sutirtha Dutta, Dr. Amit Kumar, Dr. Navendu Page, Dr. I.P Bopanna (WWF India), and Dr. Manjari Roy are acknowledged for providing training to research biologists.

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Shri Aman Deep Rathi	Shri Moulik Sarkar
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Ms. Ananya Dutta	Ms. Nupur Rautela
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Shri Arif Ahmad	Ms. Pooja Latwal
Ms. Aritra Roy	Shri Prayas Auddy
Shri Ayan Khanra	Shri Rajrajeshwar Thakar
Ms. Deepali Chatrath	Shri Richard S Sangma
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Ms. Drashti Gosai	Ms. Sagarika Das
Ms. Farah Naz	Shri Rohan Desai
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Shri Himanshu Kumar	Shri Sourav Das
Ms. Juri Roy	Ms. Stuti Anjaria
Ms. Kalpana Roy	Shri Sultan
Ms. Kamakshi Singh Tanwar	Ms. Sumandrita Banerjee
Shri Kathan Bandyopadhyay	Ms. Susmita Nilesh Patil
Shri Kaushik Mohan Koli	Ms. Udita Garbyal
Ms. Kesha Patel	Ms. Umang Kaur Josan
Ms. Maitreyee Vishwas Bhave	Ms. Vaishnavi Gusain
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Shri Akash Rana	Shri Pratik Pansare
Shri Ankan Halder	Ms. Preeti Parihar
Shri Anurag Nashirabadkar	Ms. Richa Joshi
Ms. Archana Negi	Ms. Ritupriya Debnath
Ms. Arti Adhikari	Shri Rohit Kumar
Ms. Arukshata Thakur	Shri Rudrajyoti Barman
Shri Ashish Joseph	Shri Rushikesh Kadam
Ms. Ashwini Mamgain	Ms. Saana Benurwar
Shri C. Jebin Bristo	Ms. Shankhamala Ghosh
Ms. Chaiti Tripura	Ms. Sheela Kanswal
Shri Gorati Arun Kumar	Shri Shiladitya Acharjee
Shri Hritik Dhami	Ms. Shrawani Wankhade
Shri K. M. Sooraj Murali	Ms. Shreya Yadav
Ms. Kiran Rawat	Shri Shubham Kumar Maletha
Shri Lakshman Bhajarang	Ms. Shweta Singh
Shri Lalitkumar Patil	Ms. Sneha Madhwal
Shri Manas Shukla	Ms. Sonali Aswal
Ms. Maneesha Bhatt	Ms. Sonika Phogat
Ms. Monal Rajendra Jadhav	Ms. Subhalaxmi Muduli
Shri Mukesh Kumar	Shri Suraj Chauhan
Ms. Nandita Barman	Ms. Suranjita Roy
Ms. Neelam Negi	Ms. Sushree Subhangi Sahu
Ms. Neetu Bathla	Ms. Susmita Panggam
Ms. Neha Kumari	Shri Swadhin Kumar Jena
Ms. Neha Tolia	Ms. Swati Chandola
Ms. Neharika Virdi	Ms. Swati Gairola
Ms. Nibedita Basu	Ms. Swati Kukreti
Shri Nishant Saraswat	Ms. Swati Singh
Shri Nishi Nath Halder	Shri Tryambak Dasgupta
Ms. Pallabi Majhi	Ms. Upasna Thakur
Shri Piyush Tripathi	Ms. Vartika Negi
Ms. Pooja Sharma	Ms. Yamini Nayal
Ms. Prateeksha Nath	Ms. Yati Gairola

Interns and volunteers

Shri Abhay Thakur	Ms. Sneha Mane
Shri Akshay Jain	Shri Pankaj Ojha
Ms. Geeta	Shri Parth Kathad
Shri Harshal Waghmare	Ms. Pinky Yadav
Shri Himanshu Matta	Shri Pranav Thapa
Shri Inderjeet Singh	Ms. Prateeksha Nath
Ms. Kavita Bisht	Ms. Preeti Parihar
Ms. Madhu Panwar	Ms. Preeti Tripathi
Ms. Mahima Gagar	Ms. Riddhi Sondagar
Ms. Monibhadra Roy	Shri Roheel Taunk
Ms. Moupika Gosh	Shri Saurav Panday
Ms. Nivedita Sharma	Shri Yajurved
Ms. Nivedita Singh	Ms. Abhilasha Srivastava
Ms. Farah Usmani	Shri Shantanu Sharma
Ms. Bhawana Pant	Shri Shantanu Ishwar Nagpure
Ms. Manisha Bhatt	

