Assessment of Wildlife Connectivity inside a Protected Area Using Circuit Theory Approach

Amrapali Tiwari[1], Amrapali Tiwari1[2], Sameer Saran1[1], and Kirti Avishek2[2]

[1]Affiliation not available
[2]Department of Civil and Environment Engineering BIT Mesra, Kirti Avishek, BIT Mesra

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Amrapali Tiwari[1,2], Sameer Saran[1], Kirti Avishek[2],

[1]*Geoinformatics Department, Indian Institute of Remote Sensing Dehradun India,*

Amrapali Tiwari, IIRS, ISRO Dehradun, tiwariamrapali61294@gmail.com

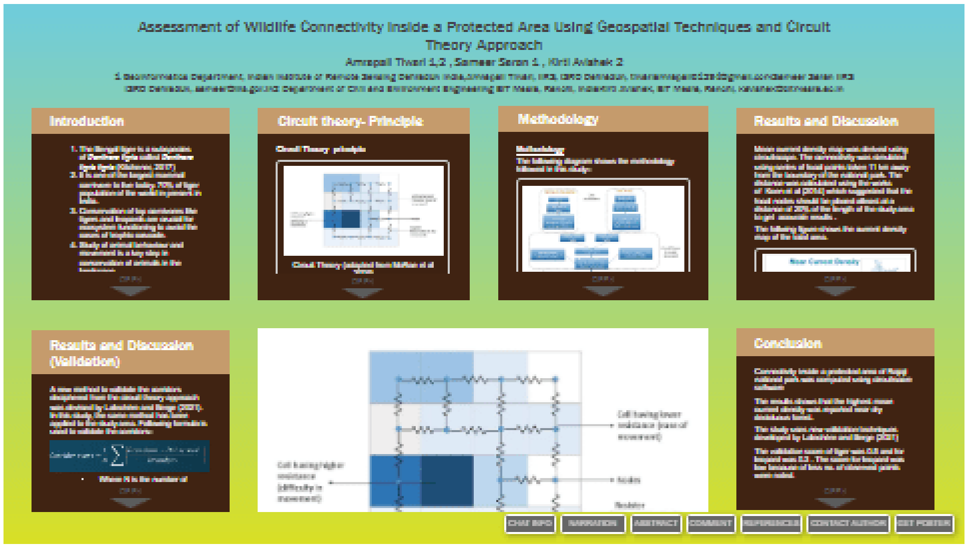
Sameer Saran IIRS ISRO Dehradun, sameer@iirs.gov.in

[2] *Department of Civil and Environment Engineering BIT Mesra, Ranchi, India*

Kirti Avishek, BIT Mesra, Ranchi, kavishek@bitmesra.ac.in

Animal behaviour such as dispersal and migration ensure their survival in the landscape. It has been established in the past few decades that wildlife conservation and study of their movement in the wilderness is vital for sustainable ecosystem. Thus, identification of regions having high movement permeability for planning and maintenance of functional wildlife corridors has turn out to be a fundamental requirement for habitat management. This study emphases on movement of big cats- Bengal Tiger (*Panthera tigris tigris*) and Leopard (*Panthera pardus fusca*) in the protected area of Rajaji National Park situated in Uttarakhand State of India. The National park is a designated tiger reserve with large amount of tigers and leopards at its disposal. Here, Circuitscape was used to generate connectivity map of the study area. The results were validated using occurrence points downloaded from GBIF. The habitat suitability and resistance of the landscape was estimated based on literature review and expert opinion survey. Since, both the species have comparable ecological niche, similar habitat parameters were used for generation of resistance map of the species. Occurrence points for the species were downloaded from GBIF. 60% of the points were used as nodes or focal points where species presence is recorded whereas 40% of the points were used in validation of the connectivity paths. Results depicts the current density map of the study area highlighting areas with high connectivity for the species.

Assessment of Wildlife Connectivity inside a Protected Area Using Geospatial Techniques and Circuit Theory Approach



Amrapali Tiwari 1,2 , Sameer Saran 1 , Kirti Avishek 2

1 Geoinformatics Department, Indian Institute of Remote Sensing Dehradun India,Amrapali Tiwari, IIRS, ISRO Dehradun, tiwariamrapali61294@gmail.comSameer Saran IIRS ISRO Dehradun, sameer@iirs.gov.in2 Department of Civil and Environment Engineering BIT Mesra, Ranchi, IndiaKirti Avishek, BIT Mesra, Ranchi, kavishek@bitmesra.ac.in

