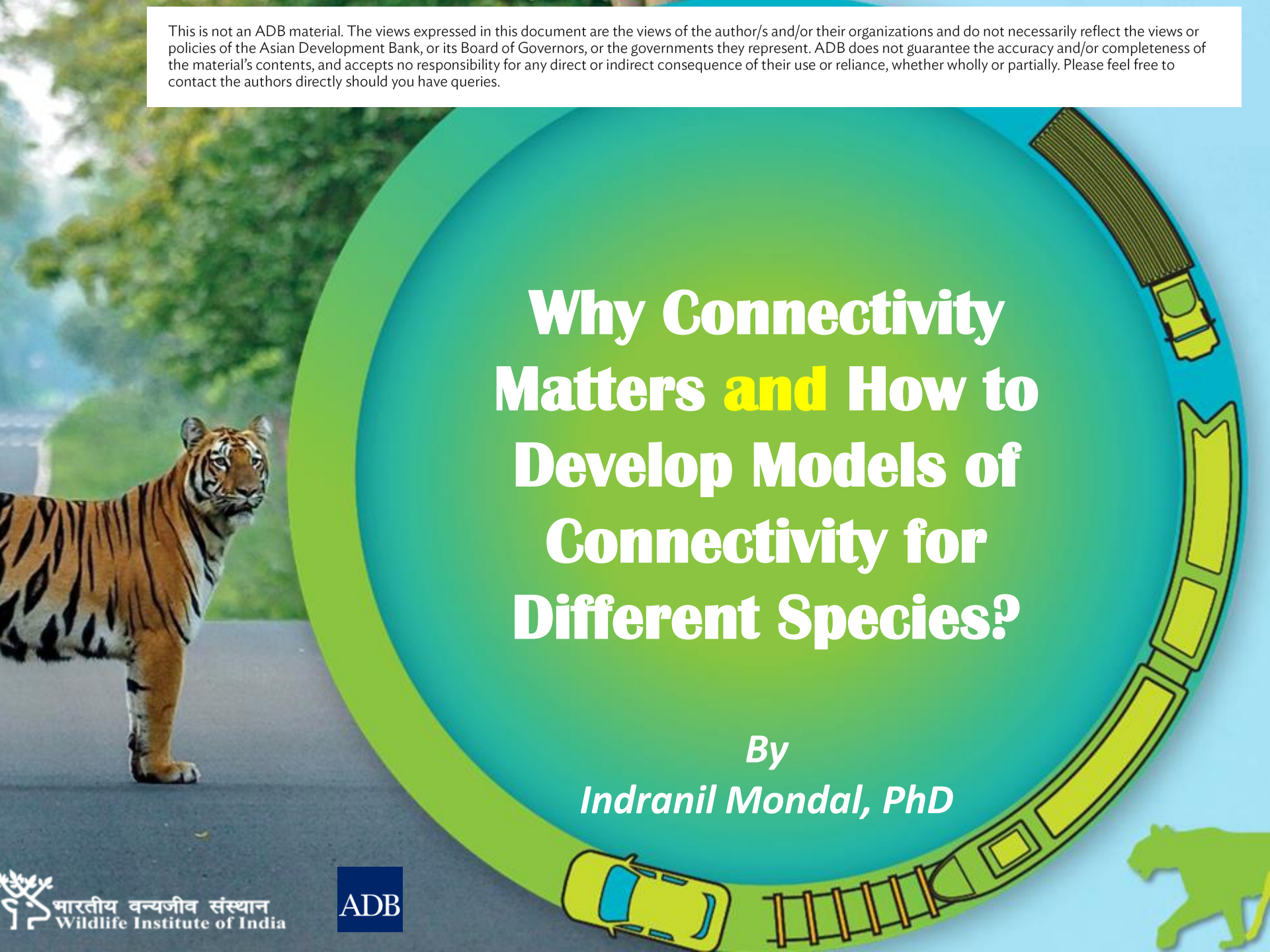


# Why Connectivity Matters and How to Develop Models of Connectivity for Different Species?

*By*

*Indranil Mondal, PhD*

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

ADB

# Fragmentation

- **Forest fragmentation is the process of dividing large tracts of forest into smaller isolated tracts surrounded by human-modified environments (Society of American Foresters 1998).**

- **Habitat fragmentation is defined as the process of dissecting large and contiguous areas of similar native vegetation types into smaller units separated by different vegetation types and/or areas of intensive human activity (Saunders *et al* 1991).**


# Habitat Fragmentation

- Fragmenting  landscapes → fragmented habitat
- Fragmentation affects habitat quality for over 80% of all mammal, reptile, bird, and amphibian species found in forest habitat (USDA Forest Service 1997).
- It has been cited as the primary cause of rapid species extinction, and the loss of native species (Wilcox and Murphy 1985).

# Landscape Connectivity

The property of a landscape arising from the interaction between animal movements and landscape structure is known as *landscape connectivity* (*Merriam 1984*).

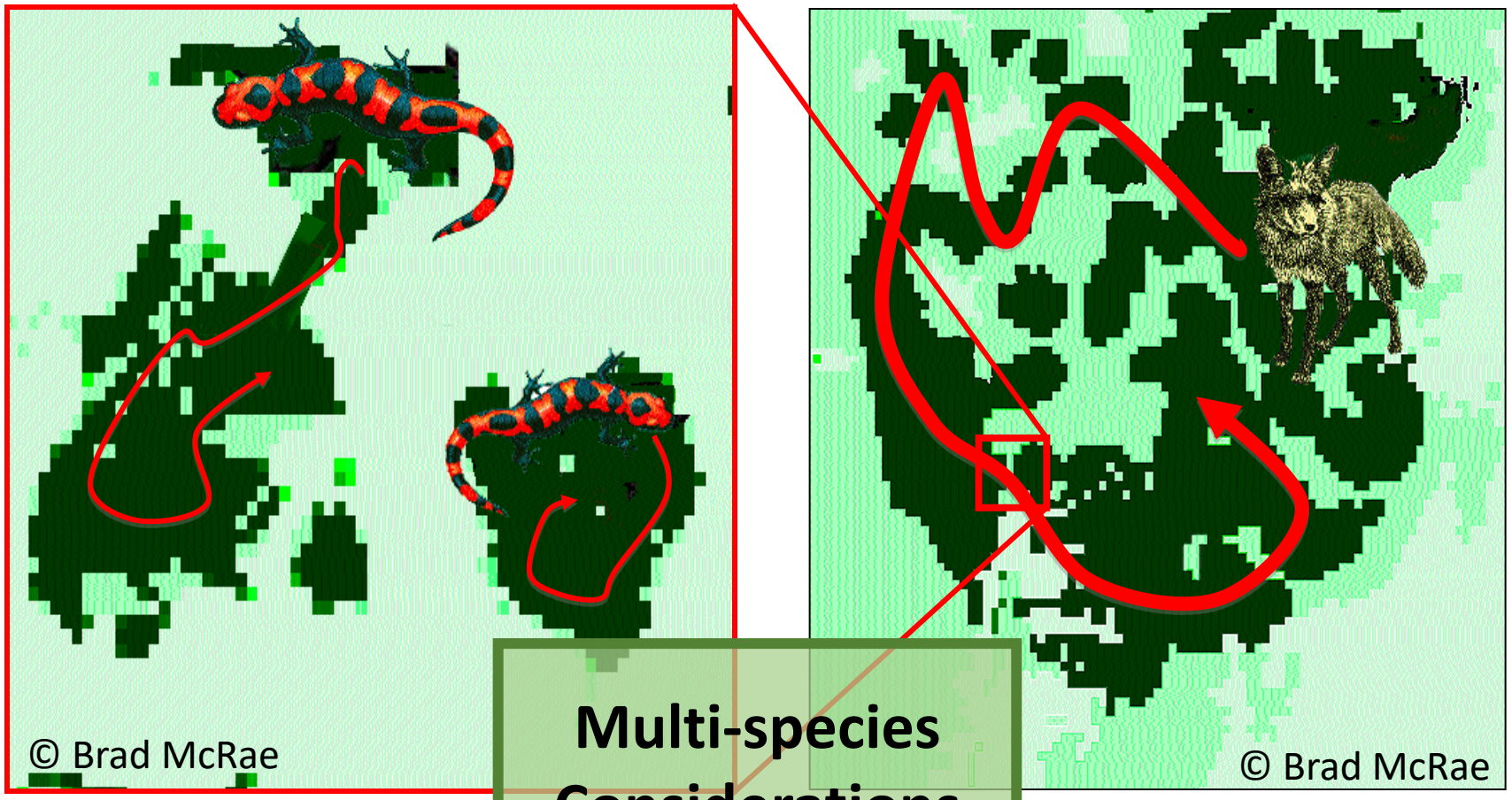
LANDSCAPE CONNECTIVITY

**Structural connectivity**:


**Functional connectivity:**

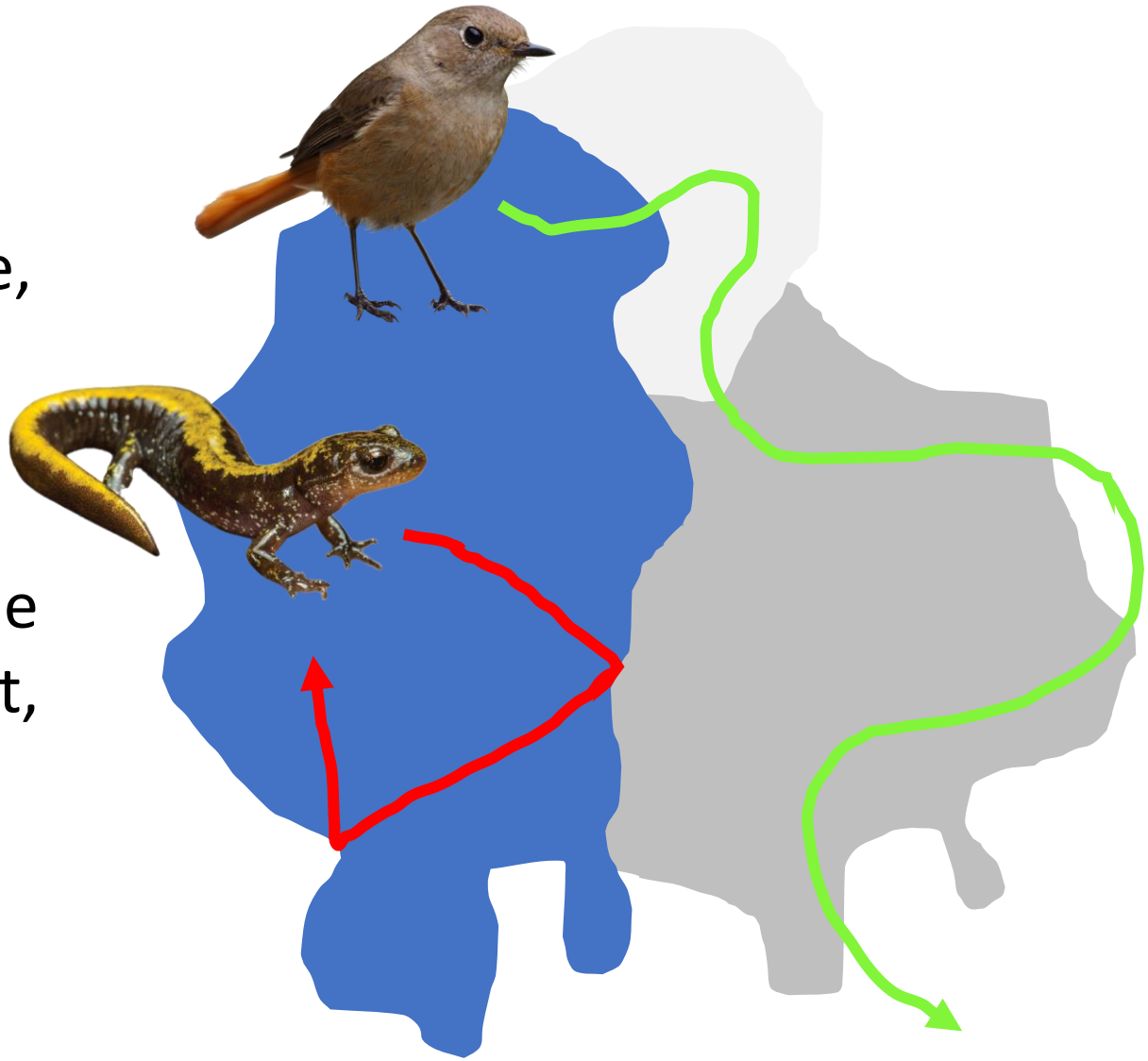
## Landscape Connectivity: Process and scale dependence

Connectivity is dependent upon both the *scale* of observation and the ecological *process* under consideration.



