ACTION HISTORY OF RTI REQUEST No.WLIOI/R/E/21/00003

Applicant Name	Ashish Garg
Text of Application	Dear Sir Kindly provide soft copy of following documents on email 1.Copy of report on study conducted by Wildlife Institute of India on elephants and other schedule -I category of animals in Thano forest range, Dehradun 2. Copy of report on study conducted by Wildlife Institute of India on Kandi Road, Corbet park Regards
Reply of Application	kindly see the attached cover letter and report mentioned in letter is being sent to you separately by email.

SN.	Action Taken	Date of Action	Action Taken By	Remarks
1	RTI REQUEST RECEIVED	18/01/2021	Nodal Officer	
2	REQUEST FORWARDED TO CPIO	19/01/2021	Nodal Officer	Forwarded to CPIO(s) : (1) P.K.Aggarwal
3	REQUEST DISPOSED OF	04/02/2021	P.K.Aggarwal-(CPIO)	

Print

Print

Government of India
Wildlife Institute of India, Dehradun
Wildlife Institute of India
P.O.Box-18, Chandrabani, Dehradun, Uttarakhand,

Dated: 04/02/2021

To

Shri Ashish Garg
D-7, Kewal Vihar, Sahastradhara Road
Dehradun
Dehradun
248001

Registration Number : WLIOI/R/E/21/00003

Dear Sir/Madam

I am to refer to your Request for Information under RTI Act 2005, received vide letter dated 18/01/2021 and to say that *kindly see the attached cover letter and report mentioned in letter is being sent to you separately by email.*.

In case, you want to go for an appeal in connection with the information provided, you may appeal to the Appellate Authority indicated below within ***thirty days*** from the date of receipt of this letter.

Director, WII
FAA & Director
Address: Wildlife Institute of IndiaChandrabaniDehradun
Phone No.: 01352646101

Yours faithfully

(P.K.Aggarwal)
CPIO & Deputy Registrar
Phone No.: 01352646110
Email : pka@wii.gov.in

सूचना का अधिकार
RIGHT TO INFORMATION

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

BY ONLINE PORTAL

No. WII/RTI/CPIO/2020-21 (Qtr-II)/87

Date: 04 February, 2021

To,

Mr. Ashish Garg,
D-7, Kewal Vihar, Sahastradhara Road,
Dehradun, Pin:248001
Email: ashishgargddn@gmail.com

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

Ref.: Your Online RTI No. WLIOI/R/E/21/00003 dated 18.01.2021

Sir,

Please refer to your application cited above under RTI Act, 2005. In this context, the point-wise response to your queries is given below:

S. No.	Information Sought under RTI	Reply under RTI
1	Copy of report on study conducted by Wildlife Institute of India on elephants and other schedule -I category of animals in Thano forest range, Dehradun	No information available
2	Copy of report on study conducted by Wildlife Institute of India on Kandi Road, Corbet park	Report is attached in email.

In case, you are not satisfied with the information provided above, you may file an appeal to the First Appellate Authority indicated below within ***thirty days*** from the date of receipt of this letter.

Director, WII
FAA & Director
Address: Wildlife Institute of India, Chandrabani, Dehradun
Phone No.: 01352640910

Thanking you,

Yours faithfully,

NO & CPIO (RTI)

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Final Report (23-08-2019)

Assessment of the proposed upgradation of Kotdwar-Ramnagar Kandi Road, Uttarakhand and the review of feasible options to promote green infrastructure to address the impacts on wildlife values

Submitted to

National Buildings Construction Company (NBCC), New Delhi

and

Ecotourism Development Corporation Limited (EDCUL), Uttarakhand

By

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

August, 2019

Assessment of the proposed upgradation of Kotdwar-Ramnagar Kandi Road, Uttarakhand and review of the feasible options to promote green infrastructure to address the impacts on wildlife values

The Team:

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Geospatial Database Creation: M/s Science, Dehradun

Table of contents

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-The Team

Executive summary

Roads connect people and promote economy. At the same time, roads also imperil biodiversity directly by fragmenting the otherwise contiguous landscapes resulting in disintegrated and degraded wildlife habitats and consequent reduction in wildlife populations and road-induced animal injuries and mortality. Hence, the planning and implementation of road development projects should take into account the full range of potential threats on biodiversity and long term conservation of key wildlife values for planning adequate and effective measures to mitigate significant impacts and promote the concept of 'smart green transportation infrastructure'.

An all-weather road connecting Kumaon and Garhwal regions of Uttarakhand has been a long-standing demand of the local populace. Currently, a 84 km forest road traversing through Corbett Tiger Reserve, or the *Kandi Marg*, provides fair weather connectivity between Ramnagar and Kotdwar. The Government of Uttarakhand intends to upgrade this road into a four-lane highway, with the National Buildings Construction Corporation Ltd. (NBCC), New Delhi as the Implementing Agency and Ecotourism Corporation of Uttarakhand Ltd, Dehradun (EDCUL) as the Nodal Agency. The road impact zone holds important populations of the endangered tiger *Panthera tigris*, Asian elephant *Elephas maximus*, and a range of wild animal and plant species. In view of these biodiversity relevant considerations, the Government of Uttarakhand requested the Wildlife Institute of India (WII) to conduct a feasibility study following green infrastructure guidelines (WII 2016). Subsequently, WII entered into an agreement with NBCC, and carried out an ecological assessment of the proposed Ramnagar–Kotdwar road, to: a) assess wildlife values and potential impacts of road, b) review the feasibility of alternative routes, and c) recommend appropriate mitigation measures.

We carried out this feasibility study in the context of two alignments and their combined impact zones between May 2018 and March 2019. These include an existing 84 km forest road through Corbett Tiger Reserve that was proposed by Government of Uttarakhand (hereafter current alignment / Kandi road), and a longer route bypassing Corbett National Park that was approved by the Hon'ble Supreme Court of India (hereafter SC alignment).

For ecological assessment of the project area, we: a) characterized the habitat in terms of land-uses, forest types, drainages and other relevant geographical features using most advanced high resolution WorldView-3 satellite imagery, b) sampled vegetation plots for ground truthing of very high resolution satellite imagery for assessment of vegetation composition, structure and ecologically important trees of conservation importance, c) generated spatially explicit abundance / usage data on representative mammals, including Rare Endemic Threatened (RET) species, using camera-trap based analytical approaches, supplemented with sign surveys to quantify indirect evidence of animal usage inside and at increasing distances from forest, d) assessed bird species and their vertical distribution along the Kandi road, and e) conducted social surveys to understand local perceptions about human-wildlife conflicts linked to proposed upgradation of the road. We considered route alternatives with appropriate mitigation measures in light of our ecological assessment. To identify the optimal alignment, we estimated a range of matrices for evaluation of ecological issues and financial merits of the project. The

decision criteria considered for evaluation included trees to be felled, potential increase in traffic induced mortality of mammals, extent of wildlife habitat loss, costs of construction and land acquisition, and travel time; against which alternative alignments were evaluated using Multicriteria Decision Analysis (MCDA).

The project area included parts of Kalagarh Tiger Reserve Division (KTRD) and Corbett National Park in Uttarakhand, and Amangarh Tiger Reserve and Bijnor Forest Division in Uttar Pradesh. These forests were dominated by moist Siwalik Sal (13% area), west Gangetic moist mixed deciduous (8%), Sal and dry Siwalik Sal (12%), plantation (7%), and moist deciduous (3%) forest types. Additionally, 41% area was under agriculture. Tree density was 624 individuals / ha, with *Mallotus philippensis*, *Holoptelea integrifolia, Ailanthus excelsa*, *Bombax ceiba, Haldina cordifolia, Shorea robusta* and *Tectona grandis* among the dominant species. Trees ranged from 1 to 32 m in height with modal height of 6-7 m and >2 tiers of canopy. We counted 823 individuals of four ecologically important plant species along the Kandi road that provide important resources for several birds, especially RET. We recorded 124 bird species along the Kandi road, including 10 RET species such as black-necked stork *Ephippiorhynchus asiaticus,* grey-headed fish eagle *Ichthyophaga ichthyaetus,* great hornbill *Buceros bicornis,* sarus crane *Grus antigone* and Kalij pheasant *Lophura leucomelanos*. Vertically, bird richness was greater at 0-5 m, comprising understorey species including RET pheasants and storks, as well as at 10-25 m comprising RET hornbills and eagles. Both height classes would overlap with traffic movement, on plain roads and proposed elephant-friendly elevated roads respectively, that could impair movements of RET birds during landing or take-off near road, leading to traffic induced mortality.

We recorded 20 terrestrial mammal species using camera-traps. We used an innovative approach of measuring proportion of the time spent by animals on 78 km stretch of Kandi road (Ramnagar–Saneh) using elevated time-lapse camera-traps placed at 1 km intervals (n = 49). This revealed high usage of Kandi road by elephant (9.7 animal-hours / day), tiger (3.1 animal-hours / day) and its prey: chital *Axis axis* (621.3 animal-hours / day) and sambar *Rusa unicolor* (66.9 animal-hours / day). Notably, tiger density was estimated to be 19.7 animals / 100 sqkm in Kandi road impact area – amongst the highest in the world – using camera-trap based Spatially Explicit Capture Recapture approach. At least 60 tigers used the 214 sq. km area, of which, 19 home ranges were intersected by the current alignment. Relative abundance of other species in the same area were estimated to be one independent photo-capture in a camera-trap in 1.1 days for chital, 3.4 days for sambar, 7.8 days for elephant and 13.4 days for barking deer. These estimates were greater than those reported from many Protected Areas, for which information was publicly available. Such high usage of Kandi road by general wildlife, in particular RET species, revealed its high conservation value that would be impaired if the road is upgraded without adequate mitigation measures in place. According to sign surveys, usage of forest-dwelling species ($0 < U < 1$) declined exponentially with distance from forest edge, yielding the general Species Usage Decline Function:

$U = e^{-0.12 - 1.93 * \text{distance to forest (km)}}$, to predict animal usage in unsampled areas.

Social surveys using focused group discussions in 33 villages within 4 km south of Kandi road indicated that majority of villagers accessed the Park for fuelwood and fodder, typically up to 1-3 km distance. Villagers reported intensive movements of wildlife species into adjoining agricultural fields that was corroborated by our sign surveys, resulting in crop damage by elephant, nilgai, wild pig, chital and sambar, along with concurrent usage of tiger and leopard for wild prey and livestock depredation. Existing fences around villages and fields, and the ill-maintained Park boundary wall were ineffective in abating such human-wildlife conflicts, as these barriers were breached/circumvented frequently by elephants. Local perceptions on the proposed road were largely positive, as villagers believed that it would promote accessibility to basic facilities, reduce travel time, and prevent animal movements into habitations. While solutions for the prevalent human-wildlife conflict should be sought, any animal barrier along the road was unlikely to address this problem, as the high density of north-south drainages (1.5 *raus* / km) would lead to heavy siltation and flash floods that, compounded with the intensive usage by elephants, would make the wall prone to periodic breaching and therefore making them ineffective (Natarajan 2018).

In terms of quantifying metrics for ecological and financial feasibility of the project, we used visual interpretation of tree crowns from very high resolution satellite imagery that was corrected using field calibration ratio (actual tree count was estimated to be 1.97 times higher than remotely-sensed count because of overlapping canopies), to estimate tree felling. Trees to be felled ranged from ~67000 for current alignment to ~12000 for SC alignment. We predicted potential traffic collision of mammals using traversability model (Langevelde and Jaarsma 2005), which was a function of the species' crossing rate, time taken to cross the road, and probability of > 0 vehicle reaching within that time. We parameterized the model using field estimates of animal speed (from time-lapse photo-captures), animal usage (from sign surveys) and traffic volume (from vehicle counts). Given the high usage of current alignment, its upgradation would potentially induce hourly collision rates of 0.09 individuals / km of RET species (tiger, elephant and sambar) at the current population abundance and assuming no behavioral response of animals to traffic. Collision rate reduced by >>10 folds for roads at ≥2 km distance from forest. We predicted wildlife habitat loss from current animal usage (declining function of distance to forest) and proportional loss of usage (declining function of distance to road based on Benitez-Lopez et al. 2010) in the impact zone of each alignment. Predicted habitat loss was greatest (112 sqkm) for current alignment. Temporary disturbance, measured as kilometer-years of construction activity within 500 m of forest, was among the highest for the current alignment (168 km-yr). Financial costs of construction (estimated at 150 million INR/km for plain and 950 million INR/km for elevated road), land acquisition (based on tehsil-level circle rates for agricultural land and Net Production Value of dense forest) and travel distance/time (road length) were lower for current alignment (Table 1a). However, very high ecological costs, as highlighted above, made the current alignment unfeasible and beyond the scope of mitigation. Even the SC alignment would cause high traffic induced injuries and mortality of animals along with loss of connectivity, as it is proposed through north-south contiguous forests of the wildlife rich KTRD without any mitigation measures. Hence, we did not consider these alternatives as feasible, and evaluated other routes with appropriate mitigation measures using weighted summation MCDA (Table 1).

a) Alignment 2B, where the existing forest road was realigned along the southern edge of CTR as an elevated highway from Sawaldeh to Saneh (64 km) cost ~6300 crore INR (>1.5 times costly than other alternatives) and included ~37000 tree-fellings that made it financially and ecologically less feasible, despite being the shortest route, passing largely (67% of road-length) but not entirely through Uttarakhand. b) Alignment 1B, where the SC alignment was modified as an elevated road from Morghati to Saneh (KTRD), had much less ecological costs (~12000 tree fellings, i.e., 1/4th of the current alignment and equal to the SC alignment, and potential hourly collisions of 0.81 animals, i.e., 1/6th of current alignment and 1/2th of the SC alignment), against reasonably low financial costs (~3500 crore INR for construction + land acquisition cost and 114 km travel distance). c) Hybrid alignment 3B, where the SC alignment was realigned >2 km south of CTR from Kalluwala to Morghati through agriculture/habitation had the least ecological cost (~15000 tree-fellings, i.e., 25% greater than alignment 1A/B, potential hourly collision of 0.59 animals, i.e., 27% lower than alignment 1B, and sacrificed wildlife habitat of 26 sqkm, i.e., 14% lower than 1B), at marginally less financial costs (0-20% across criteria). d) Alignment 4A suggested by EDCUL, where the alignment 2B was realigned up to 1 km south of CTR between Morghati and Dhara, had high ecological costs (~28000 tree-fellings, i.e., 225% greater than alignment 1B, potential hourly collision of 1.5 animal, i.e., 83% greater than alignment 1B, and sacrificed wildlife habitat of 55 sqkm, i.e., 82% greater than 1B), at less financial costs in terms of travel distance/time and land acquisition (25-60% lower than 1B), but not in terms of construction (12% greater than 1B). e) Alignment 4B, where the alignment 4A was further realigned to >2 km south of CTR between Morghati and Dhara, had similar ecological costs as alignment 4A (~27500 tree-fellings, i.e., 223% greater then alignment 1B and 47 sqkm of sacrificed wildlife habitat, i.e., 55% greater than 1B) except for lower animal collision rate (potential hourly collision of 0.5 animal, i.e., 31% lower than alignment 1B). However, its financial costs were lower in terms travel distance/time and land acquisition (25-50% lower than 1B), but not in terms of construction costs (34% greater then 1B). Thus, MCDA results revealed that the hybrid alignment 3B was the most feasible alternative for the proposed Ramnagar- Kotdwar road (Table 1).

Apart from 3B, two other alignments that ranked better among alternatives were 1B and 4B. Alignment 4B shortens the travel time/distance and its predicted animal collision rate is at par with 3B, but it fails to reduce other important ecological costs i.e., tree felling and sacrificed habitat (nearly double that of 3B). Further, alignment 4B passes through core area of Corbett Tiger Reserve, which is one of the most important tiger and elephant conservation units globally, and is critical to the population viability of these endangered species in Terai Arc Landscape. Even if the road is elevated through this area, disturbances during the construction and maintenance phases and long-term avoidance of infrastructure by tiger and elephant (as also demonstrated by this study) will reduce the habitat viability, thereby detrimentally impacting the ongoing conservation efforts for these endangered species. Moreover, the construction cost of 4B is substantially high when compared to alignments 3B and 1B.

Alignment 1B has the advantage of least tree felling and low sacrificed habitat, but has higher predicted collision rate of animals than 3B/4B, and has longer travel distance/time than 4B but marginally shorter than 3B. Alignment 3B has the disadvantage of longer route (40% greater than 4B), but its ecological costs and even construction cost are among the least, and was therefore, ranked as the most feasible alternative based on all weightage systems in our MCDA (Table 1). Hence, alignment 3B is the most feasible option for the proposed Kandi road.

We suggest that alignment 3B may be considered with the following safeguards: a minimum of 1 km and preferably 2 km distance from the forest edge from Ramnagar to Kalagarh via Patrampur and Kalluwala, and an elevated road 8 m in height from Morghati to Saneh (both 1B and 3B). We also suggest installation of noise barriers (at least 3 m in height) on both sides over the suggested elevated stretches wherever the road passes through forested areas (or within 100m from forest edge) in order to minimise impacts of traffic noise on wildlife species and also to prevent bird species' mortalities. The habitat cleared of vegetation for the purpose of overpass construction should also be restored by planting native understory shrub that will discourage spread of invasive species as well as mimic the natural habitat of the landscape and thus will be conducive to wildlife movement. Regular removal of invasive species is also suggested.

Table 1: Multi-criteria decision analysis for evaluating the feasibility of alternative alignments of the proposed Ramnagar-Kotdwar road (2018–19), based on (a) absolute performance scores against ecological and financial criteria, and (b) overall performance score obtained by weighted summation of standardized criteria scores. Three sets of weightages were used: equal for all criteria, proportionally greater weights for ecological criteria, and proportionally greater weights for financial criteria.

(a)		**Alternative alignments**								
Cost criteria		**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**Units**
Ecological / conservation	a) Tree felling	12366	12366	67634	36551	28715	15675	27942	27533	number
	b) Collision rate	1.65	0.81	4.81	0.58	0.61	0.59	1.47	0.56	number / hr
	c)Temporary disturbance	66	83	168	223	149	92	154	154	km-yr
	d) Sacrificed habitat	34	30	74	56	38	26	55	47	sq km
Financial / logistic	e) Travel distance	114	114	84	79	97	123	85	87	km
	f) Land acquisition cost	718	718	200	261	570	871	290	383	million INR
	g) Construction cost	18156	34656	15288	63128	49278	39070	38702	46342	million INR

(b) Criteria	Standardized score (*Sij*)	Alignments						Weightage		
		1B	2B	3A	3B	4A	4B	Equal	Cons. driven	User defined
Ecological / conservation	a) Tree felling	1.00	0.00	0.32	0.86	0.36	0.37	0.14	0.21	0.14
	b) Collision rate	0.00	1.00	0.87	0.94	0.00	1.00	0.14	0.21	0.21
	c) Temporary disturbance	1.00	0.00	0.53	0.94	0.49	0.49	0.14	0.14	0.07
	d) Sacrificed wildlife habitat	0.84	0.00	0.60	1.00	0.04	0.30	0.14	0.21	0.21
Financial / logistic	e) Travel distance	0.20	1.00	0.59	0.00	0.86	0.82	0.14	0.07	0.14
	f) Land acquisition	0.25	1.00	0.49	0.00	0.95	0.80	0.14	0.07	0.07
	g) Construction cost	1.00	0.00	0.49	0.84	0.86	0.59	0.14	0.07	0.14
Overall score (*Vj*)	Equal weightage	0.61	0.43	0.56	**0.65**	0.51	0.62			
	Conservation driven weightage	0.64	0.36	0.57	**0.79**	0.35	0.59			
	User defined weightage	0.59	0.43	0.59	**0.73**	0.41	0.63			

In addition to the Multi-criteria Decision Analysis (MCDA) (Table 1), we also developed a Simplified/Qualitative Conservation Value Matrix (SCVM) (Table 2) derived from the quantitative values obtained from MCDA. On the basis of MCDA and SCVM analysis carried out as part of the feasibility study the Government of Uttarakhand would have to decide the further course of action. We understand that the proposed road alignments being part of Corbett Tiger Reserve, Rajaji Tiger Reserve and Amangarh Tiger Reserve necessary approvals from the NTCA (National Tiger Conservation Authority), the State Board for Wildlife, Uttarakhand and the National Board for Wildlife (Standing Committee) would have to be taken, taking into account the directions issued by the Central Empowered Committee, the Hon'ble NGT (National Green Tribunal) and the Hon'ble Supreme Court of India in the context of various cases pertaining to the proposed road upgradation.

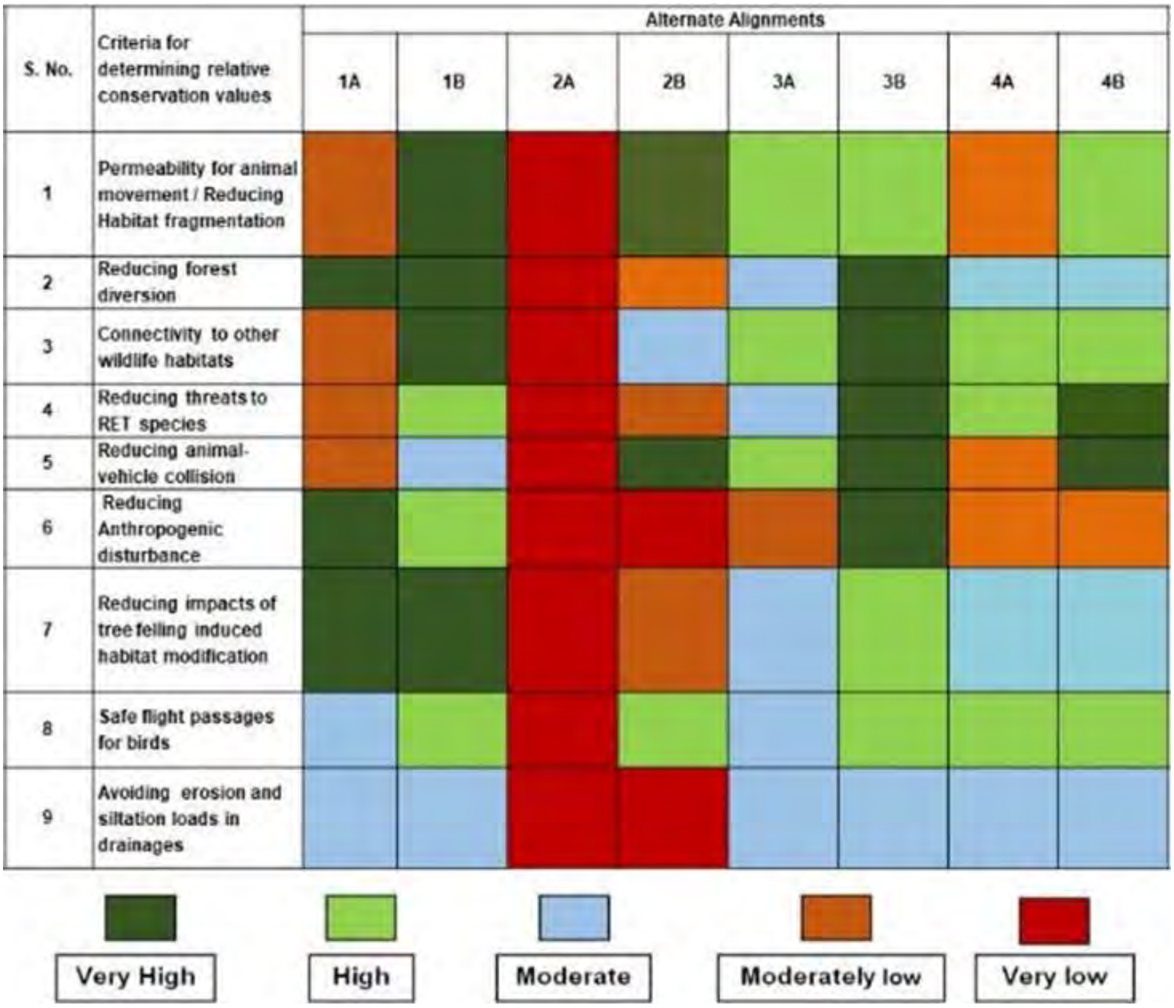


Table 2: Simplified/Qualitative Conservation Value Matrix derived from the quantitative values obtained from ecological assessment and multi criteria decision analysis results (Table 1) to identify the ecologically feasible alignment(s)for the proposed Ramnagar-Kotdwar road. Shades of colors indicate how much the alignment safeguards an ecological value / concern (from very high in dark green to very low in dark red).

Based on the simplified conservation value matrix (above) it becomes further evident that Alternative 3B is the most feasible option followed by 1B and 4B respectively, for ensuring long term prospects of conservation of wildlife species and their habitats in this ecosystem and taking into account the use of best available construction technology under constant oversight and compliance monthly by a joint team of forest, wildlife and transport professionals during a) pre-construction b) construction and c) post-construction phases.

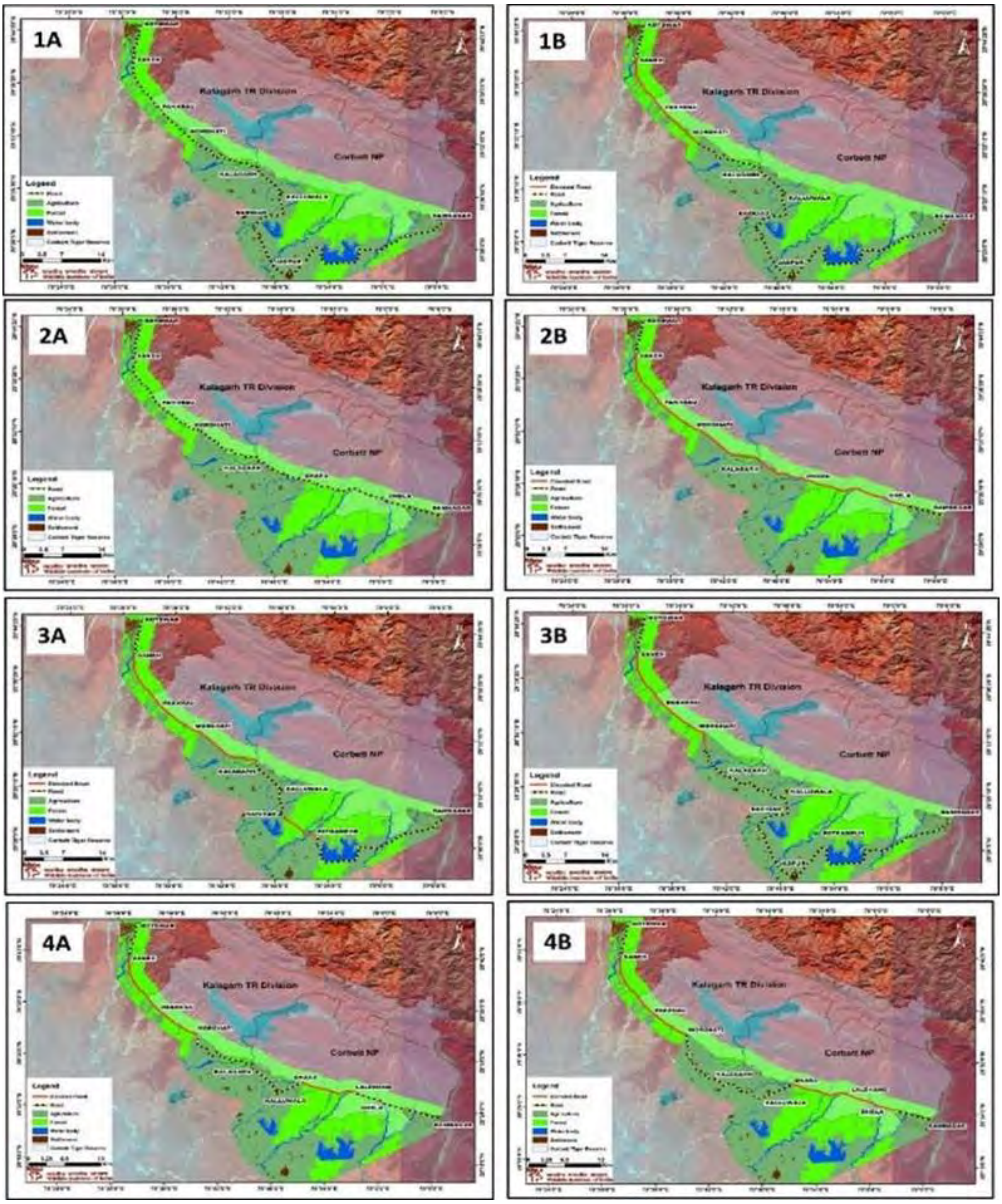


Figure 1 : Comparative mapping of the alternative routes with mitigation measures for the proposed Ramnagar–Kotdwar road (2018-19), showing alignments: 1A, 1B, 2A, 2B, 3A, 3B, 4A amd 4B.

1. INTRODUCTION

1.1 Road Infrastructure: Challenges for Conservation

Roads, that are essential features for connecting people, transporting goods and connecting centres of trade for promoting national economy, often pose diverse and complex challenges for conserving wildlife in roaded landscapes. Many ecologists have singled out roads as the factor posing the greatest challenges for biodiversity (Noss 2002; Grilo *et al.* 2011; Bennett 2017; Lechner *et al.* 2018; Mehri *et al.* 2018) and leading to the widest form of modifications of natural landscapes (Bennett 1991; Noss & Cooperrider 1994; Liu *et al.* 2008; Laurance 2008). Studies have demonstrated that relationships between roads and natural environment often result in negative impacts on wildlife values, ecosystem processes and landscape functions (Forman 2003; Ree et al. 2011). The most significant negative impacts of roads include a) barrier effects that impair movements of wildlife, eventually leading to genetic isolation of populations; b) traffic induced mortality of wild animals in crossing zones; and c) loss of vital habitat due to physical presence of roads (Bank et al. 2002; Meese et al. 2009; Baskaran and Boominathan 2010; Daigle 2010; Ree et al. 2015). Alteration of alignment to avoid critical wildlife habitats, and construction of overpasses, underpasses and waterways can address impacts on wildlife species that are dependent on road and making it permeable for movement across habitats.

Landscapes fragmented by roads cannot be reconnected and made more permeable. Responsible agencies and organisations need to be aggressive about promoting mitigation and conservation ethic into road planning. Projects conceived with the objective of improving road infrastructure must therefore take cognizance of the impacts on wildlife and the need to ensure that such projects adopt eco-friendly approaches to avoid and minimize their impacts (Rajvanshi and Mathur 2015). Road and rail networks passing through Protected Areas and other sensitive habitats interspersed between such areas should be given highest consideration for developing eco-friendly measures or ‘green infrastructure’ to minimize their impacts on biodiversity conservation. Adequate guidance is now available (Clevenger and Waltho 2005; WII 2015; Beben 2016; Pragatheesh 2019) for adopting eco-friendly crossing structures such as overpasses, underpasses, culverts and channels for facilitating animal movements and thereby reducing the barrier effects and avoidable fragmentation of wildlife habitats. At the same time, a crossing structure will only be effective if it is accessible and acceptable to the species that will potentially utilize it.

1.2 Project Background

With this background, the study on potential impacts of ‘Kotdwar-Ramnagar Kandi Marg / Road’ on wildlife values, and the feasibility of mitigation measures provides an appropriate opportunity to adopt the principles of road ecology in developing ‘green infrastructure’ for an important conservation area. The project area holds high conservation importance because it: a) includes the Corbett National Park, one of the earliest Protected Areas of India, b) supports the single largest source population of tigers in North India and is considered a top-priority Tiger Conservation Unit, and c) forms the northwestern distributional limit of the Asian elephant population, with this landscape holding 90% of total elephant population of north-west India (Johnsingh and Joshua 1994), among other reasons.

1.3 Kotdwar-Ramnagar Kandi Road

A road connecting Kumaon with Garhwal regions through the shortest possible route has been a long-standing demand for people of the state of Uttarakhand. An existing 95 km forest road provides fair weather connectivity between Kotdwar, Kalagarh, Ramnagar and Laldhang. Substantial portion of this road passes through Corbett and Rajaji Tiger Reserves. The 25 km stretch of this road between Pakhro to Kalagarh is aligned through the buffer zone of Corbett Tiger Reserve and another 20 km stretch between Kalagarh and Laldhang is aligned through the core zone of Corbett Tiger Reserve. A significant portion of this road aligned along the southern boundary of Corbett Tiger Reserve is referred to as the 'Kandi Marg' (Figure 3).

In the past, attempts have been made to upgrade this road to a metal-topped road. The initial section of the road from Ramnagar to Khara gate of Corbett Tiger Reserve was widened and metal-topped (between 2002–2007). Between Dhela and Laldhang, this metalled road passes through the buffer zone of Corbett Tiger Reserve. From Khara gate, the road enters the National Park and construction in this stretch was halted at that time, owing to the legal status of the area. Between Khara gate and Kalagarh, the forest road passes through core zone of Corbett Tiger Reserve (Jhirna and Kalagarh ranges) and is partly open for tourism (till Jhirna). From Kalagarh to Pakhro, the forest road passes entirely through the buffer zone of Corbett Tiger Reserve (Sonanadi and Pakhro Ranges). This stretch is open for public during fair weather (15 November through 15 June) with certain regulations.

An attempt was also made to pave the Kandi road between Kalagarh and Morghati in the past (mid-1990s). Bridges and culverts were made along the southern boundary of buffer zone of Corbett (currently in the Sonanadi Range). However, due to judicial intervention, work on this road was stopped. One can clearly see this road along the southern boundary that is now overgrown with vegetation.

From Pakhro to Kotdwar, the black-topped road is open for public use. Part of the road from Kotdwar to Laldhang (from Chillarkhal to Laldhang) that is existing and is partially metalled, passes through the buffer zone of Rajaji Tiger Reserve.

1.4 Conservation issues linked to the project

A substantial portion of the proposed road passes through core and buffer zones of Corbett and Rajaji (buffer only) Tiger Reserve. The Corbett Tiger Reserve is intensively used by tiger, leopard, elephant, and several prey species like sambar, chital, wild pig, muntjac and other wildlife (Johnsingh and Joshua 1994). The earliest impacts that can be visualized are those resulting from clear felling along the roadway and associated disturbances to animals. Once this road is upgraded, heavy traffic volume on it is likely to pose a barrier for the movements of most animals, eventually causing genetic isolation of populations of elephants in particular. Fatal collisions with speeding vehicles is likely to pose significant threat to the persistence of the local populations of endangered animals such as tiger and elephant. Therefore, it is necessary to conduct a study that examines the wildlife values of the area, the potential impacts of the proposed road on these values, and the feasibility of developing wildlife-friendly mitigation options to address these detrimental negative impacts.

1.5 WII's role in impact assessment and green infrastructure planning

The Forest and Environment Department, Government of Uttarakhand assigned the responsibility of developing wildlife-friendly road infrastructure for the proposed 'Kotdwar - Ramnagar Kandi route' to the National Buildings Construction Corporation Limited (NBCC) with the Ecotourism Corporation of Uttarakhand Ltd. (EDCUL) as the Nodal Agency (see letter No. X-2-2017-01(01)/2001 dated 29 December 2017). It was decided that agencies such as the Wildlife Institute of India (WII) would develop concepts and designs to promote Green Linear Infrastructure by adopting all possible eco-friendly measures for minimizing impacts of construction of this road on wildlife. Subsequently, the NBCC requested WII to conduct feasibility study for development of linear infrastructure with minimum impacts on wildlife, and a Memorandum of Understanding was executed (Annexures 1 a-b).

1.6 Aims and objectives of the Assessment and Feasibility study

The overall objective of this study is to assess the potential impacts of the proposed Kotdwar - Ramnagar Kandi road on wildlife values, review route alternatives, and consider appropriate mitigation measures to minimize the negative impacts of the road upgradation on the integrity of the protected areas and ecological services provided by the landscape and on the species inhabiting this landscape.

To achieve the above stated objectives of the study, it was necessary to characterize landscape features and wildlife movements along the road alignment, at high resolution. This would require:

a. Development of a spatially explicit ecological baseline of the project area, focusing on: quality and extent of wildlife habitats, land-cover features and ecological values such as critical bio-corridors, key wildlife, occupancy areas of rare-endangered-threatened (RET) species, and features such as drainages in the roaded landscape that merit conservation and protection.

b. Estimate abundance and variable use pattern of habitats by species of conservation significance such as the elephant, tigers and their co predators and prey base.

c. Delineation of animal crossing/zones points along the existing road to explore the feasibility of mitigation measures on current alignment.

d. Relate concepts of road ecology to observations in the field to delineate the road alignments and suggest specific mitigation measures to address the detrimental negative impacts of the project on wildlife values.

1.7 Scope of the study

This study was carried out primarily in the context of two alignments: one proposed by the Uttarakhand Government (EDCUL) along the existing forest Kandi road, and another proposed to and agreed upon by the Hon'ble Supreme Court that avoided wildlife rich Protected Areas. We assessed wildlife values using state-of-the-art field sampling and analytical techniques that allowed us to extrapolate our assessments to the larger landscape around these roads. In light of these assessments, we explored alternative alignments and mitigation measures/structures for each of these alignments, as per our mandated objectives. We focused on measures (alignments and mitigations) that can reduce habitat fragmentation, traffic mortality of mammals, wildlife habitat loss and tree felling. Apart from these, we also considered the local perception on human-wildlife conflict and the current project to explore options of integrating these aspects into road planning, particularly if the proposed road alignment can fulfil the secondary function of mitigating crop depredation in villages adjoining the forest.

2. STUDY AREA

We conducted the study in and around the southern section of Corbett Tiger Reserve (hereafter CTR), along the 85 km road from Pakhrau to Ramnagar and adjoining private lands in Uttar Pradesh (U.P.) from May 2018 to January 2019. The CTR is divided into two administrative divisions: Kalagarh Tiger Reserve (Forest) Division (hereafter KTRD) and Corbett National Park. This Tiger Reserve is renowned for its wildlife abundance, and home to around 643 bird species (Avibase), 617 plant species (in Corbett National Park; Pant, 1986) and one of the largest tiger populations in the world (WII 2015).

The CTR comprises different forest types, scrubland, grassland and water bodies. According to Pant (1986), vegetation of the area is broadly categorized into mixed deciduous tropical and subtropical forests, which is further categorized into nine forest types, namely (1) Moist Siwalik Sal Forest, (2) High Alluvium Sal Forests, (3) Dry Siwalik Sal Forests, (4) Northern Tropical Dry Mixed Deciduous Forests, (5) Moist Savanna Forests, (6) North Indian Moist deciduous Forests, (7) Khair-Sissoo Forests, (8) Dry Bamboo Brakes and (9) Himalayan Sub-tropical Forests.

2.1 Mapping of road alignments with geographic extent, impact zones and contiguous wildlife habitats

The Kandi road has a long history since the British rule, when it was used to carry British officers' families in palanquin from Kotdwar to Ramnagar via Kalagarh, cutting through dense forest of the then Hailey National Park. The road derives its name from palanquin ("kandi" in hindi, *pers. comm.* DFO, KTRD). Currently the road has shifted from the original alignment by 50m-500m in certain stretches. When the state of Uttarakhand was carved out from Uttar Pradesh in 2000, the original Kandi road was used to demarcate boundaries between the two states. We mapped the original Kandi road using the milestones, which are still intact at many sites. We refer to this road in its current form as the "current alignment", "existing forest road" or "Kandi road", interchangeably, throughout the report.

The current alignment connects Ramnagar to Kotdwar via Dhela-Laldhang-Kothirau-Dhara-Khatpani-Kalagarh-Nalkhatta-Morghati-Dholkhand-Pakhrau-Saneh. Starting from east, the road first enters the forested area of CTR at Babaliya near Sawaldeh village. From Babaliya to Laldhang, the road passes through contiguous habitats: CTR (buffer zone) in north and Terai West Forest Division in south, both in Uttarakhand. Around 1.5 km stretch in this segment passes through managed grassland of Laldhang. From Laldhang to Dhara, the road cuts through a critical movement corridor where the forest of CTR (core zone) is contiguous with the forest of Amangarh Tiger Reserve (UP) in south. From Dhara to Kalagarh and to Morghati, areas south to the road are largely occupied by agriculture and plantations. From Morghati to

Pakhrau, the road cuts through another wildlife corridor where forest patches of Badapur and Sahuwala in south (Bijnor Forest Division, UP) are connected with forest of KTRD (buffer zone of CTR, UK). From Gujjar Sot (Pakhrau Range) to Saneh, Kandi road passes through Landsdowne Forest Division.

The alignment suggested by the Hon’ble Supreme Court runs on an average 15 km south to the Kandi road from Ramnagar to Kalagarh via Dharampur-Hathidangar -Maldhan-Tumaria Barrage (along southern boundary)-Patrampur-Jaspur-Rehar-Badigad- Kalluwala. The 5 km stretch between Hathidagar and Maldhan passes through Terai West Forest Division, which is contiguous with Dhela range of CTR. From Kalagarh, the alignment runs through forest along the southern boundary of KTRD till Saneh.

