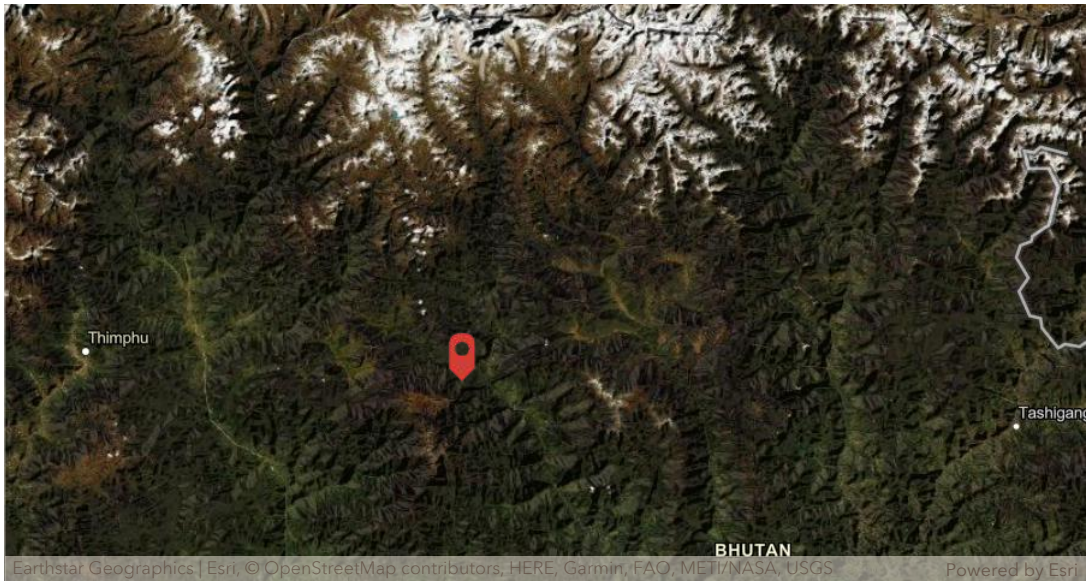
Conservation of Asian Elephants in Southern Bhutan

Utilizing NASA Earth Observations to Model Land Cover Change and Elephant Wildlife Corridors in Southern Bhutan

Thinley Yidzin Wangden, Kezang Choki Tshering, Kelzang Jigme, Thinley Jurmi, and Karma Dema | March 4, 2021



Significance of Asian Elephants

Bhutan is a small country located in southeast Asia with a size of 38,394 km2. Bhutan ensures a minimum of 60% of the land is under forest cover. The forests support rich biodiversity, roughly 51% of the country is protected (Dorji, Rajaratnam, & Vernes, 2019): 41% as protected areas and 10% as biological corridors for a wide range of species. Asian elephants (*Elephas maximus*) are a

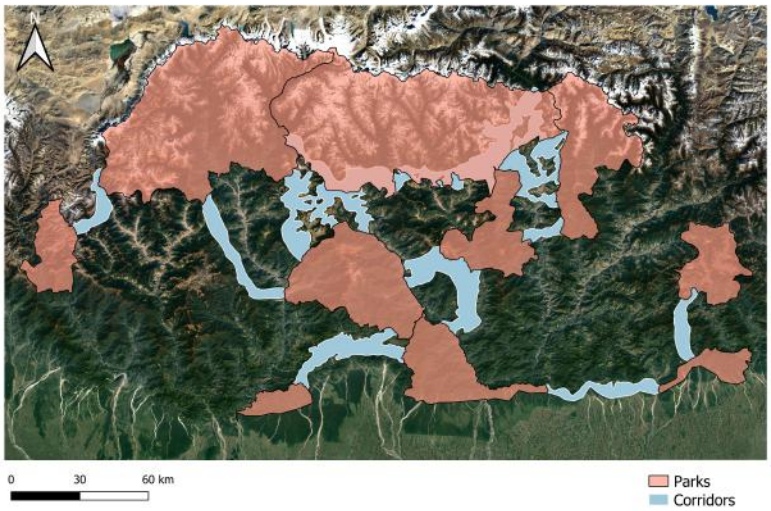
keystone wildlife species whose conservation is essential for the functioning of forest ecosystems. They tend to occur in southern Bhutan's forests and are an endangered species facing threats of habitat loss, poaching, and retaliatory killings (IUCN, 2017; Nature Conservation Division, 2018).