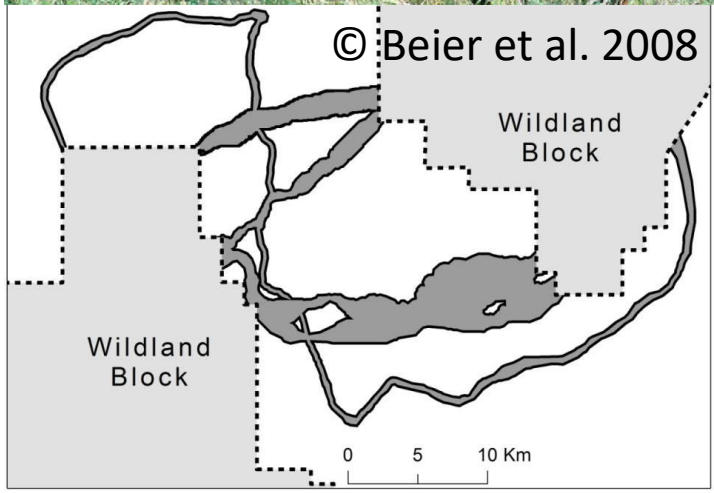

**Multi-species Considerations**

For a given landscape, its connectivity may vary radically with respect to different processes (e.g., beetle movement, bird flight, seed dispersal, fire spread).



# Need for Landscape Connectivity

- Individual movement to access resources in home range
- Immigration: can prevent local extinction (demographic rescue) or recolonize after local extinction
- Seasonal migration
- Gene flow (the ability to evolve)
- Ecological processes and flows (e.g., disturbance, predator-prey interactions, seed dispersal)
- Population movement in response to disasters or changing climate


# Connectivity "Conceptual Model"

**Wildlife Movement Requirements**:

- **Daily movements**
- **Seasonal movements**
- **Dispersal and colonization of vacant habitat**

**Fragmentation**:

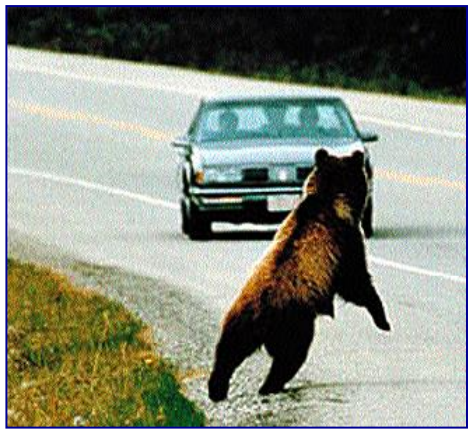
- Land clearing
- Development
- Roads / Traffic
- People

**STRESSORS**

**Habitat Effects**

**Alienation**

**Direct Mortality**



*Slides adapted from: Brad McRae (2009) Landscape connectivity, The Nature Conservancy*

# Connectivity "Conceptual Model"

**Wildlife Movement Requirements:**

- **Daily movements**
- **Seasonal movements**
- **Dispersal and colonization of vacant habitat**

**Habitat Alterations:**

- Fragmentation
- Land clearing
- Development
- Roads / Traffic
- People

**STRESSORS**

**Habitat Effects**

**Alienation**

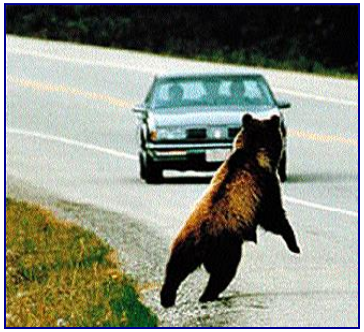
**Direct Mortality**

**Impacts to Individual Animals**

**Wildlife Population Impacts**

**Biodiversity & Ecosystem Effects**

e.g., reduced native species diversity



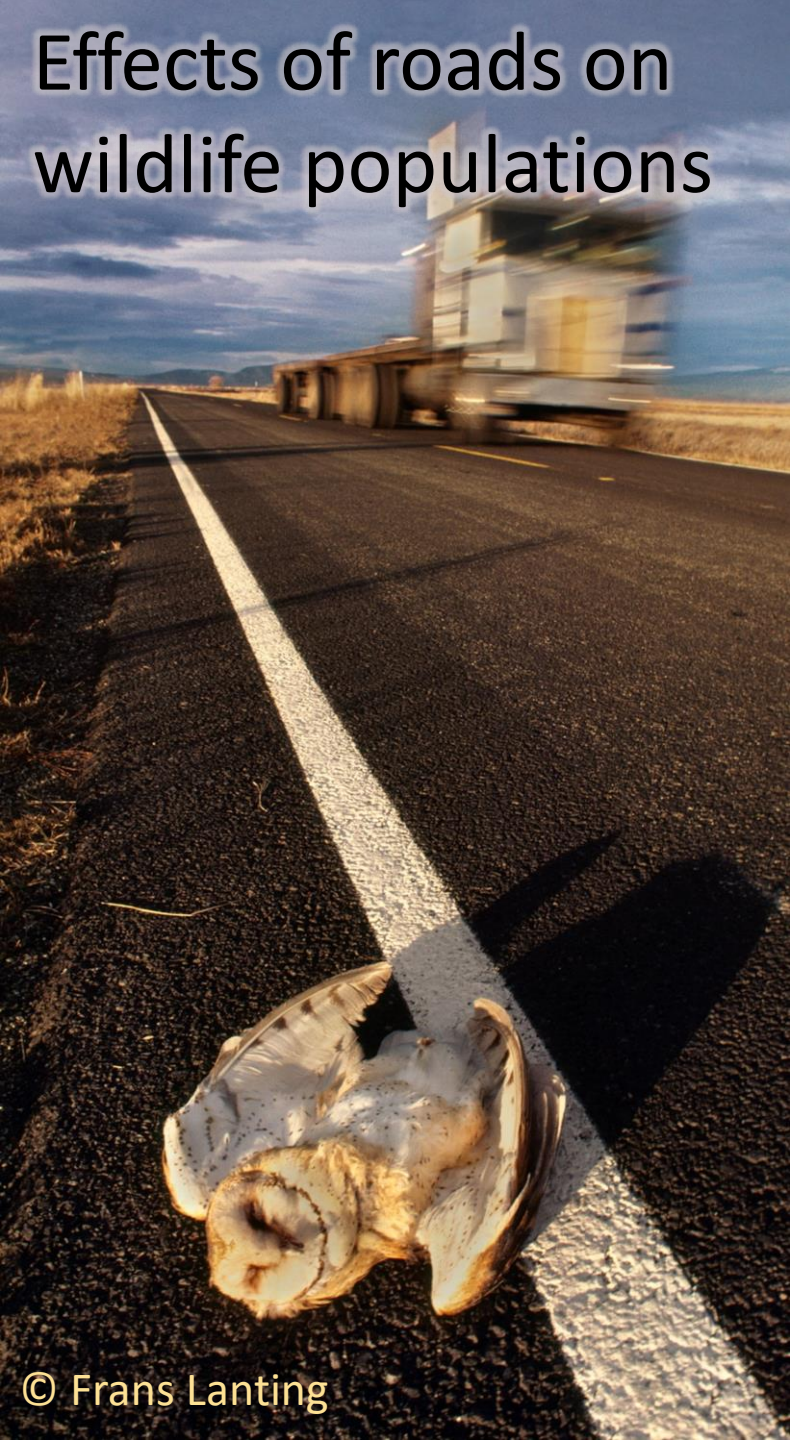
*Slides adapted from: Brad McRae (2009) Landscape connectivity, The Nature Conservancy*

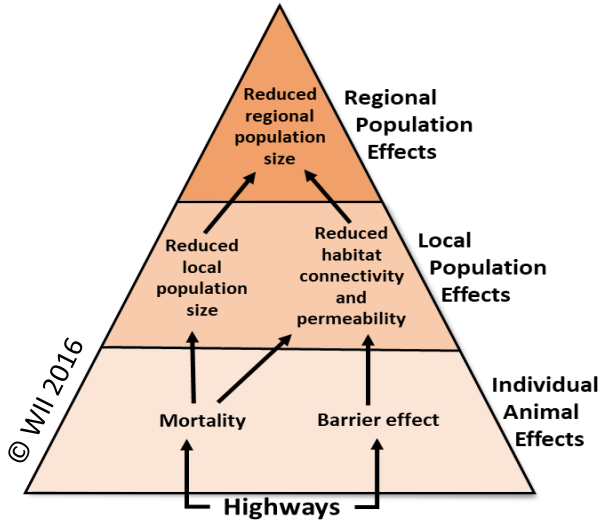

The **IUCN WCPA Connectivity Conservation Specialist Group** defines an ecological corridor as "a clearly defined geographical space, not recognized as a protected area or other effective area-based conservation measure, that is governed and managed over the long-term to conserve or restore effective ecological connectivity, with associated ecosystem services and cultural and spiritual values."

# Why should we care ??


- Keeping habitats connected is a key conservation strategy to protect biodiversity
- Connected habitats ensure undisrupted ecological flows: energy, nutrient, water cycle….
- Intact ecological flows ensures a stable climate, water in our river, more fertile soil, better air quality…..