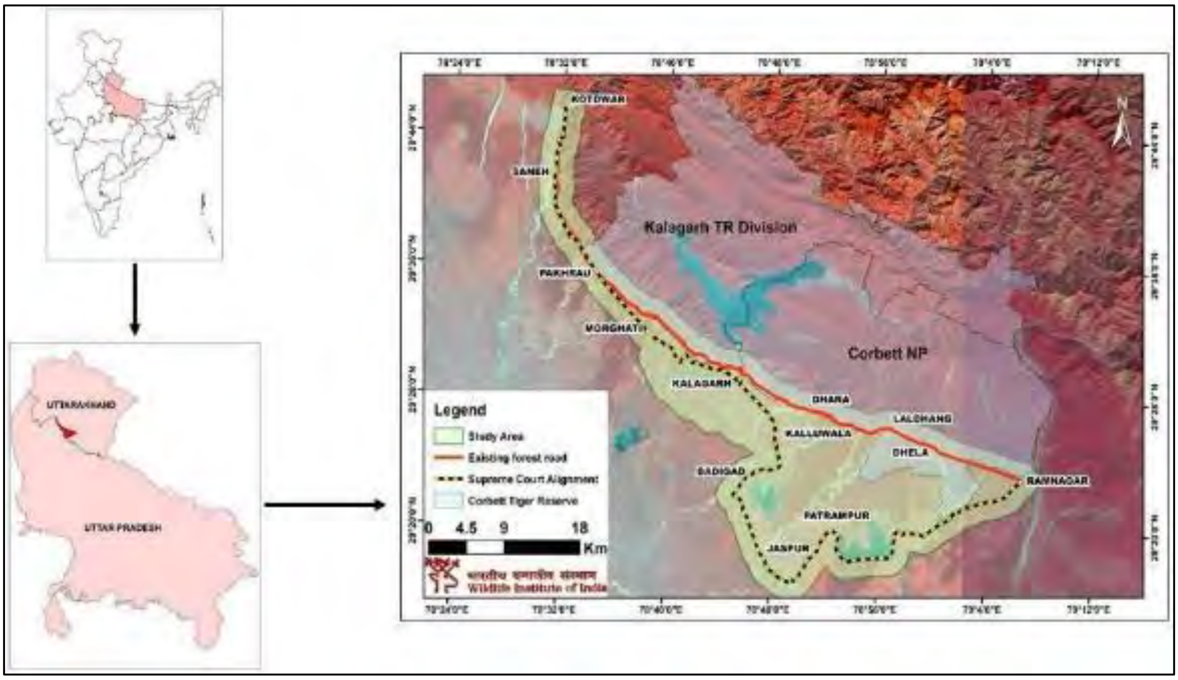


Figure 2 : Map of study area between the current forest alignment (Kandi Road) and the Hon’ble Supreme Court alignment with its location at country and state levels.

The study area was delineated as the impact zone around the current and Supreme Court alignments with the intervening area. Impacts of a road through forested habitats vary with the taxonomic class in consideration. Most impacts penetrate upto a certain distance from the road before leveling off. This distance is termed as “road-effect zone” (Forman et al. 2003). Road impact zone can extend over larger distances for mammals when compared to birds. Mammal populations can be affected upto 2 km from the road, while for birds it might satiate within 500m-1000m (Torres et al. 2016). With this rationale, we considered the road impact zone as 2 km buffer on both sides of the road (Figure 2).

Given these two alignments, we also looked for feasibility of other alignments that fall between them and can reduce the travel distance / time and financial costs, yet minimizing the ecological impacts (as per our scope 1.4). In this study (justification in subsequent sections), we evaluate six alignments for the proposed Ramnagar–Kotdwar Kandi Road, namely:

1A: Approved by the Hon’ble Supreme Court of India
1B: The Hon’ble Supreme Court alignment with mitigation measures

2A: The existing Kandi forest road
2B: Modified Kandi road along southern boundary of CTR with mitigation
3A: Hybrid alignment similar to 1B but diverted through Amangarh Division
3B: Alignment similar to 1B but farther away from forest
4A: Alignment suggested by Uttarakhand Govt. to reduce road length
4B: Modified version of alignment 4A to reduce traffic mortality of animals (Figure 3).

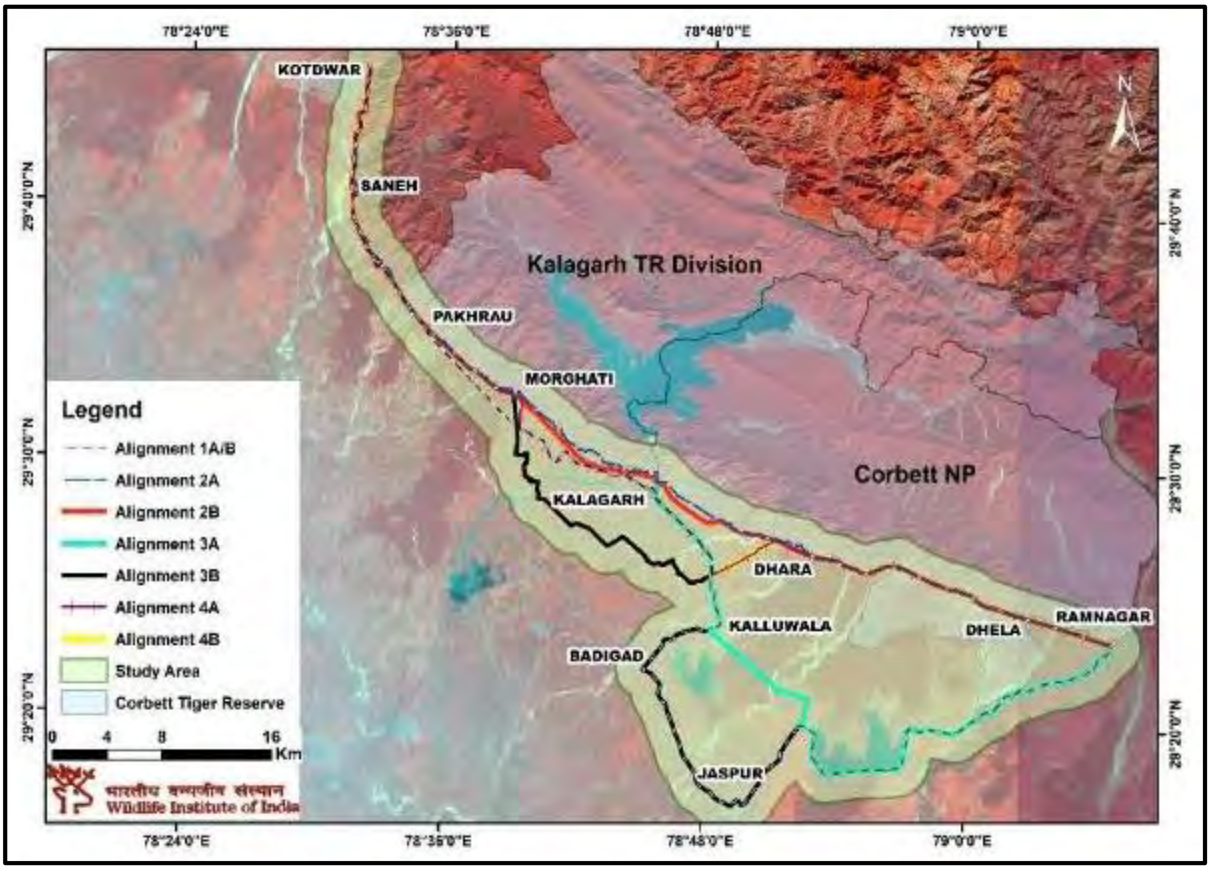


Figure 3 : Alternative alignments of the proposed Ramnagar–Kotdwar road at a glance

A comparison of the major land-use types along each of these alignments, measured as the proportion of road length through natural forest, forest plantation, grassland/scrub and agriculture/settlements, is provided below (Figure 4).

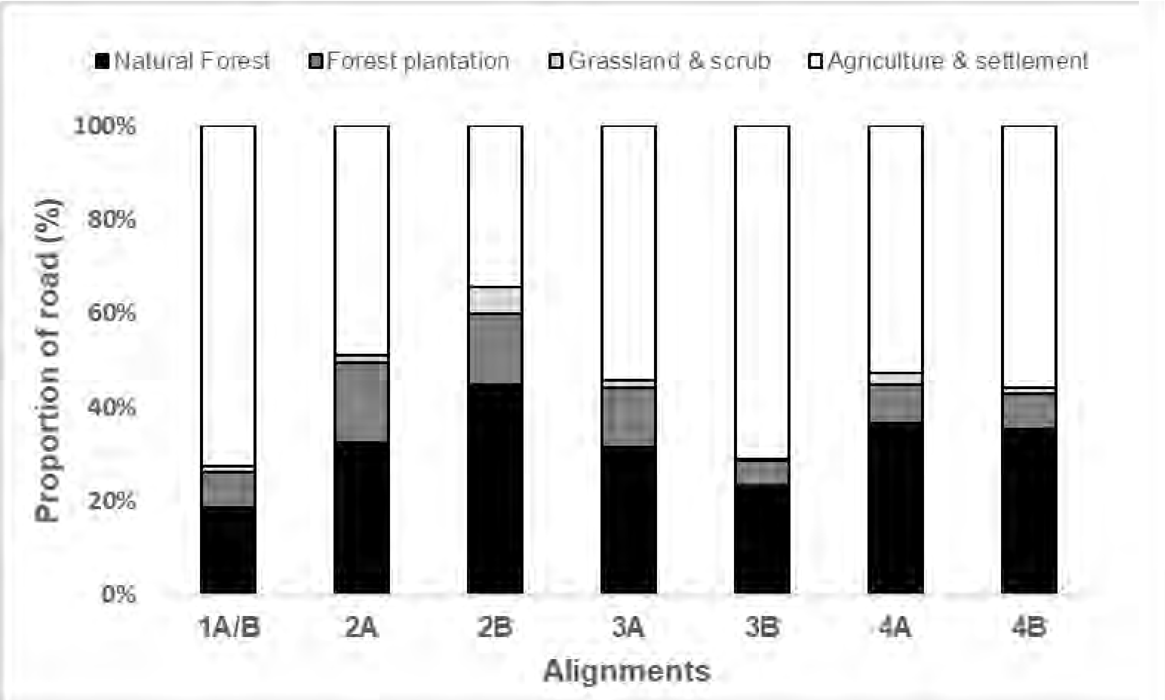


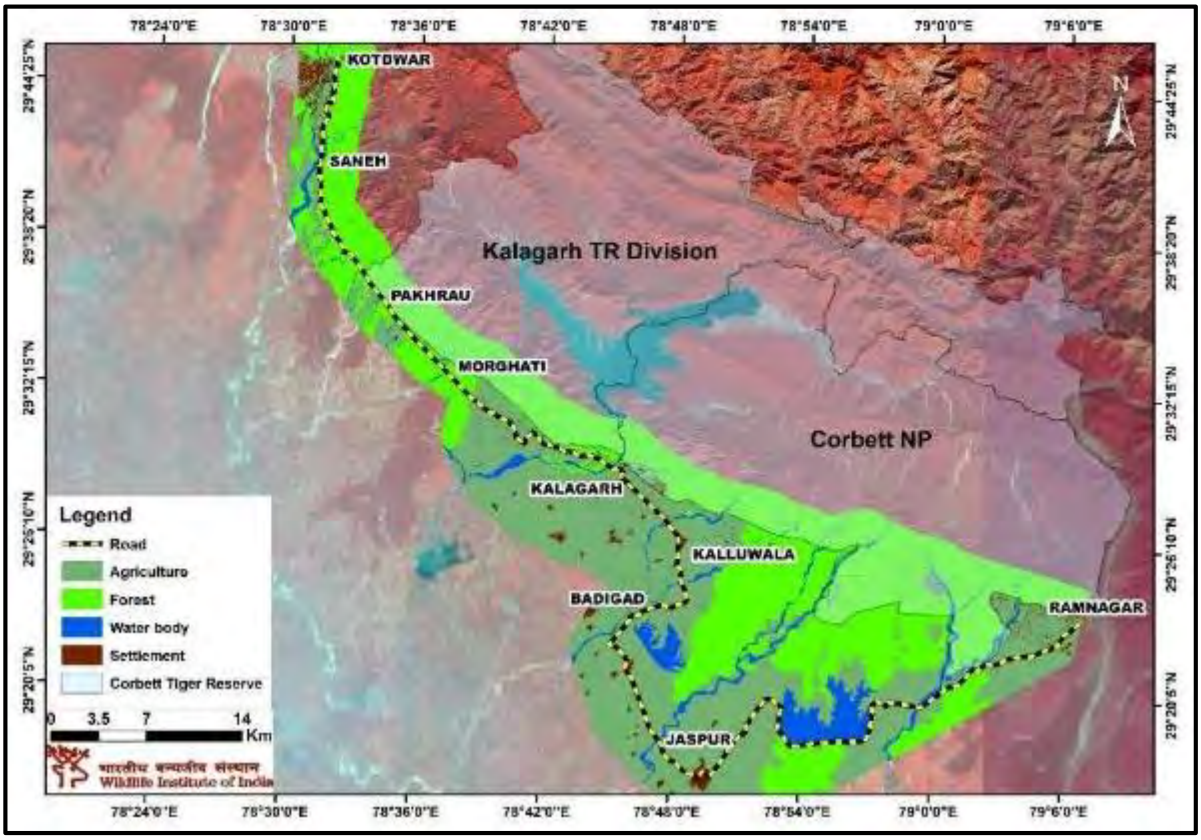
Figure 4 : Broad land-use types along alternative road alignments, measured as proportion of road lengths through each land-use type, for the proposed Ramangar-Kotdwar Kandi Road (2018-19).

Alignments 1A &1B: We reconstructed the alignment suggested to and approved by Hon'ble Supreme Court based on the approximate route and settlements mentioned in Writ Petition 47 dated 25/11/2005. Length of the alignment, as per our digitization, is 114 km (as opposed to 138.7km featured in the affidavit), which may differ from the actual route suggested to the Hon'ble Supreme Court. This route passes from Ramnagar-Kalagar through Patrampur-Jaspur (Uttarakhand) via Badigad-Kalluwala (Uttar Pradesh) and Kalagarh-Morghati-Pakhro-Saneh-Kotdwar (Uttarakhand). The major forest types along these alignments are West Gangetic Moist Mixed Deciduous Forest, which is among the most species rich forest types in the landscape, and Forest Plantations (teak and eucalyptus) (Table 3).

Alignments 2A & 2B: Length of 2A (existing forest road) is 84 km while that of alignment 2B is 79 km. These alignments go from Ramnagar-Dhela-Dhara-Kalagarh-Morghati-Pakhro-Saneh-Kotdwar through the forest. Major forest types along these alignments are West Gangetic Moist Mixed Deciduous Forest, Moist Siwalik Sal Forest and Forest Plantations (Table 3).

Alignments 3A & 3B: While the above alignments were largely known at the onset of the study or were mildly modified forms of the former, alignments 3 A/B were identified as part of the study. Lengths of alignments 3A and 3B are 98 km and 123 km respectively, of which, 47% of 3A and 34% of 3B lie inside forest. These alignments are similar in their geographical delineation as that of 1A/B with diversion of the road in 3A from Patrampur through Amangarh division in Uttar pradesh till Kalagarh after which it joins the forest road till Saneh as an elevated road. The alignment 3B is diverted further south from the forest at a distance of >2 km till Morghati, thereafter merging with the forest dirt road of Uttarakhand as an elevated road till Saneh. Major forest types along these alignments are West Gangetic Moist Mixed Deciduous Forest followed by Forest Plantation and Dry (open) Sal Forest.

Alignments 4A & 4B: Length of alignments 4A and 4B are 85 km and 87 km respectively. 35% of both the alignments lies inside forest. To shorten the distance, alignment 4A diverts between Morghatti to Dhara from the forest adge and remains ~1km south of it. It again enters into forest at Dhara as an elevated road upto Laldhang (core area of CNP) and the continues on ground till Ramnagar. Alignmnent 4B runs ~2-3km south of forest boundary between Morghatti and Dhara, from where it is an elevated road till Sawaldeh whereafter it runs on ground again. Major forest types along these alignments are West Gangetic Moist Mixed Deciduous Forest followed by Moist Siwalik Sal Forest, Forest Plantation, Khair-Sissu Forest and Dry Siwalik Sal Forest.



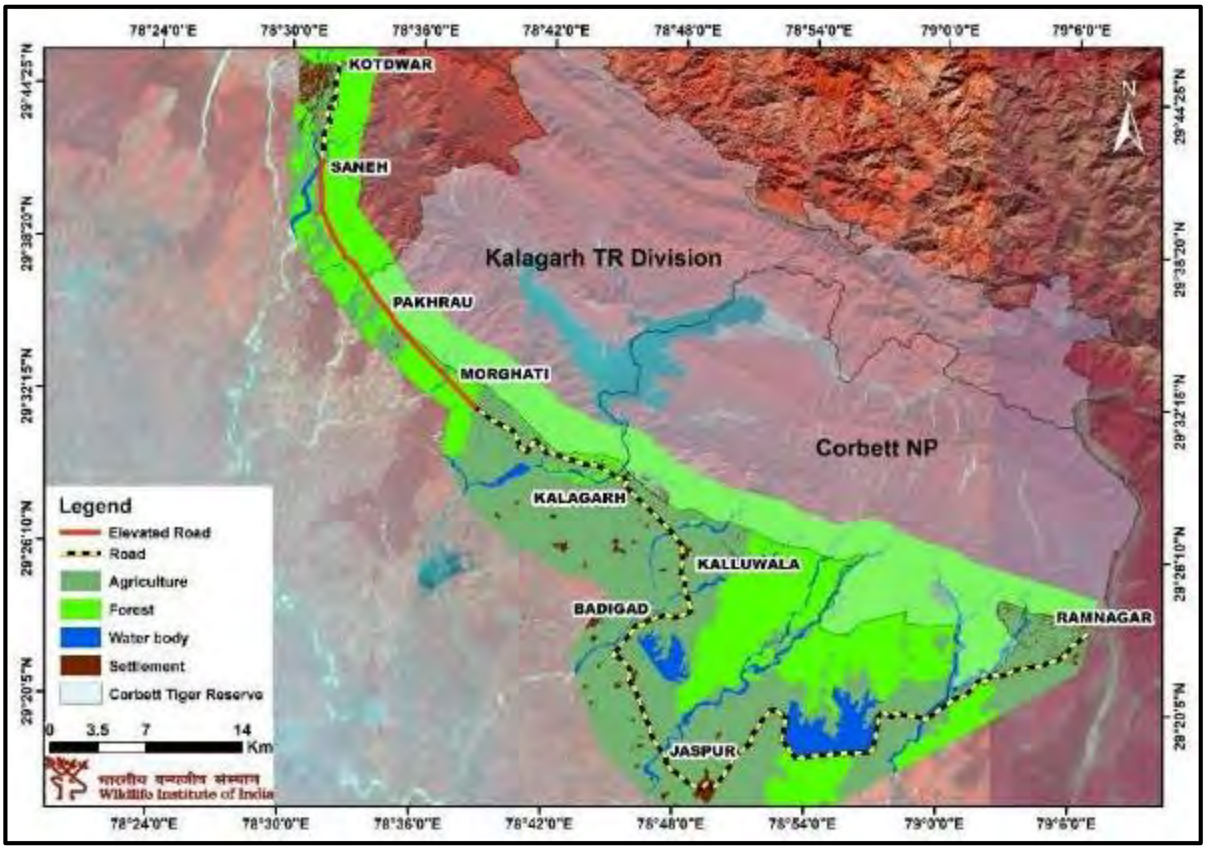
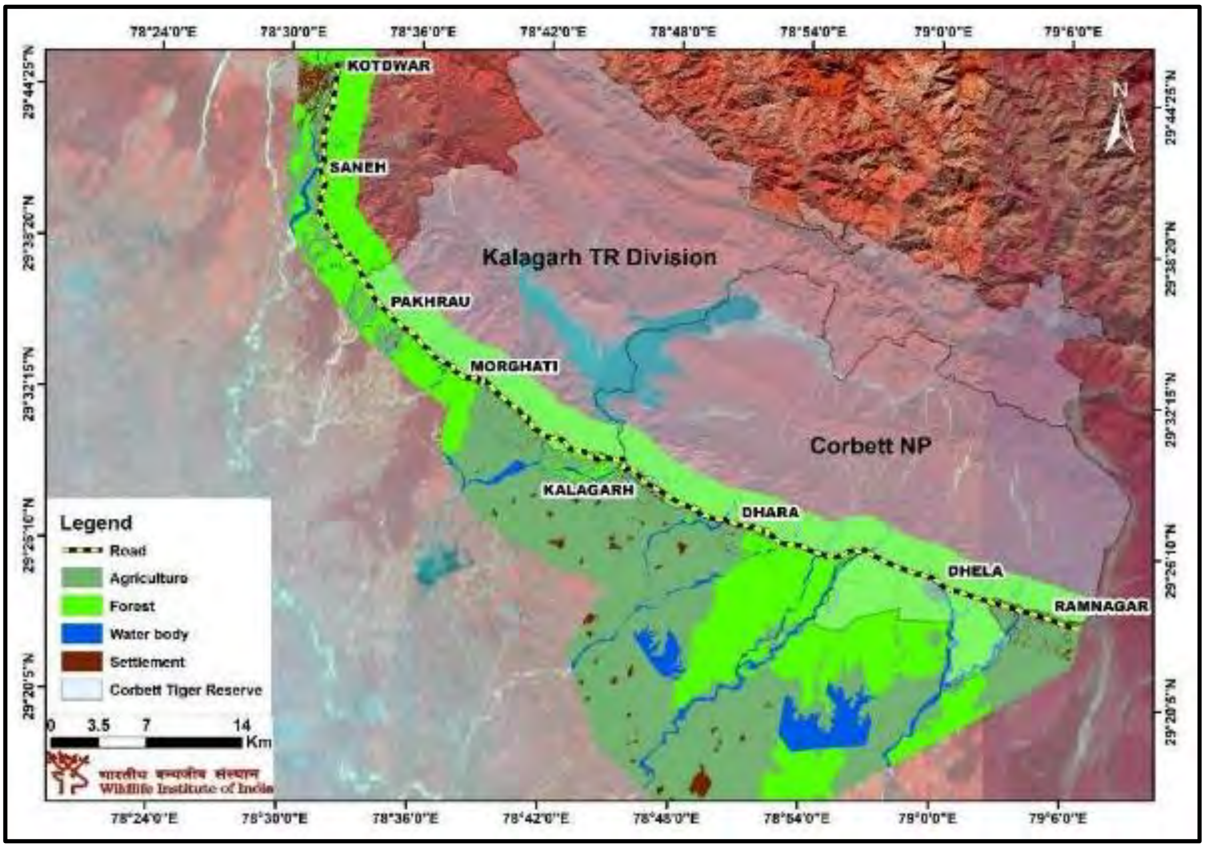


Figure 5 : Maps of alternate alignments 1A (top, without mitigation) and 1B (bottom, with mitigation) with geographic details for the proposed Ramnagar–Kotdwar road (2018-19).



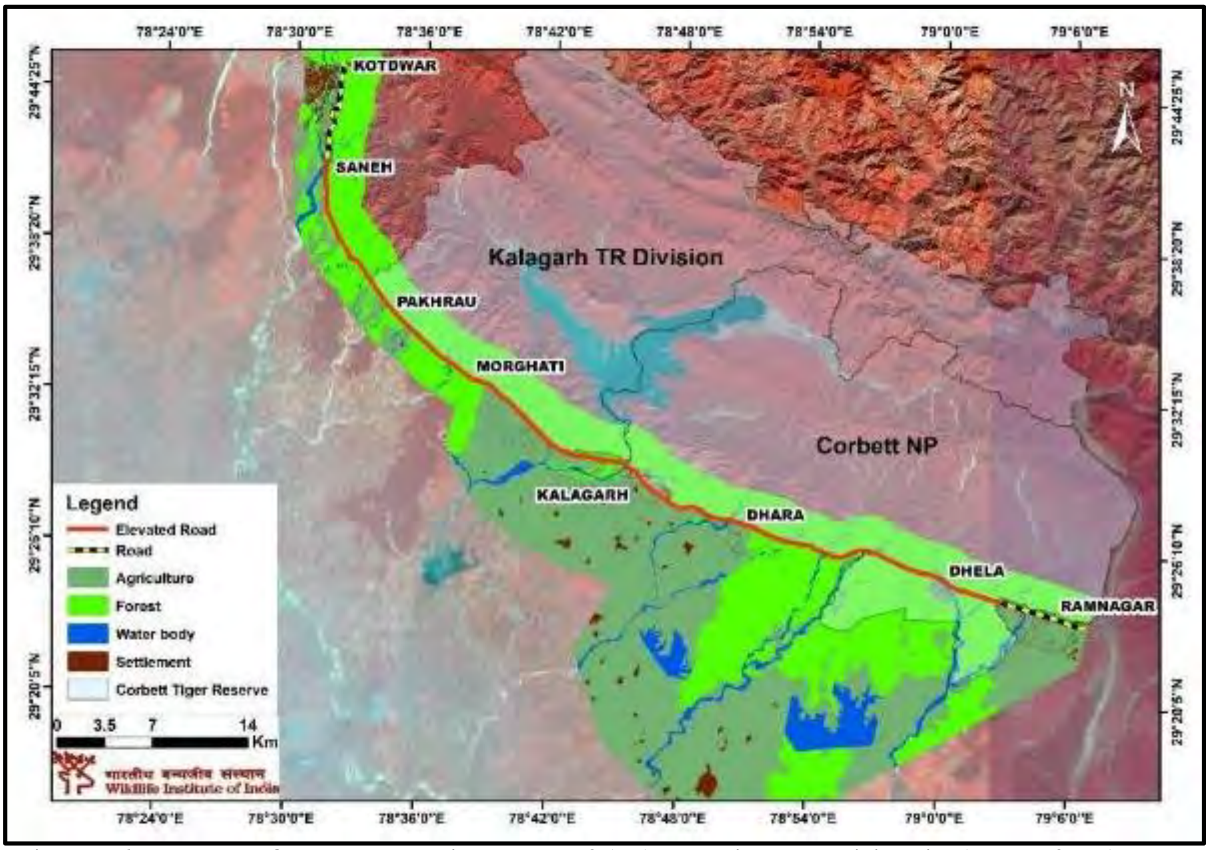
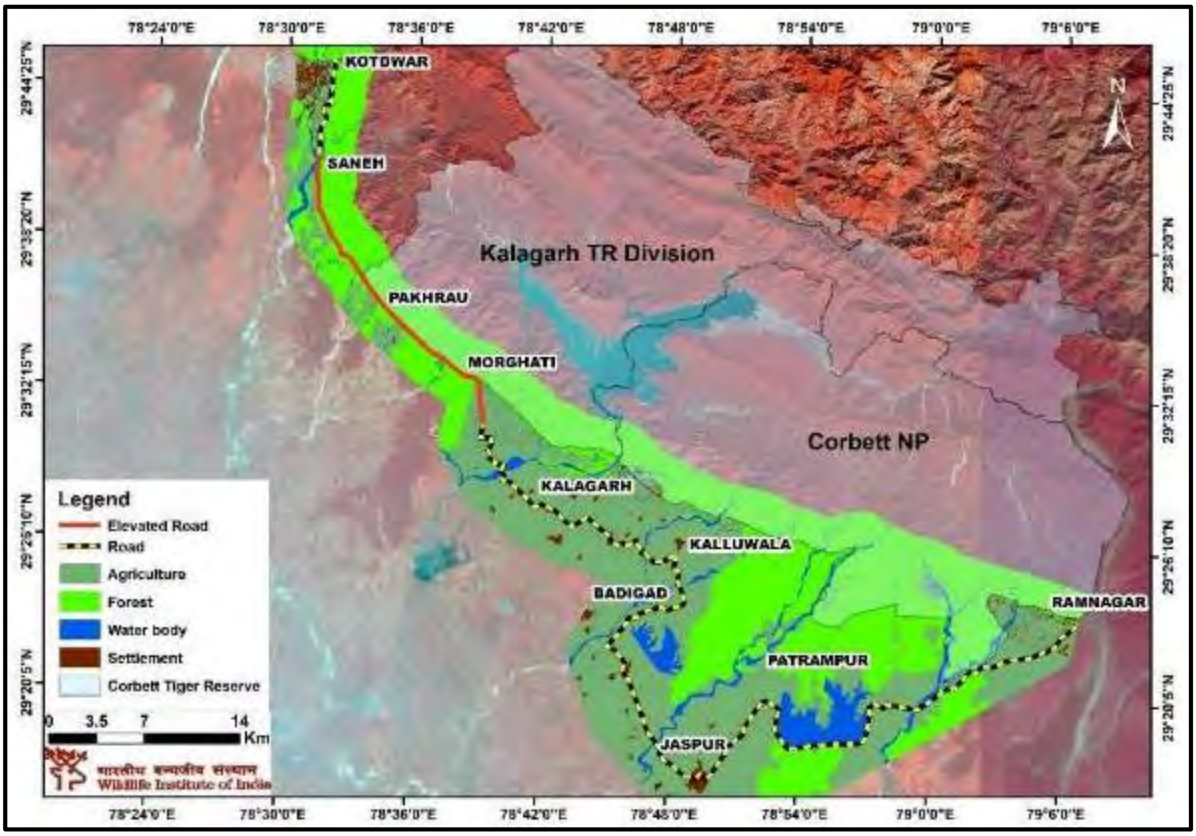


Figure 6 : Maps of alternate alignments 2A (top, without mitigation) and 2B (bottom, with mitigation) with geographic details for the proposed Ramnagar–Kotdwar road (2018-19).



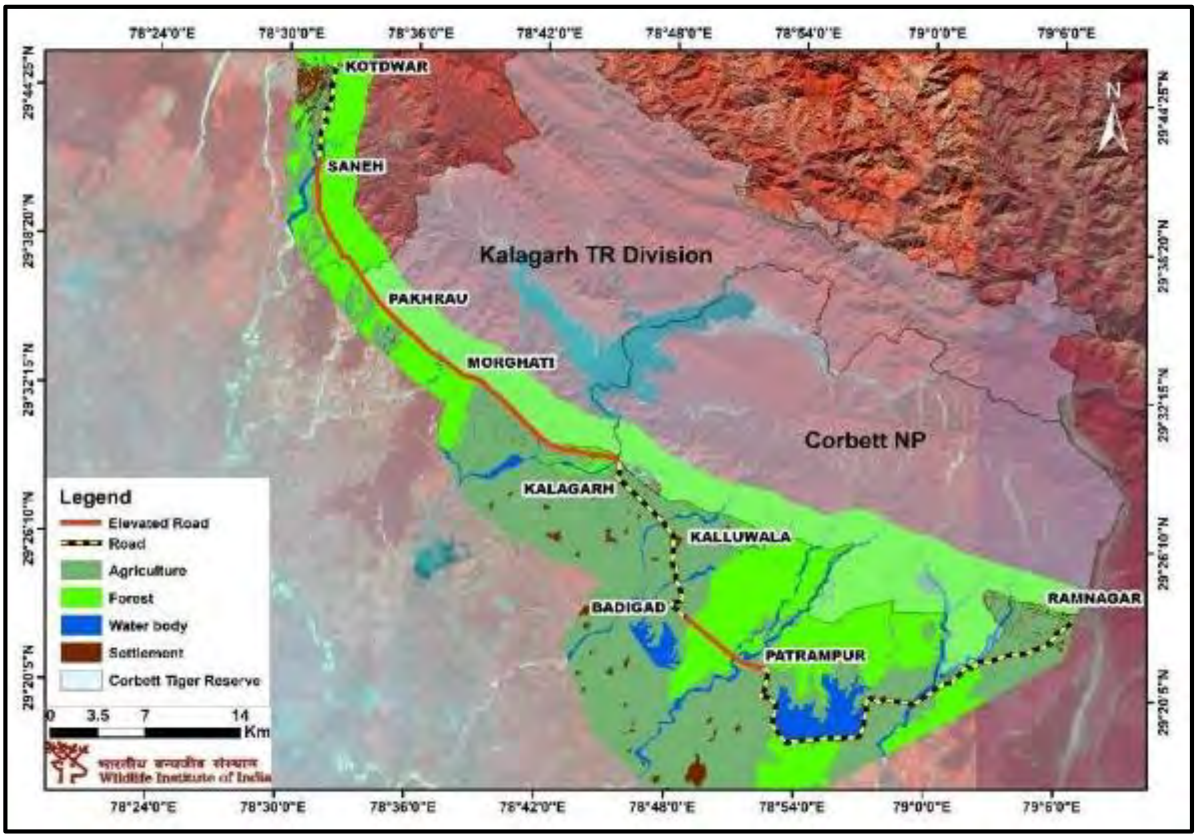
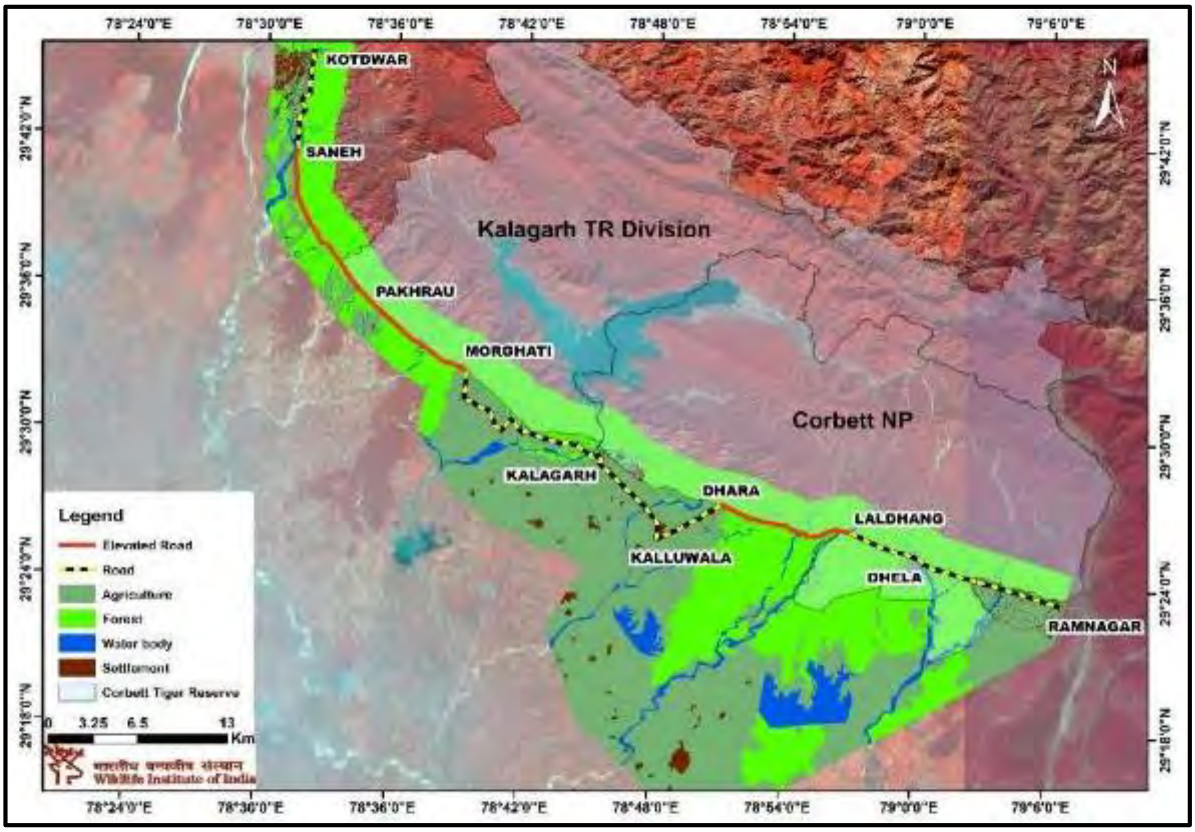


Figure 7 : Maps of alternate alignments 3A (top) and 3B (bottom) with geographic details for the proposed Ramnagar–Kotdwar road (2018-19).



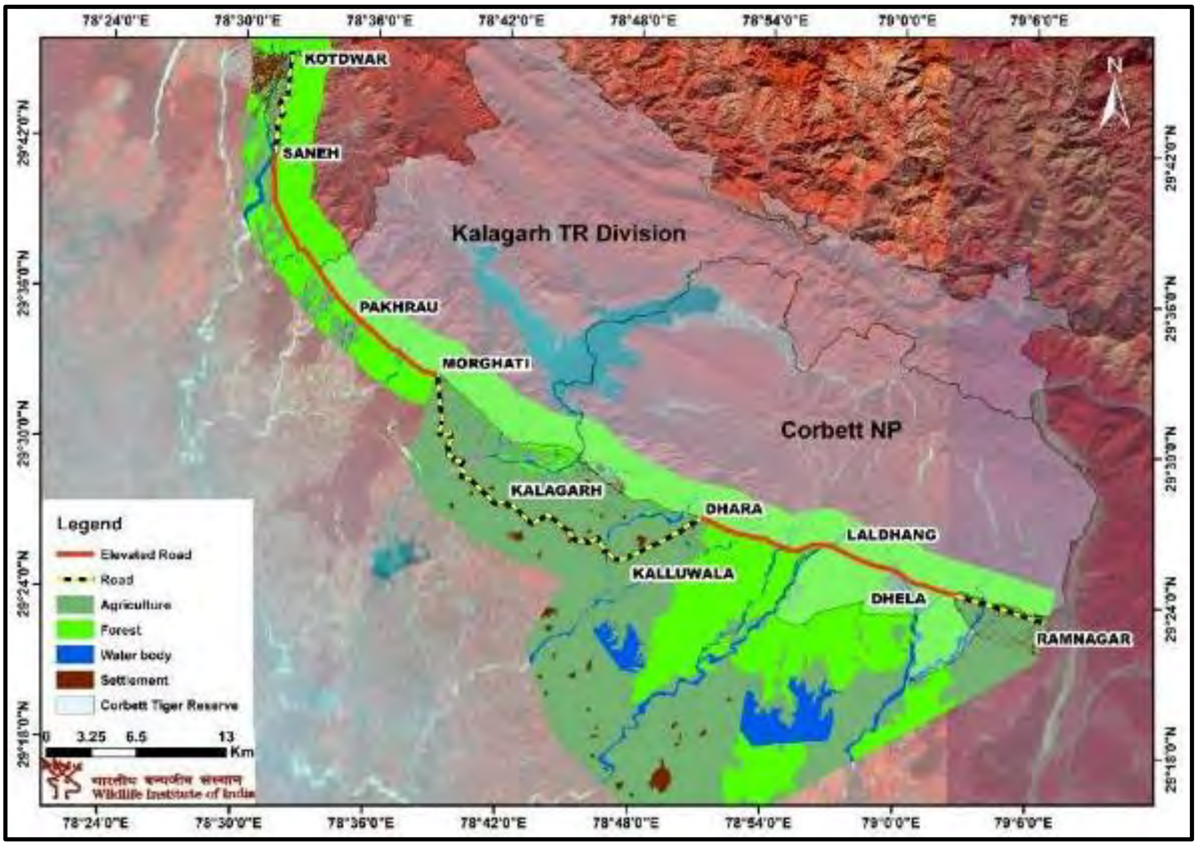


Figure 8 : Maps of alternate alignments 4A (top) and 4B (bottom) with geographic details for the proposed Ramnagar–Kotdwar road (2018-19).

Table 3 : Proportion of road length in different land-use types across alternative alignments for the proposed Ramnagar-Kotdwar Kandi Road (2018-19).

Land use type	Proportion of road length across alignments						
	1A/B	2A	2B	3A	3B	4A	4B
West Gangetic Moist Mixed Deciduous Forest	11.99	16.68	21.19	15.48	14.64	19.93	19.18
Dense Forest/ Moist Deciduous	0.00	0.00	0.00	3.65	3.48	0.00	0.00
Dense Forest/Sal	0.00	0.00	0.00	1.92	1.83	0.00	0.00
Dry Deciduous Scrub	0.00	0.53	1.23	0.98	0.00	0.00	0.00
Dry Siwalik Sal forest	0.00	2.25	2.02	0.68	0.00	1.13	1.09
Forest Plantation	7.34	16.53	14.31	12.31	6.46	7.92	7.37
Khair-Sissoo Forest	0.00	2.04	1.80	0.17	0.00	1.38	1.33

Moist Siwalik Sal Forest	1.83	11.65	16.57	2.46	2.34	12.97	12.56
Open Forest/Sal	4.18	0.00	0.00	5.06	4.83	0.00	0.00
Grassland	0.00	0.55	1.72	0.00	0.00	0.00	0.00
Scrub	1.35	0.88	3.75	1.47	0.46	2.43	1.20
Himalayan Chir Pine Forest	0.11	0.05	0.07	0.08	0.07	0.00	0.00
River	2.17	1.58	4.51	3.10	2.44	3.23	3.41
Settlement	16.29	39.90	14.73	13.01	6.84	26.04	15.13
Agriculture	54.74	7.38	18.11	39.64	56.60	24.97	38.73

3. APPROACH AND METHODOLOGY

3.1 Overview of data collection

Earlier, studies have been carried out on wildlife values and social perceptions to human wildlife conflict in Corbett National Park and adjoining forests of Terai Arc Landscape. Tiger and prey populations have been assessed and monitored across western Terai landscape, Uttarakhand (Harihar et al. 2006). Johnsingh et al. (2004) carried out study in Indian part of Terai Arc landscape looking at conservation status of tiger and associated species, and outlined the conservation strategies needed to manage Rajaji and Corbett National Parks as an elephant conservation unit (Johnsingh et al. 1994). Kontujam et al. (2005) carried out study on human-wildlife conflicts around the Corbett Tiger Reserve). Badola et al. (2010) assessed the ecosystem services of Corbett Tiger Reserve. Singh et al. (1995) analysed woody vegetation of Corbett National Park. We reviewed these studies for insights into the ecological contexts and social aspects of the project impact area.