In Bhutan, elephants are not only considered important because of their environmental significance but also because of their important role in religion and culture. Elephants are considered as one of the most precious possessions (Phuntsho, 2017) and portrayed as an integral part of religion and culture in many Bhutanese tales.

Conservation Efforts

Despite the country's reverence and its effort to conserve the species, in the southern foothills of Bhutan, habitat fragmentation and poaching continue to be detrimental to the survival of the Asian elephant. Additionally, due to rapid urbanization and human activities on known elephant feeding grounds, there is an increasing

Human-Elephant Conflict (HEC). Intervention to prevent threats to human life and property overlaps with the issue of Asian elephant conservation.

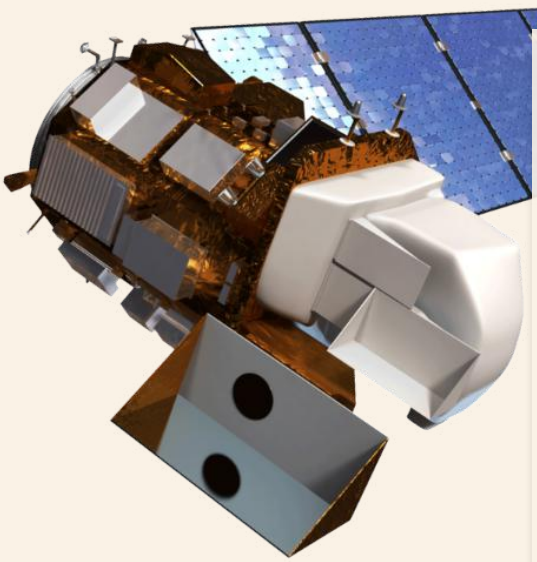


Various studies have attested to the effectiveness of biological corridors in the conservation of wildlife. Bhutan's protected areas were also found to be effective in conserving key mammals, but there is a lack of evidence about their effectiveness for enabling elephant movement between protected areas.

The map shows the protected areas in pink and the blue areas are existing biological corridors.

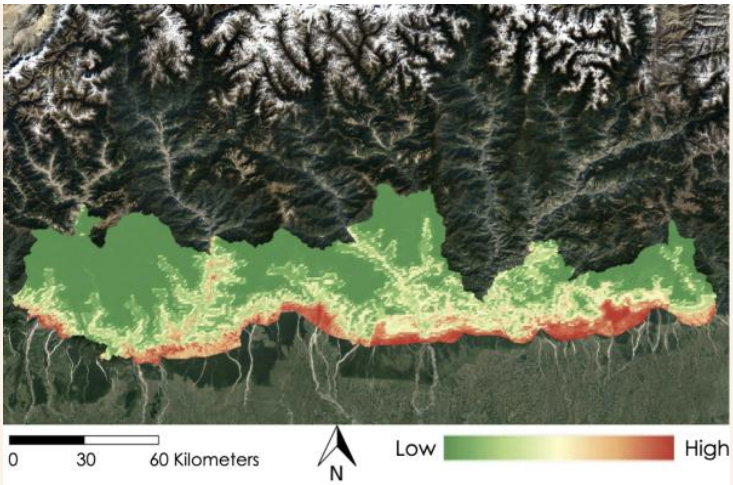
A map identifying the protected areas

Click on the pink areas to view its size in square Km.



What did the DEVELOP team do?

The NASA DEVELOP Southern Bhutan Ecological Forecasting II team partnered with the Bhutan Foundation, the Bhutan Tiger Center, and Bhutan Ecological Society to address these issues. Realignment of the biological corridors with proper empirical guidance has the potential to bring substantial improvements for the conservation of elephants and other endangered species in Bhutan. The team utilized various satellite datasets to create Land Use and Land Cover (LULC) change maps and model potential biological corridors.