# Effects of roads on wildlife populations



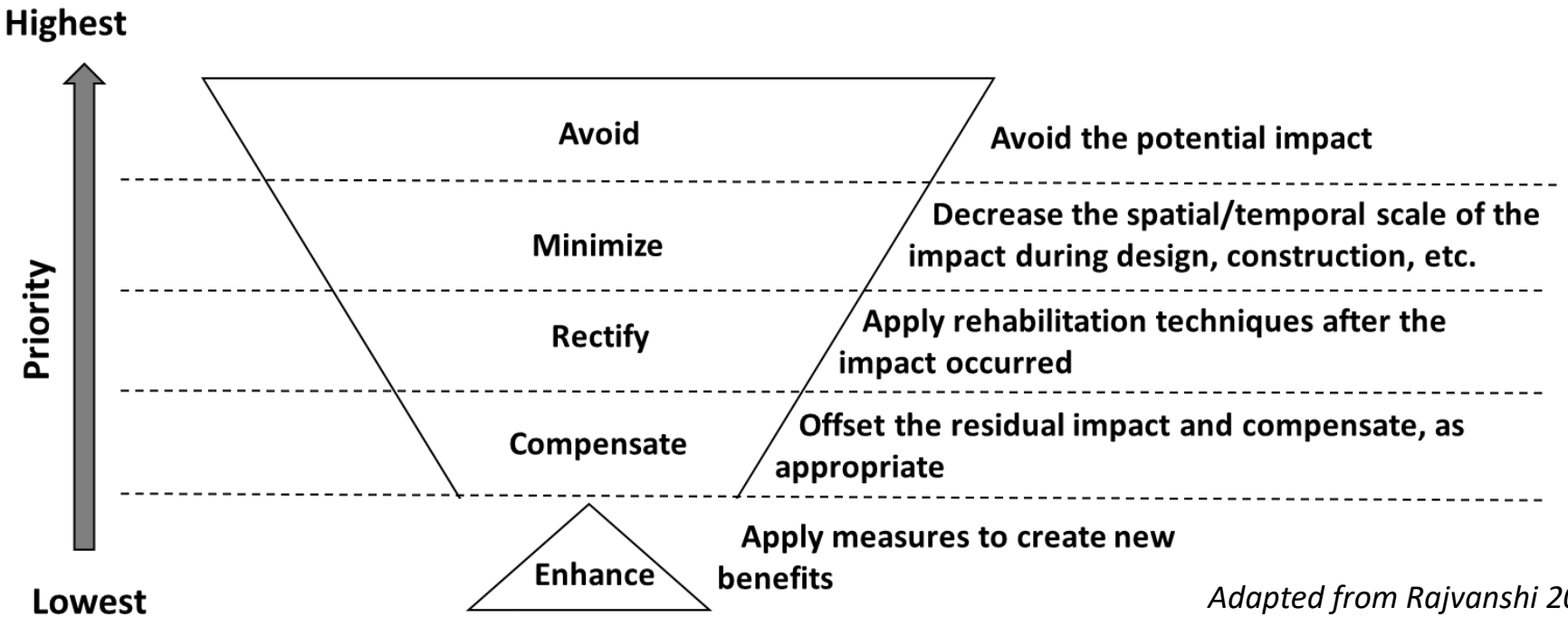

*UNEP/CMS/COP11/Doc.23.3.2: Guidelines*

| Potential Impact | Roads | Rail Lines | Fencing[1] |
|---|---|---|---|
| Wildlife strikes | high | medium | not applicable |
| Entanglement/trap mortality | not applicable | not applicable | high |
| Habitat fragmentation | high | high | high |
| Altering behaviour | high | high | high |
| Barrier to movement | high | high | high |
| Altering use of habitat | high | high | high |
| Increased human presence | high | medium | not applicable |
| Increased hunting | high | low | not applicable |
| Conduits for invasive alien species | high | high | not applicable |
| Effects on population genetics | high | high | high |
| Air pollution | high | low | not applicable |
| Altering natural processes | low | low | high |
| Changed discharges in water bodies | high | high | not applicable |

Relationship rating: high - medium - low - not applicable -



# Strategic measures to mitigate impacts of Highways on wildlife



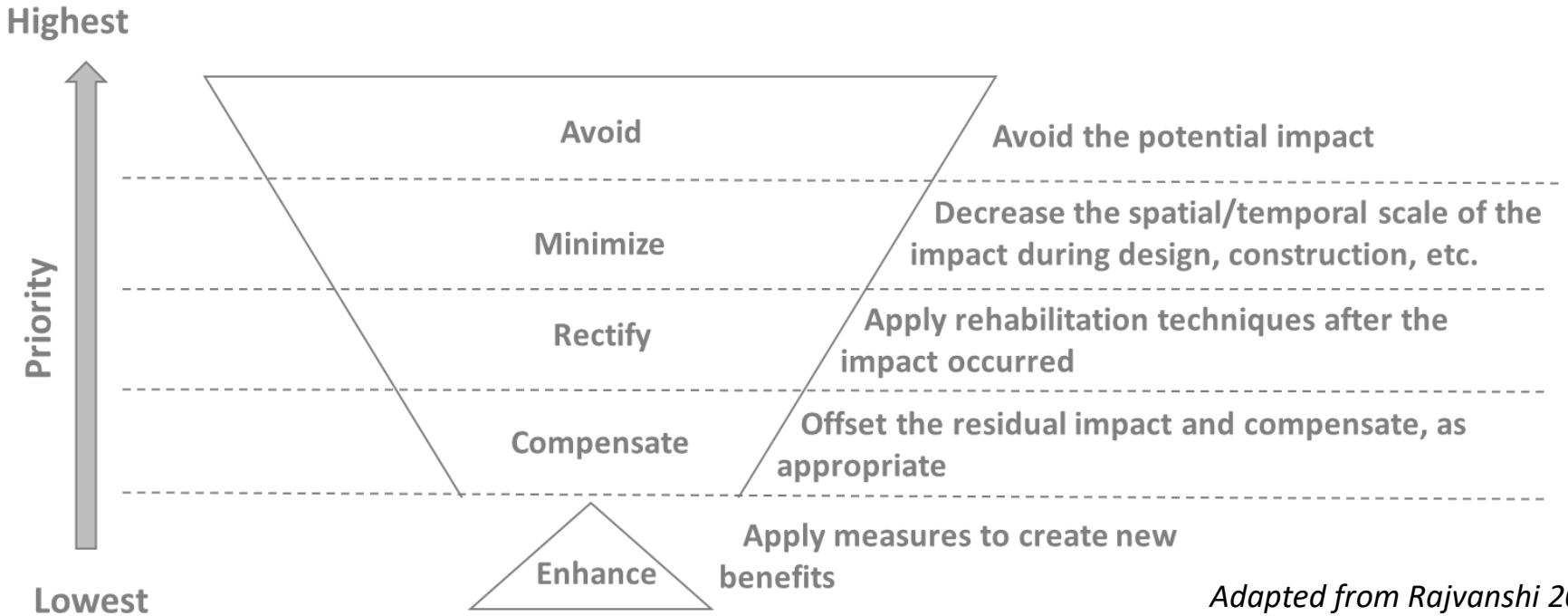

*Adapted from Rajvanshi 2008*



# Strategic measures to mitigate impacts of Highways on wildlife

**Structural:** Alter animal behavior e.g., Viaducts, Ropeway, Culvert, Passes, Fence, Canopy bridge

**Nonstructural:** Alter human behavior e.g., Ecological triage, Legal and policy instruments, Habitat Management, Plantation, Traffic management, Signage, Warning System

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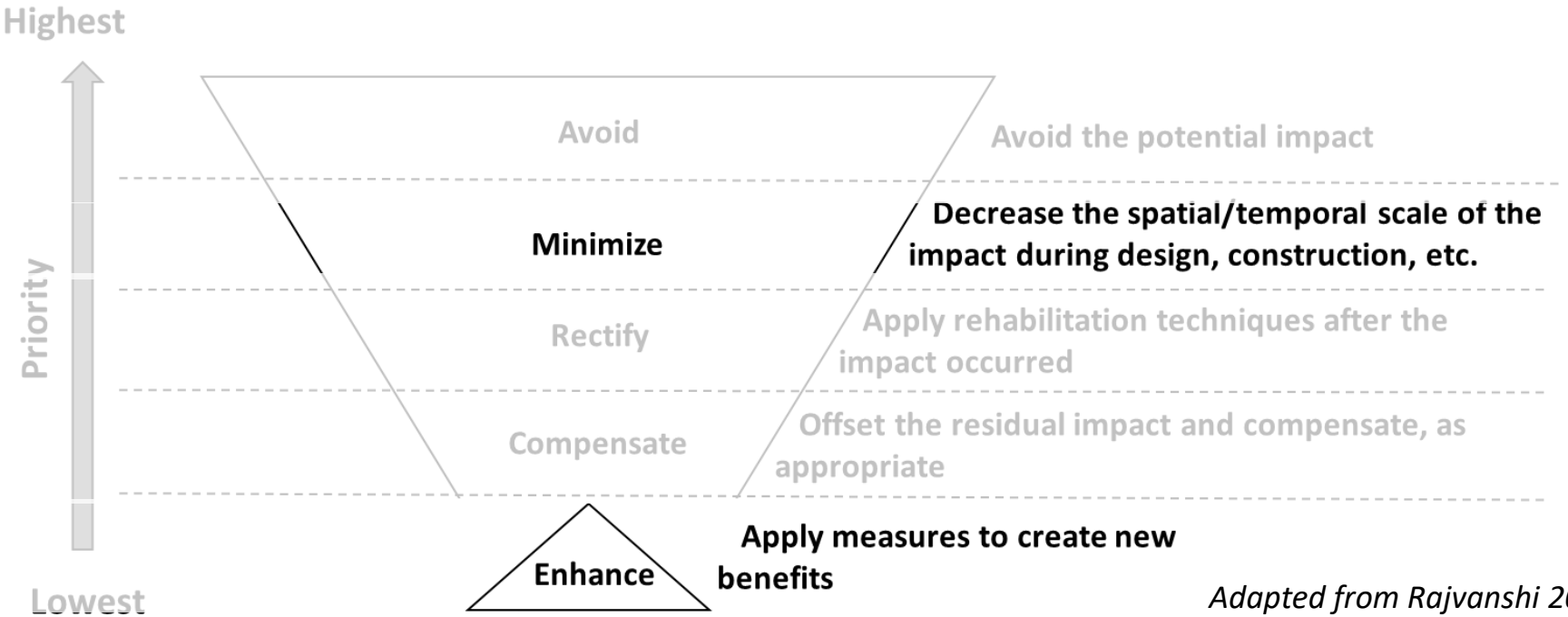
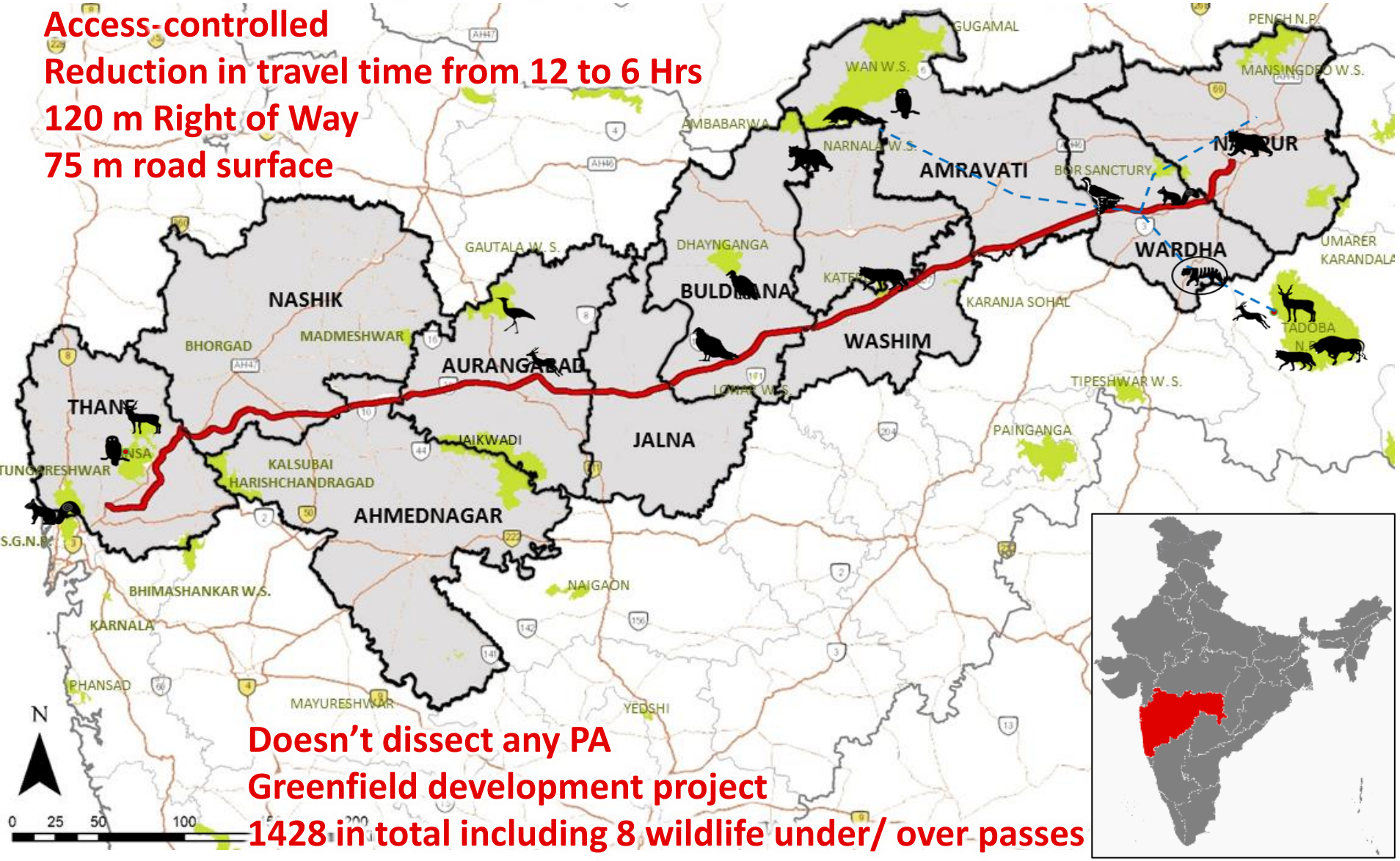