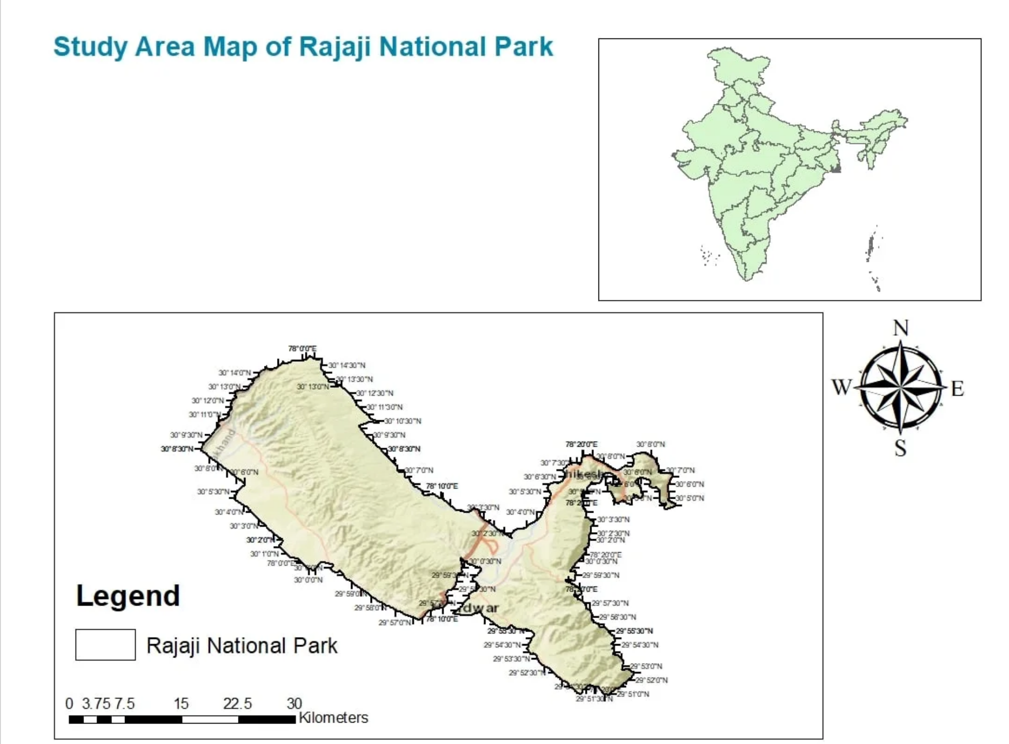
PRESENTED AT:

INTRODUCTION

1. The Bengal tiger is a subspecies of *Panthera tigris* called *Panthera tigris tigris* (Kitchener, 2017)
2. It is one of the largest mammal carnivore to live today. 70% of tiger population of the world in present in India.
3. Conservation of top carnivores like tigers and leopards are crucial for ecosystem functioning to avoid the cases of trophic cascade.
4. Study of animal behaviour and movement is a key step in conservation of animals in the landscape.

In this study, movement of top carnivores like tigers and leopard are studied. Circuitscpe is used to model the connectivity of tigers in rajajji National Park of Utarakhand state of India.

Study Area



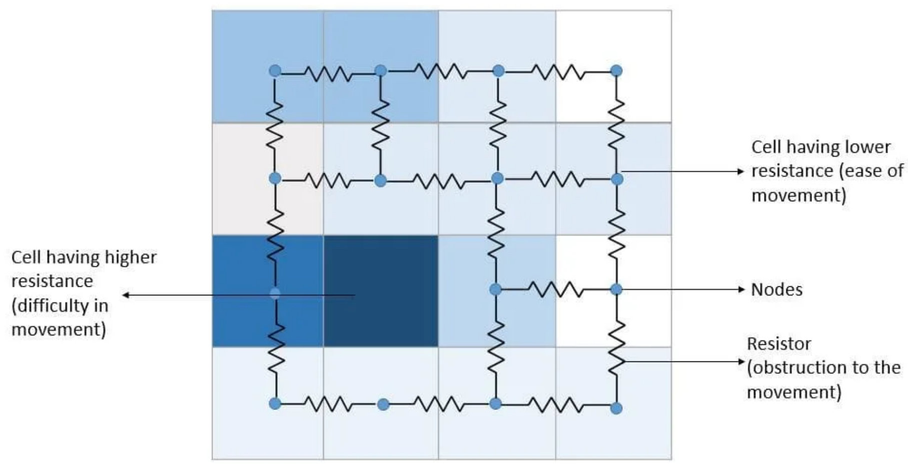
Study Area Map

Rajaji National park

Rajaji national park is spread in the area of 390 km2 in shivalik foothills. It is spread across Haridwar, Dehradun and Pauri districts of Uttarakhand. Vegetation in the area is usually tropical moist deciduous forest with vegetation like Terminalia bellirica (Bahera), Shorea robusta (Sal), Mallotus phillipinensis (Rohini), Acacia catechu (Khair), Ficus bengalensis (Bar) and Dalbergia sissoo (Shisham), Adina cordifolia (Haldu). It is a natural habitat of Asian elephants (Elephas maximus). Other animals found in the national park are Axis axis (Spotted deer), Cervous unicolor (Sambhar), Sus scrofa (Wild boar) Ophiophagus hannah (King cobra) Muntiacus muntjak (Barking deer) Panthera tigris (tiger), Panthera pardus (leopard) and Hyaena hyaena (Hyaena) (R. Joshi, 2009)