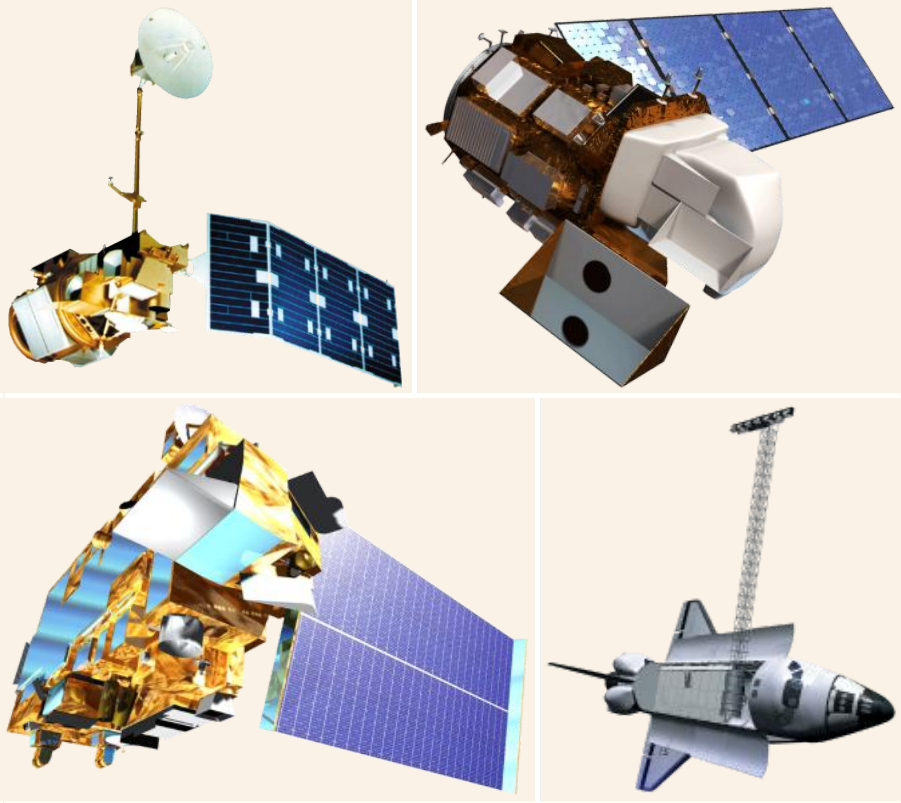


Habitat Suitability Model

In conjunction with existing protected areas data, the team used habitat suitability models generated by the previous term based on the use of NASA Earth observation data and Bhutan elephant surveys to develop potential biological corridors connecting Bhutan's protected areas for aiding seasonal elephants' migrations.

We used this map as the main input to construct a movement resistance map which was later used to identify corridors.

Earth observations satellites and sensors used



Earth observations satellites and sensors used from left to right: Landsat 5 Thematic Mapper (TM), Landsat 8 Operational Land Imager (OLI), Terra Moderate Resolution Imaging Spectroradiometer (MODIS), and Shuttle Radar Topography Mission (SRTM)

Example Products

Images of True Color Composite for years 2010 and 2015

To obtain the annual cloud-free Landsat images, the team used Google Earth Engine (GEE) codes.

Figure 1: True color composites of years 2010 and 2015

Images of LULC for 2010 and 2015

The team utilized NASA Earth observations to produce Land Use and Land Cover (LULC) maps for the years 2010 and 2015.We

generated the LULC maps of the years 2010 and 2015 by mosaicking the Landsat images, and performing an unsupervised classification method. We started with 20 different classes of land which we then manually regrouped and reclassified into five classes: mature forests, immature forests, cultivated lands, barren lands, and water bodies.