However, there has been considerable time gap since some of these studies, and aspects that are relevant to feasibility assessment of the proposed road have not been covered in these studies that necessitates additional study/assessment.

Based on the scope of the current study, we: a) characterized the habitat and other geophysical characters in the larger study area using high resolution satellite imagery (details in section 3.2), b) conducted vegetation sampling for ground calibration of satellite imagery and assessment of vegetation composition, structure and ecologically important trees of conservation importance that fed into mitigation planning (details in section 3.3), c) assessed wildlife values for representative mammals in terms of their abundance and usage in the impact zone of current alignment (2A) and at increasing distances from the forest edge using camera-trap and sign survey based analytical approaches that helped in understanding the potential road impacts on wildlife (details in section 3.4), d) assessed bird distribution along the forest road and across vertical strata for planning mitigation structures (details in section 3.5), and e) carried out social surveys to understand the status of human-wildlife conflict and perceptions of local people towards the road project (details in section 3.6). Finally, we used Multi-criteria Decision Analysis to evaluate / rank alternative alignments against various ecological and financial criteria obtained from our above activities (details in section 3.7).

3.2 Geospatial Database

3.2.1. Scope

The scope of geospatial work entailed a) delineation of the zone of impact, b) characterization of geophysical and biological attributes of the project area such as land-use land-cover type hereafter LULC) (outsourcing from SCIENCE) with respect to different alignments, c) preparation of thematic maps as outputs of various study components, and d) providing spatially explicit ecological and financial information for decision-making. Thematic maps prepared for decision-making are listed below.

i. Delineation and mapping of alternative alignments
ii. Forest types and LULC of the study area
iii. Tree count within Right of Way of alternative alignments
iv. Drainage and soil erosion intensity maps
v. Species usage/distribution maps of mammals including RET species
vi. Settlements for social surveys
vii. Zones of impact for alternative alignments
viii. Ecological and financial matrices for alternative alignments

3.2.2. Satellite data

We used WorldView-3 satellite data, a very high-resolution 8-band multispectral imagery for this study. WorldView-3 is Digital Globe's third next-generation satellite, built by Ball Aerospace and leveraging highly advanced technologies. WorldView-3 is equipped with *state of the art* geolocational accuracy capabilities and equipped with control moment gyros, which enable increased agility, rapid targeting and efficient in-track stereo collection (Table 4). Worldview-3's multispectral imagery is more comparable to airborne sensors than other satellites. This combination of spatial and spectral resolution enable greater segmentation of physical features and more granular measurements of plant vitality. Coastal band, Red edge, Yellow and Near InfraRed-2 are the four bands, which are added in WV-3 (Table 4).

Table 4 : Summary of Digital Globe Satellite World View-3 imagery used in the feasibility assessment of the proposed Ramnagar-Kotdwar road (2018-19).

Attribute	Value
Resolution	50 cm
Swath Width	13.1 km
Average Revisit	1 day
Spectral Bands	PAN + 8MS
Accuracy Spec.	< 3.5 M CE90
Collection	680,000 km^2 per
Operating Altitude	617 km
Month of acquisition	November 2017

3.2.3. DGPS data

We collected Ground Control Points (GCP) (n=21) and elevation data from Ramnagar to Kotdwar, using Differential Global Positioning System (DGPS). The GCPs were also used to enhance the spatial resolution and to generate Digital Elevation Model using the Stereo pair.

3.2.4. Data processing

We pre-processed the raw satellite data to correct distortions and enhance the spatial resolution through ortho-rectification and data pan-sharpening, before it was used for further analysis.

Ortho-rectification: Topographical variations in the surface of the earth and tilt of the satellite sensor affect the distance with which features on the satellite image are displayed. Image distortion increases with the topographic diversity of the landscape. In order to accurately remove the image distortions, a Digital Elevation Model (DEM) is used to perform image ortho-rectification. The required DEM is generated from the WV-3 high-resolution stereo satellite imageries incorporating the block file of the GCPs which was collected using DGPS survey.

Pan sharpening: The WorldView-3 dataset has 0.31 m spatial resolution in the PANCHROMATIC (PAN) band and 1.24 m in the MULTISPECTRAL (MS) bands. We merged the low-resolution MS bands and the high-resolution PAN band through Pan sharpening to create a single higher resolution image in Program ERDAS using the Modified IHS Resolution Merge spectral sharpening method, which is the recommended algorithm for WorldView-3 imagery.

The Modified IHS (intensity, hue, saturation) resolution merge function (Siddiqui 2003) combines results in an output with both excellent detail and a realistic representation of original multispectral scene colours. The technique works by assessing the spectral overlap between each multispectral band and the high-resolution panchromatic band and weighting the merge based on these relative wavelengths. Therefore, the technique works best when merging images (and bands) where there is significant overlap of wavelengths.

3.2.5. Forest type and LULC classification

We were primarily interested in producing a detailed forest type and land-use and land-cover map of the study area to fine-tune alignments, and used visual interpretation technique on the high-resolution satellite imagery for this purpose. We categorized forest types into Dry sal forest, Forest plantation, Moist Siwalik sal forest, West Gangetic moist mixed deciduous forest, Khair-sissoo forest, Upper or Himalayan chir pine forest, Dry sal forest and Dry deciduous scrub. We additionally mapped physiographic features such as agriculture land, barren land, industrial area, settlements, orchard, scrub, drainage and water body. Forest type classification was based on Champion and Seth (1968), and were categorized using tone, texture, spectral signature and altitude. We used ground truth locations to refine the classified satellite image.

Table 5 : Properties and advantages of data bands in Worldview-3 satelite image used in the feasibility assessment of the proposed Kandi road (2018-19).

WV-3 13 Aug 2014 - Present		**Wavelength** (Micrometers)	**Resolution** (Meters)	**Advantages**
PAN	Panchromatic	0.45 – 0.80	0.31 at nadir	• High spatial resolution
Band 1	Coastal	0.40 – 0.45	1.24 at nadir	• Absorbed by chlorophyll in healthy plants • useful in bathymetric studies
Band 2	Blue	0.45 – 0.51	1.24 at nadir	• Readily absorbed by chlorophyll in plants. • Provides good penetration of water
Band 3	Green	0.51 – 0.58	1.24 at nadir	• Ideal for calculating plant vigor • Precise on the peak reflectance of healthy vegetation
Band 4	Yellow	0.585 – 0.625	1.24 at nadir	• Important for feature classification • Detects the "yellowness" of particular vegetation, both on land and in the water
Band 5	Red	0.63 – 0.69	1.24 at nadir	• Absorb the red light by chlorophyll in healthy plant materials • Useful in classifying bare soils, roads, and geological features
Band 6	Red Edge	0.705 – 0.745	1.24 at nadir	• High reflectivity portion of vegetation response • Measuring plant health and aiding in the classification of vegetation
Band 7	Near IR-1	0.77 – 0.895	1.24 at nadir	• Very effective for the estimation of moisture content and plant biomass
Band 8	Near IR-2	0.86 – 1.04	1.24 at nadir	• Enables broader vegetation analysis and biomass studies

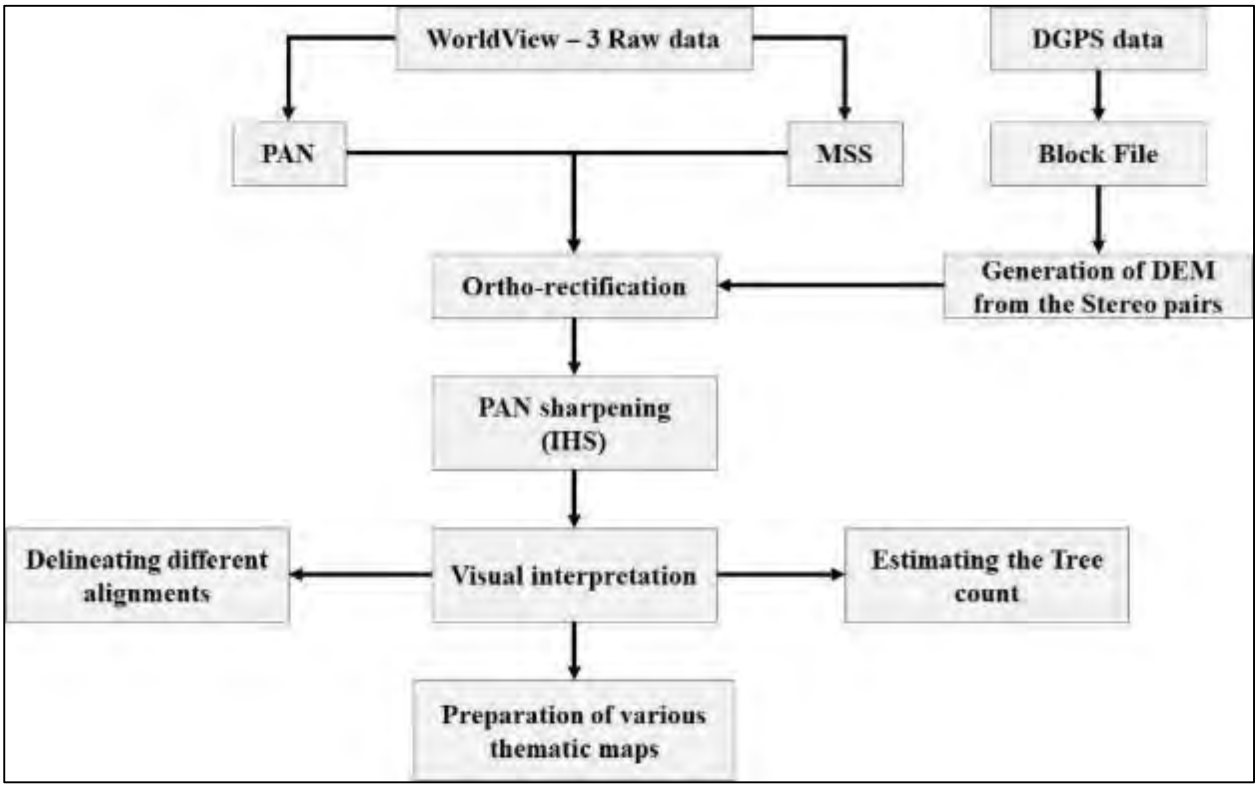


Figure 9 : Flowchart depicting geospatial methods used to prepare thematic maps in feasibility assessment of the proposed Kandi road (2018-19).

3.2.6. Tree count

We counted the number of trees along alternative alignments within 30 m buffer (Right of Way) on either side of the road, to estimate the extent of prospective tree felling. We visually demarcated trees based on their crown cover that were >1 m in dimension and were visible on high-resolution satellite imagery, with the help of variation in their tone and texture (Figure 10). Trees in lower canopy that were covered by dense upper canopy were likely to be missed in this approach, and necessitated field calibration of tree counts (see section 3.3.2).

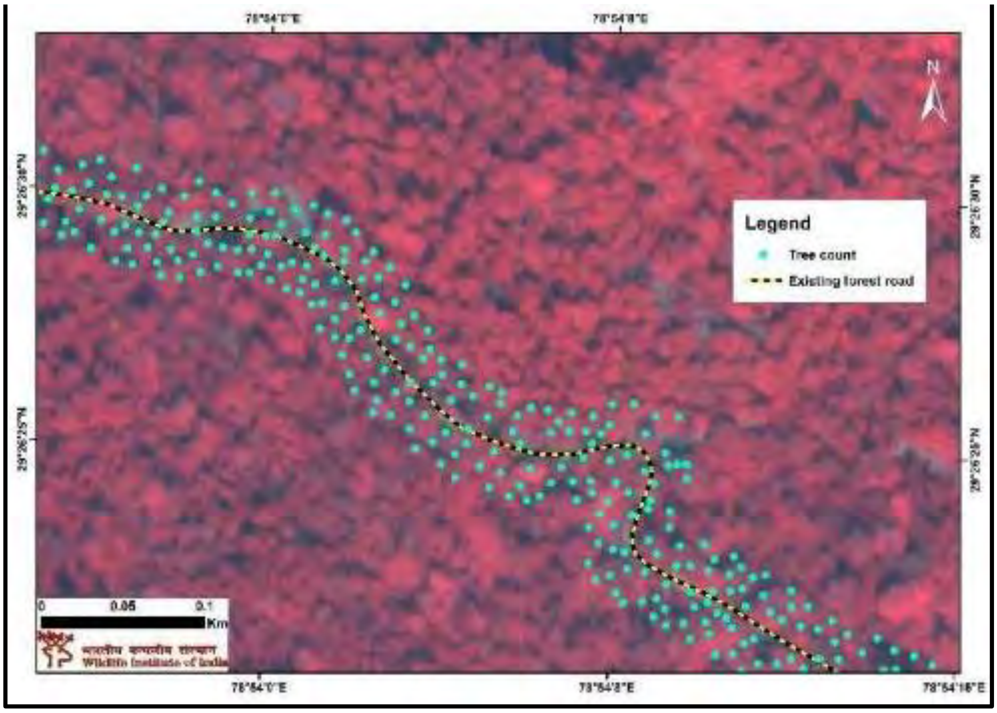


Figure 10 : Depiction of tree count from visual interpretation of crown cover using Worldview-3 satellite image in Corbett tiger Reserve (2018-2019).

3.3 Vegetation sampling

3.3.1. Species richness, density and composition

We assessed the vegetation structure, composition and diversity in the forest adjoining existing Kandi road (alignments 2A/B) using stratified random sampling. We placed random sample points proportional to the expanse of forest types using program ArcGIS, and located them on ground using handheld GPS unit. We sampled trees with girth at breast height (GBH) > 30 cm within 10 x 10 sqm plots at these locations. We recorded information on species, number of individuals, height and GBH of trees at each plot. Using this data, we estimated mean (SE) species density, richness, evenness and Simpson reciprocal index (1/D) as a measure of species diversity for each forest composition type. To identify the dominant species in a forest type, we computed Importance Value Index (IVI) by summing relative abundance, relative frequency and relative dominance of species. We processed the data using MS Excel and carried out all analyses in program R.

3.3.2. Tree calibration

We calibrated the remotely sensed tree count (details in section 3.2.6) using empirical data from field sampling (n = 150 plots). The ratio of actual number of trees to remotely sensed number of trees was computed for each plot (hereafter, tree count correction factor). The effect of detailed forest types (12 composition and density classes), broad forest types (six composition classes) and forest density types (three density classes) on the correction factor was examined using linear models (ANOVA) coupled with Information theoretic approach (Burnham and Anderson 2002) in program R.

3.3.3. Distribution of few ecologically important trees (EIT)

Trees such as figs support wide range of fauna in many forests, and are ecologically important. Although they arenumerically less, their removal can adversely impact faunal groups and trophic webs (Paine 1969, Power et al. 1996). Therefore, it was important to assess major ecologically important trees (hereafter EET) in the project impact zone, to propose mitigation measures at critical areas.

In the present study, we recorded *Ficus benghalensis, Ficus rumphii* and *Ficus racemosa* and *Bombax ceiba* as four EIT (Figure 11). The *Ficus spp.* exhibit year round and aseasonal fruiting patterns and are a major food resource for frugivores especially hornbills, even at times when fruit resources are sparse (Kannan and James 1999, Datta and Rawat 2003). Three hornbill species were reported from the study area *viz*. Great Hornbill *Buceros bicornis* (Vulnerable and shows decreasing population trend), Oriental Pied Hornbill *Anthracoceros albirostris* and Indian Grey Hornbill *Ocyceros birostris*. Presence of these figs plays an important role in the persistence of these hornbill species, and in turn sustains the dispersal services of the forest.

We quantified the number of individuals belonging to these EIT species using a rapid vehicle survey along the alignment 2A from Ramnagar to Kotdwar covering ca. 97 kms. We counted all individuals of *Ficus benghalensis, F. rumphii, F. racemosa* and *Bombax ceiba* within 10m distance of either side of the road from a slow moving vehicle (20 km/h).

Figure 11 : Images of ecologically important trees : *Ficus benghalensis, Ficus racemosa, Ficus rumphii* and *Bombax ceiba* (top to bottom). (Pic courtesy: Amit Kumar and Navendu Page)

3.4 Mammals

3.4.1. Camera trap surveys

Terrestrial mammals play an important role in conservation decisions but their rarity and elusive nature impede conventional assessment techniques. Camera trapping and related analytical approaches that can capture ecological information on such elusive species are thus becoming a mainstream tool in conservation status assessments (Rowcliffe and Carbone 2008). In this study, camera traps that are automatically triggered by an animal crossing the device to capture a photograph of itself ("selfie") have been used to assess distribution, abundance and response to road of terrestrial mammals. Passive infrared motion and heat sensor Cuddeback C1 camera traps were deployed following various placement designs across the forest with different objectives that have been described below.

3.4.2. Road usage by mammals

The stretch of road between Pakhrau and Babaliya (50 km) was divided into 1 km segments and camera traps (n=49) were placed at the centre of each segment (Figure 11) in Random Encounter model (REM) framework (Rowcliffe et al. 2014). Camera traps were installed on trees at an average height of 2 m above ground in order to capture animal movement rate on road. Placement of camera trap on trees gave a field of vision for >60 m distance across the road. We placed stones at every 10 m distance from the camera trap and considered photographs with animals captured within 60 m distance from the camera traps to mark distance of photocaptures. Camera traps were put on lapse mode and captured a photograph at every 20 seconds time interval irrespective of presence or absence of animal. This setup helped us exclude issues with detection probability that would occur due to longer field of vision. We used infrared flashes to minimize avoidance by animals. A total of 2,500,000 photos were manually segregated for different species with the help of program IrfanView and ExifPro. The photocapture rates were used to estimate proportion of time spent on/near road by each species by using null binomial model and scaled up for total length of the road, i.e. 78 km between Saneh and Ramnagar. The proportion of time spent on/near road by each species was then scaled to respective species' density and abundance reported from Corbett Tiger Reserve (Table 10).

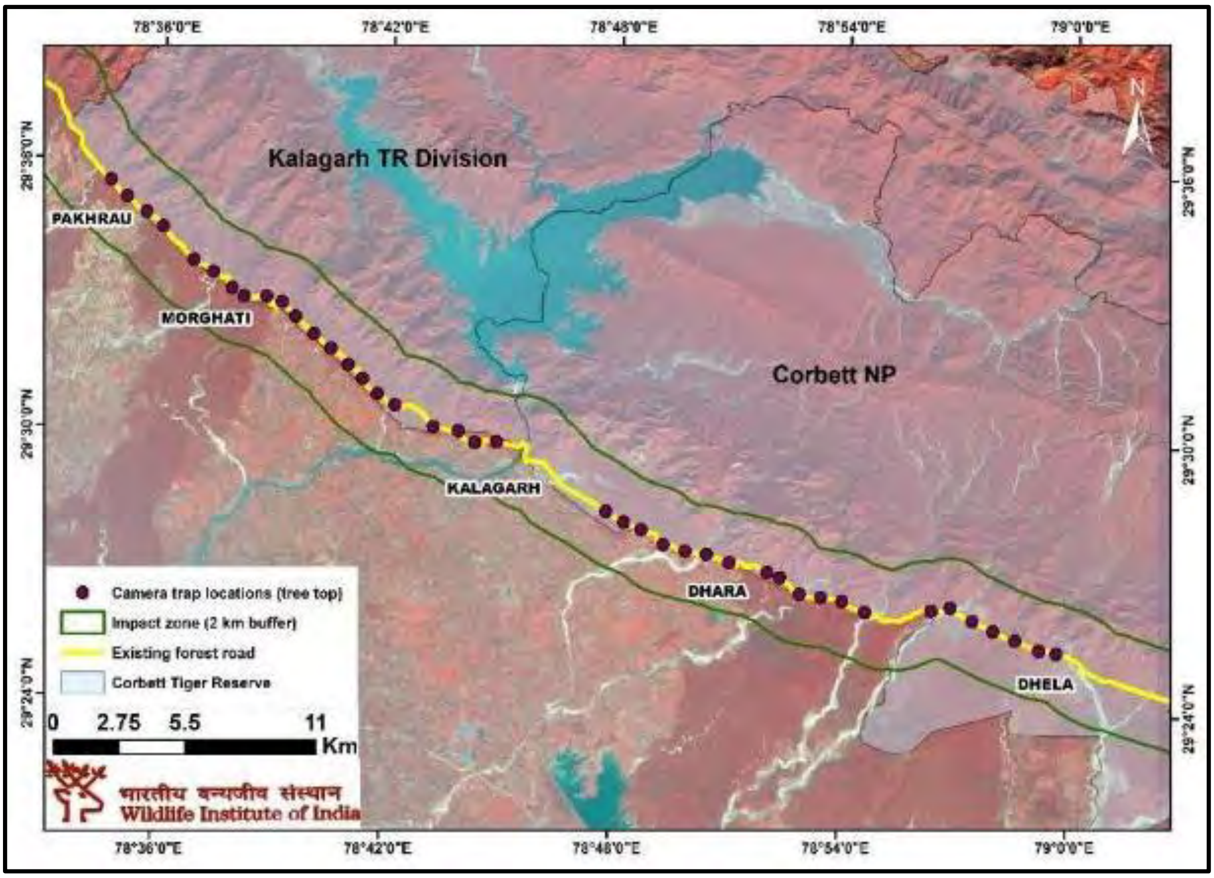


Figure 12 : Placement of elevated time-lapse camera traps to capture mammal usage of the the existing forest road between Pakhrau and Dhela in Corbett Tiger Reserve (2018-19).

3.4.3. Relative abundance indices of mammals

Relative abundance indices are used to characterize spatial distribution and abundance of species with the assumption that these indices scale linearly with actual abundance (Güthlin et al. 2014). To estimate relative abundance of terrestrial mammals, we used data from camera traps that were placed along the road and on animal trails inside the forest. The study area was divided into sampling grid comprising 1 sqkm cells, and each cell was sampled by one pair of camera traps. We placed a total of 164 camera traps units, of which 48 camera trap pairs were deployed at every 1 km on the existing 50 km of dirt road (2A) between Babaliya and Pakhrau. Another 116 pairs were placed inside the forest at up to 2 km from the road, mostly on the northern side but also in forest patches on the southern side, covering a total of 214 sq km area (Figure 12). We could not place camera traps in private agricultural areas due to the issue of camera theft, and resorted to sign surveys in these habitats.

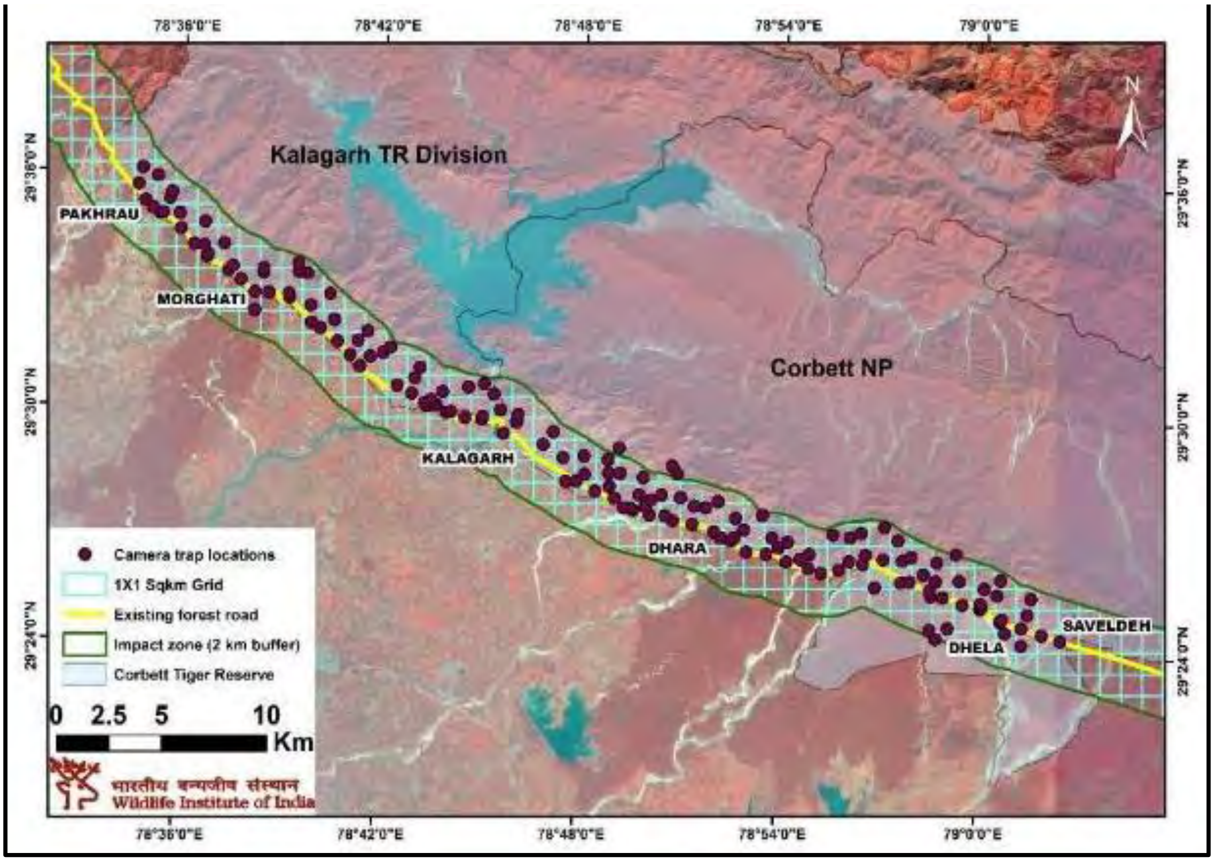


Figure 13 : Placement of automatically triggered camera traps to capture mammal abundance/usage within the proposed road impact zone (Alignment 2A/B) of Corbett Tiger Reserve (2018-19).

We calculated the number of trap-days for each camera trap from the time it was mounted until the time it was retrieved. For every animal detection, we recorded the species identity, date and location of photo-capture. We defined independent event as consecutive photographs of the same species taken more than 30 minutes apart at any camera trap. The number of independent photo-captures of a species was used to calculate two relative abundance indices (RAI) for terrestrial mammals that included RET species such as the tiger, leopard, bear, striped hyaena, elephant and sambar as well as other notable mammals such as chital, barking deer, wild pig, nilgai and porcupine.

RAI_1 was measured as the number of trap-days required for photo-capture of a species at a camera trap. This value is expected to decrease as the animal abundance increases (Carbone et al. 2001, O'Brien et al. 2003). We computed the RAI_1 as: $RAI_1 = N/A_i$

Where, N is the number of camera trap days and Ai is the number of detections of species *i*.

RAI_2 on the other hand, is the inverse of RAI_1, and was computed as:

$RAI_2 = A_i/N \times 100$ (Jenks et. al. 2011).

This index increases as the animal abundance increases. This value was scaled to photographs per 100 trap-days (O'Brien et al. 2003, Debata and Swain 2018). We computed this index for each camera trap, wherefrom we derived the mean and SE estimates. We used this index to delineate species hotspots in the sampling area using graphical and interpolation approaches.

3.4.4. Tiger density estimation

Spatially explicit capture-recapture (SECR) method is used to estimate densities of free ranging, individually identifiable animals from capture-recapture data obtained from a set of 'detectors' (camera-traps). This approach is advantageous over conventional mark recapture method as it can overcome issues related to edge effects/geographic closure and spatial heterogeneity in detection probability (Borchers and Efford 2008). The photographs taken by the above mentioned remotely triggered camera traps were used to identify individual tigers by their unique stripe patterns. Analysis using SECR requires spatial locations of camera traps and spatio-temporal information on individual captures, also termed as detection histories. Based on these information, we fitted: a) state model that described animal density or number of activity centers in unit area and b) an observation model that described the relationship between the probability of detecting an individual at a particular camera trap as a function of its distance from the the individual's activity center. These models were parameterized by maximum likelihood approach using "secr package" in program R (Efford 2015), to estimate tiger density (numbers / 100 sqkm) in the proposed road impact zone of alignment 2A/B.

3.4.5. Sign surveys for wildlife usage index

To assess wildlife usage in the impact zones of alternative alignments, sign surveys were conducted in and around CTR. Team of field biologists quantified indirect evidence (signs) of wild mammals by walking on existing trails inside forests and in agricultural areas up to 5 km south of CTR. Survey trails were 2.7 $\pm$ 0.5 km in length and were distributed across 0-0.5 km (n=17), 0.5-1 km (n=7), 1-2 km (n=5), 2-3 km (n=4) and 3-5 km (n=5) distance classes from forest edge (Figure 14).

Two observers walked these trails and recorded quantity of signs (indirect evidence) belonging to major carnivore and herbivore species in 300m segment of each trail. For carnivores such as tiger and leopard, scat, scrape marks and pugmark tracks were recorded. For herbivores such as chital, sambar, wild pig and nilgai, pellets were recorded, while for elephant, dung and foot tracks were recorded. We used Locus Map, an Android application, to record quanta, species, GPS coordinate and photographic evidence of animal signs.

We used the data on sign intensity to test the hypothesis that wildlife usage declines away from forest edge (Pfeifer et al. 2017). For this purpose, we log-transformed the signs km^{-1} (U_S) in 300 m trail-segment for a focal species S and modeled it against distance of the segment to nearest forest edge (D in km) using (log)linear models in program R (Calenge 2006).

The model: $U_S = e^{(\beta_0 - \beta_1 D)}$, represented exponential decay in the usage of focal species away from the forest edge. We compared it against the null model: $U_S = e^{\beta_0}$, where species' usage was assumed to be uniform across distance from forest edge, using Information Theoretic approach (Burnham and Anderson 2002). We constructed separate models for the following species that included RET species with adequate signage data: tiger, leopard, elephant, sambar, chital and nilgai. Examination of fitted models revealed similar decline in sign intensity away from forest edge for all above forest species, while for nilgai, the sign intensity was unrelated to distance from forest edge.

Thereafter, we built a pooled model to represent the decline in usage of general forest-dwelling mammals away from forest edge. For this purpose, we scaled sign intensity of species S in trail-segments to their mean sign-intensity at the forest edge $[T(U_S)]$, and modeled that against distance of the segment to nearest forest edge using (log) linear modeling, as above. We compared the pooled model: $T(U_S) = e^{(\beta_0 - \beta_1 D)}$ against a model that incorporated variation in decline of usage between species: $T(U_S) = e^{(\beta_0 + \beta_i S - \beta_1 D)}$, using Information-Theoretic approach. The pooled model had adequate fit, and would be referred to as the Species Usage Decline Function (hereafter SUDF).

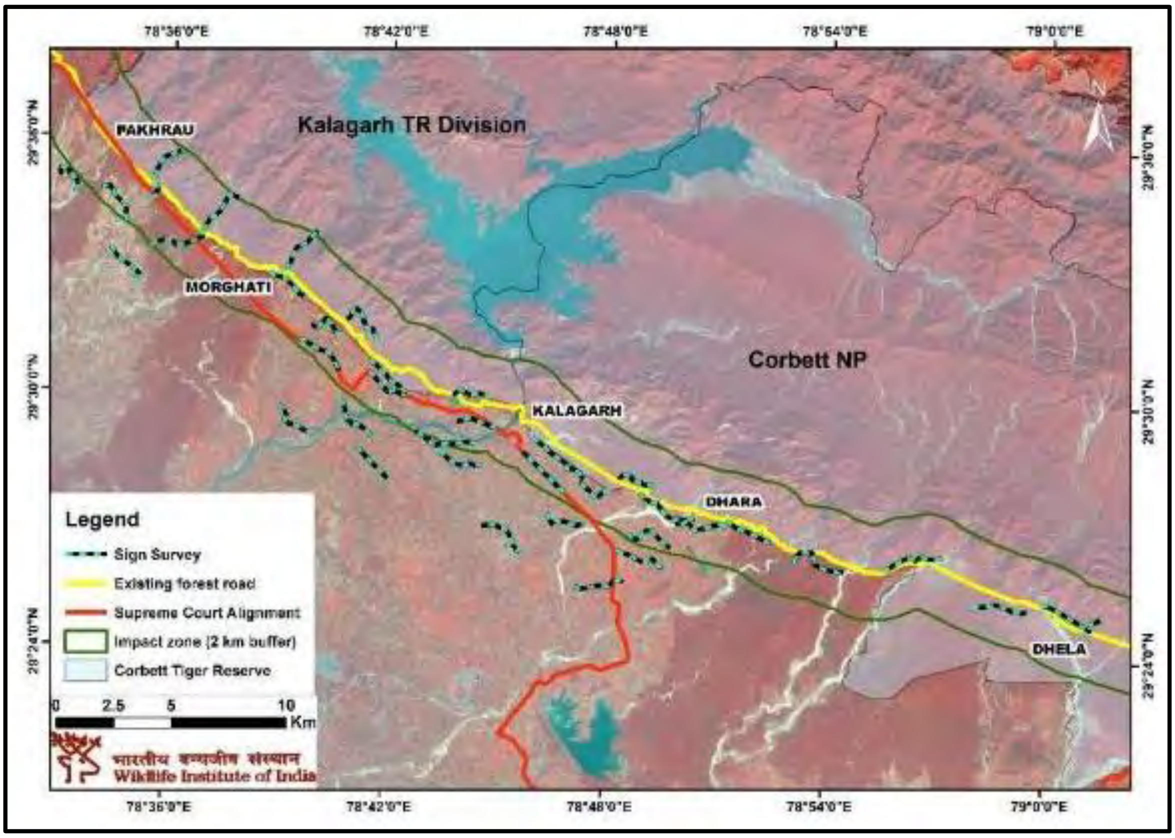


Figure 14 : Placement of sign survey trails to quantify indirect evidence of mammal usage in forests of Corbett Tiger Reserve and agricultural areas along its southern boundary (2018-19).

3.5 Avifauna

3.5.1. Bird community structure and vertical distribution

Forest bird community structure depends on the habitat use and interactions of their members, and are known to be vertically stratified in terms of species composition (Bohm and Kalko 2009). Forest with the higher heterogeneity in vertical stratification are expected to host the more diverse avian community as they provide different resources and microhabitats (MacArthur and MacArthur 1961, Huang et al. 2014). The current forest road (2A) passes through different forest habitats of the CTR and we attempted to understand the pattern of avian community at different perch heights along the road to assess the possible impact(s) of tree cutting and construction of elevated highways.

We used Mackinnon's species richness method (MacKinnon and Phillips 1993) for assessing the bird species richness on 40 km road stretch from Dhela to Pakhrau and some trail walks within two kilometer buffer of the road. This method is easily applicable in difficult terrains and has been found to be useful and efficient in generating indices of species richness from multiple site surveys. We recorded bird species on encountering them, and once a list of 15 species was completed, we prepared another list. Same species was not recorded twice in the same list, but the number of individuals were added on resighting the species. We generated lists during morning and evening hours when activity of birds is generally high.

We corroborated this data with information on species' perch heights obtained from an intensive field study in the neighbouring and comparable Rajaji Tiger Reserve (Kaushik 2015), along with secondary literature.

3.6 People's perceptions on project and wildlife usage

To understand perceptions of local people living at the southern periphery of Corbett Tiger Reserve and Landsdowne Forest Division from Ramnagar to Kotdwar we conducted rapid social surveys in 33 villages belonging to 26 Gram Panchayats, all of which were located within 4 km south of the Kandi road (Figure 15). We carried out social surveys from late November 2018 to early January 2019. Given the paucity of time, we conducted 'Focused Group Discussions', a commonly used method which generates qualitative data and essentially involves engaging a small number of people in an informal group discussion (or discussions), 'focused' around a particular topic or set of issues" (Wilkinson and Silverman 2004, Cornwall and Jewkes 1995, Hayward et al. 2004, Israel et al. 1998, Kitzinger 1994, Morgan 1996). We narrowed down on this technique after conducting a reconnaissance survey in villages with large population.

The questionnaire (Annexure 2) was designed to understand locals' perception towards issues relating to human-wildlife conflict, local dependence on forest and construction of Kandi road. We analysed the data using constant comparison analysis (Onwuegbuzie et al. 2009). This technique is used to assess if one unified theme emerges from all groups using the responses of one group as the control.

Figure 15 : Villages adjoining southern boundary of Corbett Tiger Reserve that were targeted for social surveys (2018-19): A (Maldhan chaur), B (Patrampur), C (Jaspur), D (Angadpur), E (Badigad), F (Afzalgarh), G (Bhogpur), 1 (Bhikkawala), 2 (Old Kalagarh colony), 3 (Pahadi mirapur), 4 (Maloni), 5 (Kalluwala), 6 (Fatehpur dhara), 7 (Dhela), 8 (Sawaldeh west), 9 (Sawaldeh east), 10 (Himmatpur dotiyal), 11 (Karanpur), 12 (Saneh), 13 (Veerbhan), 14 (Bhumidaan), 15 (Prem Nagar), 16 (Bagnaala), 17 (Kaderganjh), 18 (Ramjiwala), 19 (Neem sauth), 20 (Nalkatta), 21 (Kuankheda), 22 (Gangapar kuankheda), 23 (New colony kalagarh), 24 (Sewalkhaliya), 25 (Murliwala), 26 (Jamunwala), 27 (baniyawala), 28 (Gorakhpur), 29 (Bhavanipur punjabi), 30 (Dharmpur dhankola), 31 (Dharmpur ghasi), 32 (Gaujani), 33 (lalbaug).

3.7 Decision matrix for feasibility assessment

3.7.1. Computation of metrics for alternative alignments

We evaluated the potential alignments (details in section 2.2) on important ecological/conservation and project finance/logistic criteria. These criteria included:

a) damage to vegetation, in terms of the number of trees to be felled for road construction,

b) direct impact on wildlife, in terms of mortality of RET mammals due to vehicular collision on upgraded road, which poses simultaneous risk to traffic / human safety (e.g., traffic collisions with elephant and sambar),

c) indirect impact on wildlife, characterized as the wildlife habitat that has to be 'sacrificed' due to disturbances caused by the road to sensitive species,

d) temporary disturbances to wildlife due to construction activities inside or near the forest.

e) financial cost of constructing the road depending on its length and required mitigation measures,

f) financial cost of acquiring land to construct the road,

g) travel and fuel costs of users, depending on the road length or travel time.

Other costs of the project such as ecosystem services (e.g., carbon sequestration, pollination, nutrient cycling, and water/air purification) have not been factored into our analysis, since these costs are difficult to quantify within the short study period available. However, the metric of sacrificed habitat (criteria c) partly captures these costs as it is correlated with the expanse of forest within the impact zone of the road. Below, we describe the general approach of estimating the above parameters, and scoring of alternative alignments against these criteria.

3.7.2. Estimation of tree felling (criteria a)

We counted trees within a belt of 30 m (right of way) along each alignment using visual interpretation of tree crown in very high resolution (WV3) satellite imagery (details in section 3.2.2). We calibrated these estimates of tree counts to actual tree counts based on field sampling (details in section 4.1.2) and generated correction factors for forest composition types. Since correction factors were similar across major forest types (West Gangetic Moist Mixed Deciduous Forest, Forest Plantation and Moist Shiwalik Sal Forest), we used the pooled correction factor, to estimate number of trees to be felled for each alignment.

3.7.3. Prediction of vehicular collision of mammals (criteria b)

We predicted the potential number of vehicular collisions of mammals due to upgradation of road using traversibility model (following Langevelde and Jaarsma 2005) that was parameterized using field data. According to this approach, the time taken Ci (seconds) for an animal of body length Li (meters) and speed Vi (meters/second) to cross a road of width B (meters) can be calculated as:

$Ci = (B+Li)/Vi$, assuming that animals cross the road without any waiting time or traffic avoidance and at right angle. An animal will be able to successfully cross the road if no vehicle arrives at that location within time period Ci. The probability of this event can be calculated as:

$Pi = exp(-\lambda Ci) = exp(-\lambda ((B+Li)/Vi))$, where λ is the traffic volume (vehicles / second).

Here, it is assumed that the number of vehicles arriving at a certain location of the road within a time period follows Poisson distribution (following Leutzbach 1988). Based on this equation, collision rate of species i (Di) can be estimated as:

$Di = (1 - Pi)*Ki$, where Ki is its rate of attempted road crossings.