CIRCUIT THEORY- PRINCIPLE

Circuit Theory- principle



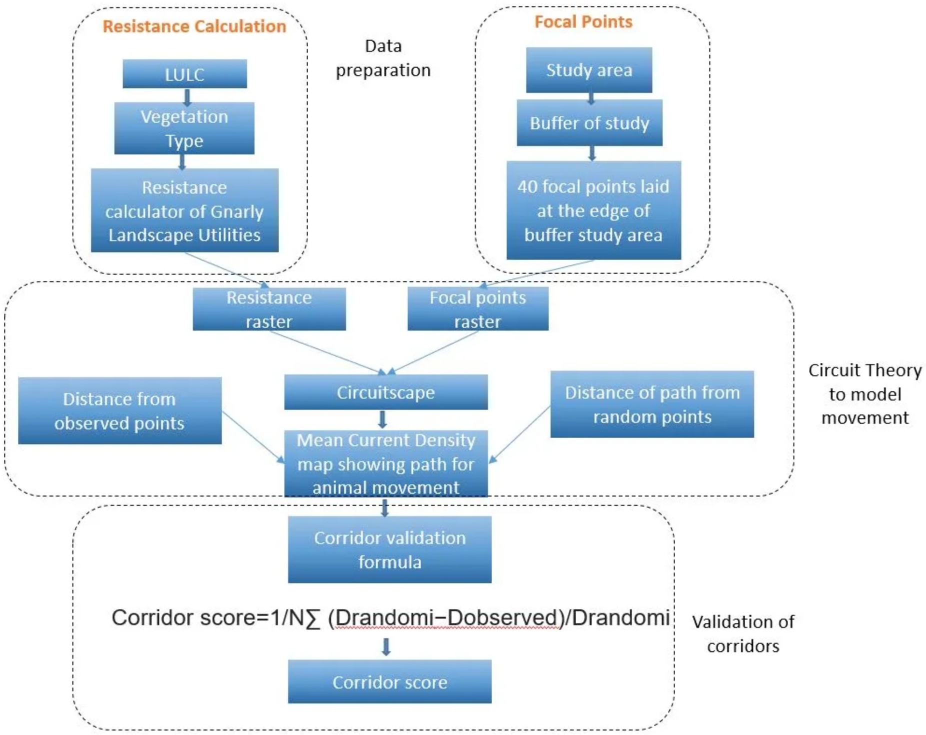
Circuit Theory (adapted from McRae et al 2009)

In circuit theory, an analogy is made between flows of current in the electrical circuits with the movement of organisms in ecological landscapes. Electrical concepts of current, voltage, charge, resistance applies here. Laws governing the flow of current is used to develop an understanding of animal movement in the landscape (Carroll et al., 2012). According to McRae et al. resistance in the electrical circuit is interpreted as obstructions present in the path of animals and conductance of electrical circuit as habitat permeability. Current flowing through the circuit can be used to compute the expected probabilities of movement of random walkers. Voltage or potential difference is used to predict the probability that random walkers would leave any point in the landscape and reach the destination before another.

METHODOLOGY

Methodology

The following diagram shows the methodology followed in this study:-



Methodology used in the study

In this study, circuit theory is used to compute the connectivity inside the Rajaji National park.

Resistance

Land use and vegetation type are considered primary parameters that are used to optimize the resistance surface for the study area. The gnarly Landscape utility toolbox is used to execute the process. The resistance surface indicates the amount of resistance incurred by the animal while moving across the landscape.

Focal Points

Focal points are the regions between which connectivity is to be modeled. For this study, firstly a buffer of 20% of the length of the rectangular study area was taken around the study area. Focal points were taken at the boundary of the buffer region. This step was particularly important to reduce the biases caused by placing the focal points at the boundary of the study area (Koen et al.,2014).