Land classes in the LULC maps

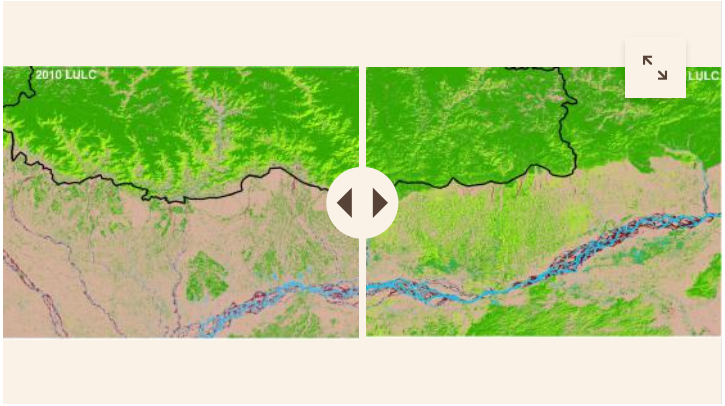
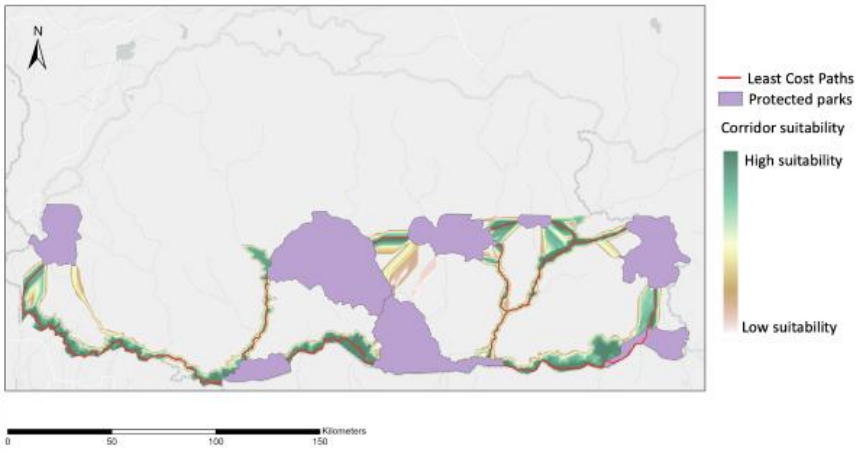


Figure 2: Images of LULC 2010 and 2015

To get a better visualization, you can use swipe to compare the two different maps.

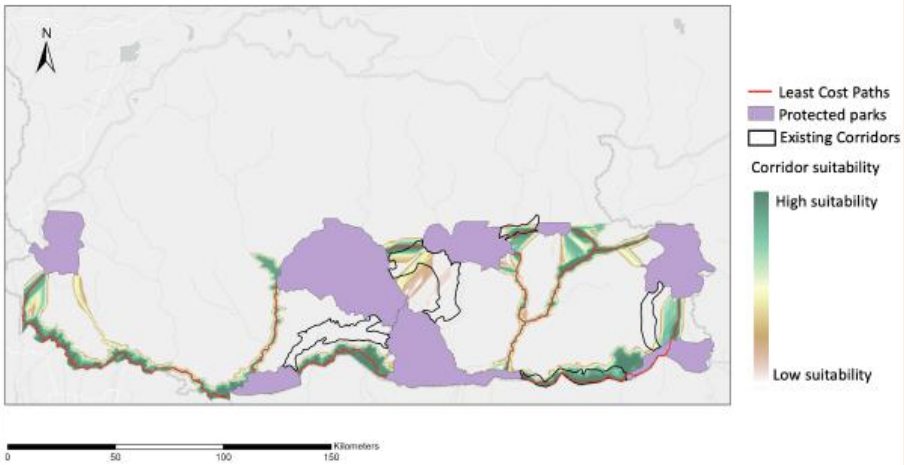
Figure 3: Figure comparing 2010 true color and LULC map

Figure 4: Figure comparing 2015 true color and LULC map



Potential Biological Corridors

Using Circuitscape Linkage Mapper, we used a habitat suitability model for the Asian elephants calculated by the previous term to create a potential corridor map. We were able to map corridors connecting the protected areas in southern Bhutan that are the most suitable for Asian elephants' movement. We also found suitability for corridors as gradients in terms of distance away from the ideal corridors. Areas less suitable for elephant corridors are further away from ideal paths and down the gradient (brown to white tones).