We computed the model parameters as follows:

i) traffic volume by sampling segments of the southern roadway between Afzalgarh and Kashipur as well as that of an extended section of the Kandi road near Chidiyapur (Sultan 2017) and simulating scenarios of varying traffic volumes

ii) road width was considered to be 14 m, equivalent to the width of vehicle lanes of a four lane highway (source: NBCC)

iii) average body length of target species were obtained from published literature (Menon 2009; Sukumar et al. 1998)

iv) mean speed of target species was computed from time-lapse camera photo-captures. These camera-traps were fixed at 2 m height on trees with view of 60 m of the existing forest road that was calibrated on ground at every 10 m radial distance from the camera-trap (described in section 3.4.2). The set up allowed us to quantify speed from the distance moved by an animal walking linearly or perpendicularly to the road, based on the sequence of time-tagged photo-captures. Apart from this empirical approach, we also estimated the theoretical speed of a species using the allometric function of its body weight:

   $Vi(max) = 10.4\ Wi^{0.38}$, *where* Wi is body weight (kg) following Peters (1986). We considered that animals would cross roads at 25% of this maximum speed (following Langevelde and Jaarsma 2005).

v) crossing rate, or the number of animal groups crossings per km road per day, was estimated from the frequency of independent crossings of the existing Kandi road by a species based on the elevated time-lapse camera-trap data (described in section 3.4.2). Each camera photographed 60 m road-length at every 20 seconds, resulting in 4320 photographic events per day. We calculated the proportion of photographic events with independent crossing of a species from this data. We scaled this metric to 1 km road-segment and the maximum number of daily photographic events that could capture independent crossing, given the time required by the species to cross the entire road (28 m road width). Crossing rates thus obtained were representative of roads cutting through the forest or its edge. We further corrected this crossing rate by the differential abundance of focal species between core area of Tiger Reserve (inviolate PA), buffer area (PAs with settlements) and adjoining multiple-use forests (hereafter, outside forest). For this, we multiplied the crossing rate by a factor of 1, 0.6 and 0.4 respectively for road segments passing through core area, buffer area, and outside forest. These factors were decided based on existing studies (Harihar, Pandav and MacMillan 2014) and our data that indicated such proportionally greater tiger and principal prey density in the core area compared to buffer and outside forests. For alignments away from forest, where animal use intensity and proportionally the frequency of crossing would be lower, we corrected crossing rates using the Species Usage Decline Function (details in section 4.3.5. For this, we sliced each alignment into 1 km segment, extracted the distance to forest edge from its centroid, and fitted it to the SUDF. Potential traffic induced mortality rates of RET mammals (tiger, elephant and sambar) were integrated over the road length for each alignment and reported as numbers/hr in decision matrices.

3.7.4. Estimation of habitat loss (criteria c)

Global studies have demonstrated the deterioration of habitat due to roads (Torres et al. 2016), and our study revealed reduced usage of RET species such as the tiger and elephant in proximity to Kandi road (see section 4.3.3). Therefore, we quantified habitat loss due to alternative road alignments from the perspective of wildlife value, as follows. We divided the larger study area into 1 sq km cells, and extracted the distance of cell centroids from forest edge and that from alternative road alignments using ArcGIS software. We first computed the current wildlife value of a cell based on its distance from the forest, weighted by the type of forest so as to incorporate the differential abundance of focal species between core area of Tiger Reserve (inviolate PA), buffer area (PAs with settlements) and adjoining multiple-use forests (hereafter, outside forest). For this, we considered the Mean Species Abudance (MSA) to be 1, 0.6 and 0.4 respectively for cells inside core area, buffer area, and outside forest. These MSA values, representative of current wildlife value for a cell inside the forest, were decided based on existing studies (Harihar, Pandav and MacMillan 2014) and our data that indicated such proportionally greater tiger and principal prey density in the core area compared to buffer and outside forests. For cells in non-forest areas, we corrected the current wildlife value by fitting the distance of each cell from forest edge to the SUDF (section 4.3.5).

Thereafter, we computed the prospective wildlife value of a cell, if the road is developed. The general decline of species usage in proximity to roads has been characterized by a meta-analysis, as: $MSA_{estimate} = e^U/(1+e^U)$,

where U (logit-transformed probability of species' occurrence)= $-0.607 + 0.00083*Dist\text{-}road$ (Benitez-Lopez et al. 2010). We used this model to estimate the prospective wildlife value of a cell given its distance from the road alignment. Assuming that the loss of habitat would be less severe for mitigated / elevated sections of the road, we reduced the MSA of elevated road to 75% of that of plain road. We integrated the difference between current and prospective wildlife values over all cells within 2 km impact zone of the road, to surrogate the extent of habitat loss due to each alignment. This index can be interpreted as the effective habitat area to be sacrificed for road construction.

3.7.5. Assessment of temporary construction disturbances (criteria d)

Construction activities in proximity to forest are likely to create temporary disturbances to wildlife. Further, construction of elevated road might require longer times (3-4 years) than construction of plain road (2-3 years) (source: NBCC). We computed the kilometer-years of construction activity within 500 m of the forest edge for each road alignment, given its attributes such as length and required mitigation measures.

3.7.6. Estimation of financial/logistic costs of road construction (criteria e-g)

We calculated construction costs for each alignment based on the lengths of elevated and plain road-segments, and considering their respective unit costs to be 950 million INR/km for elevated road and 150 million INR/km for plain road (Mukhopadhyay pers. comm., 2019). We also added the cost of noise attenuation structures (a recommended mitigation measure, see

Discussion) for road segments that were inside or within 500 m from the forest edge, considering unit cost of 32 million INR/km (based on available market prices, see www.indiamart.com).

We computed financial costs of land acquisition for each alignment based on the lengths of road through private agricultural lands and public forest lands. Cost of agricultural land was obtained from tehsil level circle rates (1.9 - 6.0 million / ha) and was reduced by 25% if the land fell within 500 m of forest edge (due to crop depredation by wild animals). We considered the Net Production Value of forest land to be 0.93 million/ha, equivalent to dense moist deciduous forest (Verma et al. 2014), the dominant forest type in the study area.

Finally, we surrogate travel distance / time / costs by road length for each alignment.

3.7.7. Multi-criteria decision analysis

Multi-criteria decision analysis (hereafter MCDA) provides a structured framework to analyze decision problems faced with multiple, conflicting objectives (Nijkamp et al. 1990). This approach typically involves defining objectives, choosing the criteria to evaluate alternatives, transforming criteria scores into commensurable units, weighing the different objectives by their relative importance, and using mathematical algorithms that combines these weighted scores to rank alternatives (following Ananda and Herath 2009).

Our study attempts to identify road alignment(s) that optimizes ecological and financial objectives, measured by the abovementioned criteria (a-f). Since none of the road alignments was clearly superior over others across all criteria, discrete MCDA framework was the obvious panacea for this problem (Hajkowicz et al. 2000). We used weighted summation approach, one of the most widely used decision-making tools, to compare alternative road alignments (Ananda and Herath 2009). Our criteria scores were ecological and financial costs where greater values were less preferred. Following Ananda and Herath (2009), we standardized the scores against criteria a-f into commensurable units using the following formulae:

$S_{ij} = (max\,j - x_{ij}) / (max\,j - min\,j)$,

Where, S_{ij} is the standardized score for i^{th} alternative against j^{th} criteria;

x_{ij} is the real score of i^{th} alternative against j^{th} criteria;

$min\,j$ and $max\,j$ are respectively the minimum and maximum scores among alternatives against the j^{th} criteria.

Standardized scores were weighted and summed across criteria into a total score (V_i) that determined the overall performance of each road alignment, using the following formulae:

$V_i = \Sigma\, w_j * S_{ij}$.

For this, we assigned weightage (w_j) to criteria i following three settings: 1) equal importance to all criteria, 2) greater importance to ecological/conservation criteria as expected from conservation decision-makers, 3) greater importance to financial/logistic criteria as expected from financial decision-makers, to assess the sensitivity of our inferences to the difference in relative importance attributed to various project objectives by multiple decision-makers. We ranked alternative alignments and identified the optimal solution based on the overall performance score.

4. RESULTS AND FINDINGS

4.1. Habitat characterization

4.1.1. Forest type, land-use and land-cover map

Land-use land-cover classification of the study area revealed that agriculture, moist Siwalik sal forest, west Gangetic moist mixed deciduous forest, forest plantation, sal forest, dry Siwalik sal forest and moist deciduous forest were the dominant land-covers (Table 6, Figure 16). Below we describe some of these land-cover types.

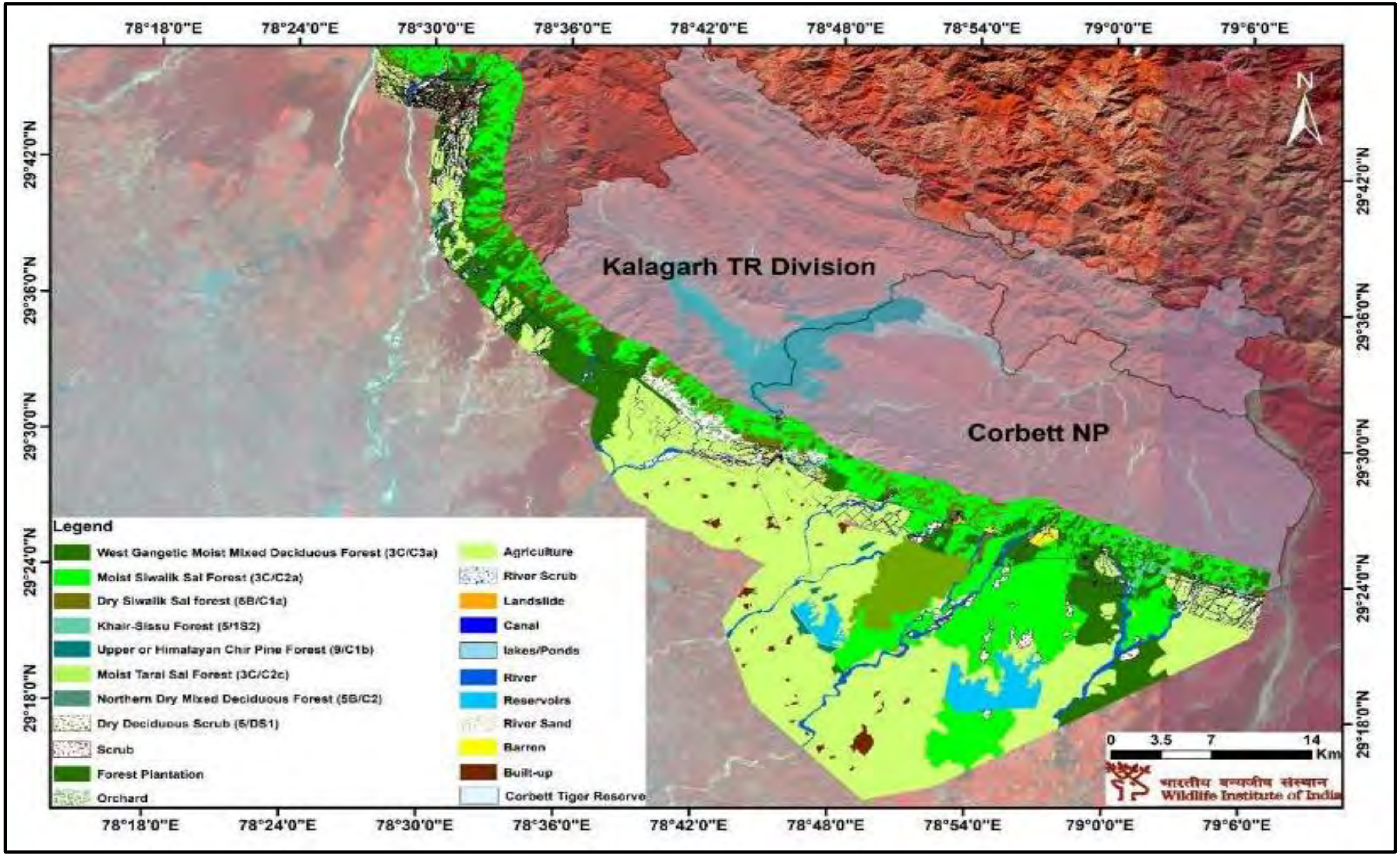


Figure 16 : Distribution of different Land Use Land Cover (LULC) types across the study area (2018-2019).

Table 6 : Area under various land-use land-cover (LULC) types in the study area (2018-19).

S.no	LULC type	Area (Sqkm)	%
1	West Gangetic Moist Mixed Deciduous Forest	113.54	11.46
2	Moist Siwalik Sal Forest	226.98	22.92
3	Dry Siwalik Sal forest	33.99	3.43
4	Khair-Sissu Forest	7.16	0.72
5	Upper or Himalayan Chir Pine Forest	0.77	0.08
6	Moist Tarai Sal Forest	0.05	0.01
7	Northern Dry Mixed Deciduous Forest	0.009	0.00
8	Dry Deciduous Scrub	2.96	0.30
9	Scrub	22.07	2.23
10	Forest Plantation	69.82	7.05
11	River Scrub	3.00	0.30
12	Canal	0.27	0.03
13	Waterbody	19.35	1.96
14	River	32.07	3.23
15	River Sand	4.73	0.48
16	Barren	9.80	0.99
17	Landslide	0.72	0.07
18	Orchard	14.34	1.45
19	Agriculture	410.39	41.41
20	Built-up	18.60	1.88
	Total	**990.61**	**100**

West Gangetic Moist Mixed Deciduous Forest

It is a closed forest of medium to good height including many dominant species and many second-storey trees, of which some are evergreen. This type of forest scattered freely through the hilly tracts occupied by the moist Sal type and more locally in the plains. Dominant trees in this forest type are *Terminalia bellerica, Lannea coromandelica, Garuga pinnata, Lagerstroemia parviflora, Adina cordifolia, Aegle marmelos, Anogeissus latifolia, Holoptelea integrifolia, Ehretia laevis* and *Mallotus philippensis*. It appears as bright tint of red with partially rugged texture because of the tree density.

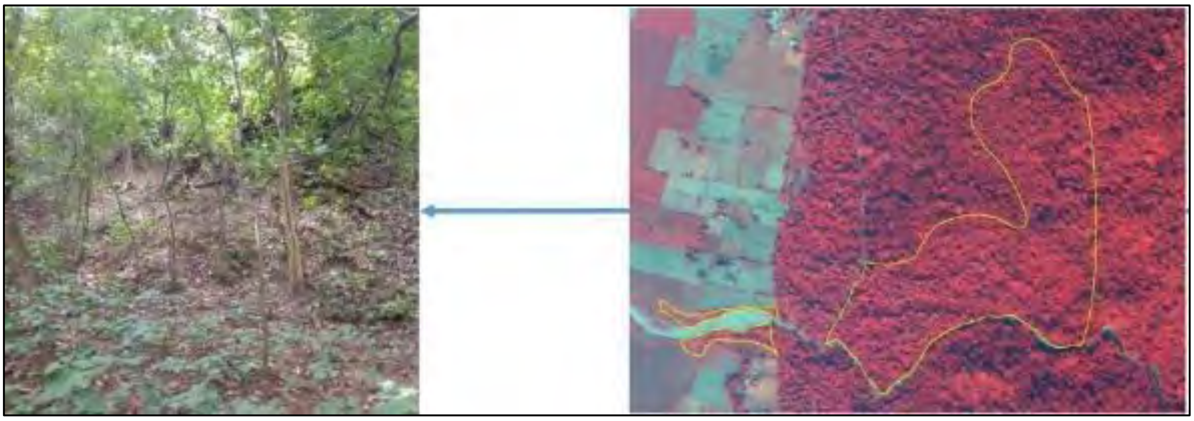


Figure 17: Depiction of West Gangetic Moist Mixed Deciduous Forest on ground (left) and in satellite image (right).

Moist Siwalik Sal Forest

This type of forest occurs up to 1000m altitude in hills where it meets the subtropical forests of pine or broadleaved trees. The slopes are moderate to precipitous. It requires mature soil. On slopes, it merges imperceptibly into the dry deciduous type. The major trees found in this type of forest are *Shorea robusta, Bombax ceiba, Bauhinia racemose, Terminalia bellerica* and *Tectona grandis*. The main associates are *Mallotus Philippensis, Miliusa velutina, Ehretia laevis, Alangium salvifolium* and *Adina cordifolia.* They appear in dark red pixels with rough texture because of the density of the trees in the satellite imagery.

Figure 18: Depiction of Moist Siwalik Sal Forest on ground (right) and in satellite image (left).

Dry Siwalik Sal Forest

Dry Sal forest is the transitional form of Moist Siwalik Sal. It occurs mostly on the plains and low hills, being particularly associated with eroded hillsides and alluvial terraces with an irregular canopy. *Adina cordifolia, Cassia fistula, Dalbergia paniculata, Holoptelea integrifolia, Mallotus philippensis, Putranjiva roxburghii, Ziziphus mauritiana, Ziziphus xylopyrus* were the most common associates found in this type of forest. This appears as light red tone with scattered tree crowns in the satellite imagery**.**

Figure 19: Depiction of Dry Siwalik Sal Forest on ground (right) and in satellite image (left).

Khair-sissu forest

Khair-sissu forest occur all along the larger streams, on new sandy or gravelly alluvium, which are very porous hot, dry during the summer and almost devoid of humus. They are scattered in nature. The major trees are *Cassia fistula* and *Dalbergia sissoo* found in this forest type, which are associated with *Aegle marmelos*, Ailanthus *excelsa, Ehretia laevis, Mallotus philippensis, Miliusa velutina, Ficus spp.,* and *Eucalyptus tereticornis*. In satellite imagery, it appears in bright red pixels, which gives a high reflectance value with a smooth texture and scattered tree crown.

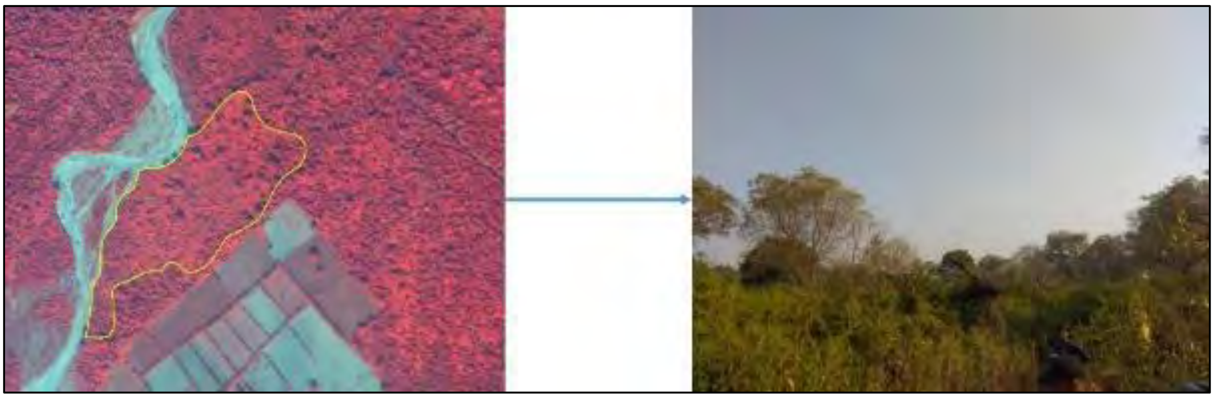


Figure 20: Depiction of Khair-sissu forest on ground (right) and in satellite image (left).

Upper or Himalayan Chir Pine Forest

High forest of 20-35m height usually forming a light canopy from one-third to two thirds complete. No other trees can reach the top canopy and there are only scattered trees representing a second storey. During the monsoon a rich grass growth develops, which dries up and is flattened down in the winter and from then till the next rains, the soil appears completely bare of vegetation. This type of forest occurs from 1200 to 1800 m altitude, which overlaps with the tropical deciduous forest at the lower elevations notably on the Siwalik Hills and giving way to the temperate forests. It shows a smooth texture with mixed tone of red varies from dark to light in the higher altitudes.

Figure 21: Depiction of Upper or Himalayan Chir Pine Forest on ground (right) and in satellite image (left).

Moist Tarai Sal Forest

This forest type is extensive in Great Plains of Siwalik Hills which spread up to outer Himalayan slopes in the north wherever the moisture and soil conditions are favourable. This type of forest occurs on grey clayey alluvium with wet subsoil. *Shorea robusta, Adina cordifolia, Syzygium cumini, Lagerstroemia parviflora* are the major species found in this forest

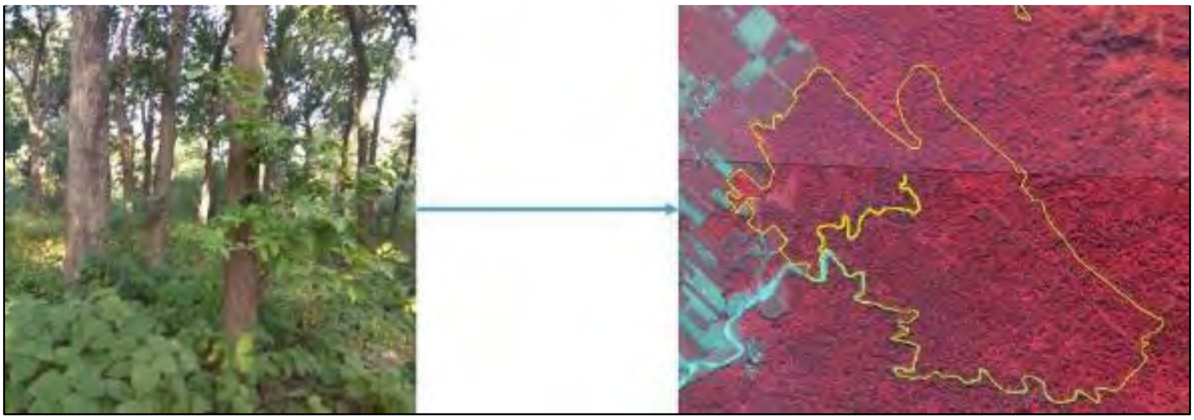


Figure 22: Depiction of Moist Tarai Sal Forest on ground (left) and in satellite image (right).

Northern Dry Mixed Deciduous Forest

The distribution of this forest type extends throughout northern India. This forest type occurs in the lower slopes of the Himalaya, particularly on the outer range altitude about 1.250m and higher. *Acacia catechu, Mallotus philippensis, Anogeissus latifolia, Shorea robusta, Bauhinia spp.* are the major species found in this type of forest.

Figure 23: Depiction of Northern Dry Mixed Deciduous Forest on ground (right) and in satellite image (left).

Dry Deciduous Scrub

This type occurs in low broken soil cover of shrubby growth 3 to 6m height that includes some tree species. It extends throughout the dry deciduous forest zone of India.

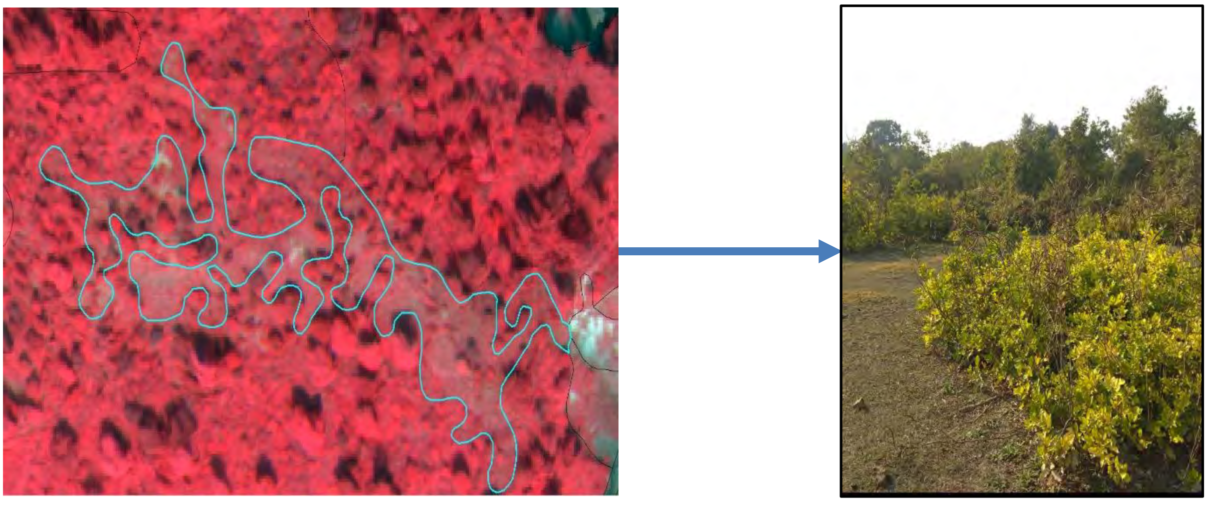


Figure 24: Depiction of Dry Deciduous Scrub on ground (right) and in satellite image (left).

Scrub

Scrubland is a type of vegetation, which is dominated by shrubs, i.e. low woody plants, which typically forms an intermediate community between grass and forest. Successional change is not necessarily implied, though the term is often used for the transitional stage in succession to climax woodland when shrubby plants predominate. Some tree species assosiated with scrubland are *Acacia catechu, Anogeissus latifolia, Dalbergia sissoo, Haplophragma adeno-phyllum* and *Ziziphus mauritiana.* It appears as similar to barren land but with a slight tone of red and grey with a very smooth texture in the satellite imagery.

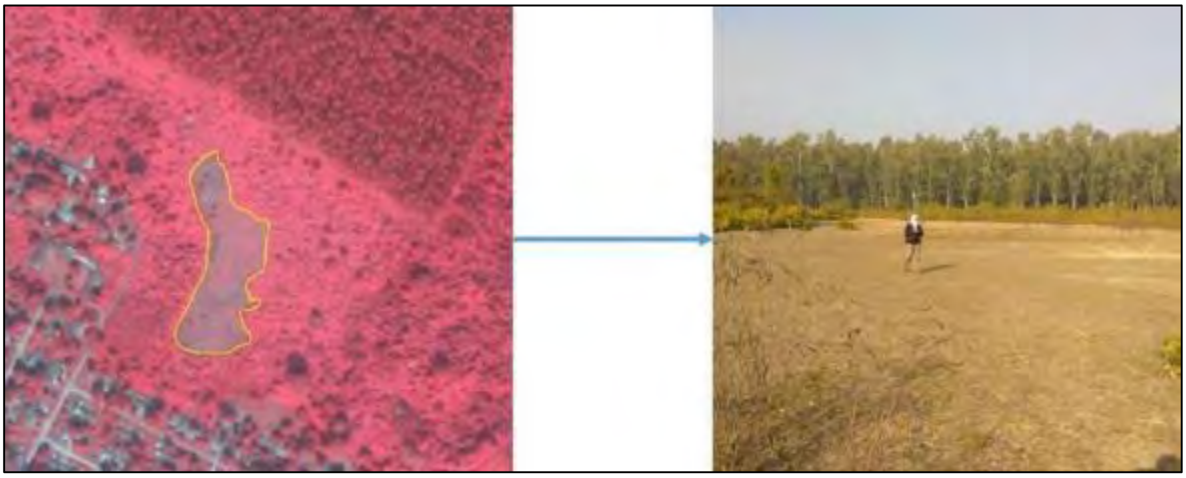


Figure 25: Depiction of scrubland on ground (right) and in satellite image (left).

Forest plantation

Forest plantations embrace a range of forest types with one common feature that the great majority of trees present were established on the site by planting and/or seeding (sowing). *Tectona grandis, Eucalyptus tereticornis, Shorea robusta and Holarrhena antidysenterica* are the major forest plantation found in the study area. The main associates were *Mallotus philippensis, Dalbergia sissoo, Acacia catechu and Adina cordifolia etc.* It shows a uniform and linear tree crown structures with a defined land parcels in the satellite imagery.

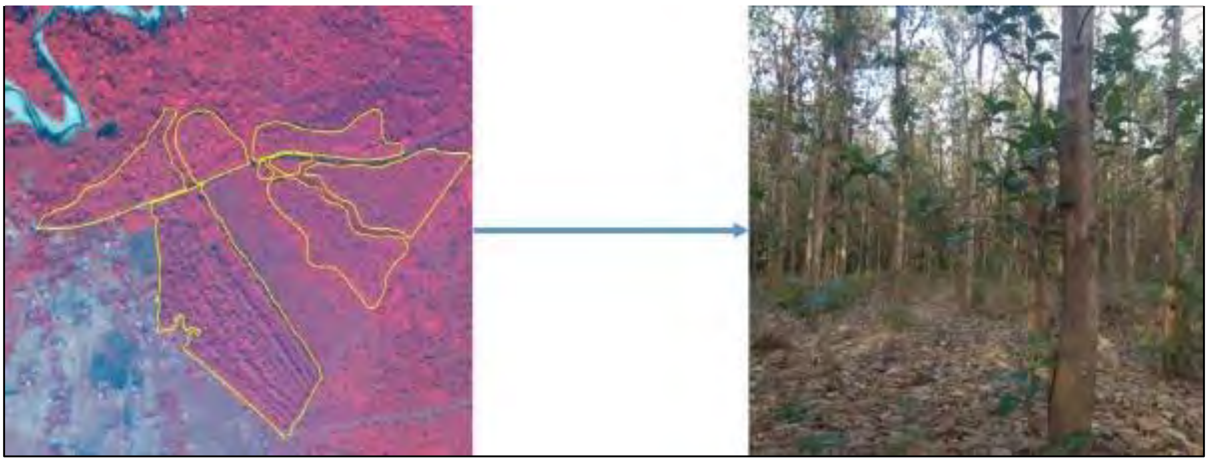


Figure 26: Depiction of forest plantation on ground (right) and in satellite image (left).

Orchards

Orchards comprise fruit or nut producing trees, which are generally grown for commercial production. Orchards are also sometimes a feature of large gardens, where they serve an aesthetic as well as a productive purpose. Most commonly, it is associated with agriculture land and settlements.

Figure 27: Depiction of orchards on ground (right) and in satellite image (left).

Agriculture land

This category comprises of various agricultural activity in the study area. They appear as a well-defined land parcels with smooth dotted texture and dark tone where it is mostly associated with the settlements.

Figure 28: Depiction of agriculture land on ground (right) and in satellite image (left).

Canal, Water bodies and River

River and water channels, which were clearly seen on the satellite imagery in blue and cyan colour depending on the depth of water with a long narrow wide pattern was associated with the drainages on hill slope. There are also various similar classes like canal, reservoir and Lakes/ponds.

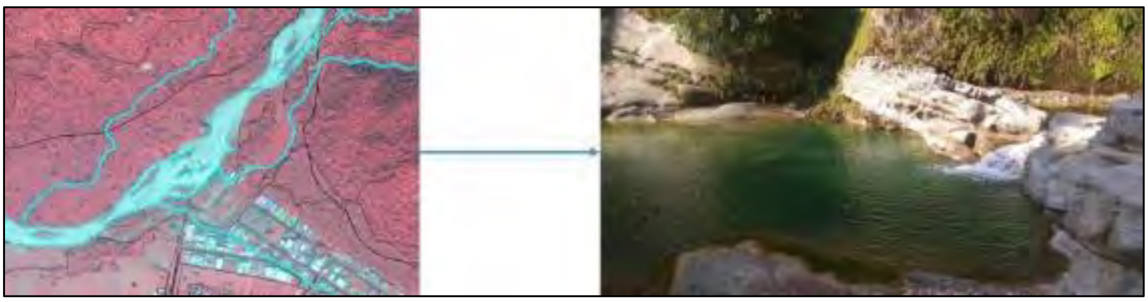


Figure 29: Depiction of agriculture land on ground (right) and in satellite image (left).

Built-up areas

The built up areas are identified by its greyish tone in the FCC image shows a light, rough and defined shape, which are mostly associated with the Orchards and Agricultural field. Under this broad class, there were many sub classes such as settlements, Road, industrial area, railway lines and stations and utility.

Figure 30: Depiction of agriculture land on ground (left) and in satellite image (right).

4.1.2. Species richness, density and composition and structure across forest types

We sampled six forest types with 150 plots and enumerated 53 tree species. Mean species richness at plot-level was similar across forest types and was greater than scrub vegetation. However, due to the larger expanse of West Gangetic moist mixed deciduous forest and moist Siwalik sal forest, total number of species was greater in these forest types. Although not statistically significant, dry sal forest tended to have the highest diversity (Simpson index) and mean species richness per plot. The overall tree density in the study area was 624 ha^{-1}. Tree density was similar across forest types, although tending to be highest in West Gangetic moist mixed deciduous forest and least in scrub vegetation (Table 7).

The dominant species varied among forest types. However, *Mallotus philippensis* was found to be the most common tree species in the landscape. *Mallotus* was the dominant species for Dry sal forest (IVI=88.25), Moist siwalik Sal forest (IVI=64.17) and West Gangetic moist mixed deciduous forest (IVI=59.55), and the co-dominant species for Khair-sissoo forest (IVI=45.25). Other dominant species were: *Holoptelea integrifolia* (IVI=83.12) in forest plantation; *Ailanthus excelsa* (IVI=48.62) in Khair-sissu forest; and *Ziziphus mauritiana* (IVI=75.47) in scrub. West Gangetic moist mixed deciduous forest, the major forest type in this landscape, was characterized by *Mallotus philippensis*, *Bombax ceiba*, and *Haldina cordifolia*. Forest plantation, the second major forest type, was characterized by *Holoptelea integrifolia*, *Tectona grandis* and *Ficus benghalensis* (Table 8).

The vertical structure of forest, represented as the proportion of trees in different height classes, was characterised as a right skewed unimodal distribution ranging from 1 to 32 m, with modal tree height of 6-7 m (Figure 31). The proportion of trees in different height classes differed to some extent between forest types (Figure 32). We estimated the vertical heterogeneity at a plot from proportion of trees in 5 m height classes, as the exponent form of Shannon-Weiner index, to be 2.20 $\pm$ 0.07 SE. Thus, crudely speaking, each plot was represented by more than two tiers of canopy. We discuss the implications of such multi-tiered canopy structure on remote sensing of tree count, in section 4.1.3.

Table 7 : Vegetation parameter estimates of forest types in the proposed road impact zone (Alignment 2A/B) of Corbett Tiger Reserve (2018-19).

Forest type	Plots	Species richness	Mean (SE) species/ plot	Simpson diversity index	Mean (SE) density / plot	Density (# / ha)
Dry Sal Forest	3	8	3.67 (1.53)	2.89	6.33 (1.16)	633
Forest Plantation	39	19	2.26 (1.04)	1.88	6.90 (2.91)	690
Khair-Sissoo forest	11	14	2.27 (1.49)	2.14	3.45 (3.27)	345
Moist Siwalik Sal forest	24	26	2.83 (0.82)	2.27	6.08 (2.02)	608
Scrub	12	9	1.17 (1.40)	1.38	2.42 (3.85)	242
West Gangetic Moist Mixed Deciduous Forest	61	45	2.89 (1.33)	2.21	7.13 (3.44)	713

Table 8 : Dominant tree species across forest composition types within the proposed road impact zone in Corbett Tiger Reserve (2018-19).

Forest type	Dominant species	IVI
Dry Sal forest	*Mallotus philippensis*	88.25
	Holoptelea integrifolia	59.97
	Dalbergia paniculata	30.77
Forest plantation	*Holoptelea integrifolia*	83.12
	Tectona grandis	81.64
	Ficus benghalensis	33.71
Khair-Sissoo forest	*Ailanthus excelsa*	48.62
	Ficus benghalensis	46.33
	Mallotus philippensis	45.25
Moist Siwalik Sal forest	*Mallotus philippensis*	64.17
	Haldina cordifolia	30.56
	Ehretia laevis	29.97
Scrub	*Ziziphus mauritiana*	75.47
	Dalbergia sissoo	63.25
	Holoptelea integrifolia	57.72
	Mallotus philippensis	59.55

West Gangetic moist mixed deciduous forest	*Bombax ceiba*	34.86
	Haldina cordifolia	31.04

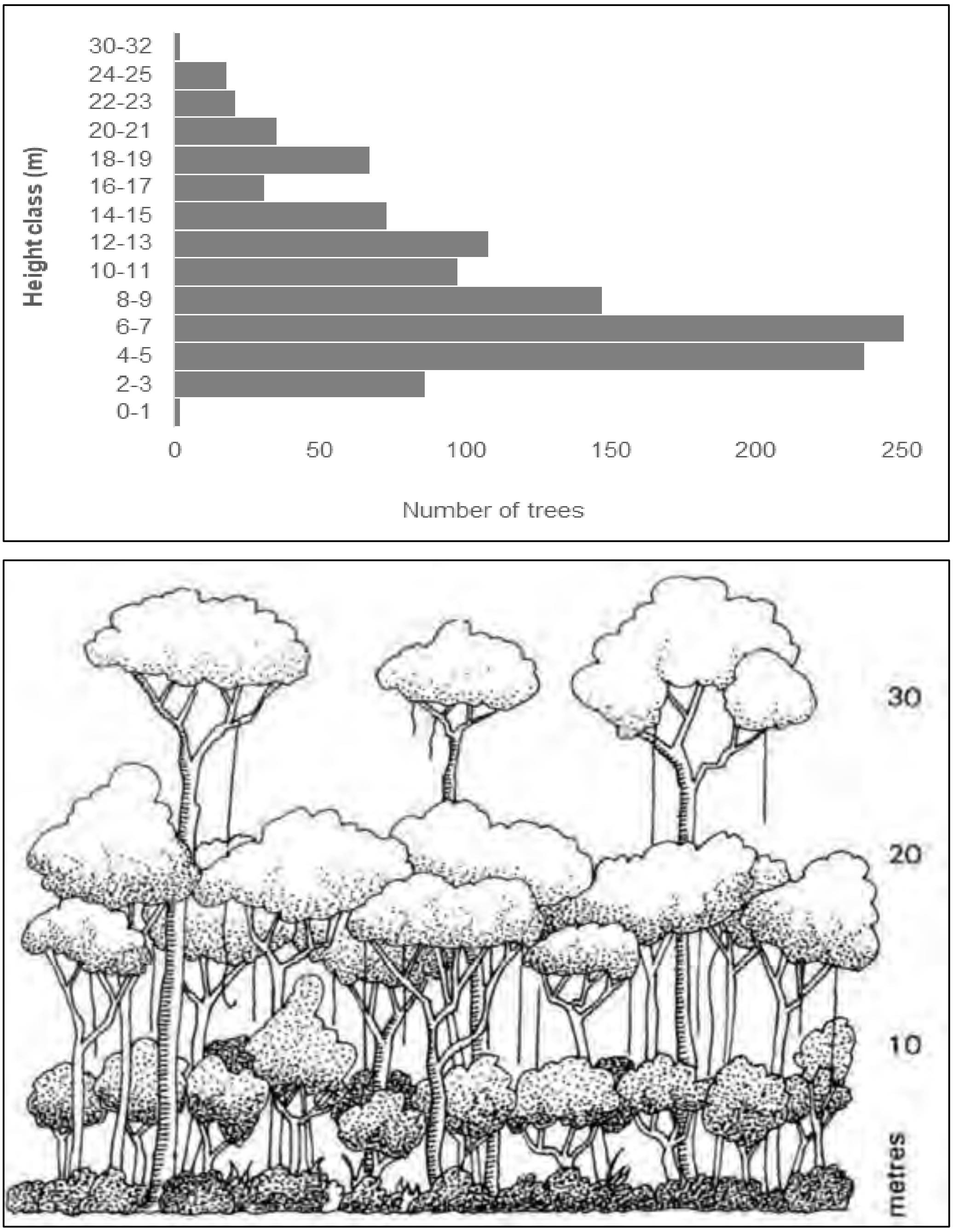


Figure 31 : Vertical stratification of forest, represented as frequency of trees in different height classes (top), within the proposed road impact zone of Corbett Tiger Reserve (2018-19) and a pictoral representation of the general canopy structure (bottom). (Source: Internet)

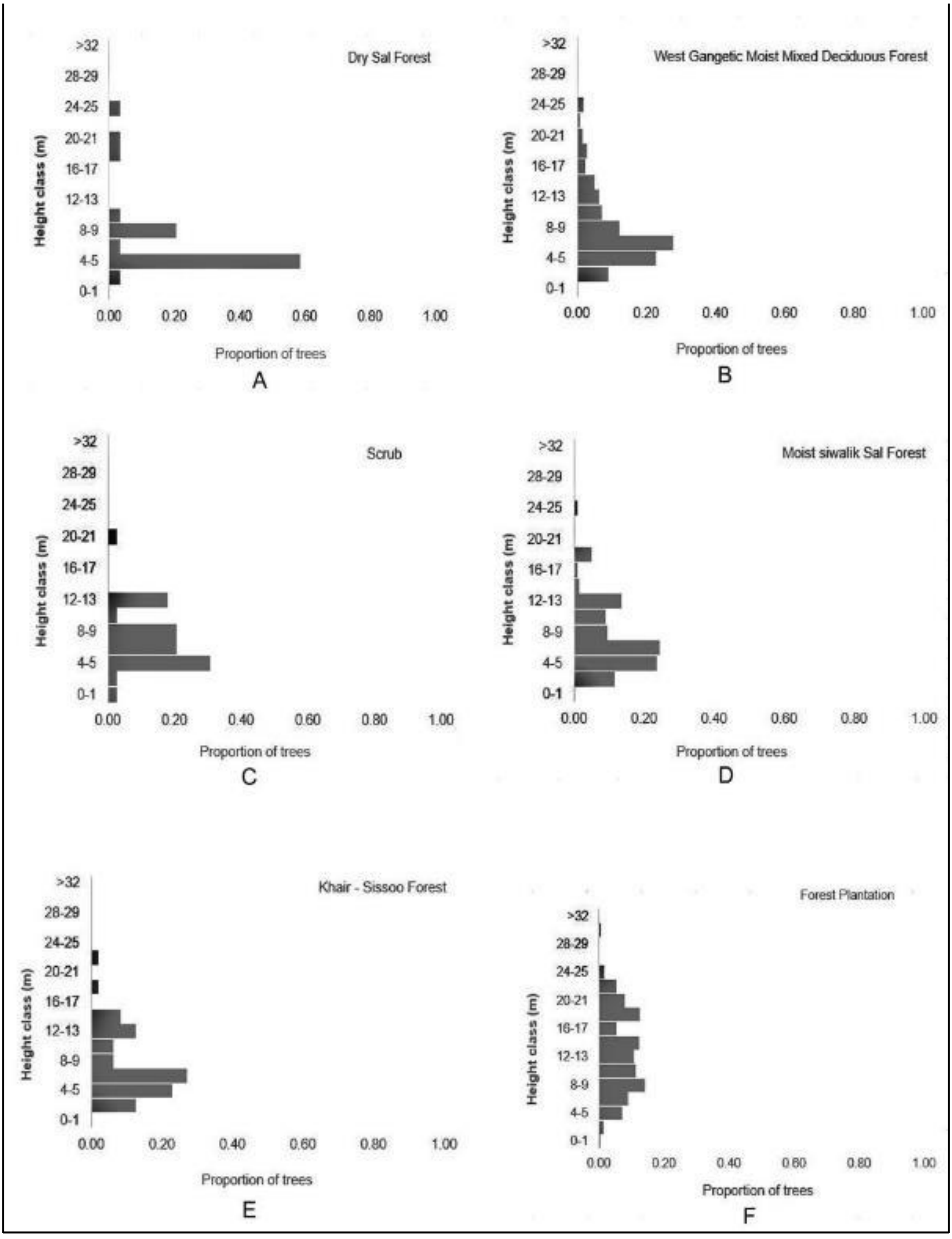


Figure 32 : Vertical stratification of forest types, represented as frequency of trees in different height classes, within the proposed road impact zone of Corbett Tiger Reserve (2018-19).