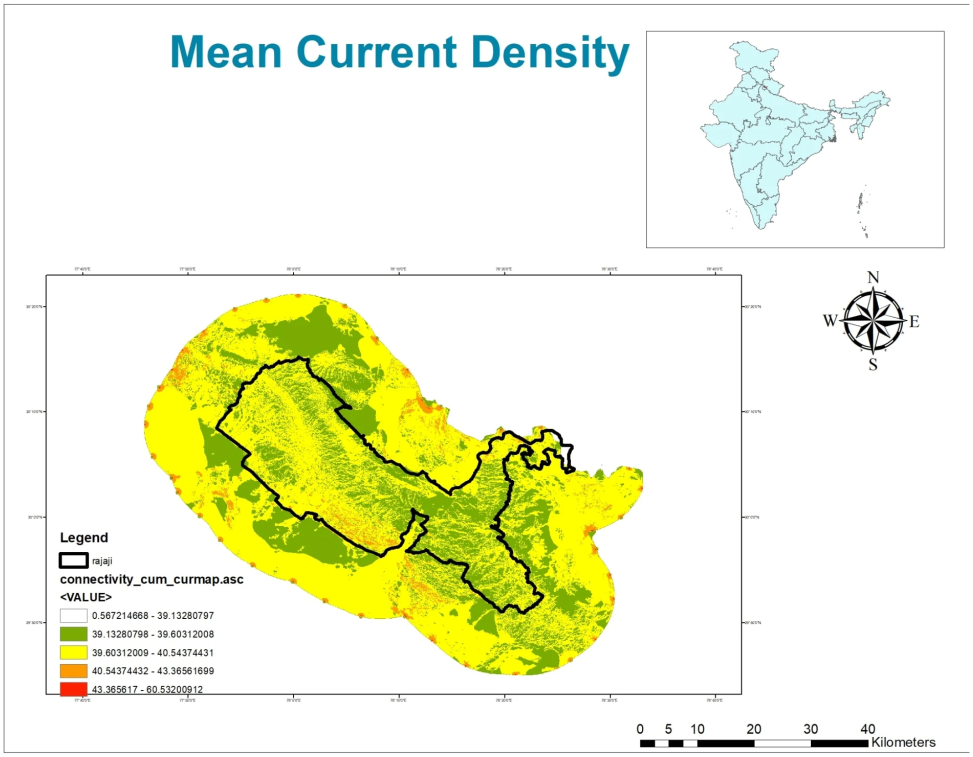
Circuitscape

Circuitscape uses the circuit theory approach to model connectivity in the landscape. It uses resistance surface and focal points as input and gives mean current density as output. For this study, circuitscape was run in pairwise mode.

RESULTS AND DISCUSSION

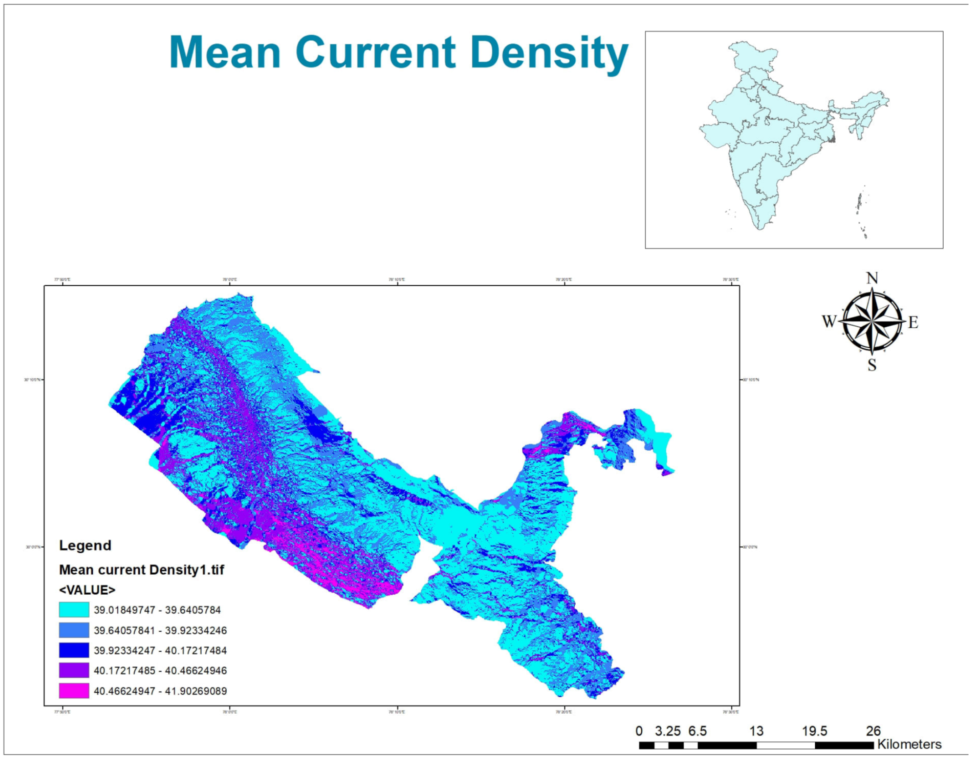
Mean current density map was derived using circuitscape. The connectivity was simulated using series of focal points taken 11 km away from the boundary of the national park. The distance was calculated using the works of Koen et al (2014) which suggested that the focal nodes should be placed atleast at a distance of 20% of the length of the study area to get accurate results .

The follwing figure shows the current density map of the total area.



Mean current density map with buffer area

The black boundary shows the boundary of the national park.