C. CHIEF WILDLIFE WARDENS IN THE STATES INVOLVED IN THE TIGER STATUS ESTIMATION 2022-23

States	Name
Andhra Pradesh	Shri N. Prateep Kumar, Shri Y. Madhusudhan Reddy
Arunachal Pradesh	Shri G Kumar, Shri R.K Singh, Shri N. Tam
Assam	Shri M.K. Yadava
Bihar	Shri Prabhat Gupta
Chhattisgarh	Shri P.V. Narsingh Rao, Shri Sudhir Agarwal
Goa	Shri Santosh Kumar, Shri Saurabh Kumar
Jharkhand	Shri P.K. Verma, Shri Sanjay Kumar Srivastva, Shri Ashish Rawat, Shri Shashikar Samanta
Karnataka	Shri Sanjay Mohan, Shri Vijaykumar Gogi, Shri Rajiv Ranjan
Kerala	Shri Surendra Kumar, Shri Devendra Kumar Verma, Shri Bennichan Thomas, Shri Ganga Singh
Madhya Pradesh	Shri Alok Kumar, Shri J.S. Chouhan
Maharashtra	Shri Mahip Gupta, Shri Sunil Limaye
Mizoram	Shri R. S. Sinha, Shri Ritu Raj Singh
Nagaland	Shri Ved Pal Singh, Shri Satya Prakash Tripathi
Odisha	Shri S. K. Popli, Shri Shashi Paul
Rajasthan	Shri Arindam Tomar, Shri M.L Meena
Tamil Nadu	Dr. Shekhar Kumar Niraj,Shri Thiru. Shri K.K. Kaushal, ShriThiru. Syed Muzammil Abbas, Shri I. Anwardeen, Shri Thiru, Srinivas R. Reddy, Shri Thiru, Akash Deep Baruah, Shri Yogesh Singh
Telangana	Ms R Sobha, Shri Swargam Srinivas, Shri Rakesh Mohan Dobriyal
Uttar Pradesh	Shri S. Singh, Shri K.P. Dubey
Uttarakhand	Shri J.S. Suhag, Dr. P.M. Dhakate, Dr. Samir Sinha
West Bengal	Shri V.K. Yadav, Shri Debal Ray

D. ALL INDIA TIGER ESTIMATION NODAL OFFICIALS OF THE STATES

States	Name
Andhra Pradesh	Shri D.A. Kiran, Ms T. Nagamaneswari
Arunachal Pradesh	Shri Millo Tasser
Assam	Dr. Satyendra Singh
Bihar	Shri Surender Singh
Chhattisgarh	Shri T. Ashish Kumar Bhatt
Goa	Shri Jabestin A.
Jharkhand	Shri Kumar Ashutosh
Karnataka	Shri Kumar Pushkar, Shri Subhash Malkhede
Kerala	Shri P.P. Pramod, Shri K. Vijayananthan, Shri K.V Uthaman, Shri P Muhammed Shabab
Madhya Pradesh	Dr. H.S. Negi, Shri Subharanjan Sen, Shri Rajnish Kumar Singh
Maharashtra	Shri B.S. Hooda
Mizoram	Shri Pu Laltlanhlua Zathang
Odisha	Dr. J.D. Pati
Rajasthan	Shri Sharda Pratap Singh, Shri Nandlal Prajapat
Tamil Nadu	Shri Thiru. K.K. Kaushal, Shri Thiru. D. Venkatesh, Shri Tmt. C.H. Padma, Shri Thiru. Akash Deep Baruah.
Telangana	Dr. D. Samhita, Shri B. Srinivas, Shri C.P. Vinod Kumar
Uttar Pradesh	Shri Sanjay Kumar Pathak
Uttarakhand	Shri Ranjan K. Mishra
West Bengal	Shri Piar Chand, Shri Rajesh Kumar

E. OFFICIALS AND BIOLOGISTS WHO COORDINATED SAMPLING EXERCISE IN THE STATE 2022-23

State	Persons
Andhra Pradesh	Shri Srinivasa Reddy, Shri Alan Chong Teron, Shri Vigneesh Appavu, G, Shri Vineet Kumar Nanyal, Shri Ravindra Dhama, Shri P. Venkata, Sandeep Reddy, Shri C.Chaitanya Kumar Reddy, Shri Y. V. Narashimha, Rao, Shri G. Satish
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