*Adapted from Rajvanshi 2008*

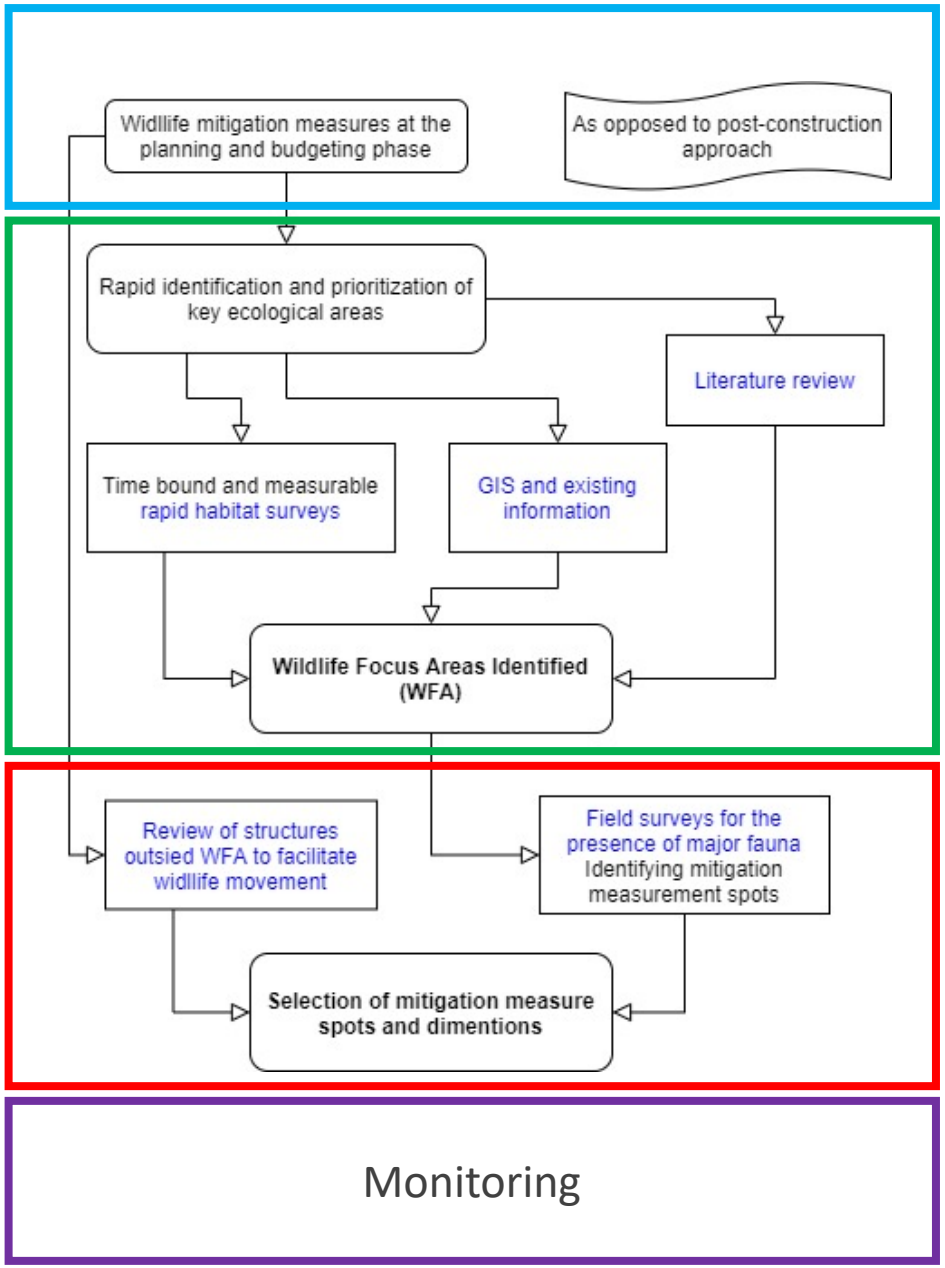
MAHARASHTRA
SAMRUDDHI
MAHAMARG

701 km long 8 lane expressway
Access-controlled
Reduction in travel time from 12 to 6 Hrs
120 m Right of Way
75 m road surface




Doesn't dissect any PA
Greenfield development project
1428 in total including 8 wildlife under/ over passes

# Process formulation




1

Consideration in planning phase

2

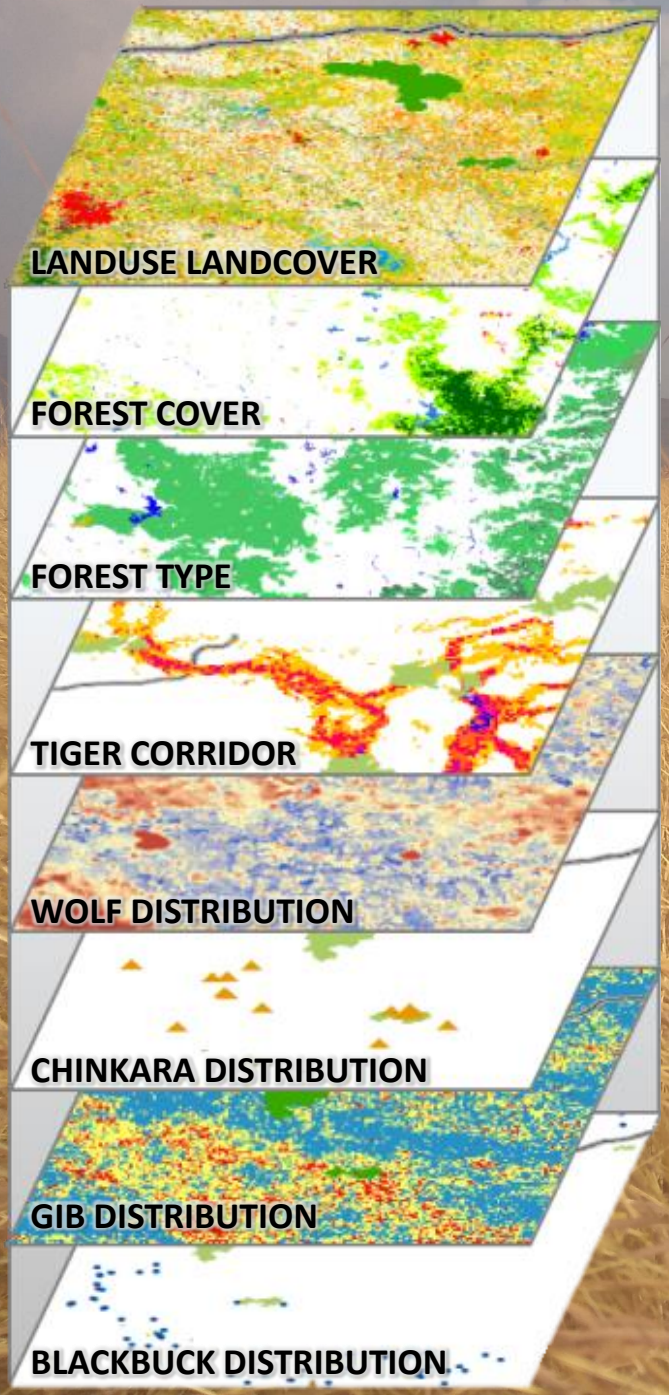
Identification of "**Go"/** "**No-go"** areas to avoid delays in project implementation

3

Field surveys, data analysis and prescription of mitigation measures

4

Simultaneous and post-construction monitoring




## Remotely sensed Indicators for prioritizing segments for assessment and mitigation

- Adjacency to **PAs** or **Eco-sensitive zones**
- Habitat of **Tiger** and key **prey** species
- Presence or **probable habitat** of **conservation priority species**
- **Priority habitats** with **high endemism in plants and lower taxa**

# Reconnaissance survey

Data on **habitat**, **animal sightings** (direct or indirect), **road kills** and **public questionnaire surveys** through ***ad-libitum*** sampling

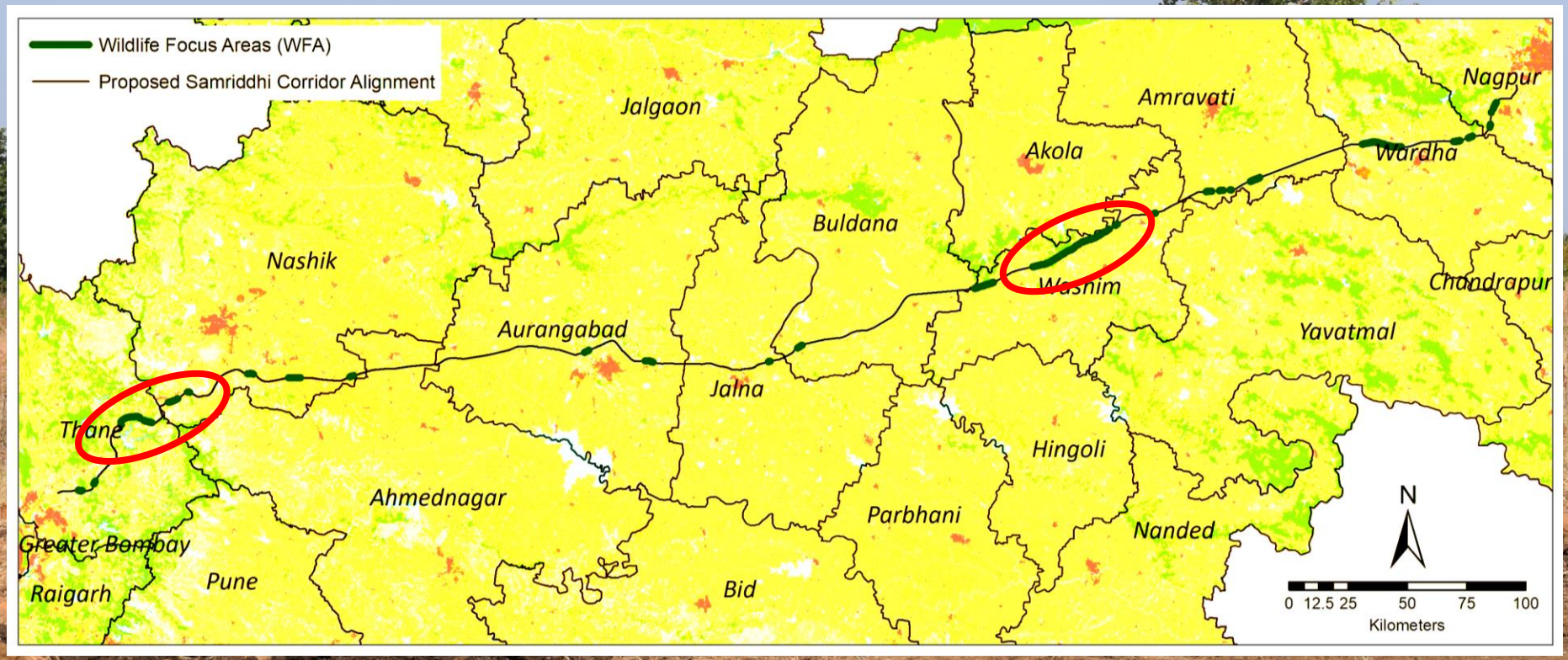
**Joint visits** to the sites along with **forest officials** and **road agency engineers** from the construction contractor

**Plans and drawings** were consulted to visualize the proposed road in three dimensions

# Identification of Wildlife Focus Area

A **hierarchical approach** was adopted to arrive at the WFAs

A total of **117.73 km** long stretch was identified as **the wildlife focus areas (WFA).** They occur in **35** discrete segments.