Mean current density map of the study area. For the delineation of corridors, a current density greater than 40 was taken into account

High current density is observed at the dry deciduous forest. The high current density areas also shows the 'pinch points areas' with respect to conservation of species. These are the areas where change in habitat loss or fragmentation could lead to complete loss of connectivity in the area.

RESULTS AND DISCUSSION (VALIDATION)

A new method to validate the corridors deciphered from the circuit theory approach was devised by Lalechère and Berge (2021). In this study, the same method has been applied to the study area. Following formula is used to validate the corridors:-

$$Corridor\ score = \frac{1}{N} \sum \left[\frac{Drandomi - Dobserved}{Drandomi} \right]$$

- Where N is the number of random draws i,
- Drandom i is the average cost distance (or Euclidean
- distance) to the corridors from randomly selected points in the landscape for draw i,
- Dobserved is the average cost distance (or Euclidean distance) to the corridors from the validation points

validation of the pathways for two carnivores:-

<u>For Tigers</u>:-

Observed points:100

Random points:100

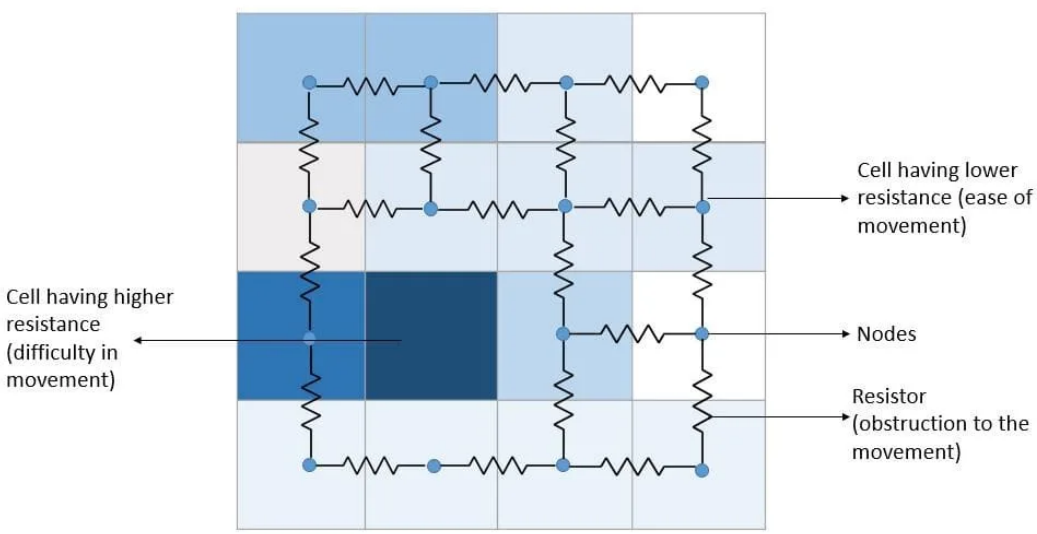
corridor score calculated for Tiger: 0.5