4.1.3. Tree calibration

Tree calibration results indicated that the ratio of actual to estimated tree counts differed between broad forest types (Table 9), ranging from 0.70 ± 0.30 SE (scrub) to 2.27 ± 0.13 SE (West Gangetic moist mixed deciduous forest), with an average estimate of 1.97 ± 0.09 SE (Figure 33). The difference between actual and remotely sensed number of trees largely results from the multi-tiered nature of the canopy, as described in section 4.1.2. In other words, the actual number of trees, inclusive of upper and lower canopies, is roughly twice the number that can be estimated based on satellite imagery. We use the pooled/average correction factor to correct for the estimated number of trees to be felled for a particular road alignment in section 4.5.

Table 9 : Comparison of models examining the effects of forest composition and density types on the ratio of actual (based on field sampling) to estimated tree count (based on visual interpretation of satellite imagery) in Corbett Tiger Reserve (2018)

Hypothesized effects	Akaike weight	ΔAICc	AICc	Deviance	Model parameters
Forest composition type	0.6	0.0	438.0	423.2	7
Forest composition and density type	0.2	2.4	440.4	411.7	13
Forest vs. scrub	0.2	2.6	440.6	434.4	3
Forest density type	0.0	13.0	450.9	442.7	4
Null model	0.0	18.6	456.5	452.4	2

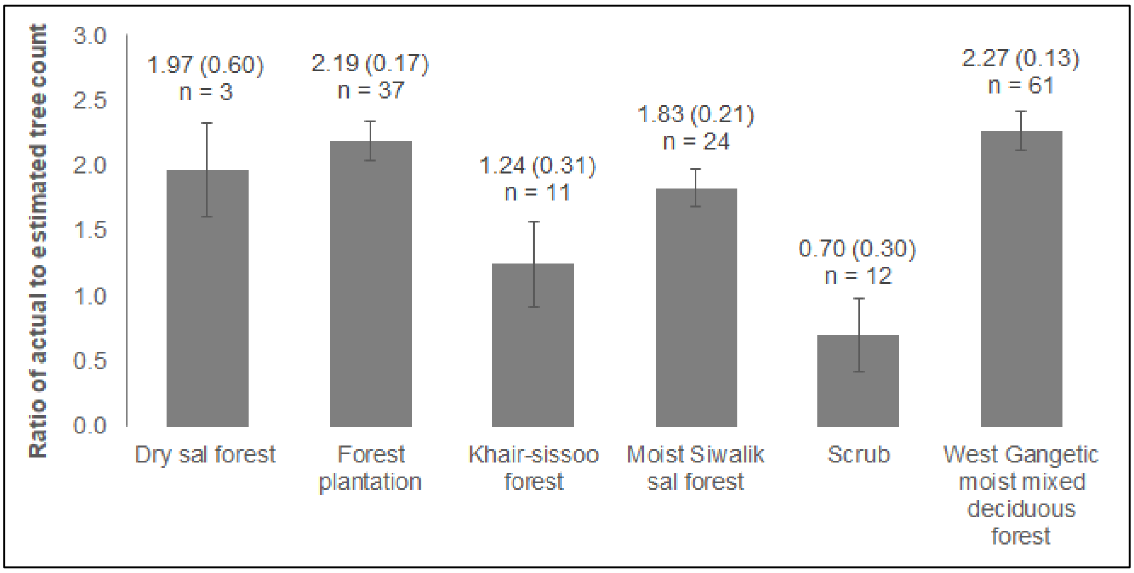


Figure 33 : Ratio of actual tree count to remotely sensed tree count across major forest types of Corbett Tiger Reserve (2018-2019).

4.1.4. Number of ecologically important trees

A total of 89, 61, 08 and 665 individuals of *Ficus rumphii, Ficus benghalensis, Ficus racemosa* and *Bombax ceiba* respectively were recorded along the current Kandi road from Ramnagar to Kotdwar. These species were distributed randomly along the road. They have high conservation value as they provide foraging resources for many bird species especially hornbills and other birds, and should be considered for mitigation planning in the case of upgradation of the current alignment.

4.2. Mammals

4.2.1. Road usage by mammals

We recorded 20 mammal species along the road using camera traps (Annexure 3). Species such as rhesus macaque, hanuman langur, common palm civet, small Indian civet, leopard cat, Indian fox, golden jackal and jungle cat were collectively considered as small mammals. We developed an index that is equivalent to the total hours spent by all individuals of a species daily on/along the entire Kandi road. Carnivores such as tiger, bear and common leopard spent 3.14 ± 0.24SE, 1.93 ± 0.19 and 0.12 ± 0.05 animal hours/day, respectively. RET herbivores such as sambar and elephants also had high road usage of 66.90 ± 1.13 and 9.70 ± 0.43 animal-hours per day. Edge species such as chital and small mammals (mostly macaque and langur) had particularly high usage on dirt road, with 621.28 ± 3.41 and 390.53 ± 2.71 animal-hours on/along the road per day, respectively (Figure 34).

These results indicate the generally high usage of animals of the existing road and its adjoining forests (Figures 36).

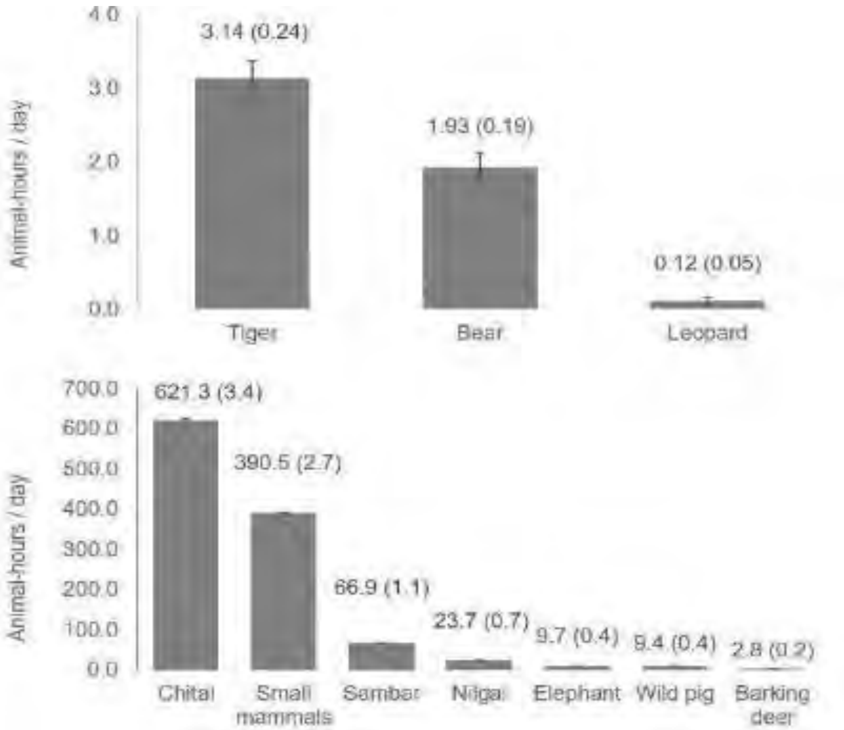


Figure 34 : Mean (SE) animal-hours spent by carnivore (top) and herbivore (bottom) species per day on/along the current forest road (Saneh to Ramnagar), based on proportion of photographs with a species' capture in elevated time-lapse camera-traps (2018-19).

The estimate of animal-hours spent on road by a species is a function of its density/abundance that is relatively high in Corbett Tiger Reserve for most of the species enlisted above. We advise caution while comparing these estimates with other protected/forested areas and recommend that estimates that have been scaled to density/abundance should be used. For the sake of comparing a species' animal-hours spent on road in the study area to that of other protected/forested areas, we report the estimates scaled to the species' density (animal-hours/day/density) and abundance within 214 sqkm project impact area (hours/day/animal) assuming that all individuals in the area can potentially access the road. (Table 10).

Table 10: Animal hours spent on road by large mammal species per day (as shown in above figure 34) scaled to their respective density and abundance estimates within 214 km^2 area between Saneh to Ramnagar (78 km) and upto 2km (buffer) from the current forest road in Corbett Tiger Reserve (2018-19). Note: It is recommended that while comparing these estimates with other protected/forested areas, to use only the estimates scaled to density/abundance (bold figures in the table).

Species	Animal-hours spent on road (hrs/day)	Density/km^2 (Jhala et al. 2015)	Animal-hours/day/density	Hours/day/animal
Tiger	3.14 ± 0.24	0.19 (current study)	**16.53**	**0.08**
Elephant	9.70 ± 0.43	2.46 ± 0.74	**3.94**	**0.02**
Sambar	66.90 ± 1.13	9.09 ± 1.1	**7.36**	**0.03**
Chital	621.28 ± 3.41	64.38 ± 8.6	**9.65**	**0.05**
Barking deer	2.8 ± 0.2	3.06 ± 0.59	**0.92**	**0.00**
Wild pig	9.4 ± 0.4	8.7 ± 1.84	**1.08**	**0.01**
Nilgai	23.7 ± 0.7	3.63 ± 1.25	**6.53**	**0.03**

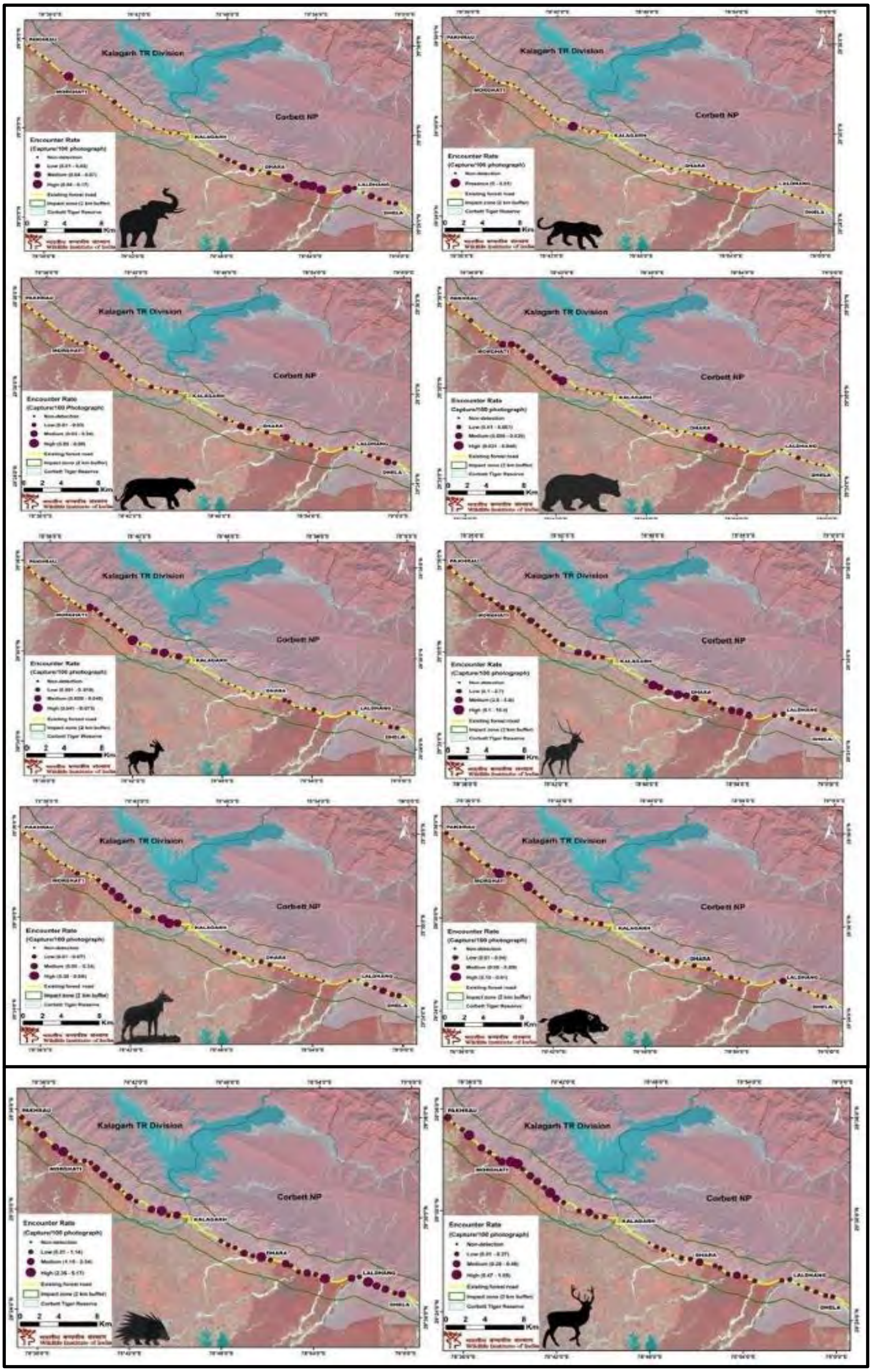


Figure 35 : Spatial distribution of animal encounter rates based on the elevated time-lapse camera traps along the existing forest road in Corbett Tiger Reserve (2018-19).

4.2.2. Relative abundance indices of RET mammals

Relative abundance of mammals were represented using RAI_1 which is interpreted as trap-days required to get an independent detection of a species and RAI_2 which is interpreted as the number of independent detections per 100 trap-days. These indices indicated that abundance of chital >> sambar >> elephant > barking deer = nilgai > wild pig among herbivores, and that of tiger >> bear > leopard > striped hyena among carnivores in the study area (Table 11). Further comparison of RAI_2 between camera-traps showed lower estimates in camera traps on road compared to that away from road for species such as tiger, elephant and barking deer. Whilst, for species such as chital and nilgai, RAI_2 estimates were greater in camera traps on road compared to that away from road. Assuming that camera traps away from the road reflect expected/random animal usage, it can be concluded that species such as tiger, elephant and barking deer show avoidance towards the existing forest road and are particularly sensitive to its "habitat loss" effects, while species such as chital and nilgai are preferring the road for daily usage (Figure 36).

Table 11 : Relative abundance indices of mammalian species based on camera trap photo-captures in the impact zone of alignments 2A/B in Corbett Tiger Reserve (2018). Reported estimates include mean (SE) RAI_1 or the number of trap-days required to capture one independent detection of a species based on all camera-traps, and mean (SE) RAI_2 or the number of independent detections of a species per 100 trap-days based on all camera-traps ("Pooled"), only those on road ("Road") and those away from road ("Buffer").

Species	RAI_2 (Events/100 Trap days)			RAI_1 (Trap days/detection of species)
	Buffer	Road	Pooled	
Tiger	11.76 (0.85)	5.26 (1.15)	10.04 (0.71)	9.96 (7.07)
Bear	1.10 (0.20)	1.44 (0.54)	1.19 (0.21)	83.92 (17.25)
Leopard	0.58 (0.12)	0.91 (0.32)	0.67 (0.12)	149.68 (18.39)
Striped hyaena	0.05 (0.03)	1.07 (0.28)	0.32 (0.08)	314.52 (25.51)
Chital	81.07 (8.45)	125.93 (17.31)	92.96 (7.79)	1.08 (8.38)
Sambar	29.95 (2.30)	28.05 (4.20)	29.45 (2.02)	3.40 (6.87)
Elephant	14.45 (1.39)	8.59 (1.22)	12.90 (1.08)	7.75 (8.38)
Barking deer	9.51 (1.26)	1.84 (0.63)	7.48 (0.96)	13.37 (12.86)
Nilgai	1.54 (0.50)	18.75 (8.39)	6.10 (2.28)	16.40 (37.45)
Wild pig	2.87 (0.46)	3.98 (1.16)	3.16 (0.46)	31.60 (14.41)
Small mammals	24.61 (2.22)	65.36 (29.07)	35.40 (7.91)	2.82 (22.33)

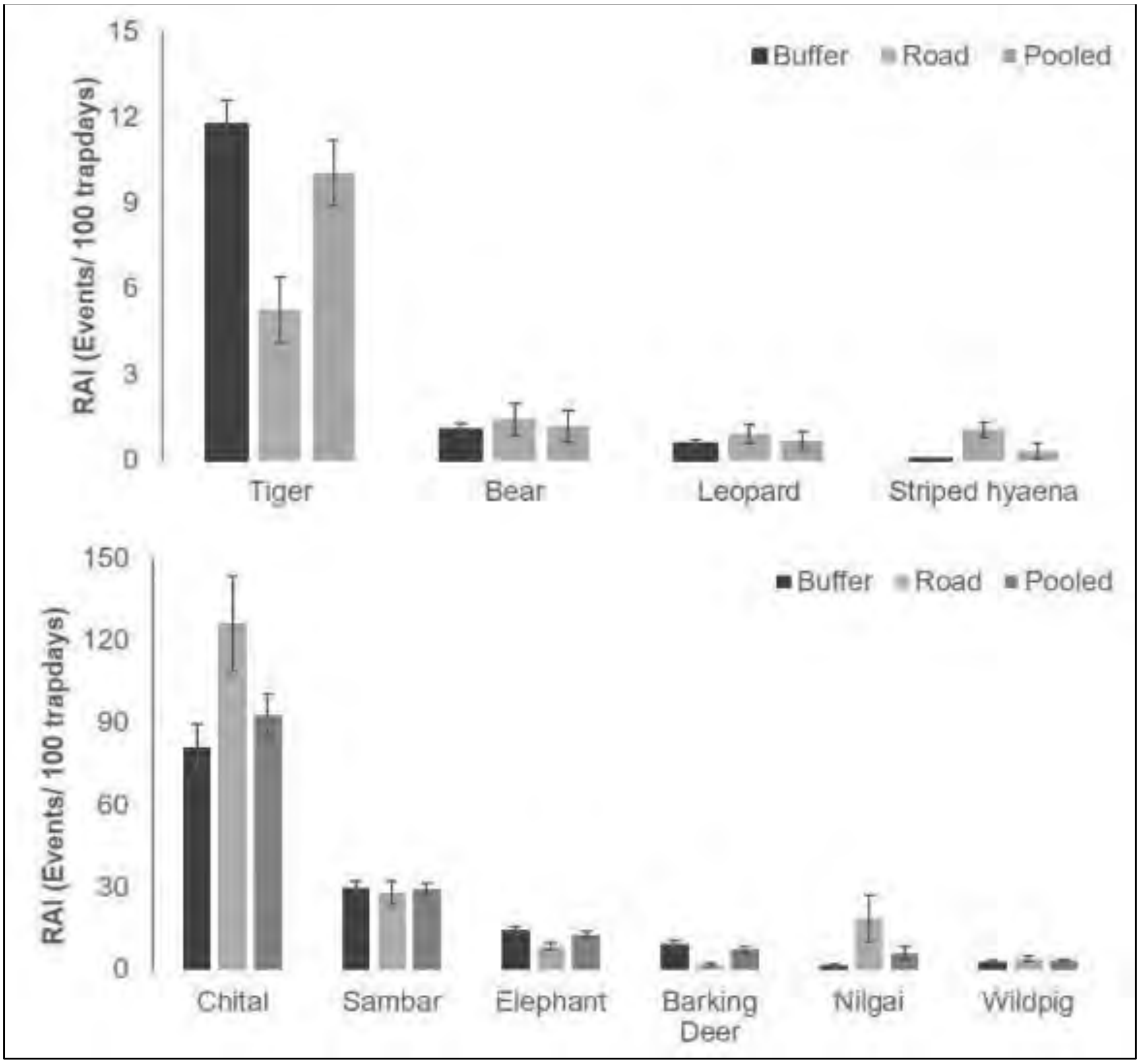


Figure 36 : Mean RAI_2 (independent detections / 100 trap-days) of carnivores (top) and herbivores (bottom) across all camera-traps (pooled), those on road and those away from road (buffer) in the impact zone of alignments 2A/B in Corbett Tiger Reserve (2018-19).

Spatial Distribution of relative abundance indices (RAI) showed the following trends. Among herbivores, a) elephant distribution was relatively uniform although higher at north-south contiguous forest patches such as Pakhrau to Morghati and Dhara to Laldhang, b) sambar distribution was relatively uniform although higher between Pakhrau and Kalagarh (Kalagarh TR Division), c) chital distribution was relatively uniform although higher between Kalagarh and Dhela (Corbett national Park), and d) barking deer distribution was patchy and high near Pakhrau, Morghati, Kalagarh and Dhela (Figure 37). Among carnivores, a) tiger distribution was uniform but relatively higher between Kalagarh and Dhela (Corbett national Park), b) bear distribution was patchy with higher detection near Pakhrau, Kalagarh and Dhara, c) leopard was sporadically detected near Pakhrau and Dhela, and d) hyaena was very sporadically detected between Pakhrau and Kalagarh near road (Figure 38).

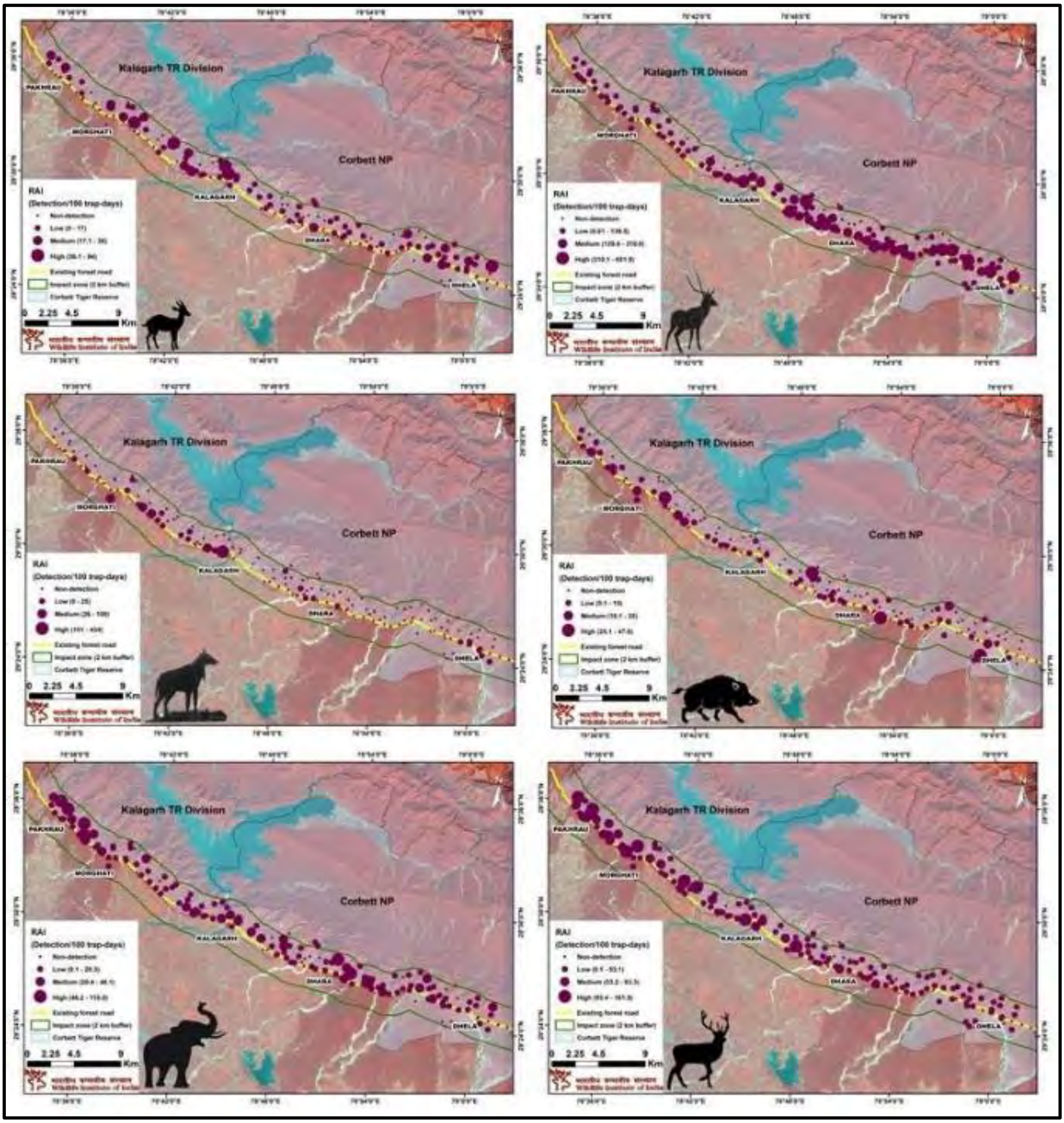


Figure 37 : Spatial distribution of relative abundance indices of herbivores based on camera-trap photo-captures within the proposed road impact zone (alignments 2A/B) in Corbett Tiger Reserve (2018-19).

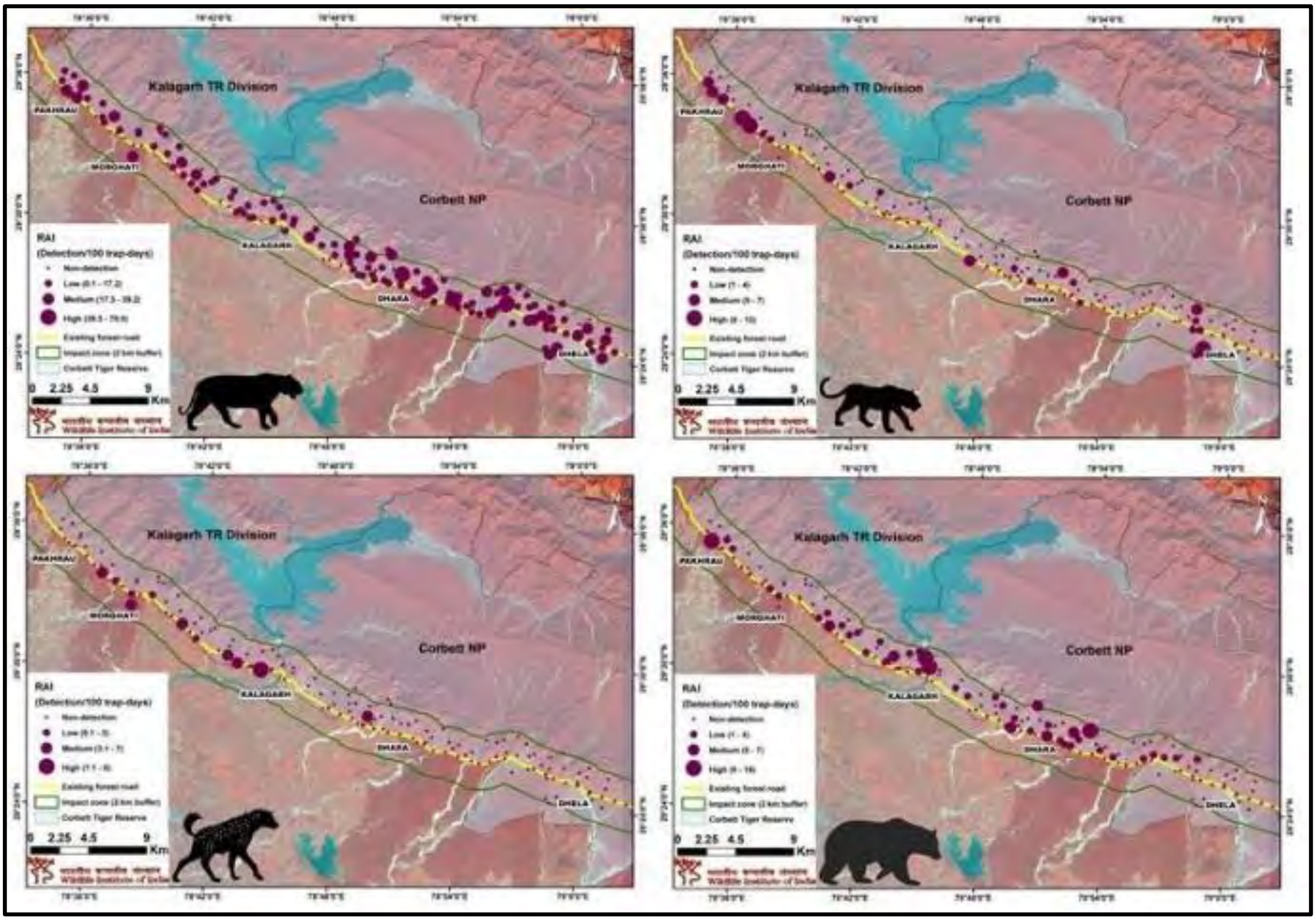


Figure 38 : Spatial distribution of relative abundance indices of carnivores based on camera-trap photo-captures within the proposed road impact zone (alignments 2A/B) in Corbett Tiger Reserve (2018-19).

4.2.3. Tiger density estimation

Camera trapping with 167 paired detectors for 50 trap-days resulted in 800 independent photo-captures of 60 tigers in 52 camera-traps that were used to develop spatially explicit capture recapture (SECR) matrices. Sampling duration was adequate for capturing majority of tigers in the project impact zone, as cumulative number of tigers stagnated with increasing trap-days (Figure 39). Comparison of candidate SECR models indicated maximum support for the model *D~1, g0~h2, σ~h2, p~h2* representing constant density and heterogeneity between individuals in g0 (capture probability intercept) and σ (spatial scale) (Table 12). Tiger density was estimated by this model to be 19 (14.57 - 26.63 95% CI) individuals per 100 sq km (Table 13). Tiger abundance or the number of activity centers inside the impact zone of alignments 2A/B (214 sq km area) was estimated to be 42 (31 - 57 95% CI). However, the number of tigers that will be potentially impacted by the project is minimum 60 whose ranges overlap with the project impact zone (Figure 40). Out of these, at least 19 tiger ranges are intersected by the existing forest road whose ranging patterns will be directly affected if the Kandi road is upgraded along alignments 2 A/B.

Table 12: Summary statistics of candidate Spatially Explicit Capture Recapture models used to estimate tiger density in the proposed road impact zone (alignments 2A/B) of Corbett Tiger Reserve (2018-19). Model comprises state parameter: tiger density (*D*), and observation parameters: capture probability of an individual in a trap located at the activity center (*g0*) and the spatial extent of capturing an individual (*σ*). *D* was modeled as constant (~1) to represent a homogeneous Poisson point process, and on geographic coordinates (x,y). Detection parameters *g0* and *σ* were modeled as half-normal function that were assumed to be constant (~1), varying between individuals following a 2-class finite mixture (h2) or as learned response to trapping (~b) following standard notations (Efford 2019).

Model	Akaike wt	ΔAICc	AICc	Deviance	Parameters
D~1 g0~h2 σ~h2 p~h2	**1.00**	**0.00**	**3315.65**	**3302.07**	**6**
D~1 g0~h2 σ~1 p~h2	0.00	866.83	4182.48	4171.37	5
D~1 g0~1 σ~1	0.00	886.19	4201.84	4195.41	3
D~1 g0~1 σ~h2 p~h2	0.00	890.87	4206.52	4195.41	5
D~1 g0~b σ~b	0.00	890.87	4206.52	4195.41	5

Table 13: Tiger density and detection parameter estimates from least-AICc Spatially Explicit Capture-Recapture model in proposed road impact zone (alignments 2A/B) of Corbett Tiger Reserve (2018-19).

Parameter	Interpretation	Units	Esti-mate	95% CI
D	Tiger density	# / 100 sqkm	19.70	14.57 - 26.63
g0	Capture probability intercept for group 1	Probability	0.33	0.26 - 0.40
	Capture probability intercept for group 2		0.05	0.04 - 0.06
σ	Spatial scale of capture for group 1	meters	602	562 - 645
	Spatial scale of capture for group 2		4319	3995 - 4671
p	Probability, individual belongs to group 1	Probability	0.87	0.79 - 0.93

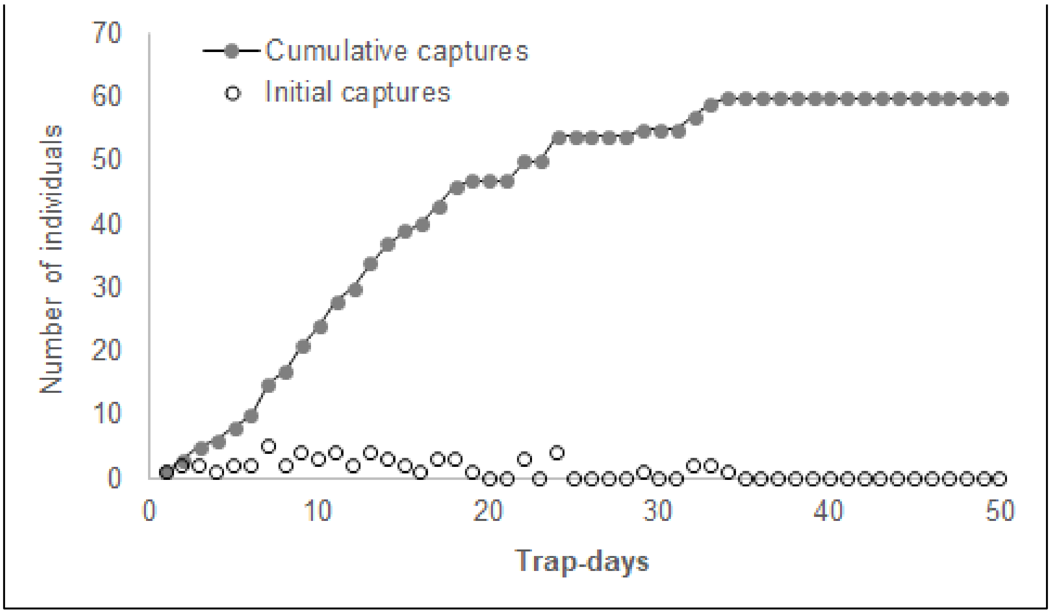


Figure 39 : Adequacy of capture-recapture sampling for estimating tiger abundance based on the cumulative number of tigers captured (closed circles) and number of tigers captured for the first time (open circles) along increasing trap-days in the proposed road impact zone (alignments 2A/B) of Corbett Tiger Reserve (2018-19).

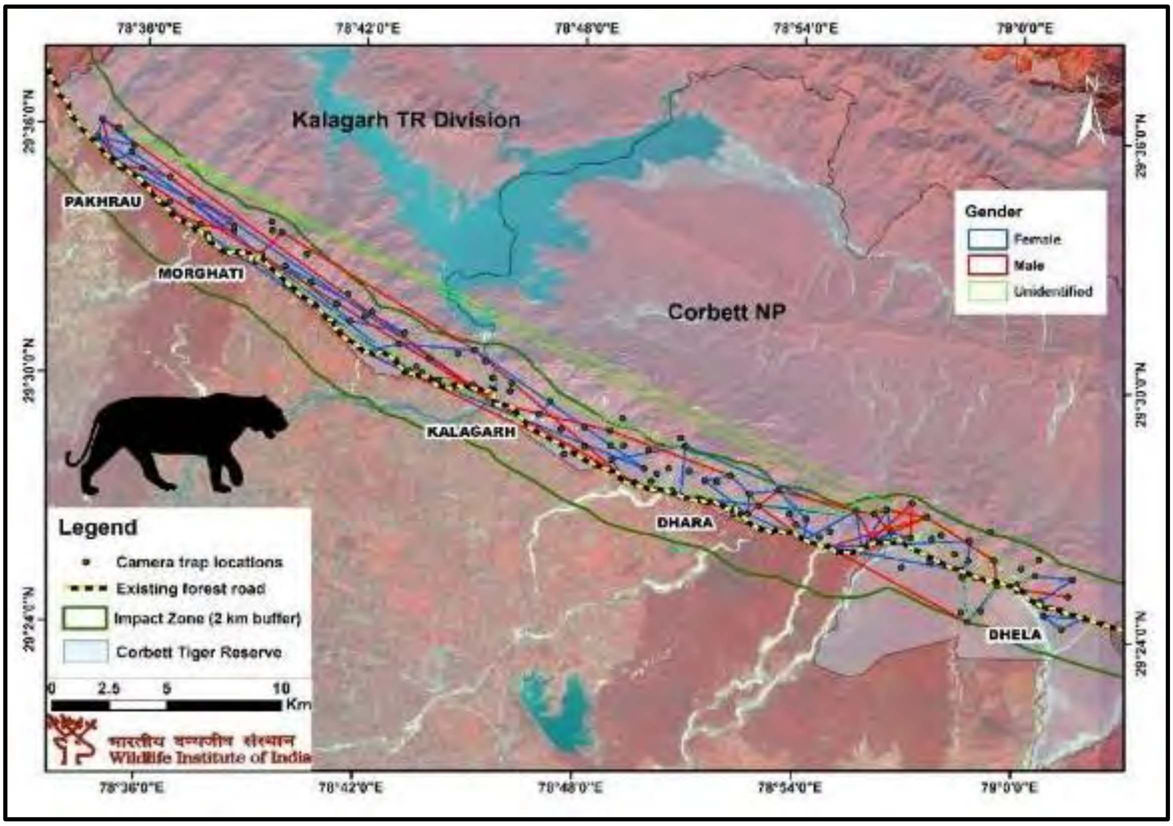


Figure 40 : Minimum Convex Polygons of 60 unique tigers photo-captured within the proposed road impact zone (alignments 2A/B) of Corbett Tiger Reserve (2018-19).

4.2.4. Sign surveys for wildlife usage index

Sign surveys along 38 trails totaling 104 km walk represented forests and agricultural habitats within 0 to 4.2 km distance from the forest. Sign intensity (number of signs km^{-1}) of chital (118.0 $\pm$ 38.5SE) > sambar (56.8 $\pm$ 18.5) > nilgai (89.9 $\pm$ 40.5) > elephant (3.7 $\pm$ 0.8) among herbivores, and that of tiger (2.9 $\pm$ 0.7) > leopard (0.4 $\pm$ 0.1) among carnivores. The effect of distance to forest on sign intensity found greater support than uniform sign intensity (Akaike weight ranged from 0.81 to 1.0), and fitted the data satisfactorily (R^2 ranged from 0.11 to 0.62) for all target species, except for nilgai (Table 14). These results indicated that usage of forest species declined exponentially with increasing distance from forest edge, while that of open habitat species remained unchanged (Figure 41). Since the decline in usage did not differ between forest-dwelling species (see model comparison in (Figure 41), a common SUDF was developed to describe reduction in animal usage away from forest. This function: *U = exp(-1.25 - 1.93 Dist-for)* fitted the pooled data reasonably well (R^2 = 0.35) and was used to predict animal usage away from sampled forested area (Figure 42).

Table 14 : Summary statistics and parameter estimates of pooled species' usage models describing the decline in general forest species (tiger, leopard, elephant, sambar and chital) from distance to forest edge in the project impact zone around Corbett Tiger Reserve (2018-19).