We compared the existing corridors with the potential corridors we identified and found that there were a few overlaps with some of the existing corridors. A few others were very close to the ideal corridors and occurred in areas with higher suitability. Our primary corridor of interest is that connecting the three key protected parks for Asian elephants: Royal Manas National Park, Phipsoo Wildlife Sanctuary, and Jomotshangkha Wildlife Sanctuary. While the existing corridor lies in areas of medium to high suitability, we identified two other linkages as being best suited for elephant movement between these three corridors. Based on elephant habitat suitability, these two corridors have the potential to be better suited to the elephants and may alleviate human-elephant conflicts. It will be useful to keep in mind that our model does not take urban settlements into account, so although the most suitable linkages according to elephant habitats have been identified, they may not actually be the most feasible.

Future Work

The corridor map, along with the habitat suitability model outputs, will inform the partners on suitable planning and placement of elephant movement corridors to promote the conservation of Asian elephants and avoid human-elephant conflicts. These results encourage the integration of NASA Earth observations for future studies and project planning for conservation efforts in Bhutan. For future work, there is an opportunity to build upon these results and those of the previous term to examine future habitat change based on patterns of landscape use. There is also potential to consider urban settlements to discern the feasibility of the potential corridors identified.

About the Team

NASA DEVELOP is part of NASA's Capacity Building Program.

NASA DEVELOP projects allow participants to conduct applied research that highlights NASA Earth observation's capabilities to determine solutions for environmental issues and concerns. The Southern Bhutan Ecological Forecasting II spring 2021 team worked at the Goddard Space Flight Center. The team is comprised of 5 students: Thinley Yidzin Wangden (Team Lead), Kezang Choki Tshering, Karma Dema, Kelzang Jigme, and Thinley Jurmi. The team's educational background includes Computer Science, Biology, Mathematics, and Physics.

Credits and Acknowledgements

References

Beier, P., & Noss, R. F. (1998). Do habitat corridors provide connectivity? *Conservation Biology, 12*(6), 1241-1252. https://doi.org/10.1111/j.1523-1739.1998.98036.x

Chamling, M., & Bera, B. (2020). Spatio-temporal patterns of land use/land cover change in the Bhutan-Bengal foothill region between 1987 and 2019: Study towards geospatial applications and policy making. *Earth Systems and Environment, 4*, 117-130. https://doi.org/10.1007/s41748-020-00150-0

USGS. (2013). Collection-1 Landsat TM Level-2 Surface Reflectance Science Product, accessed February 2021. doi: doi.org/10.5066/F7KD1VZ9

USGS. (2014). Collection-1 Landsat OLI Level-2 Surface Reflectance Science Product, accessed February 2021. doi://10.5066/F78S4MZJ

Esri Inc. (2021). *ArcGIS Pro* (Version 2.7.0). Esri Inc. https://www.esri.com/en-us/arcgis/products/arcgis-pro/overview.

Gilani, H., Shrestha, H. L., Murthy, M. S. R., Phuntso, P., Pradhan, S., Bajracharya, B., & Shrestha, B. (2015). Decadal land cover change dynamics in Bhutan. *Journal of Environmental Management, 148*, 91-100.https://doi.org/10.1016/j.jenvman.2014.02.014

Lhamo, N. (2008). *Extent of human-elephant conflicts and the threat to elephant populations in southern Bhutan*. [Unpublished master's thesis]. University of Natural Resources and Applied Life Sciences, Vienna.

Gallo, J. A., & Greene, R. (2018). *Connectivity Analysis Software for Estimating Linkage Priority*. Conservation Biology Institute.

https://doi.org/10.6084/m9.figshare.5673715

Nature Conservation Division. (2018). *Elephant conservation action plan for Bhutan 2018-2028*. Nature Conservation Division, Department of Forests & Park Services, Ministry of Agriculture & Forests, Thimphu, Bhutan.