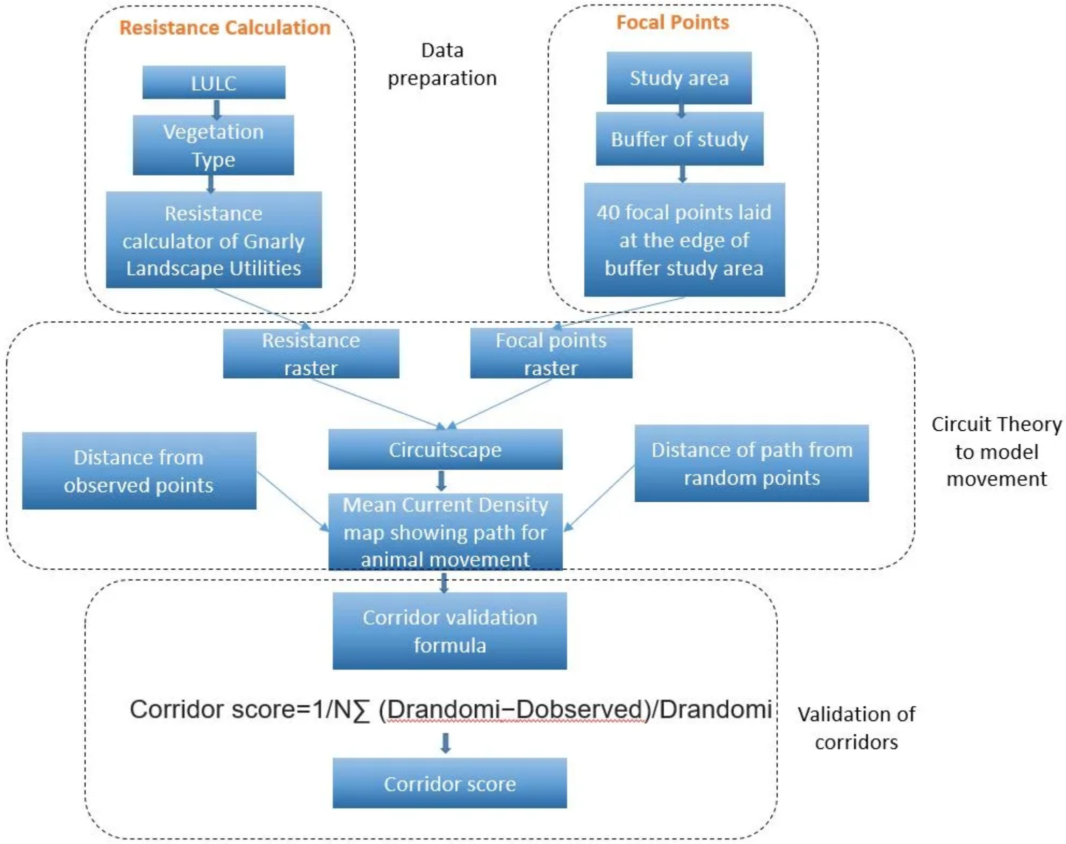
<u>For Leopards</u>:-

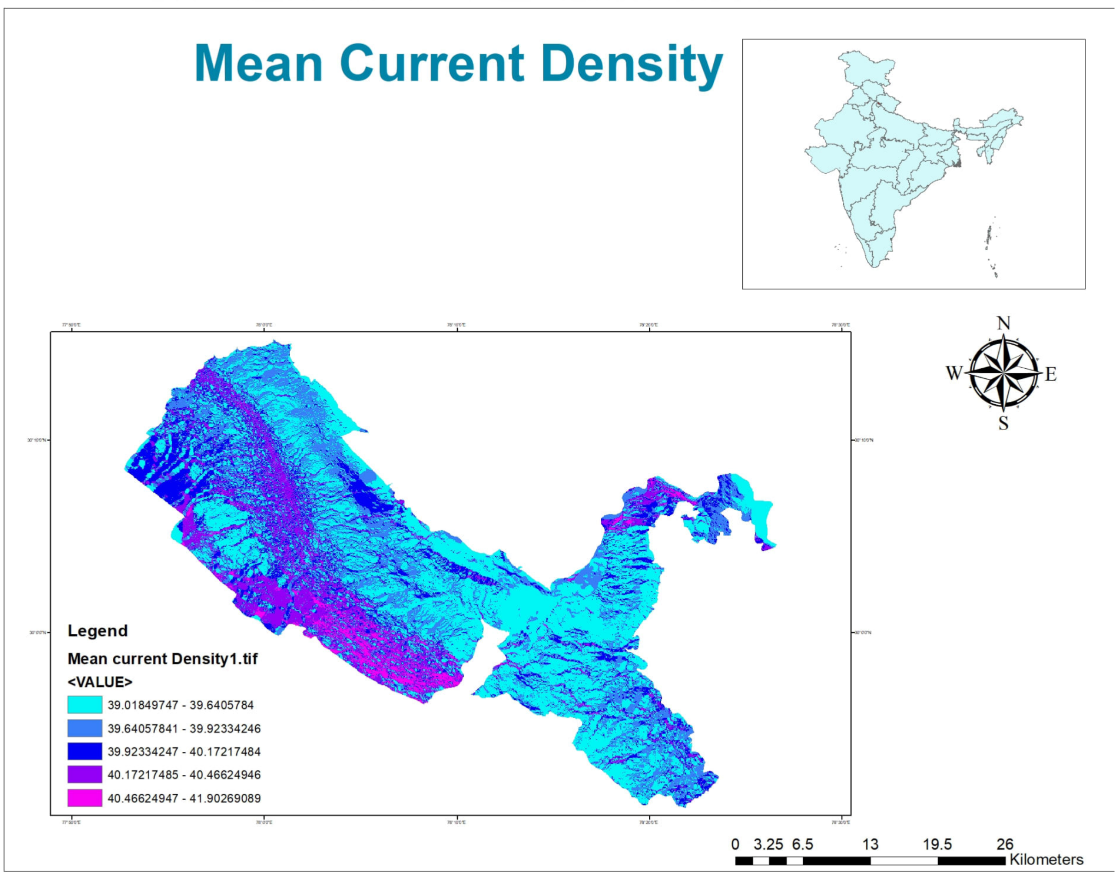
Observed points:20

Random points:20

Corridor score calculated for Leopard: 0.3




Resistance Calculation
LULC
Vegetation Type
Resistance calculator of Gnarly Landscape Utilities
Data preparation
Focal Points
Study area
Buffer of study
40 focal points laid at the edge of buffer study area
Resistance raster
Focal points raster
Circuitscape
Distance from observed points
Distance of path from random points
Mean Current Density map showing path for animal movement
Circuit Theory to model movement
Corridor validation formula
Corridor score=1/N∑ (Drandomi−Dobserved)/Drandomi
Validation of corridors
Corridor score