Species	Effect	Intercept	Slope	Ak. wt.	ΔAICc	AICc	Deviance	Parameters	R^2
Tiger	Dist. to forest	0.27	-2.51	1.00	0.00	191.70	185.02	3	0.55
	Null	-2.59		0.00	28.80	220.50	216.18	2	
Leopard	Dist. to forest	-2.46	-0.94	0.81	0.00	198.50	191.82	3	0.11
	Null	-3.53		0.19	2.87	201.40	197.06	2	
Elephant	Dist. to forest	1.03	-2.08	1.00	0.00	190.20	183.48	3	0.46
	Null	-1.34		0.00	22.14	212.30	207.98	2	
Sambar	Dist. to forest	1.04	-2.25	1.00	0.00	226.90	220.23	3	0.27
	Null	-1.53		0.01	10.55	237.50	233.14	2	
Chital	Dist. to forest	4.43	-3.21	1.00	0.00	199.00	192.31	3	0.62
	Null	0.77		0.00	35.54	234.60	230.22	2	
Nilgai	Dist. to forest	-1.27		0.76	0.00	237.20	232.88	2	
	Null	-1.35	0.07	0.24	2.35	239.60	232.86	3	0

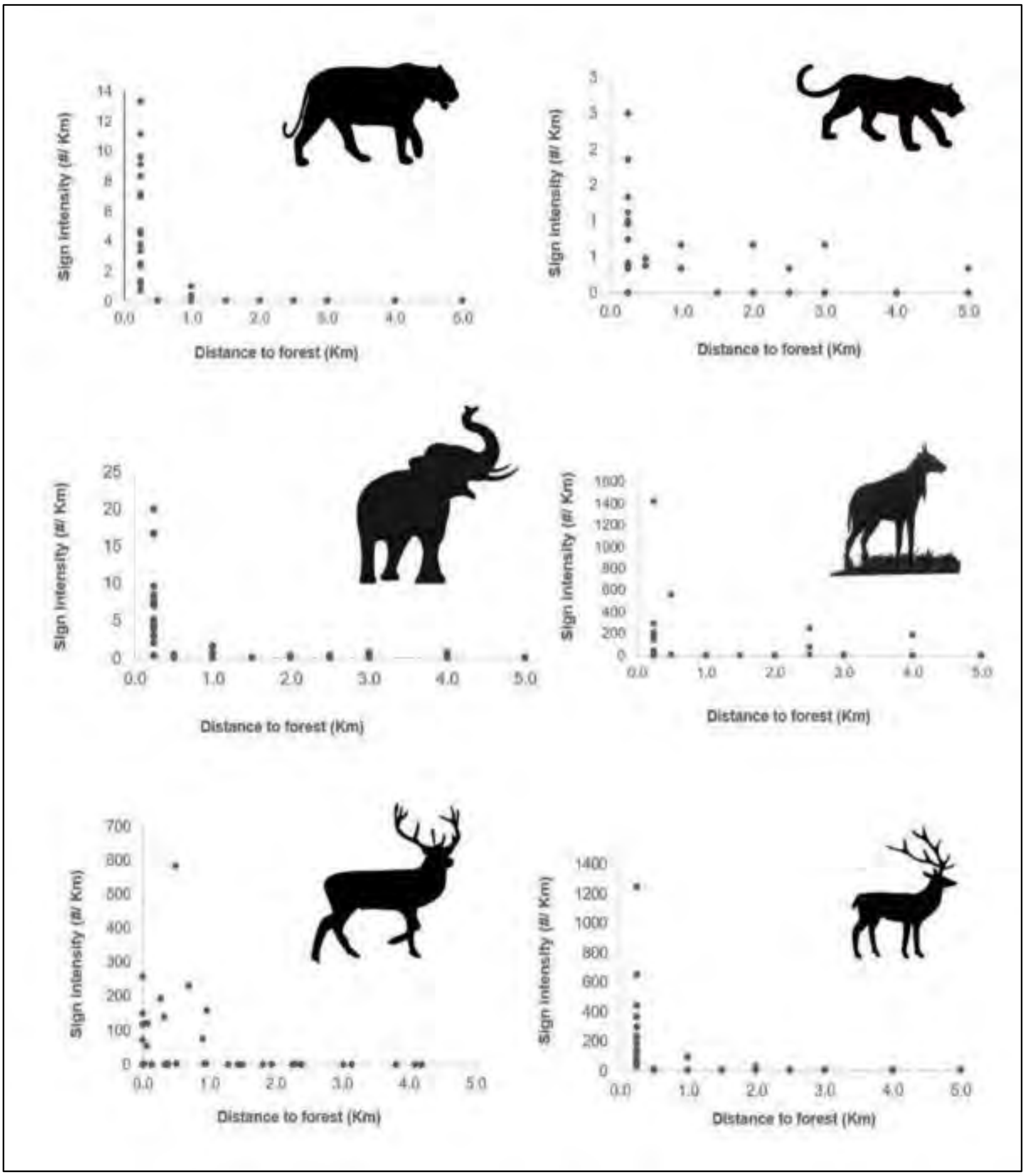


Figure 41 : Sign intensity of mammals along increasing distance from forest, based on sign surveys in forests of Corbett Tiger Reserve and adjoining agricultural areas (2018-19).

Table 15 : Summary statistics and parameter estimates of log-linear models on sign intensity for target species in the project impact zone around Corbett Tiger Reserve (2018-19).

Effect	Parameter estimates				Model summary statistics				
	β0	β (Dst-for)	β (Species)	β (Dst-for * Species)	Akaike weight	ΔAICc	AICc	Deviance	Parameters
Dist. to forest	-0.12	-1.93			0.97	0.00	989.70	983.56	3
Dist. to forest + Species	-0.28	-1.93	+		0.03	7.34	997.00	982.41	7
Dist. to forest x Species	-0.14	-2.05	+	+	0.00	12.14	1001.80	978.35	11

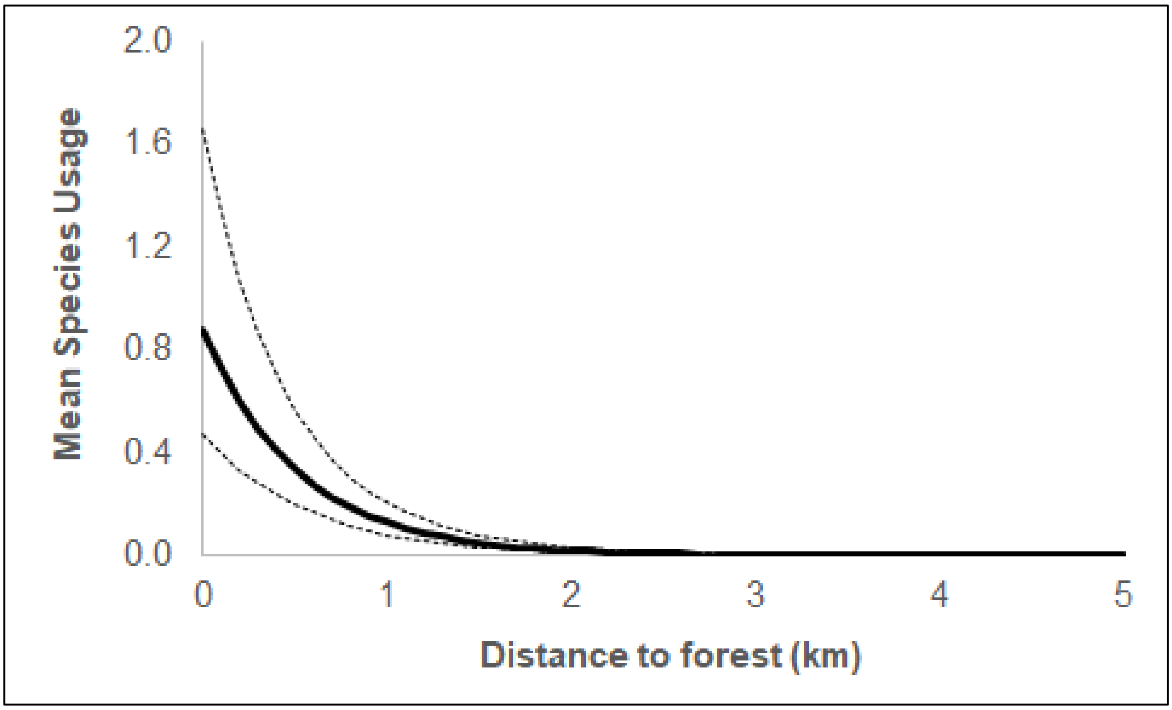


Figure 42 : Species Usage Decline Function: response of mean (95% CI) usage of forest species (tiger, leopard, elephant, sambar and chital) to distance from forest edge in the project impact zone in/around Corbett Tiger Reserve (2018-19).

4.3 Avifauna

4.3.1. Bird community structure and vertical distribution

We recorded 124 bird species, including 10 RET species (Annexure 4). Of these, four species are Threatened (IUCN), three are Near threatened (IUCN) and three species are included in the Schedule I of Wildlife (Protection) Act (1972) (Table 16).

Table 16 : List of RET bird species in the study area and their IUCN and WPA status

Species (common and scientific names)	IUCN status	WPA Schedule
Egyptian vulture (*Neophron percnopterus)*	EN	IV
Black-necked stork (*Ephippiorhynchus asiaticus)*	NT	IV
Grey-headed fish eagle (*Ichthyophaga ichthyaetus)*	NT	IV
Himalayan griffon (*Gyps himalayensis)*	NT	IV
Great hornbill (*Buceros bicornis)*	VU	I
Sarus crane (*Grus antigone)*	VU	IV
Wooly-necked stork (*Ciconia episcopus)*	VU	IV
Indian peafowl (*Pavo cristatus)*	LC	I
Kalij pheasant *(Lophura leucomelanos)*	LC	I
Oriental pied hornbill (*Anthracoceros albirostris)*	LC	I

4.3.2. Species richness along vertical strata

We found highest bird richness at perch height 0-5m, followed by 15-25m, and least in 25-30m. Under-storey bird species such as pheasants, thrushes and riverine birds contributed to the higher richness in 0-5 m height. Majority of bird species used 15-25 m perch heights for foraging, nesting and roosting. Therefore, this strata is important for conservation and project mitigation planning (Figure 43). Even among RET species, the highest richness was found on

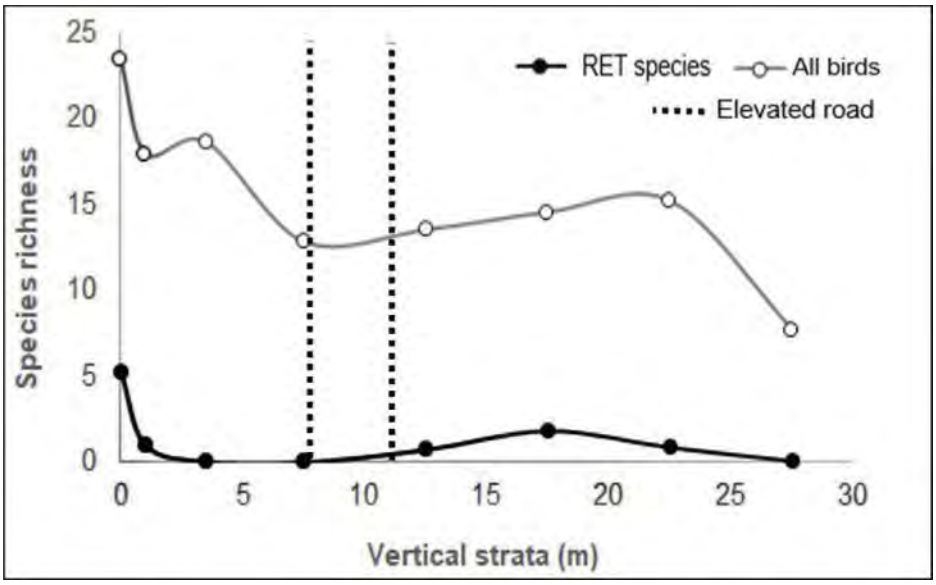


Figure 43 : Species richness of all birds and RET birds against vertical strata / perch heights in the proposed road impact zone (alignments 2A/B) of Corbett Tiger Reserve (2018-19).

the ground comprising pheasants (Schedule I) and riverine birds such as storks. Other RET birds like hornbills, vultures and eagles used perch height of 10-25m.

4.4 People's Perception

4.4.1. Social characteristics and livelihood dependency

We surveyed 33 villages to understand local livelihoods, attitude towards the prevalent human-wildlife conflict in the area, and perception towards Kandi road project. List of the villages and approximate number of families can be found in Annexure 5. Of these villages, 19 are located in Uttar Pradesh and 14 in Uttarakhand.

Based on our surveys, we found that the major occupation of the locals is agriculture followed by private/government jobs mainly in services sector and labour work on daily wages (Figure 44).

Paddy and sugarcane are the major Kharif crops (June—September) and wheat is the major Rabi crop (October—March) of this region. Orchards of litchi and mango are also grown in a few villages along with smaller cultivations of mustard, turmeric, vegetables (Figure 44).

Corbett National Park is situated in an ecologically important Bhabhar-Terai region which is a strip of land skirting the southern part of Siwalik. Villagers residing in and on the fringes of the park have long before claimed *"Hakkuko/Hakub"* which is right to claim forest resources for personal use and sustenance. Over time however, the broadness of this right has narrowed. It is now limited to collection of fuel wood and fodder. Questionnaires revealed that inhabitants of these villages remain dependent on these natural resources (Figure 44). Villagers at the lower end of the economic spectrum are heavily dependent on these resources. The role of women is significant in forest related activities as they are the ones who venture inside forest to collect fuelwood and fodder. Based on a study previously done in the same area it was found that winter was the peak season for collection of firewood, grass and fodder as compared to summer (Konthujam et al. 2005). However, findings of the current study show that villagers are engaged in collection of natural resources round the year irrespective of the season. A minuscule 4% of the people did not depend on forest resources for fuelwood because they had LPG connection at home.

Fuelwood is collected either from dried and fallen off branches and logs or cut from snags. Villagers typically venture 0-4 km inside the forest from the road to collect fuel wood/fodder (Figure 44). Their movement within forest is restricted to daylight hours with infrequent to no sighting of wildlife as they claim they move in groups and make noise to alert the animal of their presence.

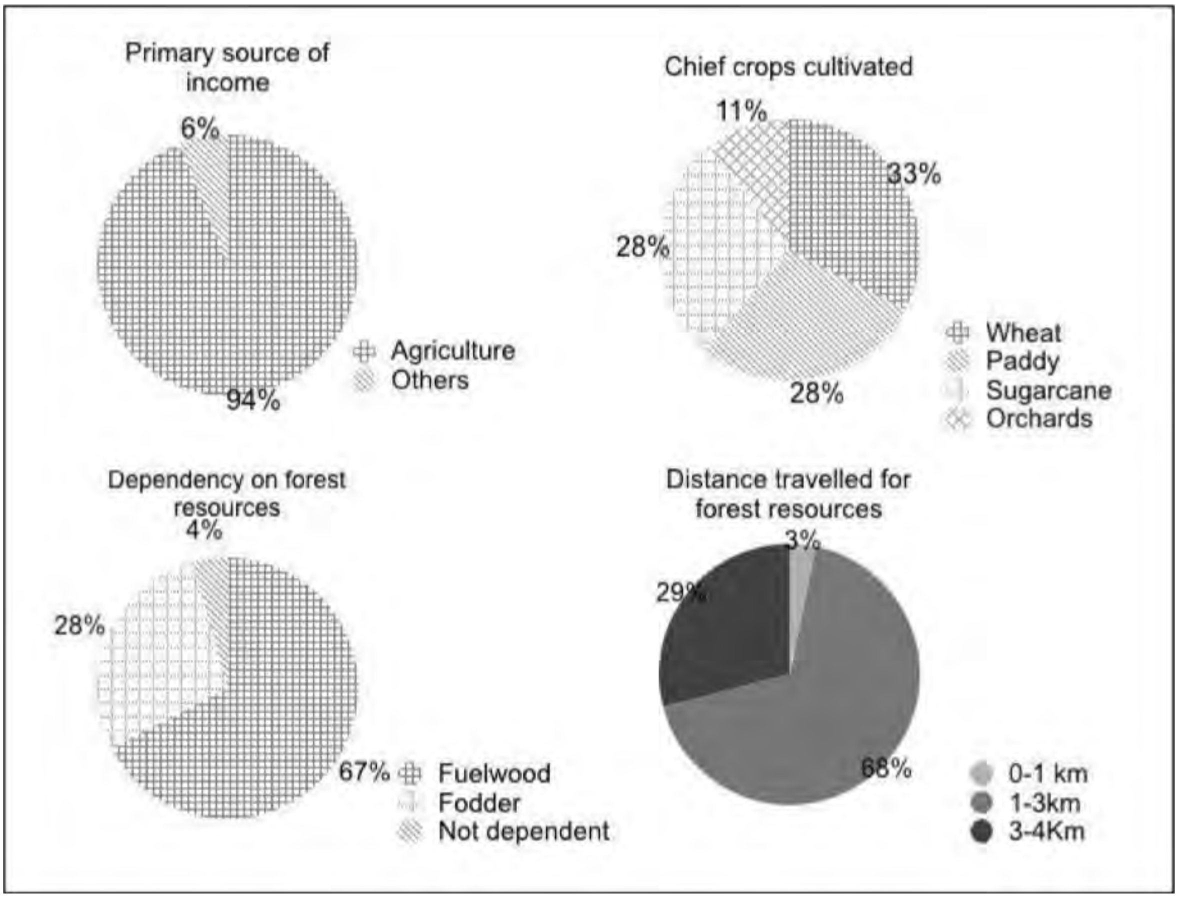


Figure 44 : (Clockwise from left top) Primary livelihood, chief crops cultivated, distance travelled by locals to procure forest resources and dependency on forest resources, as inferred from the percentage of responses from villagers living along the southern boundary of Corbett Tiger Reserve (2018-19).

4.4.2. Human-wildlife conflict

Questionnaires revealed that the movement of wild animals is not restricted by man-made boundaries. In our social surveys, people reported high animal usage in villages adjoining the CTR. Wildlife from the park crosses the forest perimeter and enters villages throughout the year (Figure 44). Among the 10 wildlife species sighted and reported by the respondents within their village and agriculture perimeters it was reported to us that a) crop damage was predominantly by elephants (chief reason due to which sugarcane is not cultivated in villages near forest as their presence in sugarcane fields was higher as compared to the other perpetrators), wild pig, chital, sambar and nilgai, b) cattle depredation by leopard, and, c) movement of tigers in fields owing to presence of its prey base with occasional incidents of injuries to human/loss of human life. Intrusion by scavengers such as striped hyenas and golden jackals into fields is also common whose movement (trampling) affects the growth of crops such as wheat and paddy in their nascent stages.

The conflicts usually increase hostility of the locals towards conservation which was evident in responses as the economic losses are high and the compensation provided is delayed and miniscule in comparison. People have also reported no compensation from the Forest department owing to political issues of state boundaries.

Agricultural fields and village boundaries were defined either by fencing or by boundary walls provided by the Forest department. Out of the total villages, 39% have fencing around their village and field while the remaining 61% have no fencing (Figure 46). Solar fencing is present in about 15% of the total 39% villages with the remaining 24% having normal wire/barbed wire fencing. Both solar and normal wire/barbed wire fencing have proven to be ineffective for the area as animals have found ways to breach/circumvent the fencing, particularly elephants which are considered to be highly intelligent species and have learned ways to overcome physical barriers like fencing/walls.

A 1m high wall has also been built to mark the boundary of Uttarakhand from Uttar Pradesh (between Kalagarh and Dhara) and to stop crossing over of animals from the National park into the agricultural fields that fall in Uttar Pradesh. Of the total villages, boundary wall is present in 45% villages and is absent in the remaining villages (Figure 46). The presence of the boundary wall has however been ineffective for villagers as it has multiple breaches/broken segments along the stretch which they believe is primarily elephant-induced or because of natural causes such as rains, resulting in weakening of wall, and non-maintenance by the Forest department. Wall/fencing breaches induced by elephants also provide easy access points to agricultural fields for other herbivores e.g. chital, sambar, wild pig and nilgai.

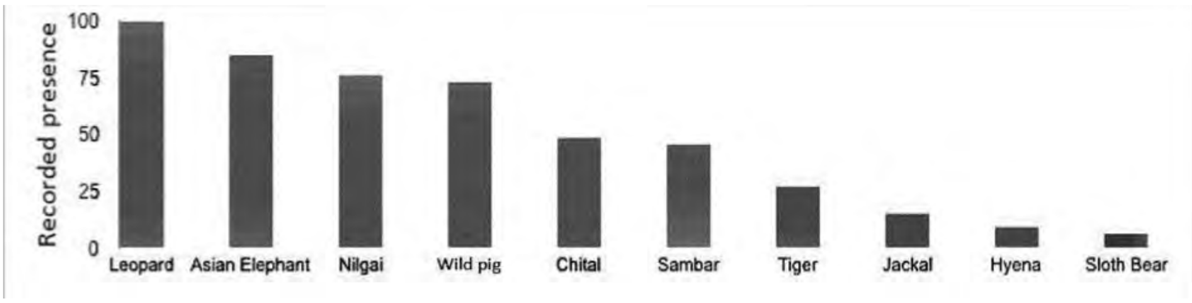


Figure 45 : Frequency of reporting of animal species by villagers in their agricultural areas in villages along the southern boundary of Corbett Tiger Reserve (2018-19).

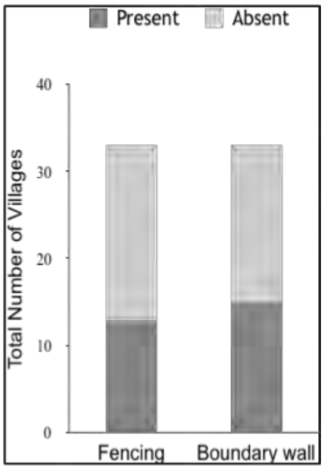


Figure 46 : Presence of fence and boundary wall around villages/agricultural fields in villages along the southern boundary of Corbett Tiger Reserve (2018-19).

4.4.3. Perception towards the project

During the focused group survey the respondents were asked if they were aware of the proposal by the Uttarakhand government about the development of the Kotdwar-Ramnagar road which is deemed to be a four-lane highway. Majority of the respondents knew about the proposed project and were also aware of the alignments that were suggested apart from the current forest road (Figure 47).

Most respondents were positively predisposed to the envisioned the Kotdwar-Ramnagar road, and believed that this project would address the issues of accessibility to basic facilities, connectivity between the Kumaon and Garhwal regions of Uttarakhand with reduced travel time and less road tax. They also believed that the road would act as an obstacle to the movement of wildlife from the forest into their village; as movement of traffic and human presence would affect/limit wildlife usage around forest boundaries. They attributed the road project to open new avenues in terms of income by hiring the locals as contractors, labourers etc. Interestingly, respondents who favoured the road project were also found to be sensitive towards wildlife and added that the road development should be elevated in areas wherein movement/usage by wildlife is high so as to lower the ecological cost that is associated with the development of this linear infrastructure.

About 10% of the respondents associated negative outcomes with the Kandi road project. They mainly aired their grievances regarding safety, cultural dissolution associated with the influx of people; movement restriction into forest due to construction activities, concerns over unavailability of access points to the road for locals; and lastly, pollution of the environment. These respondents envisaged that the construction of this road would lead to heightened noise and air pollution due to the flux of activities and would also lead to fragmentation and detrimental changes to the local environment. There were apprehensions among people who had their houses on the border of the existing metal road connecting Ramnagar and Dhela regarding construction of Kandi road along the alignment 2A/B, as they feared their evacuation and/or relocation from the village where they have lived for generations. They suggested to make a two-lane highway instead of four-lane throughout the forest and/or hastening of the construction work happening on the current four-lane road connecting Ramnagar-Kotdwar-Dehradun through Uttar Pradesh via Nagina and Najibabad.

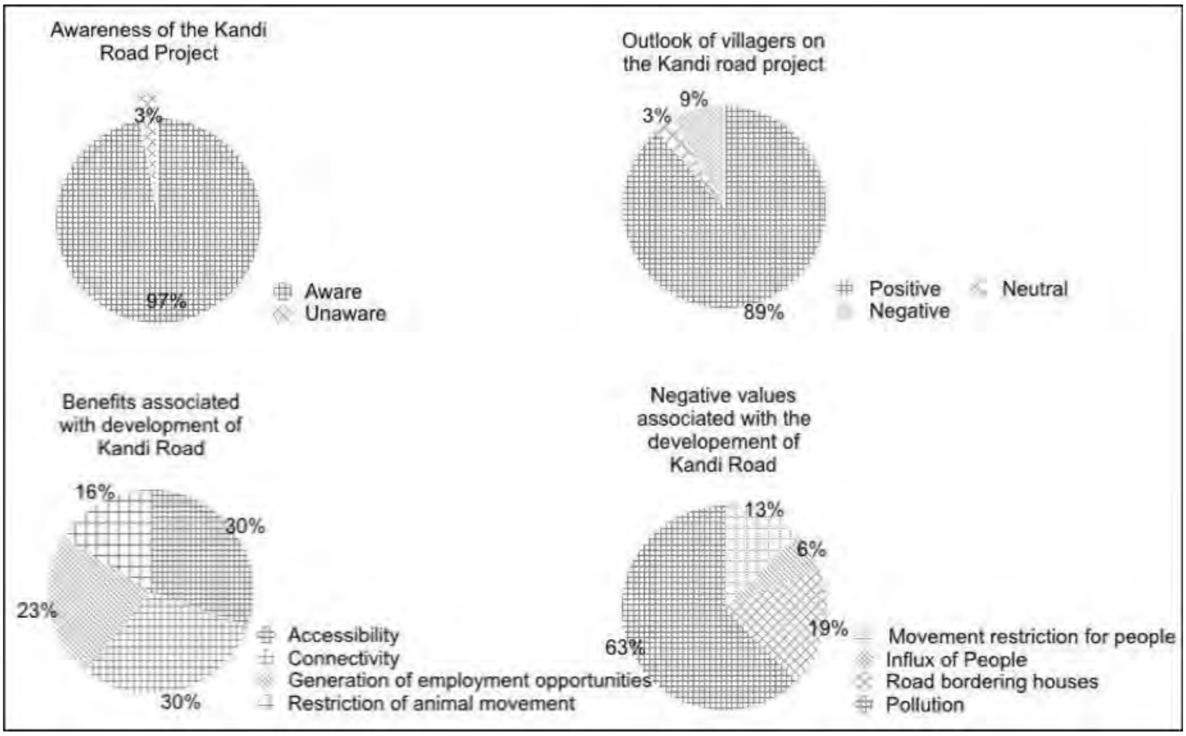


Figure 47 : Perception towards the proposed Kandi road development project in terms of (Clockwise from top left) people's awareness of the project, outlook (towards the project), negative values and benefits associated with the project, inferred from the percentage of responses of villages adjoining the southern boundary of Corbett Tiger Reserve (2018-19).

4.5 Decision criteria matrix for feasibility assessment of alternative alignments

4.5.1. Cost of tree felling

The estimated number of trees to be felled for constructing the road ranged from 12336 ± 564 SE (alignment 1A/B) to 67634 ± 3090 SE (alignment 2A) individuals (Table 18). These are approximate estimates based on remote sensing and field calibration that are useful for comparing alignments but need to be revalidated at the time of actual road construction.

4.5.2. Cost of traffic mortality of animals

Traversability model parameterized with field data indicated very high potential traffic collision of focal mammals (Table 17). Even conservative estimates of collision rates (number/km/hr) along alignments 2A were to the tune of 0.32 chital, 0.09 sambar, 0.001 elephant and 0.0006 tiger, or 0.41 individuals of the focal species. The same estimate of traffic mortality reduces by >10 fold at 1-2 km distance from forest edge.

Table 17 : Parameter estimates used in traversibility model for predicting potential collision rates of focal mammals due to proposed Kandi road in Corbett Tiger Reserve (2018-19).

Parameter		**Unit**	**Species**				
			Chital	Sambar	Tiger	Elephant	Remarks
Body mass	*Wi*	kg	38	135	98	2363	Calculated as 3/4th of female body weight based on (Schaller 1972))
Body length	*Li*	m	1.55	2.10	3.10	6.00	Based on (Menon 2009, Sukumar et al. 1998)
Speed empirical	*Vi(e)*	m/s	0.30 (0.02)	0.33 (0.03)	0.81 (0.10)	0.82 (0.08)	Calculated using movement sequence from camera-traps
Speed theoretical (maximum)	*Vi(t)*	m/s	10.36	16.77	14.85	49.76	Calculated using allometric equation (Peters 1983)
Lane width	*B*	m	14	14	14	14	Considering only traffic lanes
Traffic volume	λ	#/s	0.04 (0.01)				Based on four-wheel traffic volume sampling
Collision probability (empirical)	*Pi(e)*	-	0.87	0.85	0.56	0.61	Estimation based on empirical speed
Collision probability (theoretical)	*Pi(t)*	-	0.06	0.04	0.04	0.02	Estimation based on theoretical (maximum) speed
Crossing rate (forest)	*Ki*	#/km/hr	5.69 (3.26)	2.37 (1.77)	0.013 (0.007)	0.068 (0.041)	For forest alignment, based on Kandi road crossing data from elevated camera-traps
Collision rate (empirical)	*Di(e)*	#/km/hr	4.95 (2.96)	2.01 (1.55)	0.007 (0.004)	0.042 (0.026)	Based on empirical speed
Collision rate (theoretical)	*Di(t)*	#/km/hr	0.32 (0.2)	0.09 (0.07)	0.0006 (0.0003)	0.0011 (0.0007)	Based on theoretical speed

It should be noted that these estimates assume no behavioral response of animals to roads while crossing (no avoidance or waiting time), and no effect of mortality on animal abundance or crossing rates. Athough these assumptions may not be realistic, violating them will not bias our comparison of predicted collision rates across alignments, since numerical and behavioral responses of animals will be similar across roads. Additionally, these estimates are based on the observed traffic volume of a comparable road and may increase/decrease depending on the actual traffic volume once the road is operational (see Figure 48). Estimated collision rates were greatest for the alignment 2A (existing Kandi road) followed by alignment 1A.

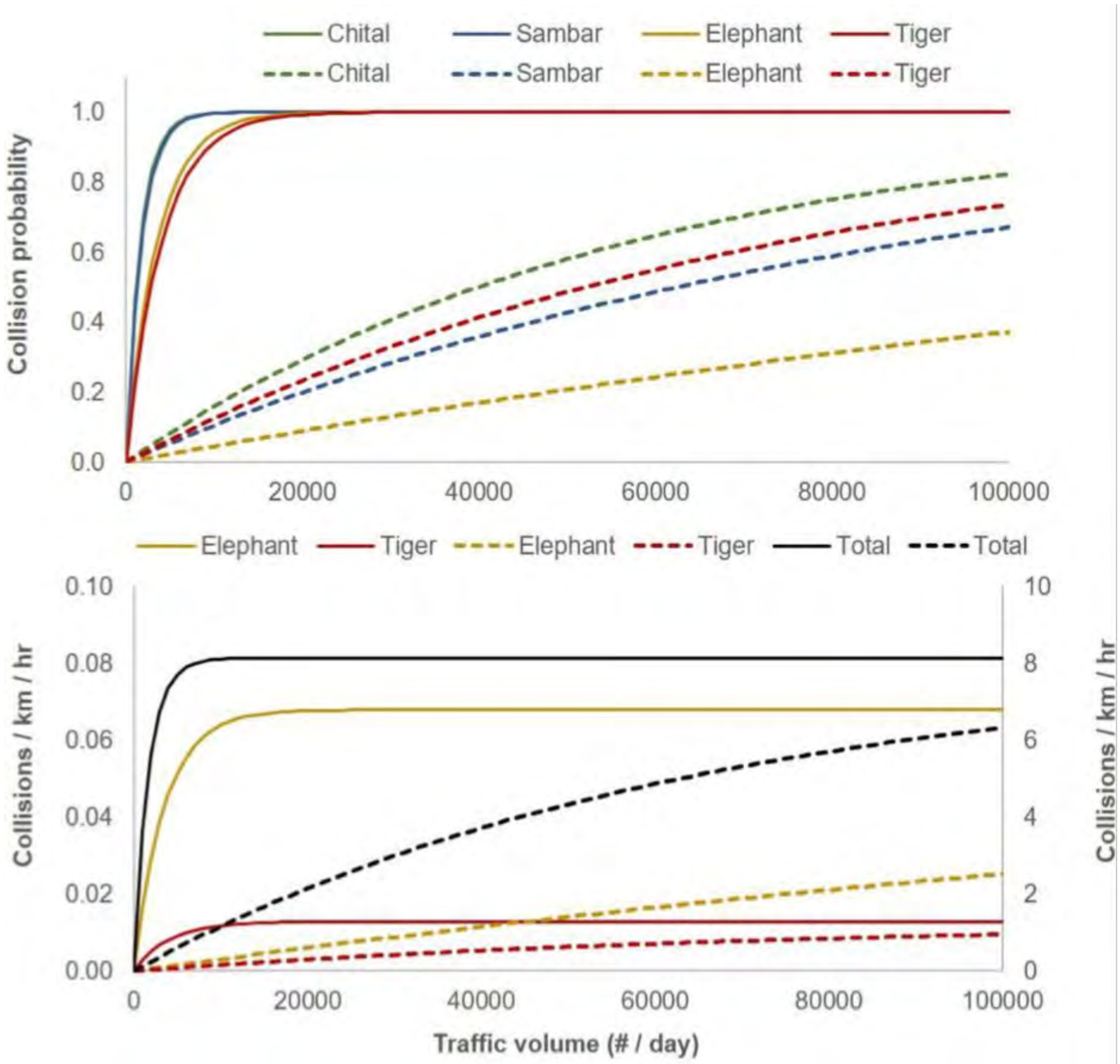


Figure 48 : Estimated collision probability (top) and collision rate (bottom) of representative / conservation-dependent mammals based on traversibility model (Langevelde and Jaarsma 2004) parameterized using field data on animal speed (continuous lines) and theoretical maximum speed based on Peters' (1983) allometric equation (dashed lines), against a range of traffic volume for Kandi road in the Corbett Tiger Reserve (2018-19). Total collision / km / hr scaled against secondary Y-axis.

4.5.3. Cost of habitat loss and temporary disturbances

Wildlife habitat to be sacrificed for the road ranged from an effective area of 26-30 km^2 for alignments 3B and 1B to 74 km^2 for alignment 2A. Temporary disturbances caused by construction activity within 500 m of forest ranged from 66-83 km-years (alignments 1A and 1B) to 223 km-years for alignment 2B.

4.5.4. Cost of construction and land acquisition

Although alignments 2A and 1A were financially superior, the lack of mitigation structures would not safeguard them against high traffic mortality of endangered animals once the road is upgraded. Incorporation of mitigation measures to reduce traffic mortality and habitat fragmentation along the existing Kandi road would increase the financial cost of alignment 2B to over 6000 crore INR (inclusive of construction and land acquisition). Financial cost would be relatively less (< 4000 crore INR) for alignments 1B and 3B since they avoid forested habitats at large and would require less mitigation structures. Land acquisition comprised a small proportion (<< 5%) of the total financial cost.

4.5.5. Multi-criteria decision-making

Performance scores of road alignments indicated that none of the alternatives was clearly superior against all ecological and financial criteria. Ecological costs were very high for alignment 2A (existing Kandi road) in terms of tree felling and predicted traffic induced animal mortality, as also for alignment 1A (Supreme Court recommended unmitigated road) in terms of predicted traffic induced animal mortality (Table 18). Further, these two alignments did not have any mitigation to allow safe passage for animal movements and connectivity between habitats that were the prime ecological concerns in assessing the feasibility of this project. Hence, we discarded the alternatives 1A and 2A from further comparison, and restricted our multi-criteria decision analysis to alternatives 1B, 2B, 3A/B and 4A/B.

Results showed highest overall performance of alignment 3B (SC alignment realigned at >2km south of CTR between Kalluwala and Morghatti to further reduce traffic collisions of animals). This alternative ranked higher than others irrespective of the different systems of weightages used. Among relatively higher ranking alignments, 3B was superior to 1B and 4B in safeguarding ecological concerns. It received greater overall performance score under equal weightage and ecologically driven weightage as would be the panacea for conservation decision-makers. Although the travel distance/time of alignment 4B was substantially less than alignments 3B and 1B, the required mitigation measures for the former increased its construction cost considerably. Thus alignment 3B surpassed the alignment 4B in our balanced weightage system, where key ecological and financial criteria (animal collision rates, sacrificed habitat and construction cost) were considered more important than others as would be the panacea for pragmatic decision-makers. Thus, alignment 3B emerged to be the most feasible alternative for the proposed Ramnagar–Kotdwar road, based on ecological and financial evaluations (Table 19).

Table 18 : Multi-criteria decision analysis matrix showing performance scores of alternative alignments of proposed Ramnagar - Kotdwar road against comprehensive ecological and financial criteria (2018-19). Alignments include alternatives 1a: Supreme Court recommended, 1b: Supreme Court recommended with mitigation, 2a: current forest road, 2b: revised forest road with mitigation, 3a & b: Hybrid alignments suggested by WII, 4a & b: alignments suggested by Uttarakhand Govt.

(a)		**Alternative alignments**								
Cost criteria		**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**Units**
Ecological / conservation	a) Tree felling	12366	12366	67634	36551	28715	15675	27942	27533	number
	b) Collision rate	1.65	0.81	4.81	0.58	0.61	0.59	1.47	0.56	number / hr
	c)Temporary disturbance	66	83	168	223	149	92	154	154	km-yr
	d) Sacrificed habitat	34	30	74	56	38	26	55	47	sq km
Financial / logistic	e) Travel distance	114	114	84	79	97	123	85	87	km
	f) Land acquisition cost	718	718	200	261	570	871	290	383	million INR
	g) Construction cost	18156	34656	15288	63128	49278	39070	38702	46342	million INR

Table 19 : Multi-criteria decision analysis matrix showing standardized performance scores (*Sij*) for alternative alignments of proposed Ramnagar - Kotdwar road against comprehensive ecological and financial criteria (2018-19) along with overall performance scores, based on three sets of weightages – equal weights to all criteria, relatively greater weights to ecological/conservation criteria and proportionally greater weights to financial criteria.

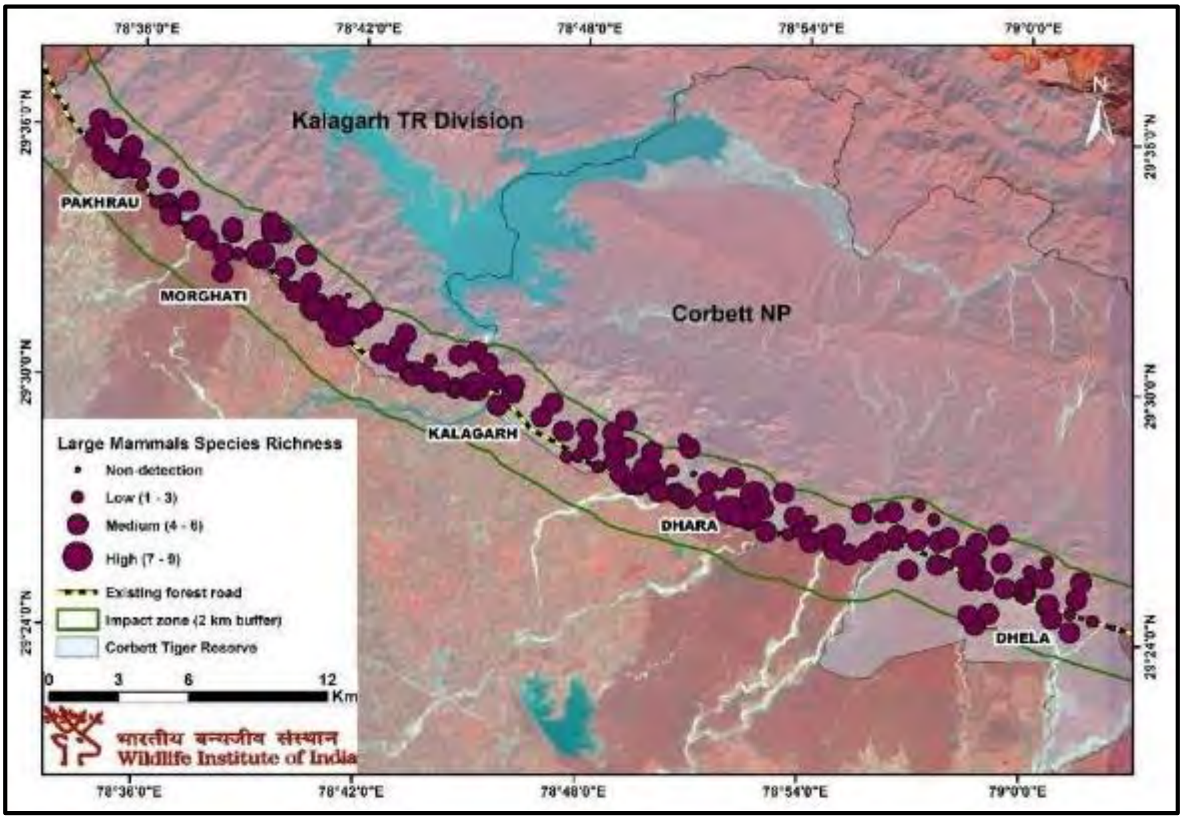
(b) Criteria	Standardized score (*Sij*)	Alignments						Weightage		
		1B	2B	3A	3B	4A	4B	Equal	Cons. driven	User defined
Ecological / conservation	a) Tree felling	1.00	0.00	0.32	0.86	0.36	0.37	0.14	0.21	0.14
	b) Collision rate	0.00	1.00	0.87	0.94	0.00	1.00	0.14	0.21	0.21
	c) Temporary disturbance	1.00	0.00	0.53	0.94	0.49	0.49	0.14	0.14	0.07
	d) Sacrificed wildlife habitat	0.84	0.00	0.60	1.00	0.04	0.30	0.14	0.21	0.21
Financial / logistic	e) Travel distance	0.20	1.00	0.59	0.00	0.86	0.82	0.14	0.07	0.14
	f) Land acquisition	0.25	1.00	0.49	0.00	0.95	0.80	0.14	0.07	0.07
	g) Construction cost	1.00	0.00	0.49	0.84	0.86	0.59	0.14	0.07	0.14
Overall score (*Vj*)	Equal weightage	0.61	0.43	0.56	**0.65**	0.51	0.62			
	Conservation driven weightage	0.64	0.36	0.57	**0.79**	0.35	0.59			
	User defined weightage	0.59	0.43	0.59	**0.73**	0.41	0.63			

5. DISCUSSION

5.1. Wildlife values in the proposed road impact zone

Our ecological assessment using multiple field approaches shows high abundance/usage of wildlife along the current forest road and its impact zone. The high primary and secondary productivity of these forests are exemplified by several indices, such as: a) tree density of ~600 trees/ha, b) occurrence of >53 tree species, c) occurrence of 20 mammalian species, d) tiger density of 19.7 / 100 sq km or 42 homerange centers within 214 sqkm impact zone , c) frequent usage of the 78 km stretch of existing road (Saneh - Ramnagar) by elephant (9.7 animal-hours/day), chital (621 animal-hours/day) and other mammals, d) relative abundances of mammals to the tune of 1 day required to capture a chital in one camera-trap, 3 days for a sambar, 8 days for an elephant, and 10 days for tiger, and e) a sharp exponential decline in animal usage with distance from forest edge. Further, we found nearly uniform usage of RET and other mammals across the entire stretch of existing forest road (78 km, Ramnagar - Saneh) based on the: a) species richness of large mammals at camera-traps, and b) average of species RAIs (z-standardized). This finding implies that it is futile to identify hotspots of usage for mitigation planning, and required realignment/mitigation should target the entire stretch of the road (Figure 48).