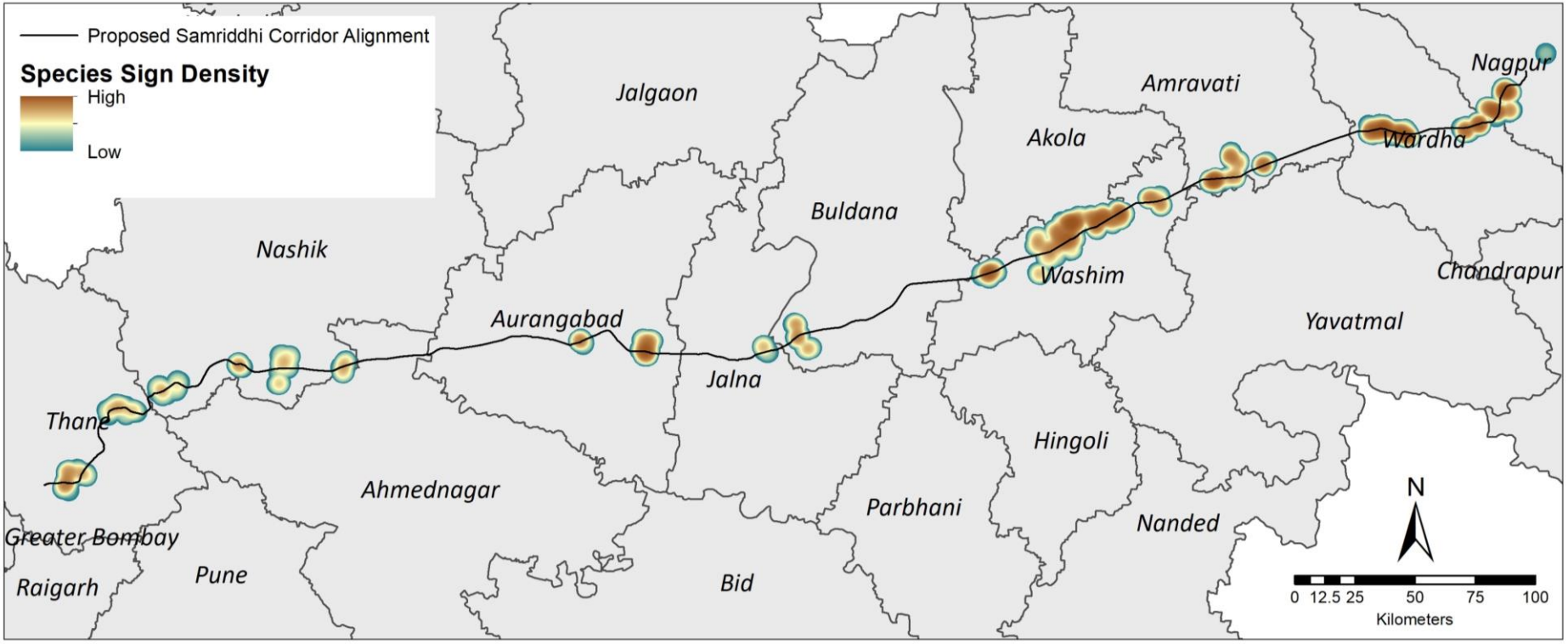


# Detailed sign survey in WFAs

*Results*

We generated ***intensity maps of animal signs*** to identify the critical locations on the alignment where mitigation measures are required.

## Species sign density hotspots



# Mitigation measures

The suggestions were made in consideration of ***species sign density***, ***surrounding habitat***, ***topography*** and ***land use land cover*** to avoid ***anthropogenic interference*** and ensure ***habitat connectivity*** across the landscape

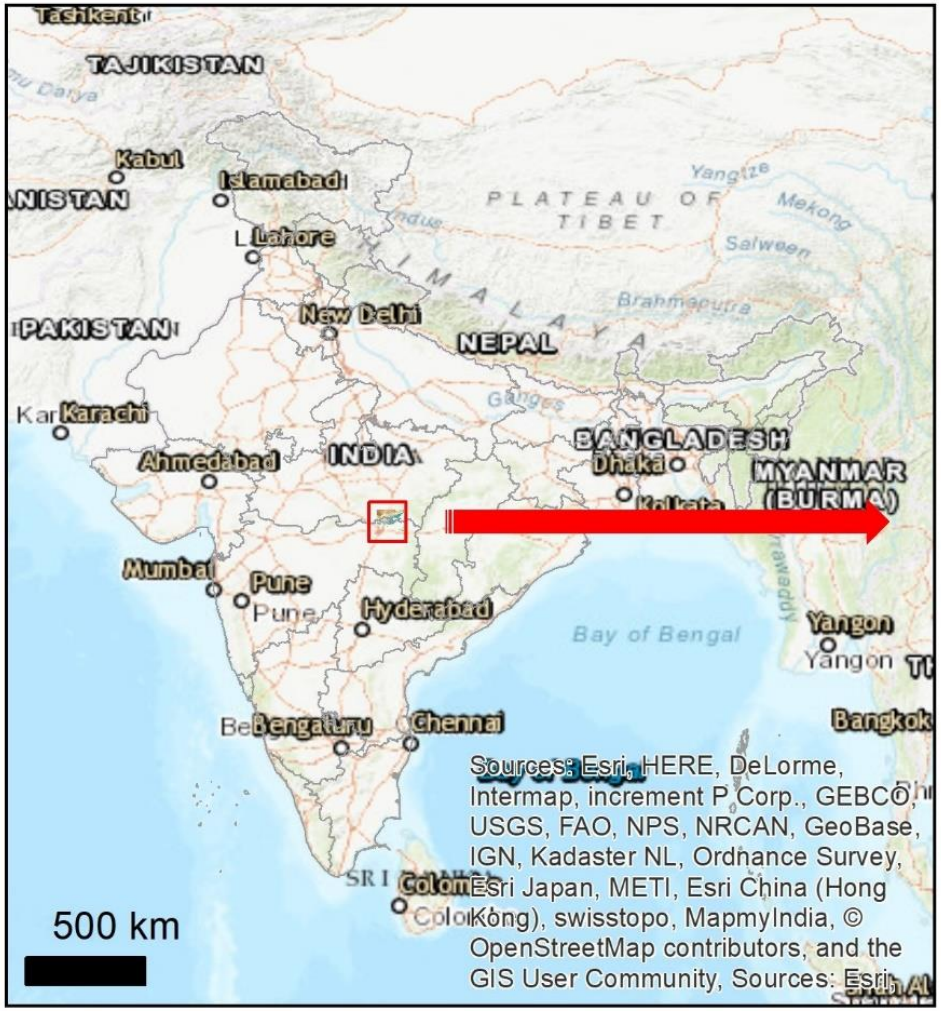
| Structure Type | Within WFA | Outside WFA |
|---|---|---|
| Box Culvert | 109 | 518 |
| Canal Bridge | 1 | 18 |
| LVUP/Cart Track | 26 | 235 |
| CUP/PUP/POP | 44 | 180 |
| Major Bridge | 5 | 26 |
| Minor Bridge | 19 | 232 |
| Viaduct/Flyover | 19 | 45 |
| VUP/VOP/ROB | 46 | 216 |
| Wildlife Overpass | 7 | 2 |
| Wildlife Underpass | 17 | 25 |
| Tunnel | 2 | 5 |
| Total | 295 | 1502 |
| | 1797 | |

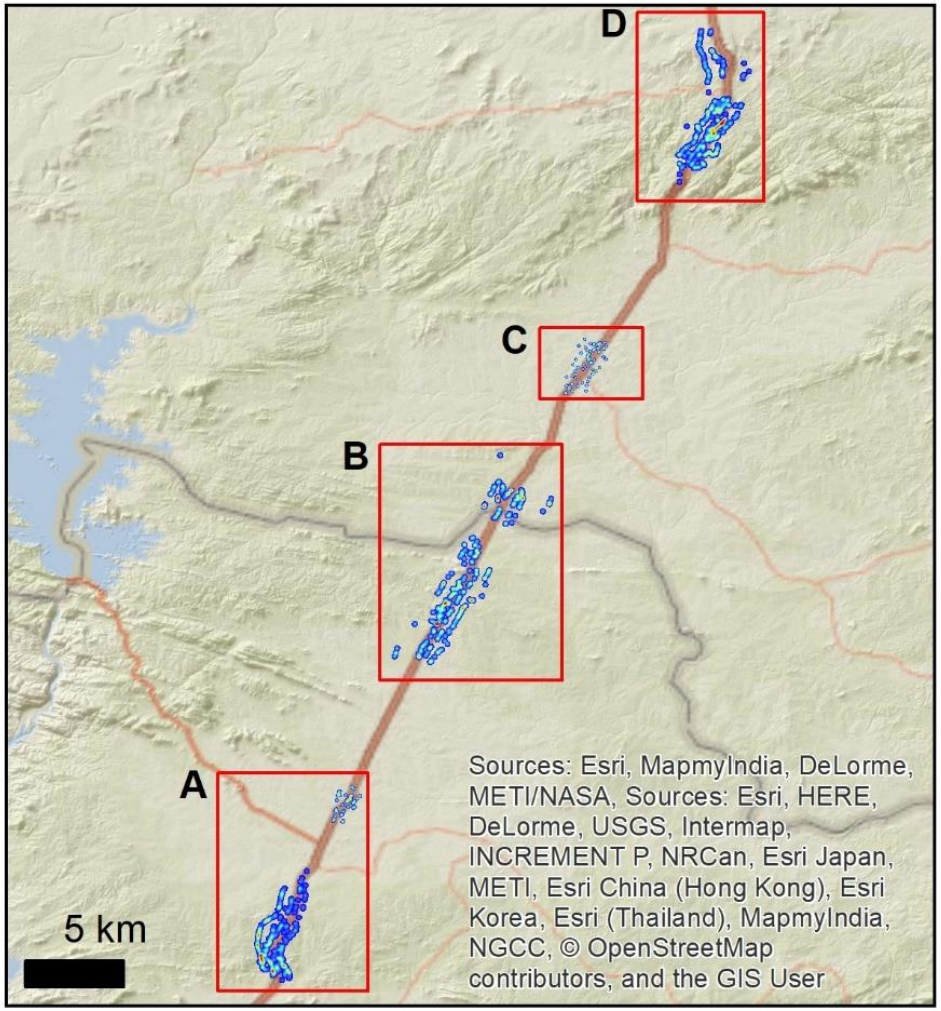
*Technical Report No. 2015/006*

# PROPOSED MITIGATION MEASURES FOR MAINTAINING HABITAT CONTIGUITY AND REDUCING WILD ANIMAL MORTALITY ON NH 6 & 7 IN THE CENTRAL INDIAN LANDSCAPE

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

May, 2015


Tashkent
TAJIKISTAN
Kabul
Islamabad
PLATEAU OF TIBET
Yangtze
Mekong
Salween
Brahmaputra
Lahore
New Delhi
PAKISTAN
NEPAL
Karachi
Ganges
BANGLADESH
Dhaka
INDIA
Ahmedabad
MYANMAR (BURMA)
Kolkata
Mumbai
Pune
Hyderabad
Bay of Bengal
Yangon
Bangkok
Bengaluru
Chennai
Colombo
500 km
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community, Sources: Esri,