Mean Current Density
N
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Mean current Density1.tif
<VALUE>
39.01849747 - 39.6405784
39.64057841 - 39.92334246
39.92334247 - 40.17217484
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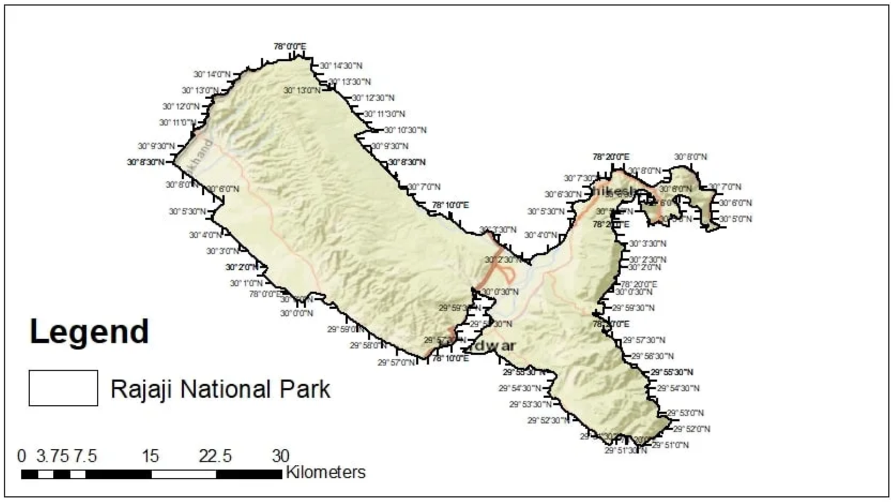
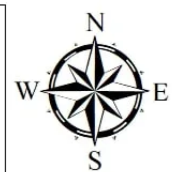
0 3.25 6.5 13 19.5 26
Kilometers

Study Area Map of Rajaji National Park





CONCLUSION

Connectivity inside a protected area of Rajaji national park was computed using circuitscare software

The results shows that the highest mean current density was reported near dry deciduous forest.

The study uses new validation techniques developed by Lalechère and Berge (2021)

The validation score of tiger was 0.5 and for leopard was 0.3 . The score for leopard was low because of less no. of observed points were noted.

Such studies are important in case of conservation biology because it helps in understanding connectivity inside the protected area and also between protected areas. Such studies are of paramount importance in addressing the cases of human animal conflicts.

ABSTRACT

Animal behaviors such as dispersal and migration ensure their survival in the landscape. It has been established in the past few decades that wildlife conservation and the study of their movement in the wilderness is vital for a sustainable ecosystem. Thus, the identification of regions having high movement permeability for planning and maintenance of functional wildlife corridors has to be a fundamental requirement for habitat management. This study emphasizes the movement of big cats- Bengal Tigers (*Panthera tigris tigris*) and Leopards (*Panthera pardus fusca*) in the protected area of Rajaji National Park situated in the Uttarakhand State of India owing to their influence on human-animal conflict in the region. The National Park is a designated tiger reserve with a large number of tigers and leopards at its disposal. In this study, Circuitscape was used to generate a connectivity map of the study area. The results were validated by calculating the corridor score using occurrence points downloaded from GBIF. The habitat suitability and resistance of the landscape were estimated using literature review/expert opinion survey and land use land cover maps generated from remote sensing satellite data of the study area. Since both the species have a comparable ecological niche, similar habitat parameters were used for the generation of a resistance map of the species. Occurrence points for the species were downloaded from GBIF including data from camera traps of the Wildlife institute of India. 60% of the points were used as nodes or focal points where species presence is recorded whereas 40% of the points were used in the calculation of corridor score for validation of the connectivity paths. Results depict the current density map of the study area highlighting areas with high connectivity for the species allowing policymakers to make informed decisions for conservation and planning.