A similar study done along the Kandi road in Corbett Tiger Reserve suggests that it is the most important high tiger density area in the Terai Arc Landscape (Pandav and Harihar 2011). The study estimated tiger density along the 47 km stretch and upto a 5 km buffer between Pakhrau and Laldhang. For the 20km stretch between Laldhang and Kalagarh which passes through core area of CTR, the tiger density estimate was 14.59 (2.06 SE)/100 km^2, while for the 25 km stretch from Kalagarh to Pakhrau (buffer zone), tiger density was estimated at 4.52 (1.17 SE)/100 km^2. The study indicated high use of the road and adjoining areas by a wide range of species viz. tiger, leopard and their prey species such as spotted deer, barking deer, sambar, and wild pig along with elephant, small cats e.g. rusty spotted, leopard and jungle cat, and other small carnivores like golden jackal, common palm civet, small Indian civet and Indian grey mongoose.



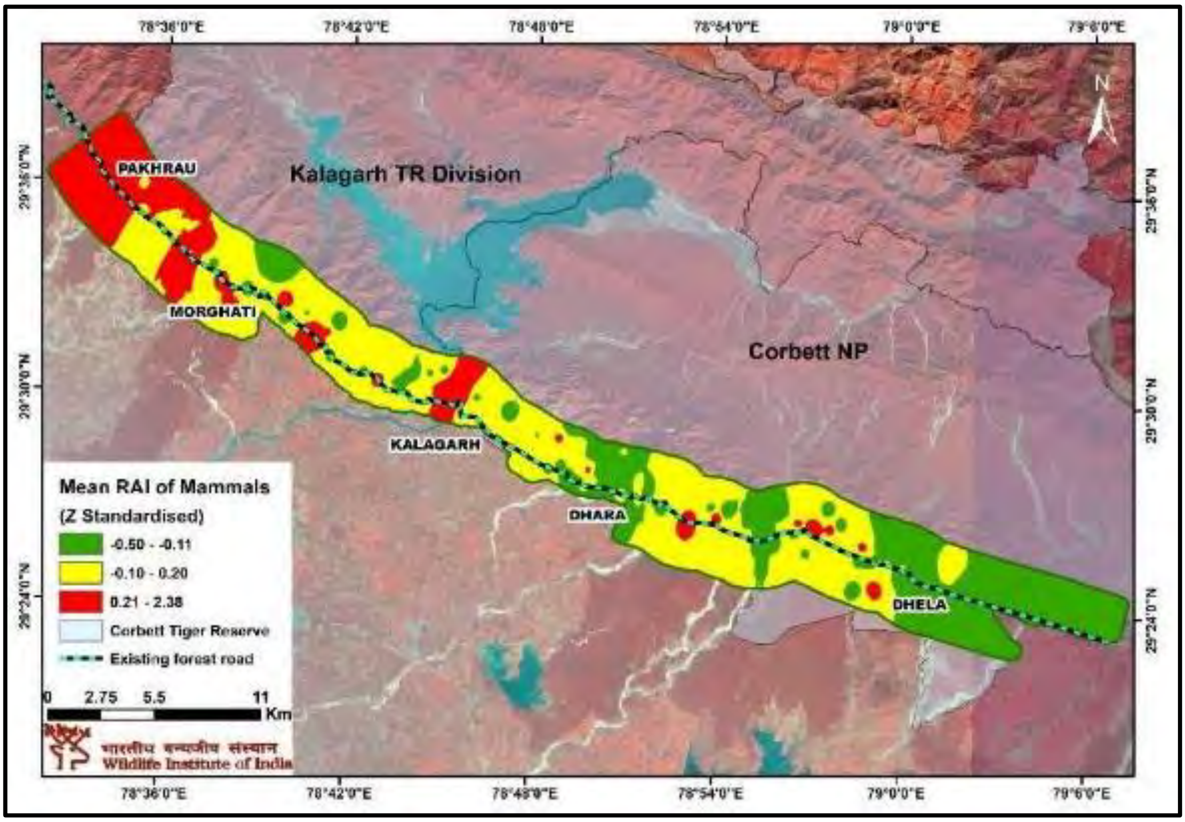


Figure 49 : Species richness of large mammals at camera trap locations (top) and interpolated surface of mean RAI values (z-standardized) of large mammals, representing near-uniform wildlife usage across the project impact zone in Corbett Tiger Reserve (2018-19).

Other studies done in the landscape have also stated the critical importance of CTR as the largest source population of tigers and our last hope to maintain a viable tiger population in the entire Terai Arc Landscape (Jhala and Qureshi 2015, Johnsingh and Panwar 1992, Harihar et al. 2014, Bisht et al. in press). The tiger reserve also harbours one of the highest populations of Asian elephant in the landscape (Johnsingh and Joshua 1994). Given the prolific abundance and high diversity of all wildlife ranging from plants, reptiles and amphibians, birds, small and large mammals including the iconic tiger and the elephant, it can be stated that any intrusive development activity in this pristine habitat is bound to interfere with the integrity of the landscape and can entail long-term irreversible changes on the forest.

5.2. Impact on wildlife habitat

Roads can adversely impact wildlife habitats by degrading their quality, disrupting ecosystem processes, and fragmenting the landscape (Coffin 2007). Our assessment sheds light into the extent of habitat degradation caused by felling of trees, particularly the ecologically important species that supports functionally important faunal elements such as the hornbills. Number of trees to be felled would range from ~13000 to ~67000 between alignments. Road construction can affect physical characteristics of the environment such as soil density, pH and temperature, surface water flow, dust and soil water content (Trombulak and Frissell 2000) that can adversely affect both flora and fauna. Roads and accessory anthropogenic disturbances facilitate dispersal of exotic invasive species by providing altered conditions that is proved to be a serious concern for conservation management (Greenberg et al. 1997). Ecological effects of road can spread over substantial distances in terrestrial ecosystem, causing habitat loss (Trombulak and Frissell. 2000), and depressing mammalian populations up to 2-3 km from roads (Torres et al. 2016). Based on our assessment and available literature (Benitez-Lopez et al. 2010), we predict that the effective large mammal habitat that will suffer from the adverse impact of road may range from 53 to 101 sqkm between alignments. Thus, road design, management and restoration need to be carefully tailored and monitored to address the ecological impacts on wildlife habitat (Weaver et al. 1987).

The Shivalik landscape (29°57' to 31 °20'N and 77°35' to 79°20' E), is the youngest of all mountains in India and is marked by fragile land formation, sub-tropical climate, varied topography and rich alluvial soils (Sivakumar et al. 2010). It has been categorized under Indo-Gangetic plains and has special significance in India's biogeography due to intermingling of taxa from the Indo-Malayan and Palaearctic regions. The landscape is typically, low rolling hills, bisected by innumerable gullies, seasonal streams (locally known as Rau), which drain this region (Rawat and Mukerjee 2005; Agrawal et al. 2002; Johnsingh et al. 2004; Jerath et al. 2006). The seasonal streams play havoc during the monsoons and they cut across fertile fields and spread sheets of sand over the flooded areas and a flash flood can bring huge boulders tumbling down. Thus Shivalik region, is characterized as the most fragile landscape in India (Dhruva Narayana 1987; Sidhu et al. 2000) and is affected by moderate to severe soil erosion due to water, thus playing a major role in land degradation process in the region. Rate of soil erosion is greater in the Shivaliks compared to other physiographic regions in India (Singh et al. 1992) due to steep terrain, poor vegetation cover, unstable geology and immature soil conditions (Valdiya and Bartarya 1989). The combined impact of these factors leads to continuous depletion in the fertility and productivity of soil as well as deterioration in the water quality (Lal 1998). Added to this is the annual loss of life and property due to flash floods that disgorge from steep, rough, highly erodable catchments. All developmental activities that have been initiated around the Shivaliks is thus expected to pose a major threat to Shivaliks biodiversity in future due to habitat loss and other effects.

5.3. Impact on mammals

Comparison of our results on relative abundance of large mammals with that from other Protected Areas in India revealed generally higher abundance/usage of species in this area (Table 20). For example, relative abundance indices of tiger, elephant sambar and chital were manifold higher here, compared to other Tiger Reserves and Protected Areas.

Table 20 : Relative Abundance Indices, measured as independent photo-captures per 100 trap-days, for mammalian species in some Protected Areas of India (*data calibrated to RAI values from original data).

Reference	Current study	Dutta et al. 2008*	Gubbi et al. 2012*	Ramesh et al. 2012	Palei et al. 2016	Debata and Swain, 2018
Study area	Corbett Tiger Reserve	Namdapha National Park	Nagarhole Tiger Reserve	Kalakadu-Mundanthurai Tiger Reserve	Simlipal Tiger Reserve	Kuldiha Wildlife Sanctuary
Location	Forest and road pooled	Inside forest	On road	Inside forest	Inside forest	Inside forest
RET carnivores						
Tiger	10.04 (0.71)	0	0.0015	1.4 (0.6)	0.02	-
Leopard	1.19 (0.21)	0	0.0017	1.3 (0.6)	1.68	0.55
Bear	0.67 (0.12)	-	-	0.3 (0.2)	0.47	2.51
Striped hyaena	0.32 (0.08)	-	-	-	0.03	0.33
RET herbivores						
Elephant	12.90 (1.08)	-	0.1219	2.7 (0.8)	2.09	9.72
Sambar	29.45 (2.02)	0.03	0.0127	0.8 (0.4)	1.39	1.97
Other herbivores						
Chital	92.96 (7.79)	-	0.0159	-	0.47	5.79
Barking deer	7.48 (0.96)	0.699	-	0.1 (0.1)	6.5	8.30
Nilgai	6.10 (2.28)	-	-	-	-	-
Wild pig	3.16 (0.46)	0.03	0.0008	0.5 (0.2)	4.52	4.91

Camera trap based SECR analysis showed 42 tigers with activity centers inside 214 sq. km area of impact around the current forest road from Ramnagar to Saneh, and a minimum of 60 tigers using this area which surpasses tiger population of more than 80% of the tiger reserves of India (Table 22). Tiger density obtained from this study (19 per 100 sq. km) as well as the All India Tiger Monitoring exercise (WII 2015) indicates that this area has one of the highest tiger densities, far greater than many Tiger Reserves (see tiger density in a few randomly selected Tiger Reserves in Table 21) in the world. This landscape is also recovering after a systematic and voluntary relocation of *Gujjar* families in 2015 from Kalagarh Tiger Reserve Division. Over the years, with natural restoration of forests, the tiger abundance has increased from 3 per 100 sq. km to 5 individuals per 100 sq. km within 3 years (2004 - 2007) in adjoining Rajaji Tiger Reserve (Harihar et al. 2009), and a similar recovery of tiger population is expected in Kalagarh Tiger Reserve Division of Corbett Tiger Reserve. The potential of the area as a breeding tiger habitat and source for repopulating surrounding low-density forests makes it critically important for achieving tiger conservation goals. Additionally, elephant usage is very high in the impact zone of current alignment, with considerably greater relative abundance of the species than many PAs that makes it an important site for elephant conservation, too.

Any infrastructural development that can disrupt the ongoing tiger recovery in this area needs to be cautiously reviewed, as also invoked by the St. Petersburg Declaration on Tiger Conservation, to which the Indian Government is a signatory that emphasizes on "making critical tiger breeding habitats inviolate areas within the larger tiger conservation landscapes where no economic or commercial infrastructure development or other adverse activities are permitted". Hence, to find alternative alignments, we conducted sign surveys in adjoining agricultural fields to the south of the reserve. Our results suggest that for most of the species, including the RET ones, usages decline exponentially from distance to forest, and become negligible beyond 2 km. This finding provided the scientific basis for searching alternate routes to minimise the impact of road on RET and other mammals.

Table 21 : Comparison of tiger densities between the current study area and other Protected Areas of India (source: Jhala et al. 2015).

Protected Areas / Tiger Reserves	**Density / 100 sqkm**
Current Study Area	**19.70 (this report)**
Rajaji National Park, Uttarakhand	2.90 (0.87)
Bandhavgarh Tiger Reserve, Madhya Pradesh	4.47 (0.58)
Ranthambore Tiger Reserve, Rajasthan	6.4 (1.03)
Melghat Tiger Reserve, Maharashtra	2.02 (0.51)
Nagarjunasagar Srisailam Tiger Reserve, Andhra Pradesh	0.85 (0.16)
Kalakkad Mundanthurai Tiger Reserve, Tamil Nadu	0.88 (0.39)
Pakke Tiger Reserve, Arunachal Pradesh	0.90 (0.30)
Sundarban National Park West, West Bengal	3.15 (0.88)

Table 22 : Comparison of tiger population between Corbett Tiger Reserve and other important tiger reserves of India (source: Jhala et al. 2015). The individual tigers photocaptured in the current study area (214 sq. km) numbered at 60 which is greater than 82% of the tiger reserves in India. Only 9 tiger reserves surpass the tiger numbers found in the current study area (highlited in table).

S.No.	Tiger Reserve	State	Tiger Population
1	Achanakmar	Chattisgarh	11
2	Annamalai	Tamil Nadu	13
3	**Bandhavgarh**	**Madhya Pradesh**	**63**
4	**Bandipur**	**Karnataka**	**120**
5	Bhadra	Karnataka	22
6	**BR Temple**	**Karnataka**	**68**
7	Bor	Maharashtra	5
8	Buxa	West Bengal	2
9	**Corbett**	**Uttarakhand**	**215 (n=60, current study)**
10	Dampa	Mizoram	3
11	Dandeli-Anshi	Karnataka	5
12	Dudhwa	Uttar Pradesh	58
13	Indravati	Chattisgarh	12
14	Kalakad-Mundanthurai	Tamil Nadu	10
15	**Kanha**	**Madhya Pradesh**	**80**
16	**Kaziranga**	**Assam**	**103**
17	Manas	Assam	11
18	Melghat	Maharashtra	25
19	**Mudumalai**	**Tamil Nadu**	**89**
20	**Nagarhole**	**Karnataka**	**101**
21	Nagarjunsagar	Andhra Pradesh	54
22	Namdapha	Arunachal Pradesh	11
23	Nameri	Assam	5
24	Nawegaon-Nagzira	Maharashtra	7

25	Pakke	Arunachal Pradesh	7
26	Palamau	Jharkhand	3
27	Panna	Madhya Pradesh	17
28	Parambikulam	Kerala	19
29	Pench	Madhya Pradesh	43
30	Pench	Maharashtra	35
31	Periyar	Kerala	20
32	Pilibhit	Uttar Pradesh	25
33	Ranthambore	Rajasthan	37
34	Sahyadri	Maharashtra	7
35	Sanjay-Dubri	Madhya Pradesh	8
36	Sariska	Rajasthan	9
37	**Sathyamangalam**	**Tamil Nadu**	**72**
38	Satkosia	Odisha	3
39	Satpura	Madhya Pradesh	26
40	Simlipal	Odisha	17
41	**Sunderban**	**West Bengal**	**68**
42	Tadoba-Andhari	Maharashtra	51
43	Udanti-Sitanadi	Chattisgarh	4
44	Valmiki	Bihar	22

5.4. Impact on avifauna

Our rapid surveys and existing literature (Dhakate et al. 2007, Kidwai et al. 2013) indicated high bird richness in CTR, with several functionally important RET species such as the great Indian hornbill, oriental pied hornbill and grey hornbill along the current forest alignment. Species richness was greatest at vertical strata of 0-5 m and 10-25 m for birds in general and RET species in particular. Both these ranges fall in the purview of construction activities. Laying of plain roads will affect ground-dwelling birds. On the other hand, elevated roads, which should be a minimum of 8 m in height to allow free passage of elephants (WII 2016), may affect birds using 10-25 m perch height, because of the flyover traffic. The potential adverse impacts of this linear infrastructure on birds include: a) temporary disturbances during construction phase, b) impaired movements, particularly during landing and take-off near the road, and c) felling of trees particularly those of ecologically important species resulting in the loss of roosting, foraging and nesting resources that may not be compensated through afforestation. Presence of ecologically important tree species such as *Ficus benghalensis, F. rumphii, F. racemosa* and *Bombax ceiba* has to be taken into consideration for any road alignment, and there are a large number of these trees along the existing Kandi road (alignment 2A). Thus, elevated sections of the road should be exactly 8 m high where RET birds are relatively few. Habitat within 10 m on either side of these sections should be maintained without large trees, which can induce birds to land or take-off close to the road making them prone to vehicle collisions.

5.5. Impact on people

Social surveys revealed frequent movement of wild animals across the Park boundary into agricultural fields, particularly that of elephant, nilgai, wild pig, chital and sambar resulting in crop depredation, leopard was also reported as the major perpetrator for causing occasional livestock depredation in all villages. Although leopard abundance was found to be low inside the forest based on our camera trap surveys, it was sighted often on the periphery of the forest. This finding corroborates that of previous studies, wherein it was found that leopards inhabited the periphery of Protected Areas, especially when tiger abundance was high (Odden et al., 2010, Harihar et al., 2011). Tiger movement within human habitation was reported to be concurrent with the presence/sightings of their prey base in fields. These responses were corroborated by our sign survey results that revealed near identical usage of forest and adjoining fields for herbivores (Figure 50). Although human-wildlife conflict is highly prevalent in the study area, respondents reported that the existing Park boundary wall and fences around villages or fields were prone to breaching by wild animals and inadequate in controlling the crop damage. A recent study by Natarajan et al. (2018) that looked at effectiveness of physical barriers as a mitigation to reduce crop damage by elephants in Uttarakhand suggest that even well-maintained walls pose only a minor challenge for elephants. In areas criss-crossed by seasonal streams ("raus"), it is not feasible to erect these walls due to heavy siltation and flash floods during monsoon. However, brick wall coupled with solar fencing that provided two-layered protection was found to be the best mitigation against elephants but installing such multiple layered barriers is very expensive.

Social perception surveys indicated positive attitude of majority of villagers towards the road, although a small section shared apprehensions about deterioration of the quality of life and threat of relocation due to this project. The main advantage that respondents attributed to this road would be improved connectivity between Garhwal and Kumaon regions of Uttarakhand at reduced travel distance and time, and access to basic facilities. Respondents who were positively inclined to the project, were of the opinion that the road should be built on the southern boundary of CTR to address the issues of safety and cause minimum interference with the wildlife, and even agreed to part with a portion of their agricultural fields for the construction of the road. Respondents also said that such linear infrastructure development, if implemented by taking into account the grievances and opinions of locals, would make the schemes more beneficial and acceptable to public.

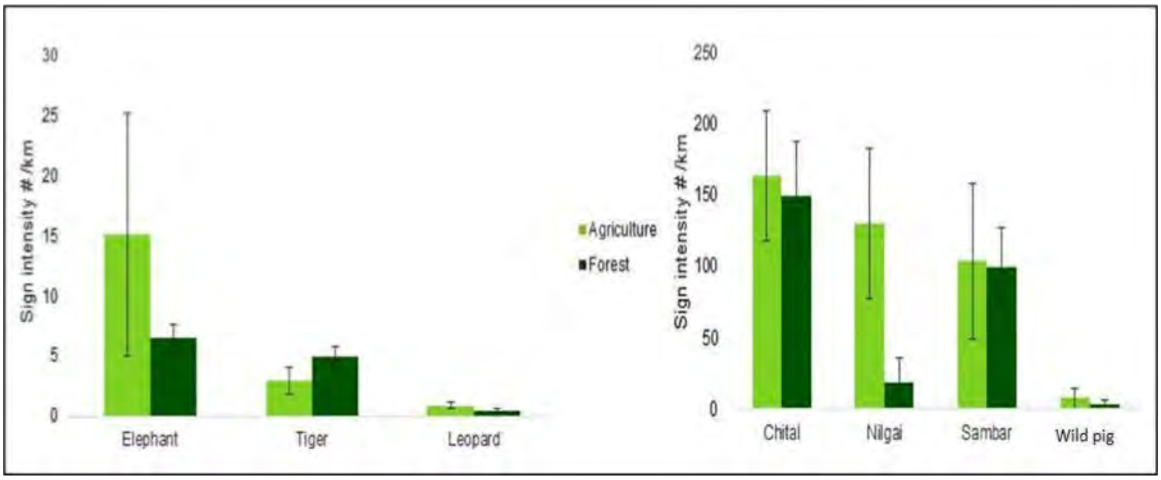


Figure 50 : Comparison of mean (SE) quanta of signs / km of large mammals between forest and immediately adjacent agricultural fields in the proposed road impact zone, indicating permeability of Corbett Tiger Reserve boundary to animal movements (2018-19)

5.6. Green infrastructure measures to mitigate detrimental impacts of the road

Elevated roads to retain connectivity between importatn wildlife habitats

Roads that cut through forested habitats are a serious threat to biodiversity (Laurance et al. 2009; Coffin 2007). They can alter natural habitats through pollution (noise and chemical), habitat fragmentation & degradation and facilitate proliferation of invasive species (Forman et al. 2003; Laurance et al. 2006). Wildlife road-kills and barrier effect are the most serious and widely acknowledged impacts of roads on wild fauna (Seiler 2003; Oxley et al. 1974). Barrier effects that result from changes in behavioral responses of wildlife species can be categorised as 1) road avoidance (surface or gap avoidance), 2) vehicle avoidance and 3) traffic (emissions) avoidance (Jaeger et al. 2005; Trombulak and Frissell 2000). These behavioral responses can cause fragmentation of large and connected population and may lead to smaller isolated populations and may result in local extinctions (Mulero-Pázmány et al. 2016; Laurance et al. 2009).

Building elevated roads through such forested areas as a mitigation measure resolves the issue of wildlife mortalities (except avian mortalities) as well as allows wild species to pass underneath the structure and thus maintains population connectivity (van der Ree et al. 2015).

Habitat restoration under elevated roads and along ROW of plain road

The clearing of existing vegetation for construction of overpass highway is likely to create vast open habitats on the sides and below the overpass. Such a forest clearing can provide an easy opportunity for the colonization and spread of number of invasive alien species into the wildlife habitat, which in turn can cause adverse ecological damage (eg. affect the wildlife usage of the habitat) in the near future (Meunier and Lavoie 2012). Therefore, it is vital to devise a long-term management plan to maintain the cleared habitats free of invasive species. Habitat restoration with the native understory shrubs would be the better option, as (i) they will saturate the cleared habitats in few years and will restrict the establishment or spread of invasive species, and (ii) selecting native understory shrubs will maintain a gap between the overpass and vegetation, at the same time, mimicking the natural habitat of the landscape. In addition, long-term monitoring of these cleared vegetation and frequent removal of invasive species (once in every six months) should be carried out to maintain the ecological integrity of the forest.

Acoustic barriers to reduce disturbances caused by traffic

The proposed highway is expected to have high traffic volume which will result in chronic and frequent noise that can act as an environmental stressor to wildlife (Barber et al. 2011). Exposure to noise may elicit a variety of responses in wild organisms ranging from signal modifications (e.g. changes in the timing, frequency or pattern of vocalisation) to avoidance of the area due to perception of noise as a threat or disturbance from the noise/source of the noise further resulting in changes in foraging rate, predation, habitat occupancy, habitat use and density (Francis and Barber 2013, Goodwin and Shriver 2011, Kerth and Melber 2009, Schaub et al 2008, Simers and Schaub 2011). Studies reveal that large predators avoid roads and their associated traffic, where noise emanating from traffic also is a contributing factor (Fahrig and Rytwinski 2009, Van Dyke et al. 1986). Presence of a species in an area with elevated noise levels cannot be interpreted as evidence of low or no impact on the species. There are several costs associated with the effects of noise on animal physiology and behaviour, many of which are understudied, may not be evident in the short term but can directly or indirectly lead to fitness costs (Barber et al. 2010, Francis and Barber 2013, Kight and Swaddle 2011).

To attenuate noise for mitigation of impacts of wildlife, noise barriers have been used as one of the commonest measure (WII 2016). A noise barrier is a physical obstruction that is constructed between the highway noise source and the noise sensitive receptor(s) that lowers the noise level. These can be ground-mounted systems or standalone noise walls, noise berms (earth or other material), and combination berm/wall systems; and structure-mounted systems for bridges, for instance.

Alignment 1B includes construction of an elevated road >8 m in height from Morghati to Saneh. As high traffic volumes including both heavy motor vehicles and light vehicles are expected on the highway, there is a need to factor in measures for noise abatement.

Effective noise barriers can cut the amplitude of traffic noise by half by a 10 dB(A) reduction in sound (WII 2016). The design of noise barriers is determined through noise prediction models and acoustical requirements influenced by factors including topography, surrounding vegetation, noise receptors and their sensitivities to noise (i.e. wild species likely to be affected by the noise) (van der Grift et al. 2013) and is to be determined by appropriate technical developers with inputs from ecologists/wildlife scientists. In addition to traffic volume, types of vehicles/vehicular engines, vehicle horns and brakes, speed (Rajpurohit et al. 2017), the duration of the construction period will also be an important consideration.

5.7. Feasibility assessment of proposed alignments

We assessed the feasibility of road alternatives, based on our findings of wildlife values in their respective impact zones with regard to reducing the ecological impact of road vis-a-vis its financial costs (Table 23). We also explored the scope of using the road as means to reduce human-animal conflict since local villagers reported high levels of crop depredation by wild herbivores. However, a careful review of the landscape ecological context indicated that, building a barrier/wall along the road would not resolve the conflict, as the high density of north-south drainages (1.5 / km) along Kandi road would lead to heavy siltation and flash floods. These events, compounded with intensive usage of the entire Kandi road and adjoining forests by elephants, would make such barriers highly susceptible to periodic breaching. Ecological costs of tree felling, potential collision of mammals (as a surrogate of other taxa) with vehicles, extent of effective habitat loss for disturbance-sensitive species, temporary construction disturbances, along with financial costs related to construction, land acquisition and travel were integrated into a cohesive and objective decision-making framework, to identify the optimal alignment. Although habitat fragmentation is an important ecological cost, we did not factor it into decision analysis, as mitigation measures were built-in for habitat contiguity, for alignments that were finally considered for decision analysis.

Table 23 : Details of road lengths with respect to State boundaries, mitigation measures, forested habitats and drainages against alternative alignments for financial/logistic considerations of the proposed Ramnagar-Kotdwar Kandi Road Project

Attributes	Alt 1A	Alt 1B	Alt 2A	Alt 2B	Alt 3A	Alt 3B	Alt 4A	Alt 4B
Total length of road	138.7	115.15	84.24	79.30	102.58	123.27	85.12	87.85
Overall length of the alignment in Uttarakhand (UK)	46.87	46.87	2.03	5.00	36.84	55.96	28.04	31.54
Overall length of the alignment in Uttar pradesh (UP)	68.28	68.23	82.21	74.30	65.74	67.31	57.08	56.30
Length of road passing through forest in UK	22.4	31.0	71.0	41.1	42.1	42.1	43.2	43.2
Length of road passing through forest in UP	0	0	13.3	1.7	5.6	0	4.1	4.1

Total length of elevated road	0	31.0	0	64.3	41.7	26	32.4	41.3
Total length of plain road	138.7	83.0	84.3	15.1	56.1	97	52.7	46.5
Length of elevated road in UK	0	31.0	0	57.8	35.3	21.1	32.4	41.3
Length of elevated road in UP	0	0	0	6.4	6.4	9	0	0
Length of plain road in UK	95.0	33.0	0	15.1	22.6	55	24.7	14.7
Length of plain road in UP	43.7	50.0	0	0	33.5	42	28.0	31.8
Drainages	92	92	126	125	92	94	118	118
Forest land in Right of Way (ROW) (ha)	91	91	133	149	129	91		

* According to information provided in SC Writ Petition 47; differs from the length of road re-digitized by WII (114 km) based on coarse-resolution hand-drawn maps and village landmarks provided in the affidavit

Alignment 1A

The alignment proposed to and agreed by the Hon'ble Supreme Court has a road length of 138.7 km (based on the affidavit filed), of which, 95 km falls in Uttarakhand (22.37 km in forest and 72.63 km in non-forest) and a significant 43.7 km falls in Uttar Pradesh (entirely in non-forest). It lies at a range of 0-5.6 km distance from the southern boundary of CTR up to Morghati Forest Range, after which it merges with the forest road up to Saneh village, without any mitigation (Figure 5, Table 23).

This alignment has less ecological costs in terms of tree felling, temporary disturbances and sacrificed wildlife habitat. However, other ecological costs such as the predicted traffic induced mortality of animals and loss of connectivity are high between Morghati and Saneh in the absence of any mitigation measure. Additionally, although construction cost *per se* is very less for this alignment (as no mitigation measure has been proposed), other project finance costs (travel distance and land acquisition) are high. **These high costs of animal mortality and habitat fragmentation makes this alignment less feasible.**

Alignment 1B

To address the above shortcomings of Hon'ble Supreme Court approved alignment 1A, WII has proposed alignment 1B with the addition of mitigation measure (Figure 5). Betwee Morghati and Pakhrau, the forest of CTR north of the road is contiguous with Badapur and Sahuwala ranges of Bijnor Forest Division. Our results indicate very high usage of animals, especially elephants, in this stretch. Between Pakhrau and Saneh there is north-south contiguity of forest in the initial stretch. Towards Saneh the forest of Landsdowne Forest Division is contiguous with forest of Bijnor Forest Division and further Haridwar Forest Division in an east-west orientation (Figure 51) which is an established and critical tiger corridor between Corbett and Rajaji Tiger Reserves, south-east of Kotdwar township (Qureshi et al. 2014). This corridor is already threatened by land use changes and the growing township of Kotdwar; hence, a road without any mitigation will be unwarranted in this stretch. Thus, to maintain the habitat contiguity, safeguard the Corbett-Rajaji tiger corridor, and reduce traffic induced mortality of animals, the entire stretch of road between Morghati and Saneh (31 km and 27% of road length) needs to be elevated (Table 23). Apart from these issues, there are multiple drainages intersecting the road along this stretch (Pakhrau-Saneh) which will require regular/intensive maintenance if the road is constructed on ground. Local people have also raised their grievances regarding commuting during monsoon as flash floods/fast flow in the drainages (*raus*) make these areas inaccessible.

Ecological cost of this alignment is least among alternatives. Incorporation of mitigation measure increases its construction cost by 1.9 - 2.7 folds compared to 1A and 2A, but its combined cost of construction and land acquisition is still lower (~3400 crore INR) than other viable alternatives (2B, 3A/B). The travel distance / cost is not remarkably greater than other alternatives (13-35% higher). **Thus, multi-criteria decision analysis ranked this alignment as one of the most feasible alternative**, particularly under financially inclined decision-making (Table 18).

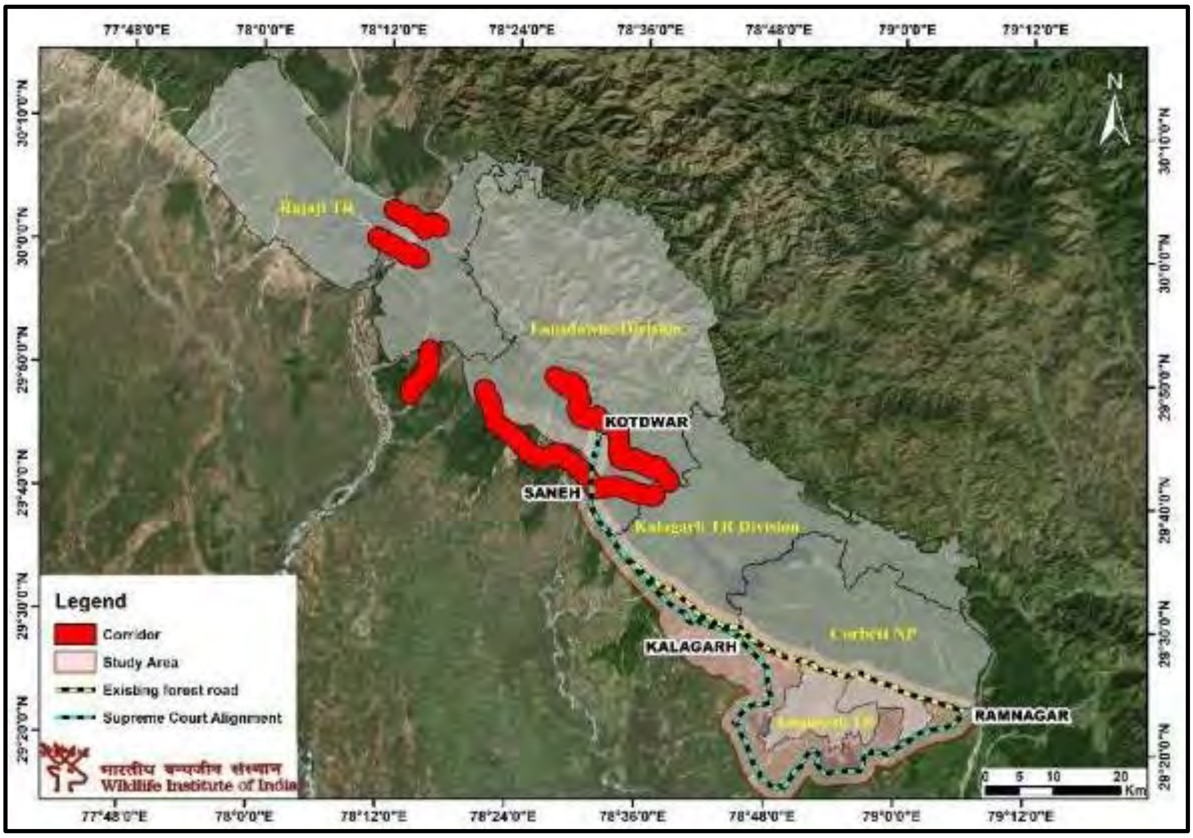


Figure 51: Critical tiger corridors (red) connecting Corbett and Rajaji Tiger Reserves via Landsdowne Forest Division-Bijnor Forest division-Haridwar Forest Division (Qureshi et al. 2014).

Alignment 2A

This alignment, proposed by Uttarakhand Government, has the dual advantage of being shorter in length (84 km) and passing largely, **although not entirely**, through Uttarakhand (entirely through forest) that makes it financially/logistically most lucrative (Figure 6). Indeed, the costs of travel, construction and land acquisition for this alignment are respectively, 74%, 74% and 27% of that of alignment 1A (Table 18).

However, we found very high usage of many RET species such as tiger and elephant along this alignment. A minimum of 60 tigers were using the impact zone of this alignment and the relative abundance of elephant was greater than many other PAs. Consequently, ecological costs of this alignment are highest among alternatives. Compared to 1B, this alignment will result in five folds greater tree felling and vehicle collision rates, 2.5 folds greater sacrificed wildlife habitat, and 2.7 folds greater temporary disturbances. Additionally, it will cause substantial habitat fragmentation between Morghati and Saneh, as discussed above. These large ecological costs deem this alignment unfeasible without any mitigation measure (Table 18).

Alignment 2B

This alignment attempts to rectify the critical ecological shortcomings of alignment 2A, by realigning the route along the southern edge of forest, and incorporating appropriate mitigation measures (Figure 52). The road length (79 km) is shortest among alternatives, with 53 km in Uttarakhand (41.0 km forest area and 12.0 km non-forest area) and a significant 26 km in Uttar Pradesh (1.7 km forest area and 24.3 km non-forest area) (Table 23).

Since wildlife usage is uniformly high all along the alignment, the proposed mitigation measure to reduce habitat fragmentation and traffic induced mortality of animals is an elevated road from Sawaldeh to Saneh (64 km). We explored the alternative option of constructing a wall on the northern side of this section of road, to curb movement of wild herbivores into agricultural fields. However, this measure is unlikely to succeed in long-run, as the entire stretch is dissected by ~74 drainages, which would result in sedimentation along the wall, breaching by elephants that use these areas intensively, and make it vulnerable to both traffic induced mortality and crop depredation by wildlife. Because of the required mitigation, construction cost of this alignment, estimated at 6313 crore INR, is ~1.5 times higher than other viable alternatives (1B, 3A/B). Even then, ecological cost of this alignment remains high due to tree felling (~37000 trees), temporary disturbances and sacrificed wildlife habitat for building the road in proximity to the forest. According to our decision analysis, such high financial and ecological costs render this alignment **less preferable among alternatives (**Table 18**)**.

Alignment 3A

This alignment was considered for evaluation based on the request of the Government of Uttarakhand to find a shorter route than the Hon'ble Supreme Court alignment that passes largely through the state, yet avoiding the high priority Corbett National Park. This route reduces road length by about 15% of alignment 1B, with 64 km stretch falling in Uttarakhand (42 km in forest and 22 km in non-forest) and 34 km falling in Uttar Pradesh. Road length through Uttar Pradesh is ~30% less than that of alignment 1B (Table 23). It passes through Ramnagar-

Maldhan-Patrampur, crosses over Amangarh Tiger Reserve in the form of a 6.4 km long elevated road, and runs south of the CNP at a distance of 0–3.3 km from forest. Thereafter, it merges with alignment 2B near Kalagarh, in the form of a plain road till Morghati followed by an elevated road till Saneh (Figure 7).

The reduction in road length comes at the cost of rerouting it through Amangarh Tiger Reserve in Uttar Pradesh. Since this Forest Division also has high wildlife value, inclusive of at least 20 tigers (Bopanna pers. comm.), it is not suggested to construct a plain road in this section. Further, the presence of *Dhela barrage* (south of suggested flyover), which is a perennial water source for the wildlife in the area, regularly attracts large herds of elephants and a range of other species, more so during summer when most of the seasonal rivers (*raus*) run dry (Pandav, pers. comm.). To minimize animal mortality due to traffic and permeability of animal movement to this important water resource,we suggest elevation of the road in this 6.4 km stretch.

Despite the suggested mitigation, ecological cost of this alignment is greater than that of alignment 1B by 1.3–2.3 folds across different criteria: tree felling, habitat loss, vehicle collisions and temporary disturbances; although significantly lower than that of alignments 2A/B. Additionally, its combined construction and land acquisition costs was greater than alignment 1B. Since the ecological benefits of this alignment did not outweigh its financial costs (Table 18), besides adding infrastructure and anthropogenic disturbances in a Tiger Reserve, **this alternative was also found to be less feasible**, according to our decision analysis**.**

Alignment 3B

This alignment was proposed by WII to further strengthen the ecological safeguards of the mitigated SC alignment. It passes from Ramnagar to Maldham-Patrampur away from the CNP similar to alignment 1B, then runs along the southern boundary of CTR from Kaluwala to Morghati through agriculture and built-up areas at a distance of >2 km from forest contrary to 1B, and finally merges with the forest road as an elevated highway to Saneh (Figure 7). The major distinction of this alignment from 1B is the realignment of route at >2 km from forest, as our Species Usage Decline Function indicated negligible animal usage beyond this threshold.