D
C
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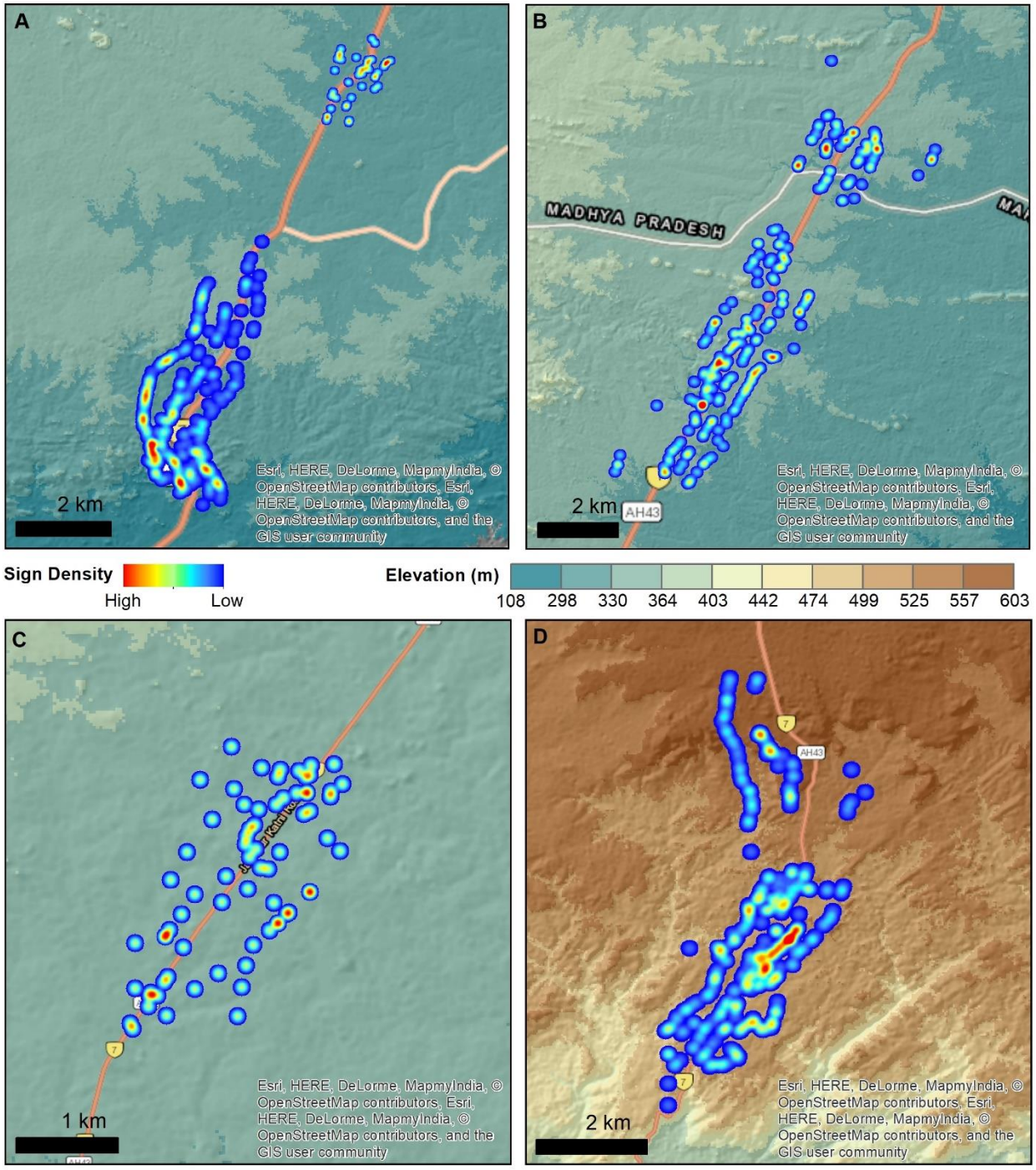
A
2 km
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community
B
MADHYA PRADESH
2 km
AH43
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Sign Density
High
Low
Elevation (m)
108 298 330 364 403 442 474 499 525 557 603
C
1 km
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D
AH43
2 km
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**Smart integration of wildlife conservation concerns**
**Intelligent formulation of policies**

# Wildlife Habitat Connectivity Modelling

# Steps to approach a connectivity analysis

## 1. Data Selection

- Species selection (consideration of scale)
- Habitat covariate selection
- Data selection (remotely sensed data, primary field data, open access data)
- Data preparation

## 2. Model parameterization

- Model parameterization (empirical approach, expert opinion)
- Final cost surface

## 3. Connectivity modelling

- Corridor mapping
- Barrier mapping
- Corridor prioritization

# Tiger corridors of Vidarbha, Central India


# *Data used….*

- Species data:
  - *Tiger presence data (sign survey, camera trap)*
  - *Tiger tracking data*
- Habitat covariate data:
  - *Normalized difference vegetation index (NDVI)*
  - *Distance from roads*
  - *Land use*
  - *Livestock population*
  - *Terrain ruggedness*
  - *Annual precipitation*
  - *Distance from forest*
  - *Distance from Protected Areas*
  - *Annual mean temperature*

# *Model parameterization and combination*

***Habitat Suitability Index***

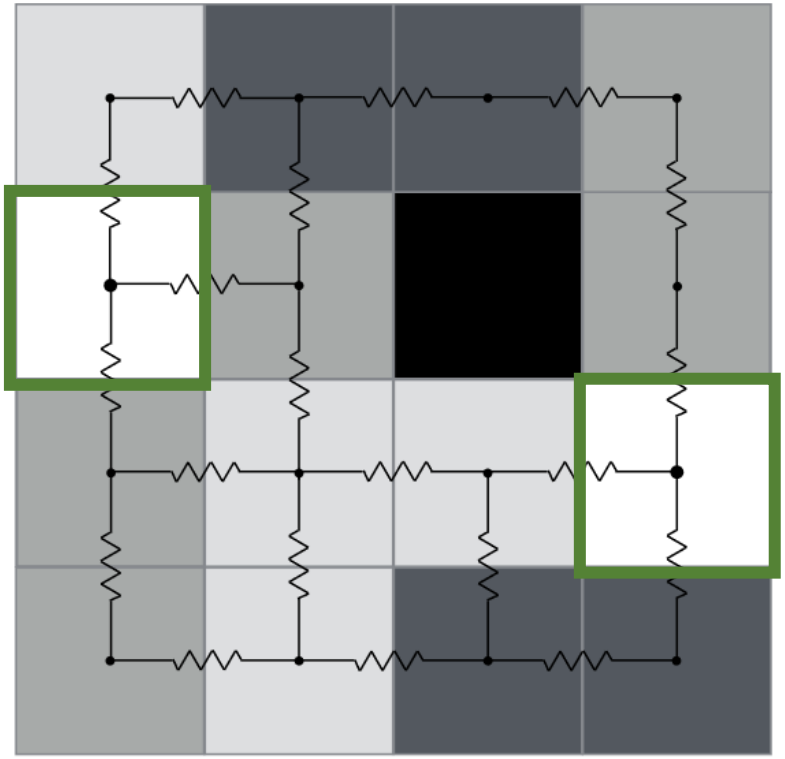
**MAXENT Model**

*Proxy for habitat permeability (cost)*

Circuit Theory

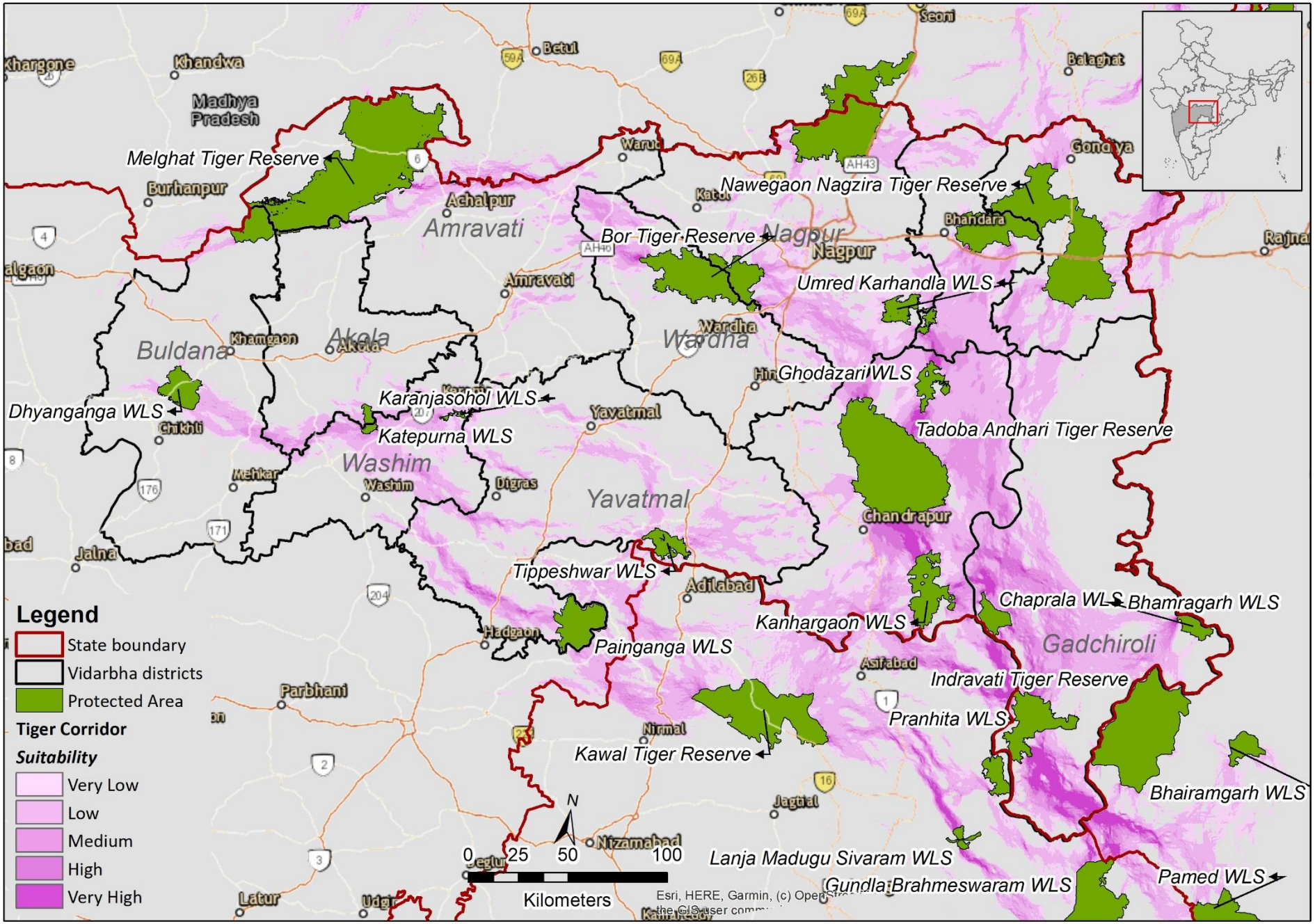
# *Circuit Theory*

- Habitats patches (Protected areas) = nodes
- Connectivity (corridors) = linear edges (resistors as in electronic circuit).
- RESISTANCE (Ω) = amount of resistance offered by the landscape to the movement of an animal from one node to the other.
- Current values → To identify landscape corridors, features through which dispersers have a high likelihood of passing.