NASA Jet Propulsion Laboratory (JPL). (2013-2017). NASA Shuttle Radar Topography Mission Global 1 arc second [Data set]. doi:10.5067/MEaSUREs/SRTM/SRTMGL1.003

Penjor, U., Wangdi, S., Tandin, T., & Macdonald, D. W. (2021). Vulnerability of mammal communities to the combined impacts of anthropic land-use and climate change in the Himalayan conservation landscape of Bhutan. *Ecological Indicators, 121*(2021), 1-10. https://doi.org/10.1016/j.ecolind.2020.107085

Phuntsho, K. (n.d.). *Rinchen Nadun – The Seven Precious Possessions*. Retrieved March 18, 2021, from https://kuenselonline.com/rinchen-nadun-the-seven-precious-possessions/

Running, S., Mu, Q., Zhao, M. (2017). MOD11A1 MODIS/Terra Land Surface Temperature/Emissivity Daily L3 Global 1Km SIN Grid V006. NASA EODIS LP DAAC. DOI: 10.5067/MODIS/MOD11A1.006

Thinley, P. (2010). Technical comments on the design and designation of biological corridors in Bhutan: global to national perspectives. *Journal of Renewable Natural Resources, Bhutan, 6*, 91-106. https://doi.org/10.13140/RG.2.1.2917.2321

Tobgay, S., & Mahavik, N. (2020). Potential habitat distribution of Himalayan red panda and their connectivity in Sakteng Wildlife Sanctuary, Bhutan. *Ecology and Evolution, 10*(23), 12929-12939. https://doi.org/10.1002/ece3.6874

Tshering, K., Thinley, P., Shafapour Tehrany, M., Thinley, U., & Shabani, F. (2020). A Comparison of the Qualitative Analytic Hierarchy Process and the Quantitative Frequency Ratio Techniques in Predicting Forest Fire-Prone Areas in Bhutan Using GIS. *Forecasting, 2*(2), 36–58. MDPI AG. http://doi.org/10.3390/forecast2020003

Wangchuk, S. (2007). Maintaining ecological resilience by linking protected areas through biological corridors in Bhutan. *Tropical Ecology, 48*(2), 177.

Image Credits

Asian Elephants: Partner, Bhutan Foundation

DeShea, D. (n.d.). *Asian elephants* [Photograph]. https://unsplash.com/photos/kwDueqdEzao [CC by https://unsplash.com/license]

Landsat 5, Landsat 8, Terra, & STRM satellite images: NASA

Acknowledgement

The team would like to thank the following for their input and guidance throughout this Spring 2021 term:

Tshering Tempa	End-User: Director of Bhutan Tiger Center
Tshewang Wangchuk,	Partner: Executive Director of Bhutan Foundation
Nawang Norbu	Partner: Director Bhutan of Ecological Society, Director
Joe Spruce	Science Advisor: Diamondhead, Science Systems & Applications, Inc Consultant
Dr. Kenton Ross	Science Advisor: NASA Langley Research Center
Sean McCartney	Science Advisor: Science Systems & Applications, Inc., NASA Goddard Space Flight Center
Darcy Gray	DEVELOP FELLOW at NASA Georgia Center of Geospatial Research
Nicole Ramberg-Pihl	DEVELOP Fellow at NASA Goddard Space Flight Center
Palchen Wangchuk	Past Contributor
Tashi Choden	Past Contributor
Kuenley Pem Dem	Past Contributor
Sonam Choden	Past Contributor
Kelzang Jigme	Past Contributor
This material is based upon work supported by NASA through contract NNL16AA05C.	Any opinions, findings, and conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration and partner organizations.
NPR 2200.2C D.6.4.1:	Trade names and trademarks are used in this report for identification only. Their usage does not constitute an official endorsement, either expressed or implied, by the National Aeronautics and Space Administration.