REFERENCES

1. Adriaensen, F., Chardon, J. P., De Blust, G., Swinnen, E., Villalba, S., Gulinck, H., & Matthysen, E. (2003). The application of ‘least-cost’ modeling as a functional landscape model. Landscape and urban planning, 64(4), 233-247.
2. Ayad, Y. M. (2005). Remote sensing and GIS in modeling visual landscape change: a case study of the northwestern arid coast of Egypt. Landscape and Urban Planning, 73(4), 307-325.
3. Balaji, G., & Sharma, G. (2022). Forest cover in India: A victim of technicalities. Ecological Economics, 193, 107306.
4. Barnes, J. A., & Harary, F. (1983). Graph theory in network analysis. Social networks, 5(2), 235-244.
5. Bastille-Rousseau, G., & Wittemyer, G. (2021). Characterizing the landscape of movement to identify critical wildlife habitat and corridors. Conservation Biology, 35(1), 346-359.
6. Biewener, A. A., Bomphrey, R. J., Daley, M. A., & Ijspeert, A. J. (2022). Stability and manoeuvrability in animal movement: lessons from biology, modelling and robotics. Proceedings of the Royal Society B, 289(1967), 20212492
7. Castillo MG, Jaime Hernández H, Estades CF. Effect of connectivity and habitat availability on the occurrence of the Chestnutthroated Huet-Huet (Pteroptochos castaneus, Rhinocryptidae) in fragmented landscapes of central Chile. Landsc Ecol. 2018;33: 1061–8.
8. Chetkiewicz, C. L. B., & Boyce, M. S. (2009). Use of resource selection functions to identify conservation corridors. Journal of Applied Ecology, 1036-1047.
9. CK, S. (2019, September). Automated Wildlife Monitoring Using Deep Learning. In proceedings of the International Conference on Systems, Energy & Environment (ICSEE).
10. Clements, S. J., Ballard, B. M., Eccles, G. R., Sinnott, E. A., & Weegman, M. D. (2022). Trade-offs in performance of six lightweight automated tracking devices for birds. Journal of Field Ornithology.
11. Compton, B. W., McGarigal, K., Cushman, S. A., & Gamble, L. R. (2007). A resistant-kernel model of connectivity for amphibians that breed in vernal pools. Conservation Biology, 21(3), 788-799.
12. Crooks, A. T., & Heppenstall, A. J. (2012). Introduction to agent-based modelling. In Agent-based models

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of geographical systems (pp. 85-105). Springer, Dordrecht.
13. Crowley, M. A., & Cardille, J. A. (2020). Remote Sensing’s Recent and Future Contributions to Landscape Ecology. Current Landscape Ecology Reports, 5, 45-57.
14. Cushman, S. A., Elliot, N. B., Bauer, D., Kesch, K., Bahaa-El-Din, L., Bothwell, H., ... & Loveridge, A. J. (2018). Prioritizing core areas, corridors and conflict hotspots for lion conservation in southern Africa. PloS one, 13(7), e0196213.
15. de Weerd, N., van Langevelde, F., van Oeveren, H., Nolet, B. A., Kölzsch, A., Prins, H. H., & de Boer, W. F. (2015). Deriving animal behaviour from high-frequency GPS: tracking cows in open and forested habitat. Plos one, 10(6), e0129030.
16. DeAngelis, D. L., & Diaz, S. G. (2019). Decision-making in agent-based modeling: A current review and future prospectus. Frontiers in Ecology and Evolution, 237.
17. Derocher, A. E., Lunn, N. J., & Stirling, I. (2004). Polar bears in a warming climate. Integrative and comparative biology, 44(2), 163-176.
18. Doherty, T. S., Hays, G. C., & Driscoll, D. A. (2021). Human disturbance causes widespread disruption of animal movement. Nature Ecology & Evolution, 5(4), 513-519.
19. Doligez, B., Boulinier, T., & Fath, D. (2008). Habitat selection and habitat suitability preferences. Encyclopedia of Ecology, 5, 1810-30.
20. Downs, J., Horner, M., Lamb, D., Loraamm, R. W., Anderson, J., & Wood, B. (2018). Testing time-geographic density estimation for home range analysis using an agent-based model of animal movement. International Journal of Geographical Information Science, 32(7), 1505-1522.
21. Drielsma, M., Ferrier, S., & Manion, G. (2007). A raster-based technique for analysing habitat configuration: The cost–benefit approach. Ecological Modeling, 202(3-4), 324-332.
22. Dumont, B., & Hill, D. R. (2004). Spatially explicit models of group foraging by herbivores: what can Agent-Based Models offer?. Animal Research, 53(5), 419-428.
23. Dupras J, Marull J, Parcerisas L, Coll F, Gonzalez A, Girard M, et al. The impacts of urban sprawl on ecological connectivity in the Montreal Metropolitan Region. Environ Sci Pol. 2016;58:61– 73.
24. Forman, R. T., & Godron, M. (1981). Patches and structural components for a landscape ecology. BioScience, 31(10), 733-740.
25. Froese, J. G., Smith, C. S., Durr, P. A., McAlpine, C. A., & van Klinken, R. D. (2017). Modelling seasonal habitat suitability for wide-ranging species: Invasive wild pigs in northern Australia. PloS one, 12(5), e0177018.
26. Fust, P., & Schlecht, E. (2018). Integrating spatio-temporal variation in resource availability and herbivore movements into rangeland management: RaMDry—An agent-based model on livestock feeding ecology in a dynamic, heterogeneous, semi-arid environment. Ecological Modelling, 369, 13-41.

27. Koen, E. L., Bowman, J., Sadowski, C., & Walpole, A. A. (2014). Landscape connectivity for wildlife: development and validation of multispecies linkage maps. Methods in Ecology and Evolution, 5(7), 626-633.

28. Lalechère, E., & Bergès, L. (2021). A Validation Procedure for ecological corridor Locations. Land, 10(12), 1320.