(McRae 2006; McRae and Beier 2007; McRae et al. 2008; Shah and McRae 2008)

# Tiger Corridor Map of Vidarbha, Central India

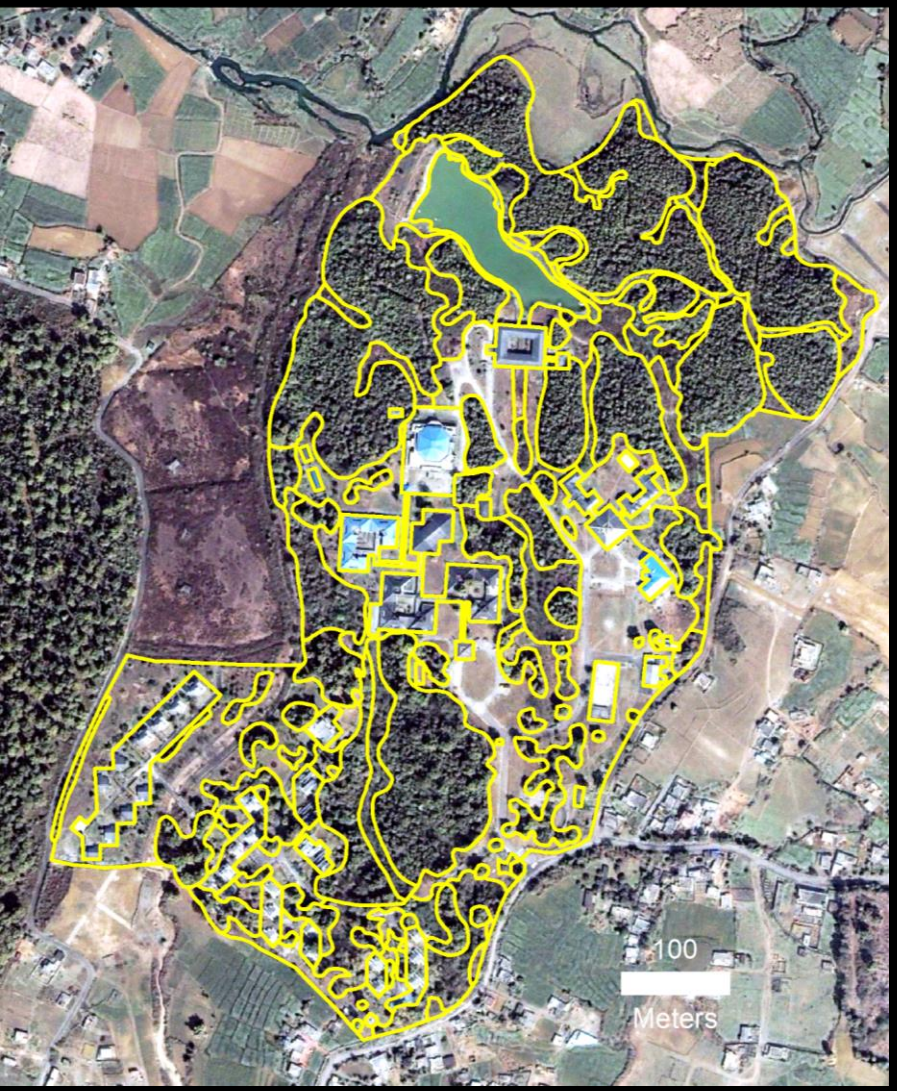


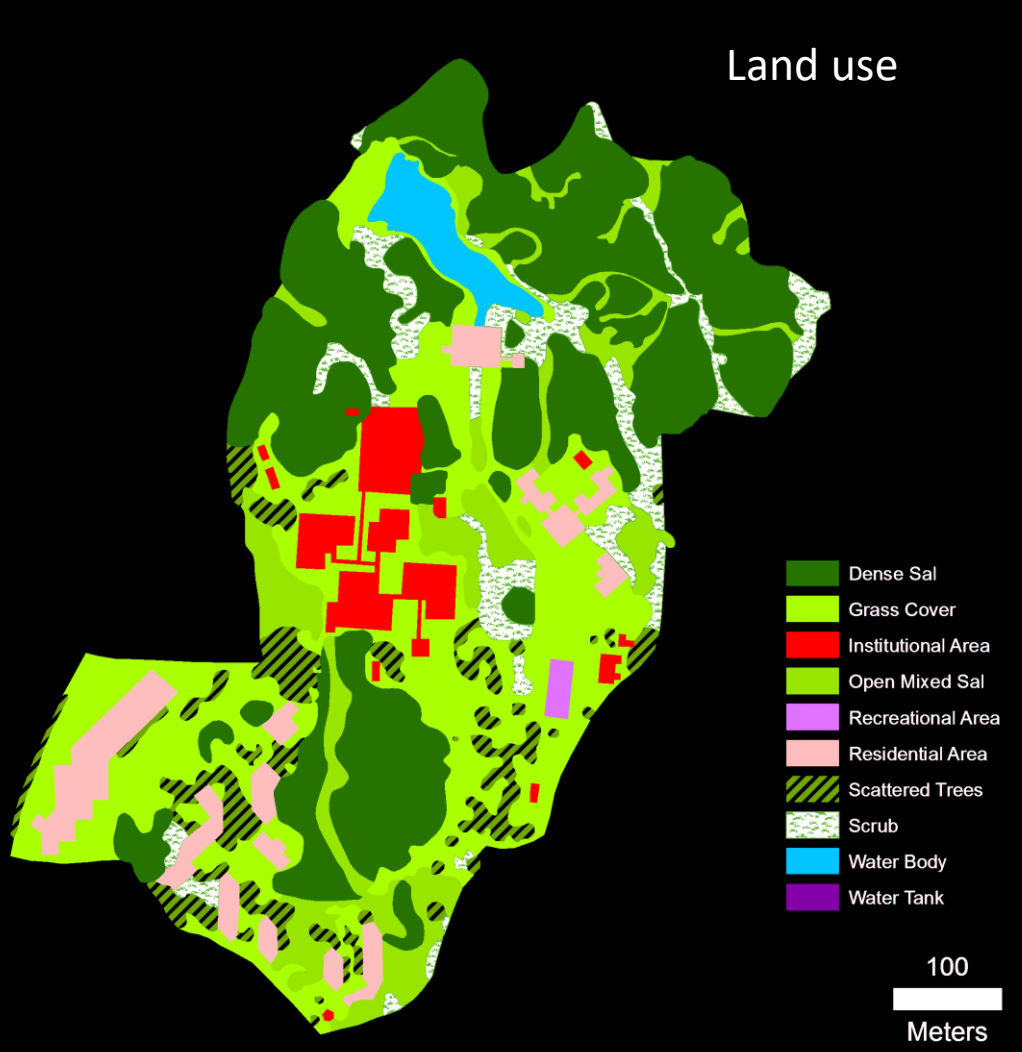
# Fine scale movement corridors for the Tricarinate Hill-turtle

# *Data used….*

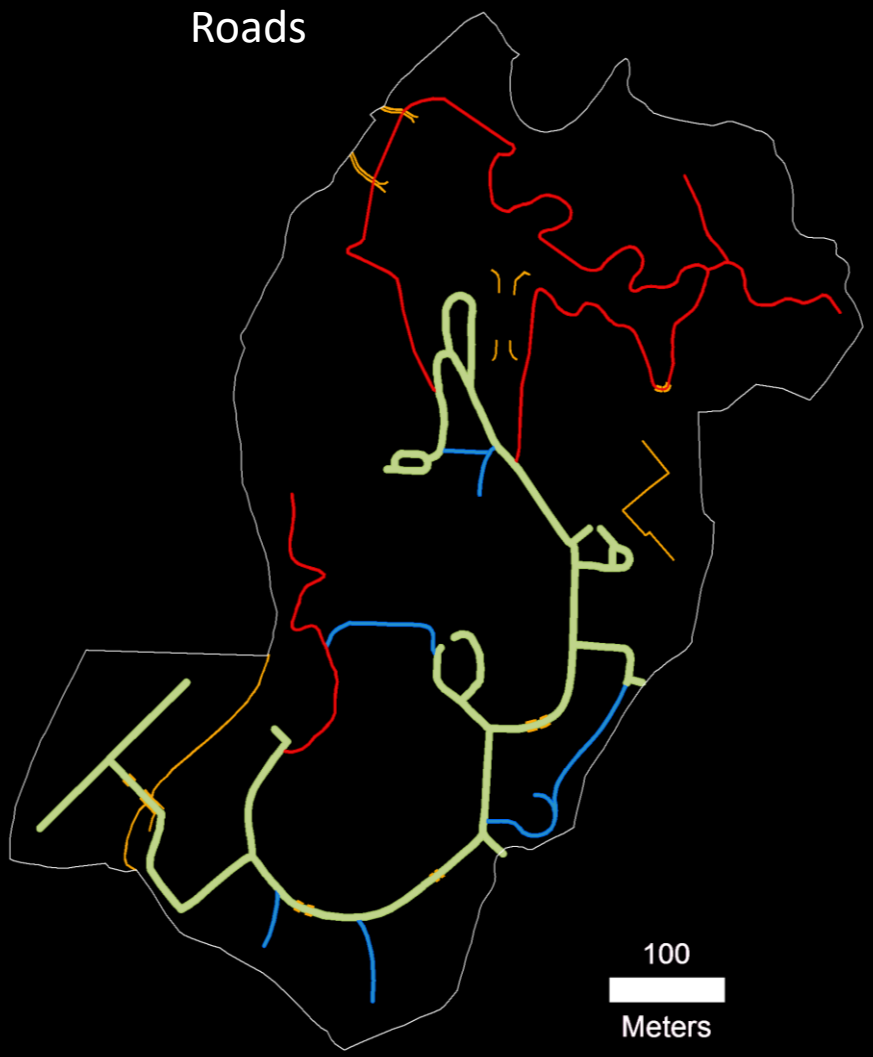
- Habitat (mapped from 0.5m satellite imagery)
- Roads (mapped using handheld GPS unit)
- Resource (food)
- Slope (mapped from contours generated from ground surveys)

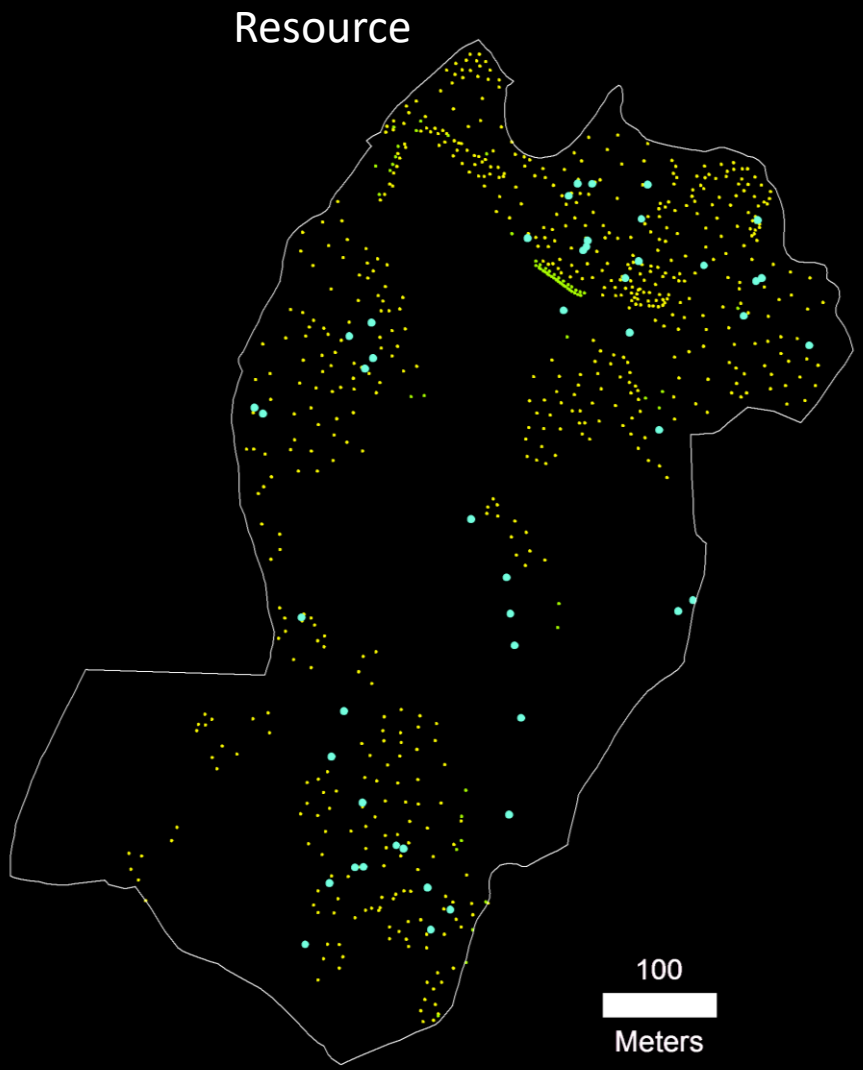
# Fine-scale habitat covariate generation