Length of the road is marginally greater than alignment 1B (the other viable alternative) by 8% without any increase in road length through Uttar Pradesh. The mitigated section (elevated road) is similar in length to that of 1B, half the length of 2B, and 76% of the length of 3A. Thus, combined cost of construction and land acquisition for this alignment in ~3990 crore INR, marginally greater than 1B, but 20-37% less than alignments 2B and 3A (Table 18).

Contrasted against 1B, this alignment had lower ecological costs in terms of traffic induced animal mortality, wildlife habitat to be sacrificed and forest land diversion, but marginally greater costs of tree felling and temporary disturbances. Therefore, alignment 3B has less ecological footprint among the assessed alternatives, as it avoids areas of contiguous habitat close to the forest and passes through human habitation wherein country roads exist, with elevated roads through forests to minimize habitat fragmentation and road induced animal mortality. **Decision analysis indicated this alignment to be a feasible alternative,** ranking better than alignment 1B when ecological / conservation criteria were given priority, and marginally worse than 1B when financial criteria were given priority (Table 19).

Alignment 4A

This alignment was suggested by EDCUL. It runs as an elevated road between Saneh and Morghatti. Between Morghatti and Dhara it diverts south of the park boundary (varying100m-1km). At Dhara it enters the core area of CNP as an elevated road till Laldhang and runs on ground upto Ramnagar without any mitigation. The total length of the alignment is 85km which is only a marginal increase as compared to the shortest alignments 2A/B (84 and 79 km). Total length of the elevated road for the alignment is 32 km. Tree felling for this alignment is more than twice when compared to 1B. Potential animal collision rate for this alignment is 81% greater than that of alignment 1B. Higher collision rates in 4A is because the 20km stretch between Laldhang and Ramnagar runs on ground passing through Dhela forest range upto Sawaldeh. As the species usage decline function suggests animal use upto 2km from the forest edge, the stretch between Morghatti and Dhara in 4A which is deviated only upto 1km south of the forest boundary adds to the increase in collision rate values Despite the suggested mitigation of elevated stretches the alignment has high ecological costs (1.8-2.3 times 1B across all ecological criteria such as tree felling, collision rate, sacrificed habitat and temporary disturbance). It also has greater financial costs which are higher than 1B and only marginally less than 3B. Given the high ecological and financial cost, **alignment 4A was found to be less feasible among alternatives.**

Alignment 4B

This alignment was suggested to minimise the high ecological costs of alignment 4A. Alignment 4 B has slight modifications where the stretch between Morghatti and Dhara deviates 2-3 km south of the forest boundary to minimise collision rates and the elevated road suggested in 4A between Dhara and Laldhang extends upto Sawaldeh and then runs on ground till Ramnagar. The length of 4B is 23% less compared to 1B; however substantial portion of it runs through UP (38 km) although 24% less compared to the segment of 1B that passes through UP. However, given that 41 km road has to be elevated to mitigate collision rate, construction costs are considerably large (35% greater than 1B and 18% greater than 3B) (Table 18).

Because of the mitigation measures against traffic mortality, the potential collision rate of animals is among the least for this alignment (30% less compared to 1B but only 5% less compared to 3B). However other ecological costs of this alignment are very high as the road cuts through core area of the Corbett Tiger Reserve which has the highest abundance of many conservation dependent wildlife.Cost of sacrificed wildlife habitat is 57% greater than 1B and 81% greater than 3B) whilst cost of tree felling is 122% greater than 1B and 76% greater than 3B. Thus, the benevolence of reduced animal collision rate is compensated by the high cost of other high ecological costs resulting in poor ranking of this alignment based on conservation driven weightage. Given the high ecological costs (except collision rate) **alignment 4B was found to be less feasible among alternatives, despite its reduced travel time.**

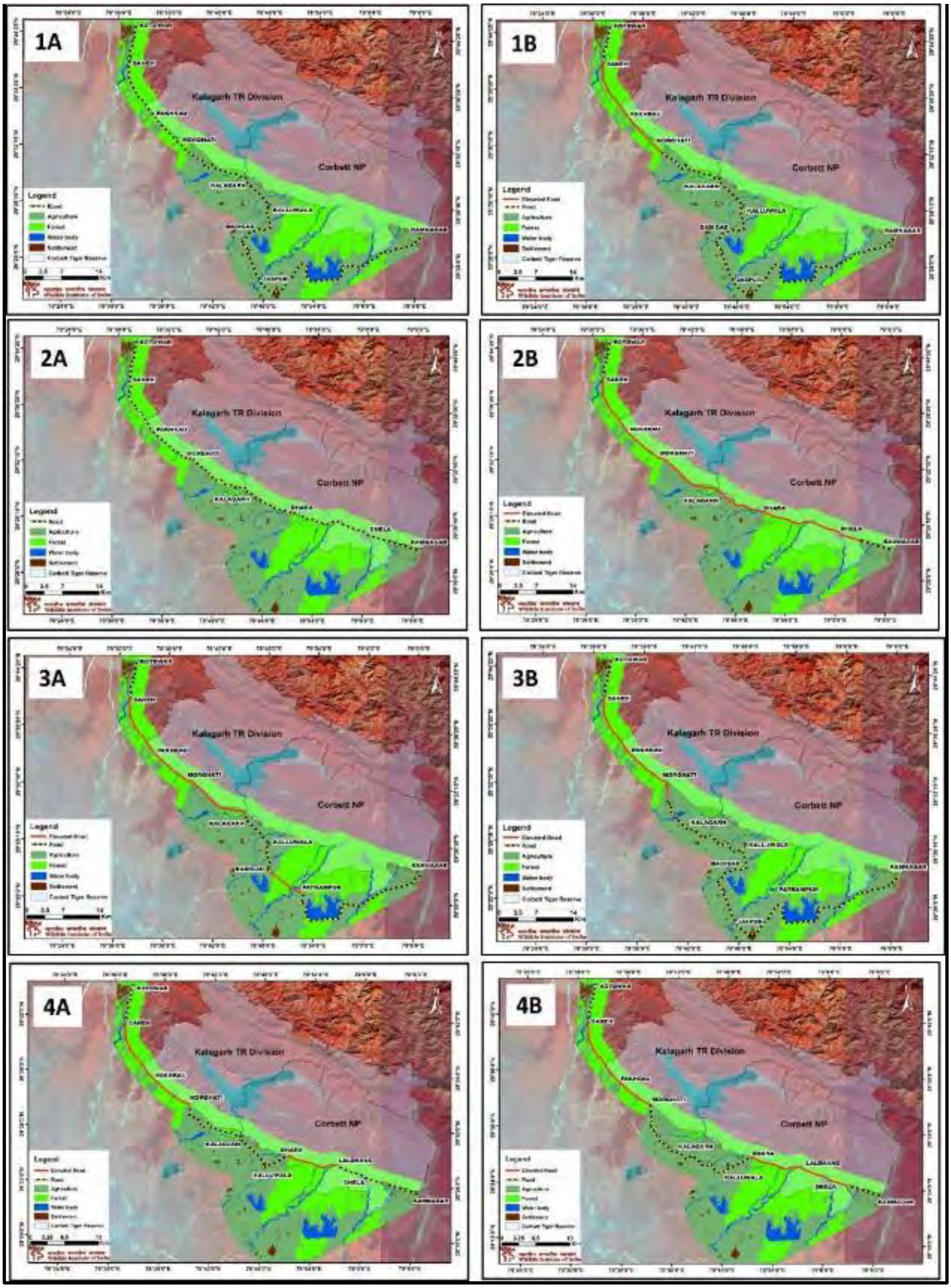


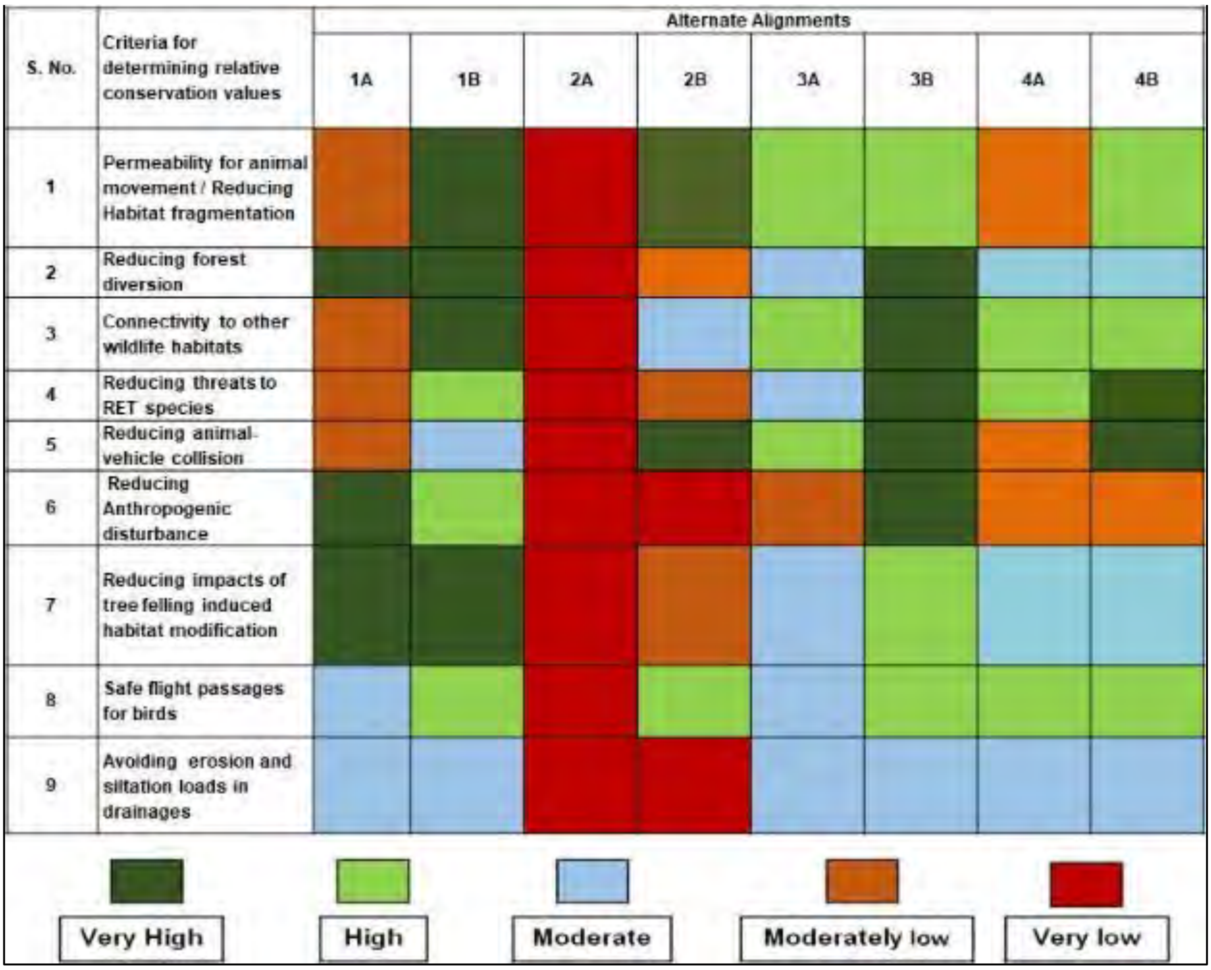
Figure 52 : Comparative mapping of proposed Kandi road alternate alignments 1A, 1B, 2A, 2B, 3A, 3B, 4A and 4B.

5.8 Key Findings

Conservation Value has been viewed as a tool to support conservation planning (Capmourteres and Anand. 2016) especially when it can be used as a relative measure to rank sites that are worthy of preservation (Dony and Denholm 1985). For the estimation of conservation value, scoring schemes have been widely used (Ratcliffe 1977; Margules and Usher 1981) These scoring schemes usually contain a list of criteria or principal used in the assessment of conservation value to help evaluate the intrinsic features of sites so these can be compared in terms of their quality and quantity (e.g., size, naturalness, diversity, rarity, fragility and several other parameters). Based on this we can compare sites to determine the goal of prioritizing conservation efforts.

A matrix to present scenarios of relative conservation benefits associated with different alternative alignments perhaps provide a more simplified outcome of the results of the in-depth ecological studies conducted in this road transportation corridor (Table 24).

Table 24 : Simplified/Qualitative Conservation Value Matrix derived from the quantitative values obtained from ecological assessment and multi criteria decision analysis results (Table 1/Table 18) to identify the ecologically feasible alignment(s)for the proposed Ramnagar-Kotdwar road. Shades of colors indicate how much the alignment safeguards an ecological value / concern (from very high in dark green to very low in dark red).



- Careful review of alternative alignments of the proposed Ramnagar-Kotdwar road in light of our ecological assessment and multi-criteria decision analysis indicated that, the existing forest (Kandi) road is not feasible for upgradation to a four-way highway, as the ecological costs of tree felling, traffic induced animal mortatliy and 'sacrified' habitat are too large and cannot be mitigated. Realigning this road along the southern boundary of Corbett Tiger Reserve as elevated highway is cost-prohibitive and has marginally higher ecological benefits (Table 18).
- We further note that, the above routes, although short and largely within Uttarakhand, have significant sections passing through Uttar Pradesh. Thus, a road entirely through the state of Uttarakhand is outrightly unfeasible (Table 22).
- Even the Hon'ble Supreme Court alignment that has been proposed through Kalagarh Tiger Reserve Division without mitigation measure will result in loss of connectivity and high traffic induced animal mortality; therefore, being unfeasible (Figure 52).
- We found that for the proposed Kandi road, alignment 3B is the most feasible alternative. This alignment is similar to the Supreme Court approved alignment with further mitigative modifications. We suggest this alignment with the following safeguards: a minimum of 1 km and preferably 2 km distance from the forest edge from Ramnagar to Kalagarh via Patrampur and Kalluwala, and an elevated road 8 m in height from Morghati to Saneh. We also suggest installation of noise barriers (at least 3 m in height) on both sides over the suggested elevated stretches wherever the road passes through forested areas (or within 100m from forest edge) in order to minimise impacts of traffic noise on wildlife species and also to prevent bird species' mortalities. The habitat cleared of vegetation for the purpose of overpass construction should also be restored by planting native understory shrub that will discourage spread of invasive species as well as mimic the natural habitat of the landscape and thus will be conducive to wildlife movement. Regular removal of invasive species is also suggested.
- In addition to the Multi-criteria Decision Analysis (MCDA) (Table 18/19), we also developed a Simplified/Qualitative Conservation Value Matrix (SCVM) (Table 23) derived from the quantitative values obtained from MCDA. On the basis of MCDA and SCVM analysis carried out as part of the feasibility study the Government of Uttarakhand would have to decide the further course of action. We understand that the proposed road alignments being part of Corbett Tiger Reserve, Rajaji tiger Reserve and Amangarh Tiger Reserve necessary approvals from the NTCA (National Tiger Conservation Authority), the State Board for Wildlife, Uttarakhand and the National Board for Wildlife (Standing Committee) would have to be taken, taking into account the directions issued by the Central Empowered Committee, the Hon'ble NGT (National Green Tribunal) and the Hon'ble Supreme Court of India in the context of various cases pertaining to the road upgradation proposed.

Based on the simplified conservation value matrix (Table 24), it becomes further evident that alignment 3B is the most feasible option, for ensuring long term prospects of conservation of wildlife species and their habitats in this ecosystem and taking into account the use of best available construction technology under constant oversight and compliance monthly by a joint team of forest, wildlife and transport professionals during a) pre-construction b) construction and c) post-construction phases.

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ANNEXURES

Annexure 1 (a)

Memorandum of Understanding signed between WII and NBCC

INDIA NON JUDICIAL

Government of Uttarakhand

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सत्यमेव जयते

Certificate No.	:	IN-UK57573040562495Q
Certificate Issued Date	:	16-Mar-2018 10:17 AM
Account Reference	:	NONACC (SV)/ uk1211904/ DEHRADUN/ UK-DH
Unique Doc. Reference	:	SUBIN-UKUK121190416066349069982Q
Purchased by	:	NBCC INDIA LTD
Description of Document	:	Article 5 Agreement or Memorandum of an agreement
Property Description	:	NA
Consideration Price (Rs.)	:	0 (Zero)
First Party	:	NBCC INDIA LTD
Second Party	:	NA
Stamp Duty Paid By	:	NBCC INDIA LTD
Stamp Duty Amount(Rs.)	:	100 (One Hundred only)

Ashwani Aggarwal

Please write or type below this line

Memorandum of Understanding

This Memorandum of Understanding is made at Dehradun on ...16... day of March, 2018 between

NBCC India Ltd., also known as National Buildings Construction Corporation Limited (a Govt. of India Enterprise), based at NBCC Bhawan, Lodhi Road, New Delhi (hereafter referred to as the **implementing agency**

AND

WII, also known as the Wildlife Institute of India, Dehradun, an autonomous organization under the Ministry of Environment, Forests and Climate Change,

Page 1 of 4

Wildlife Institute of India, Dehradun

NBCC (INDIA) LTD DEHRADUN

Government of India, and based at Chandrabani, Dehradun, Uttarakhand, hereafter referred to as the **feasibility assessment agency**

This agreement shall come in force on the day of signing of this MoU.

Introduction

Vide the Office Memorandum number 2915/x-2-2017 dated 29 December 2017, it has been decided by the State Government of Uttarakhand, that Ecotoursim Corporation of Uttarakhand Ltd (EDCUL) shall be the **Nodal Agency** for **Upgradation/Construction of Link Road between Kotdwar and Ramnagar (hereafter referred to as the project)** and the work of construction will be entrusted to the NBCC, on the concept of Development of Green Linear Infrastructure developed by the WII, adopting all possible eco-friendly measures for minimizing impacts of construction of this road on wildlife.

It has been decided that the Implementing Agency shall initially conduct feasibility study with technical help of WII, based on the concept of development of linear infrastructure with minimum impacts on wildlife. Implementing agency shall submit the feasibility study report with clear delineation of alignment of the aforesaid road to the Nodal Agency for obtaining necessary approvals under extant laws.

Based on such feasibility study report, the Nodal Agency and Implementing Agency shall collectively work for obtaining necessary approvals under Wildlife Protection Act, Forest Conservation Act and any other Act, as applicable. Based on approved feasibility report, and after obtaining all necessary approvals from the Competent Authority, under extant laws, the Implementing Agency will carry out other related works such as detailed design, cost estimation and construction works, as deposit work on turnkey basis, on the terms and conditions, hereby, agreed to, between the parties, set forth as under:

1.0 DEFINITIONS

In the Agreement, the following words and expressions, unless the context otherwise requires, have the following meaning: -

i) **State Government** means the Government of Uttarakhand.
ii) **Nodal Agency** means Eco-Tourism Development Corporation of Uttarakhand Ltd. (EDCUL), Uttarakhand, Dehradun.
iii) **Competent Authority** includes State Wildlife Board, National Tiger Conservation Authority, National Wildlife Board and any other Statutory Authority under Wildlife Act, Forest Conservation Act or any other applicable law.
iv) **Approval** means approval in writing by the designated officer of the Nodal Agency.
v) **Implementing Agency** means the National Buildings Construction Corporation Limited or NBCC (India) Ltd., New Delhi.

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iv) **Approval** means approval in writing by the designated officer of the Nodal Agency.
v) **Implementing Agency** means the National Buildings Construction Corporation Limited or NBCC (India) Ltd., New Delhi.

3.0 RESPONSIBILITIES OF THE IMPLEMENTING AGENCY

3.1 Funding for this feasibility study will be provided by the Implementing agency as per the financial proposal submitted by the Feasibility Assessment Agency for a total amount of Rs. 314.20 Lakhs as annexed herewith (**Annexure-II**).

3.2 The Implementing Agency will adhere to the road alignment and mitigation measures for green infrastructure proposed by the Feasibility Assessment Agency based on their study.

4.0 PAYMENT TERMS

Funds will be disbursed by the Implementing Agency to the Feasibility Assessment Agency as per under:

a) 10% of the total amount as mentioned in Financial proposal at Annexure II will be payable subsequent to signing of the **MoU,** as the first instalment.

b) Subsequent payments will be made on the receipt of invoices from the Feasibility Assessment Agency i.e. Wildlife Institute of India during various stages of the feasibility study.

It will be ensured that the above payments shall be made by the Implementing Agency to the Feasibility Assessment Agency on receipt of funds from Nodal Agency in a timely manner so that the study is not hampered on account of funds. The time-lines for the study have been given by the Feasibility Assessment Agency on the condition that funds would be made available in a timely manner.

5.0 LIQUIDATED DAMAGES

Feasibility Assessment Agency shall be required to complete the tasks within the period stipulated in this agreement. In case of delay, which may occur due to the reasons beyond the control of Implementing Agency, it would approach the Implementing Agency with full details, giving reasons thereof, for extension in time limit for completion of the works. Any dispute will be amicably settled, and if that is not feasible, then both parties will approach the Nodal Agency for resolving the dispute.

6. FORCE MAJEURE

The Feasibility Assessment Agency shall not be considered in default if delay in completion of the work occurs due to cause beyond its control such as acts of God, natural calamities, civil wars, fire, strike, frost, floods, riots and acts of unsurpassed power. The Feasibility Assessment Agency shall notify 'Nodal Agency' in writing within ten days from the date of such occurrence. In the event of delay due to such causes, the completion schedule will be extended for a length of time equal to the period of force majeure. Any expenditure incurred by the Feasibility Assessment Agency during the period of force majeure shall be reimbursed by the Implementing Agency. In case of closer of work due to the force majeure, any liabilities towards contractor and/or expenditure of the Feasibility Assessment Agency shall be payable by the Implementing Agency.

Feasibility Assessment Agency shall not hold responsible any contractor/ agency for the delay/ stoppage of work due to force majeure conditions like natural calamities, civil disturbance, war, etc. and for losses suffered if any, by the Implementing Agency on this account. The Feasibility Assessment Agency shall also not be able in any way to bear such losses and no compensation of any kind whatsoever will be payable by the Feasibility Assessment Agency to The Implementing Agency. Suitable force majeure clause shall be incorporated in all the agreement entered into by the Feasibility Assessment Agency with the contractors/ agencies.

7. JURISDICTION

This agreement is subject to the jurisdiction of Uttarakhand High Court.

Signed at Dehradun on this day as mentioned above.

FOR and on behalf of	FOR and on behalf of
NBCC (India) Ltd.	**Wildlife Institute of India, Dehradun**
"THE IMPLEMENTING AGENCY"	**"THE FEASIBILITY ASSESSMENT AGENCY"**
R. K. SONI	डा. वि.बि. माथुर/Dr. V.B. Mathur निदेशक/Director भारतीय वन्यजीव संस्थान WILDLIFE INSTITUTE OF INDIA देहरादून/Dehradun

Witness: Priyesh Kumar Garg, Dy. PM (E), NBCC, Dehradun

Witness: Dr. R Suresh Kumar, Scientist-E, WII

Annexure 1 (b)

Supplementary Memorandum of Understanding signed between WII and NBCC

SUPPLEMENTARY AGREEMENT TO

AGREEMENT NO. IN–UK57570968716485Q dated 16.03.2018

Between

Wildlife Institute of India, Dehradun

And

NBCC (India) Ltd.

For

Up-gradation/Construction of Link Road between Kotdwar and Ramnagar

The SUPPLEMENTARY AGREEMENT is made on this 13 Day of December 2018 as a deed of addendum to existing AGREEMENT NO. IN–UK57570968716485Q dared 16.03.2018 Between Wildlife Institute of India, Dehradun (hereinafter referred as Employer) and NBCC (India) Ltd. (hereinafter referred as Executing Agency) for the Up-gradation/Construction of Link Road between Kotdwar and Ramnagar

NOW, THEREFORE THE PARTIES HERETO HEREBY AGREE AND THIS ADDENDUM OF AGREEMENT WITNESSTH AS FOLLOWS:

Sl. No.	Existing Clause 2.3 of signed MoU	Modified Clause 2.3 of MOU
1	Based on the feasibility study report and proposed alignment for construction/ up-gradation of the aforesaid road between Kotdwar and Ramnagar, WII will help and facilitate the implementing agency in obtaining necessary approvals from the Competent Authority under Wildlife Act, Forest Conservation Act and any other extant laws applicable	Based on the feasibility study report and proposed alignment for construction/up-gradation of the aforesaid road between Kotdwar and Ramnagar, WII will explain the scope, methodology and outcome of its feasibility study when called upon to do so in order to assist the implementing agency.

All other terms & conditions of the agreement dated 16.03.2018 remain unchanged.

In witness where the parties put their signature through their respective representatives on the day, month and year above written in token of acceptance of this deed.

For and on behalf of NBCC

Witness ....

For and on behalf of "WII"

13/12/18

डॉ. वि.बि. माथुर/Dr. V.B. Mathur
निदेशक/Director
भारतीय वन्यजीव संस्थान
WILDLIFE INSTITUTE OF INDIA
देहरादून/Dehradun

Witness

WILDLIFE INSTITUTE OF INDIA
CHANDRABANI, DEHRADUN

Annexure 2

Questionnaire data sheet used for carrying out focal group discussion surveys for the study

About Village	
Village Name:	GPS Co-ordinates:
Distance from kandi road	
About Respondents	
Number of respondents:	
Primary source of Income of villagers:	
Dependency on Forest: A. Fuel wood C. Fodder B. Timber D. NTFP E. Others:	
If dependency on forest is present, how far do they travel and any close encounter / interaction/sighting of animals inside the forest: A. 0-2Km C. 4-6Km B. 2-4Km D. >6 Km Species sighted -	
Awareness of the Project:	
Opinion on the project: A. Positive C. Negative B. Neutral D. Unaware Remarks:	
If negative, suggested mitigation measures:	
Crops grown in agricultural land: A. Sugarcane B. Paddy C. Wheat D. Orchards E. Others; Specify:	
Wildlife encounters: Wildlife Sighting around Species Frequency Timing Home Village Agricultural land	

Viewpoints on the Human-Wildlife Interactions:
Remarks (If any):

Annexure 3

Recoreded mammalian species in the study area (2018 - 2019)

Broad classification	Species	Scientific name	IUCN category
Large carnivores			
	Common leopard	*Panthera pardus*	VU
	Himalayan black bear	*Ursus thibetanus*	VU
	Sloth bear	*Melursus ursinus*	VU
	Striped hyaena	*Hyaena hyaena*	NT
	Tiger	*Panthera tigris*	EN
Small carnivores			
	Indian fox	*Vulpes bengalensis*	LC
	Golden jackal	*Canis aureus*	LC
	Yellow-throated marten	*Martes flavigula*	LC
	Common palm civet	*Paradoxurus hermaphroditus*	LC
	Small Indian civet	*Viverricula indica*	LC
	Leopard cat	*Prionailurus bengalensis*	LC
	Indian grey mongoose	*Herpestes edwardsii*	LC
	Jungle cat	*Felis chaus*	LC
	Rusty-spotted cat	*Prionailurus rubiginosus*	VU

Primates			
	Rhesus macaque	*Macaca mulatta*	LC
	Hanuman langur	*Semnopithecus hector*	LC
Herbivores			
	Chital	*Axis axis*	LC
	Sambar	*Rusa unicolor*	VU
	Elephant	*Elephas maximas*	EN
	Nilgai	*Boselaphus tragocamelus*	LC
	Barking deer	*Muntiacus muntjac*	LC
	Wild pig	*Sus scrofa*	LC

Annexure 4

Bird species recoreded in the study area (2018 - 19)

Species	*Scientific Name*	IUCN status	WPA schedule	Individual Sightings
Ashy drongo	*Dicrurus leucophaeus*	LC	IV	1
Ashy prinia	*Prinia socialis*	LC		5
Bar-winged flycatcher shrike	*Hemipus picatus*	LC		23
Bengal bushlark	*Mirafra assamica*	LC	IV	4
Black bulbul	*Hypsipetes leucocephalus*	LC	IV	15
Black-crested yellow bulbul	*Pycnonotus flaviventris*	LC	IV	6
Black drongo	*Dicrurus macrocercus*	LC	IV	24
Black hooded oriole	*Oriolus xanthornus*	LC	IV	3
Black Kite	*Milvus migrans*	LC		5
Black-rumped flameback wood-pecker	*Dinopium benghalense*	LC	IV	8

Species	*Scientific Name*	IUCN status	WPA schedule	Individual Sightings
Black-necked stork	*Ephippiorhynchus asiaticus*	NT	IV	1
Blue bearded bee-eater	*Nyctyornis athertoni*	LC		8
Blue-throated barbet	*Megalaima asiatica*	LC	IV	3
Blue-throated flycatcher	*Cyornis rubeculoides*	LC	IV	2
Blue-whistling thrush	*Myophonus caeruleus*	LC		19
Brahminy starling	*Sturnia pagodarum*	LC	IV	4
Brown headed barbet	*Psilopogon zeylanicus*	LC	IV	13
Brown Rockchat	*Oenanthe fusca*	LC		4
Brown-capped pygmy woodpecker	*Picoides nanus*	LC	IV	2
Brown-fish owl	*Ketupa zeylonensis*	LC	IV	1
Cattle Egret	*Bubulcus ibis*	LC	IV	8
Changeable hawk eagle	*Nisaetus cirrhatus*	LC	IV	8
Chestnut-bellied nuthatch	*Sitta cinnamoventris*	LC		4
Common coot	*Fulica atra*	LC	IV	1
Common hoopoe	*Upupa epops*	LC		1
Common kingfisher	*Alcedo atthis*	LC	IV	4
Common moorhen	*Gallinula chloropus*	LC		1
Common myna	*Acridotheres tristis*	LC	IV	17
Common stonechat	*Saxicola torquatus*	LC		1
Common tailorbird	*Orthotomus sutorius*	LC		3
Common woodshrike	*Tephrodornis pondicerianus*	LC		3
Crested kingfisher	*Megaceryle lugubris*	LC		1
Crested-serpent eagle	*Spilornis cheela*	LC		6
Crimson sunbird	*Aethopyga siparaja*	LC	IV	4
Dark sided flycatcher	*Muscicapa sibirica*	LC	IV	1

Species	***Scientific Name***	**IUCN status**	**WPA schedule**	**Individual Sightings**
Egyptian vulture	*Neophron percnopterus*	EN	IV	1
Emerald dove	*Chalcophaps indica*	LC	IV	2
Eurasian collared dove	*Streptopelia decaocto*	LC	IV	3
Eurasian griffon	*Gyps fulvus*	LC	IV	12
Golden-fronted leafbird	*Chloropsis aurifrons*	LC		4
Great hornbill	*Buceros bicornis*	VU	I	118
Great tit	*Parus major*	LC	IV	4
Greater flameback woodpecker	*Chrysocolaptes guttacris-tatus*	LC	IV	3
Greater yellownape woodpecker	*Chrysophlegma flavinucha*	LC	IV	2
Green bee-eater	*Merops orientalis*	LC		12
Greenish Warbler	*Phylloscopus trochiloides*	LC		3
Grey breasted prinia	*Prinia hodgsonii*	LC		8
Grey bushchat	*Saxicola ferreus*	LC		6
Grey francolin	*Francolinus pondicerianus*	LC	IV	4
Grey heron	*Ardea cinerea*	LC	IV	1
Grey hooded warbler	*Phylloscopus xanthoschis-tos*	LC		3
Grey treepie	*Dendrocitta formosae*	LC	IV	1
Grey wagtail	*Motacilla cinerea*	LC		2
Grey-headed canary flycatcher	*Culicicapa ceylonensis*	LC	IV	4
Grey-headed fish eagle	*Icthyophaga ichthyaetus*	NT	IV	2
Grey-headed Woodpecker	*Picus canus*	LC	IV	2
Grey-winged blackbird	*Turdus boulboul*	LC		2
Hair-crested drongo	*Dicrurus hottentottus*	LC	IV	8
Himalayan bulbul	*Pycnonotus leucogenys*	LC	IV	50
Himalayan griffon	*Gyps himalayensis*	NT	IV	26
House crow	*Corvus splendens*	LC	V	6

Species	***Scientific Name***	**IUCN status**	**WPA schedule**	**Individual Sightings**
House sparrow	*Passer domesticus*	LC		19
Hume's warbler	*Phylloscopus humei*	LC		3
Indian cormorant	*Phalacrocorax fuscicollis*	LC	IV	1
Indian-eagle owl	*Bubo bengalensis*	LC		1
Indian grey hornbill	*Ocyceros birostris*	LC		28
Indian Jungle crow	*Corvus macrorhynchos cul-minatus*	LC		9
Indian peafowl	*Pavo cristatus*	LC	I	22
Indian Pond heron	*Ardeola grayii*	LC	IV	3
Indian robin	*Saxicoloides fulicatus*	LC		9
Indian roller	*Coracias benghalensis*	LC	IV	2
Jungle babbler	*Turdoides striata*	LC	IV	27
Jungle owlet	*Glaucidium radiatum*	LC	IV	8
Jungle prinia	*Prinia sylvatica*	LC		3
Kalij pheasant	*Lophura leucomelanos*	LC	I	16
Large cuckooshrike	*Coracina javensis*	LC		4
Laughing dove	*Spilopelia senegalensis*	LC	IV	1
Lesser yellownape woodpecker	*Picus chlorolophus*	LC	IV	1
Little cormorant	*Microcarbo niger*	LC	IV	1
Little egret	*Egretta garzetta*	LC	IV	4
Little grebe	*Tachybaptus ruficollis*	LC	IV	1
Long-tailed minivet	*Pericrocotus ethologus*	LC	IV	12
Long-tailed Shrike	*Lanius schach*	LC		8
Maroon oriole	*Oriolus traillii*	LC	IV	1
Orange-headed thrush	*Geokichla citrina*	LC	IV	4
Oriental honey buzzard	*Pernis ptilorhynchus*	LC		1
Oriental magpie robin	*Copsychus saularis*	LC		9

Species	*Scientific Name*	IUCN status	WPA schedule	Individual Sightings
Oriental pied hornbill	*Anthracoceros albirostris*	LC	I	76
Oriental turtle dove	*Streptopelia orientalis*	LC	IV	8
Oriental white eye	*Zosterops palpebrosus*	LC	IV	15
Pale-billed flowerpecker	*Dicaeum erythrorhynchos*	LC	IV	1
Pied bushchat	*Saxicola caprata*	LC		7
Pied kingfisher	*Ceryle rudis*	LC	IV	3
Plum headed parakeet	*Psittacula cyanocephala*	LC	IV	240
Purple sunbird	*Cinnyris asiaticus*	LC	IV	7
Red jungle fowl	*Gallus gallus*	LC	IV	16
Red vented bulbul	*Pycnonotus cafer*	LC	IV	98
Red whiskered bulbul	*Pycnonotus jocosus*	LC	IV	16
Red-billed blue magpie	*Urocissa erythroryncha*	LC	IV	4
Rose-ringed parakeet	*Psittacula krameri*	LC	IV	39
Rufous bellied niltava	*Niltava sundara*	LC		2
Rufous treepie	*Dendrocitta vagabunda*	LC	IV	21
Rusty-cheeked scimitar-babbler	*Erythrogenys erythrogenys*	LC	IV	6
Sarus crane	*Antigone antigone*	VU	IV	2
Scaly breasted munia	*Lonchura punctulata*	LC	IV	16
Scarlet minivet	*Pericrocotus flammeus*	LC	IV	2
Shikra	*Accipiter badius*	LC		6
Sirkeer malkoha	*Taccocua leschenaultii*	LC		1
Slaty-headed parakeet	*Psittacula himalayana*	LC	IV	13
Small minivet	*Pericrocotus cinnamomeus*	LC	IV	2
Speckled piculet	*Picumnus innominatus*	LC	IV	1
Spotted dove	*Stigmatopelia chinensis*	LC	IV	19
Spotted owlet	*Athene brama*	LC	IV	3
Steppe eagle	*Aquila nipalensis*	LC		1
Striated prinia	*Prinia crinigera*	LC		1

Species	*Scientific Name*	IUCN status	WPA schedule	Individual Sightings
Velvet fronted nuthatch	*Sitta frontalis*	LC		3
Verditer flycatcher	*Eumyias thalassinus*	LC	IV	4
White bellied drongo	*Dicrurus caerulescens*	LC	IV	1
White throated fantail	*Rhipidura albicollis*	LC		9
White throated kingfisher	*Halcyon gularis*	LC	IV	11
White-capped redstart	*Phoenicurus leucocephalus*	LC		2
White-crested laughingthrush	*Garrulax leucolophus*	LC	IV	37
Woolly-necked stork	*Ciconia episcopus*	VU	IV	6
Yellow bellied fantail	*Chelidorhynx hypoxanthus*	LC		8

Annexure 5

Villages adjoining the southern boundary of Corbett Tiger Reserve that were sampled for social surveys (2018-19).

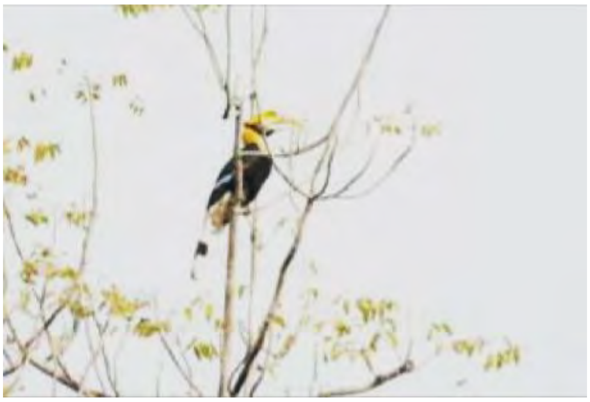
Sr. No.	Village Name	Approximate Number of families
1	Saneh	220
2	Sawaldeh East	600
3	Sawaldeh West	
4	Himmatpur Dotiyal	700
5	Sewal Khaliya	
6	Kuankheda	700
7	Gangapar Kuankheda	
8	Nalkatta	
9	Kalluwala	1200
10	Lalbaug	
11	Maloni	
12	Dhela	330
13	Neem Sot	13
14	Ramjiwala	500

<table>
<tr><td>15</td><td>Dhara</td><td>300</td></tr>
<tr><td>16</td><td>Bhikkawala</td><td rowspan="5">220</td></tr>
<tr><td>17</td><td>Old Kalagar Colony</td></tr>
<tr><td>18</td><td>Murliwala</td></tr>
<tr><td>19</td><td>Jamunwala</td></tr>
<tr><td>20</td><td>Baniyawala</td></tr>
<tr><td>21</td><td>Karanpur</td><td rowspan="5">900</td></tr>
<tr><td>22</td><td>Gorakhpur</td></tr>
<tr><td>23</td><td>Bhavanipur Punjabi</td></tr>
<tr><td>24</td><td>Dharmpur dhankola</td></tr>
<tr><td>25</td><td>Dharampur ghasi</td></tr>
<tr><td>26</td><td>Pahadi Mirapur</td><td>200</td></tr>
<tr><td>27</td><td>Veerbhan</td><td>200</td></tr>
<tr><td>28</td><td>Gaujani</td><td>400</td></tr>
<tr><td>29</td><td>Bhumidaan</td><td rowspan="3">300</td></tr>
<tr><td>30</td><td>Bagnaala</td></tr>
<tr><td>31</td><td>Prem Nagar</td></tr>
<tr><td>32</td><td>Kaderganjh</td><td>7</td></tr>
<tr><td>33</td><td>New Kalagarh Colony</td><td>150</td></tr>
<tr><td></td><td>Total families</td><td>6940</td></tr>
</table>

Annexure 6

Glimpes of field work for feasibility study of proposed Ramnagar – Kotdwar road (2018-19).

Picture Plate: Social perception surveys being conducted on field

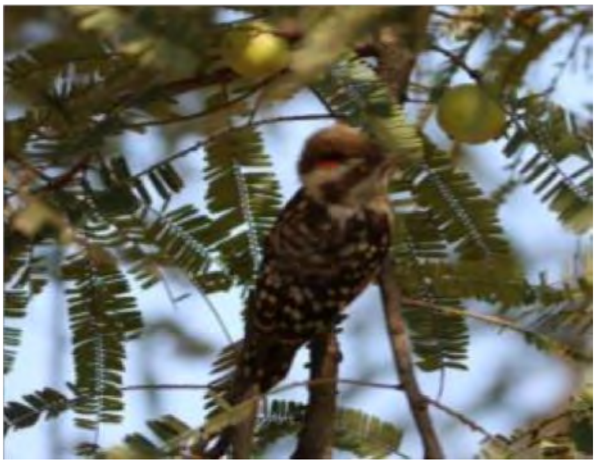


Grey francolin (*Francolinus pondcerianus*)

Great hornbill (*Buceros bicornis*)

Ashy prinia *(Prinia socialis)*

Himlayan griffon (*Gyps himalayensis*)



Brown-capped pigmy woodpecker (*Nyctyornis athertoni*)

Blue bearded bee-eater (*Dendrocopos nanus*)

Picture Plate: Some of the bird species recorded in the study area

Picture plate: Researchers deploying camera traps in the study area

Picture Plate: Wildlife recorded in camera traps


Picture plate: Vegetation survey being carried out in the study area