# Fine-scale habitat covariate generation



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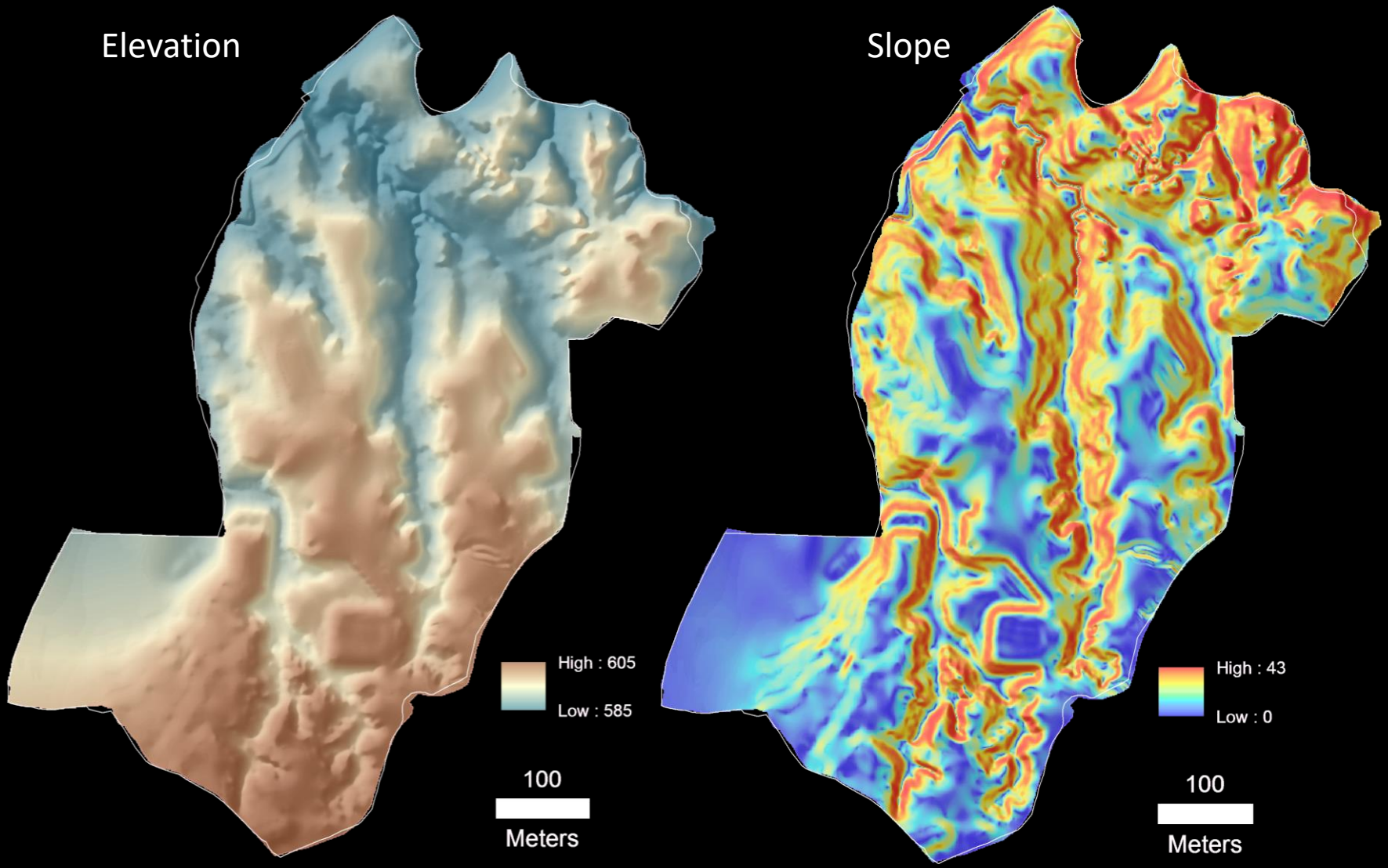


# Parameterization of conductance values

*(Expert opinion)*

| Cover type | Conductance | Cover type | Conductance | Cover type | conductance |
|---|---|---|---|---|---|
| Dense sal | 10 | Open Mixed sal | 8 | Scrub | 7 |
| Scattered trees | 3 | Grass cover | 1 | Waterbodies | 2 |
| Buildings | 0 | Road(6m) | 0 | Road(3m) | 2 |
| Nature trail | 8 | | | | |

| Resource | Conductance |
|---|---|
| Lantana | 0 |
| Carrisa and Jasmnium | 5 |
| Earthworms | 8 |
| | |

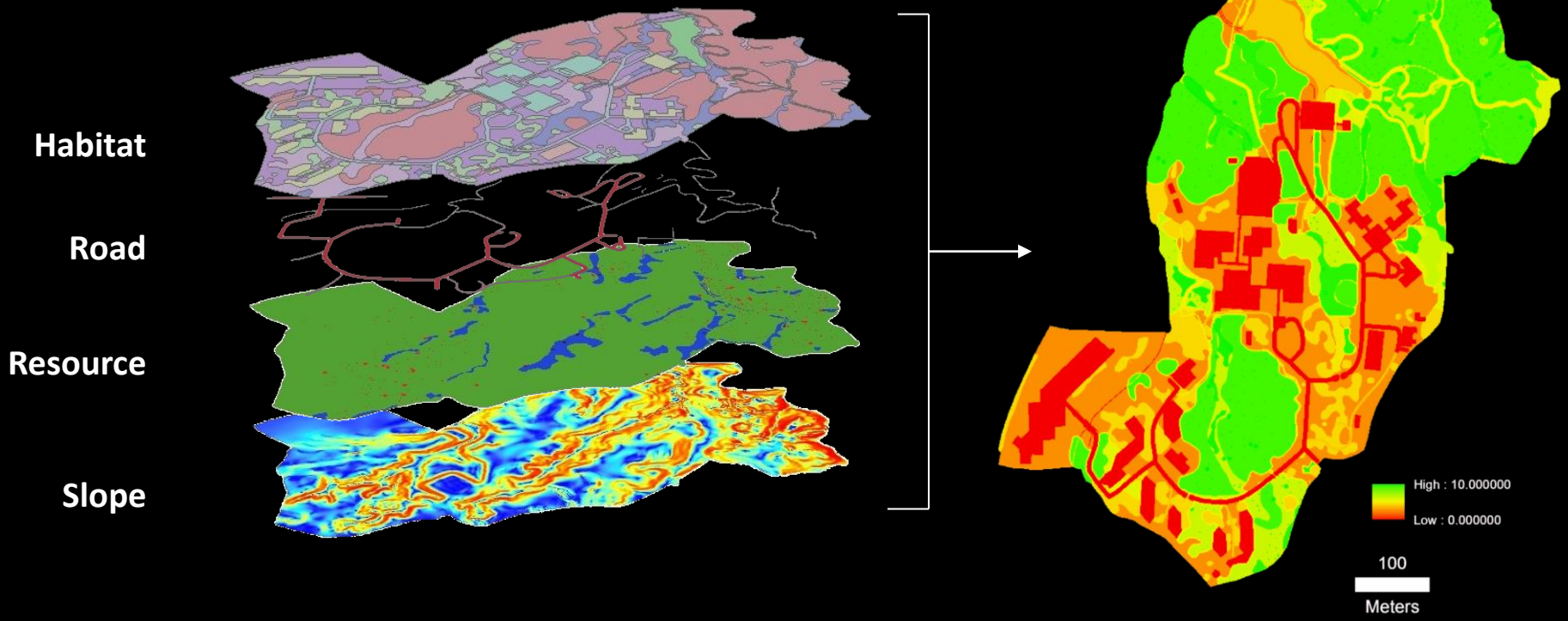
| Slope (degrees) | Conductance |
|---|---|
| 0 to 30 | 7 |
| > 30 | 4 |

***(Spear et al. 2010; Store 2001)***

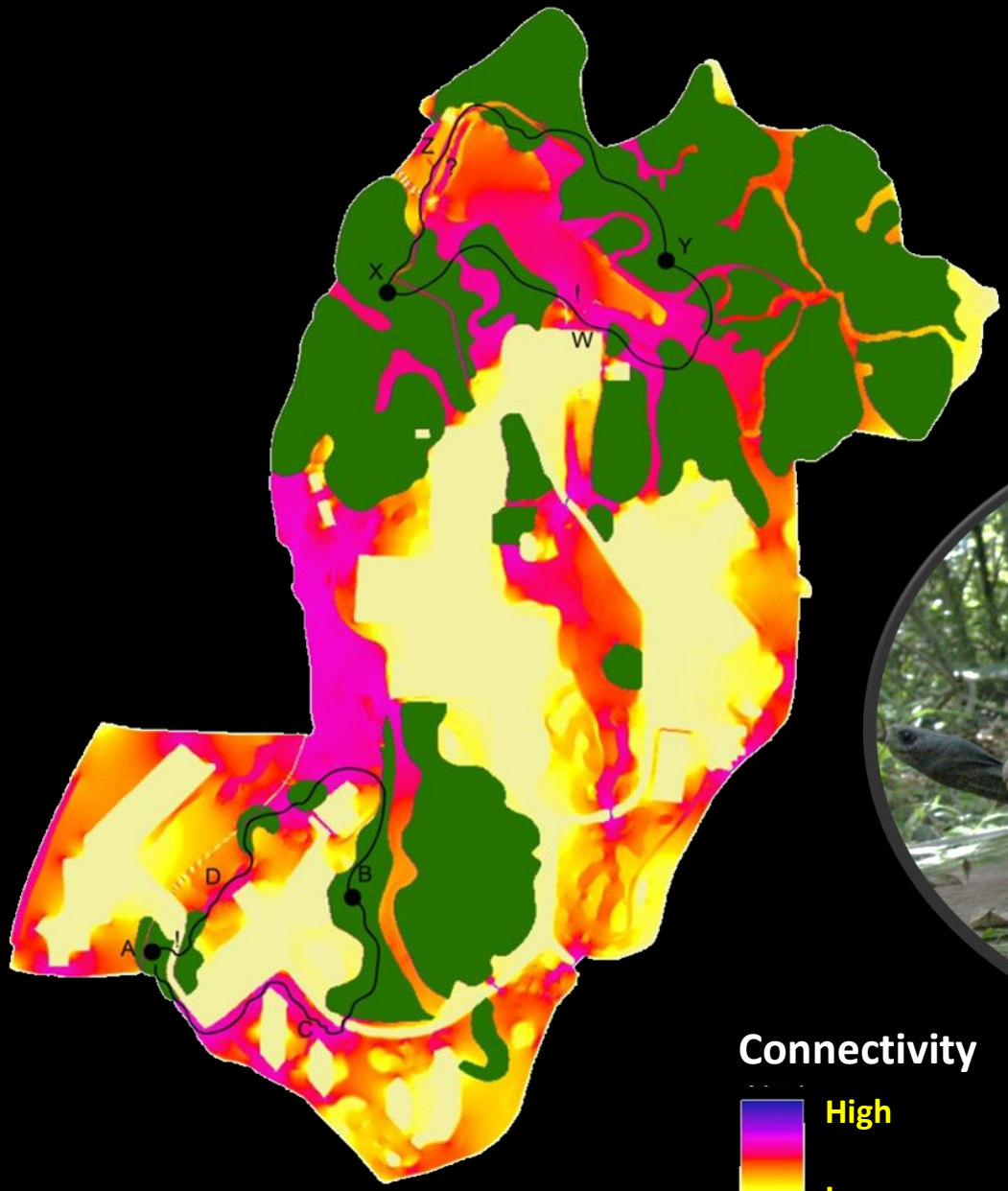
# Generation of final cost surface

AHP - Analytic Hierarchy Process (Saaty 1970)

Cost surface



# Fine scale connectivity map





**Connectivity**

**High**

**Low**

# ACKNOWLEDGEMENTS

Director & Dean, WII

National Tiger Conservation Authority

Maharashtra State Road Development Corporation (MSRDC)

Maharashtra State Forest Department

Asian Development Bank

*Thank you*