**Southern Bhutan Ecological Forecasting**

*Modeling Asian Elephant (Elephas Maximus) Habitat Suitability along the Southern Bhutan Border with NASA Earth Observations*

**Project Team**

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**Project Overview**

***Project Synopsis:***

The Asian elephant population has decreased by at least 50 percent over the last three decades, resulting in the species being listed as endangered by the International Union for Conservation of Nature (IUCN) Red List. The DEVELOP Southern Bhutan Ecological Forecasting team at NASA Goddard Space Flight Center partnered with the Bhutan Foundation and the Bhutan Tiger Center to investigate land cover change and elephant habitat suitability along the southern Bhutan border using NASA Earth observation data and other resources. This analysis provided the partners with decision-support information about the placement and conservation of elephant movement corridors with further encouragement to integrate NASA Earth observations for future studies and project planning.

***Abstract:***

Asian elephants (*Elephas maximus*) are a flagship species essential for the functioning of forest ecosystems, and they also have cultural significance in Bhutan. Elephants receive the highest legal protection as listed under Schedule I of the Bhutan Forests and Nature Conservation Act, 1995. Yet, they face threats of extinction due to poaching for ivory as well as the loss and fragmentation of their habitat. Due to the recent clearing of forests and the growing populations in these areas, there has been an increase in incidents of human-elephant conflict. These conflicts have been detrimental to farmer’s annual harvests and livelihoods and have led to retaliatory killing and injury of elephants in southern Bhutan. The DEVELOP Southern Bhutan Ecological Forecasting team partnered with the Bhutan Foundation and Bhutan Tiger Center to help address this problem. The team integrated NASA Earth observations, including Landsat 5 Thematic Mapper (TM), Landsat 8 Operational Land Imager (OLI), Terra Moderate Resolution Imaging Spectroradiometer (MODIS), and the Shuttle Radar Topography Mission (SRTM) to acquire information on land cover change and elephant habitat suitability along the southern border of Bhutan. The team utilized Esri ArcGIS Pro and Software for Assisted Habitat Modeling (SAHM) for data analysis, modeling, and visualization. The team used elephant occurrence data and environmental variables to model current habitat suitability for migrating elephant populations. This analysis provided partners with maps to inform decisions about the placement and conservation of elephant corridors and helped build their capacity to use satellite data for future studies and project planning.

***Keywords:***

remote sensing, habitat modeling, land cover change, elephant corridors, habitat loss, ArcPro, SAHM

***National Application Area Addressed:*** Ecological Forecasting

***Study Location:*** Southern Bhutan & Northern West Bengal, India

***Study Period:*** January 1999 – December 2019

***Community Concerns:***

* The diverse landscapes of Bhutan host a rich biodiversity of animal and plant species.
* Elephants are a flagship species and environmental engineers whose conservation is essential for the functioning of the forest ecosystem.
* The Asian elephant faces threats of extinction throughout its range.
* Since 1986, the Asian elephant has been listed as Endangered on the IUCN Red List, as their population has declined by at least 50% over the last three decades.
* In 2019, Bhutan implemented an elephant conservation plan with eight stated objectives, including prevention of habitat loss and improvement of the existing habitat condition.

***Project Objectives:***

* Produce Land Use and Land Cover Classification Maps to serve as a reference for historical land use trends from 1999 to 2019
* Analyze and create an Elephant Habitat Suitability Model for 2019 which can help in identifying wildlife corridors

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Bhutan Foundation** | Tshewang Wangchuk, Executive Director | End User | Yes |
| **Bhutan Tiger Center** | Tshering Tempa, Director | Collaborator | No |

***Decision-Making Practices & Policies:***

Currently, the Bhutan Foundation bases its project support decisions around priorities outlined in the Bhutan 12th Five Year Plan (FYP). This plan has been inspired by the Royal Addresses and is anchored on the provisions of the Constitution, lessons from the review of the 11th FYP, extensive stakeholder consultations including Civil Society Organizations (CSOs), political parties, and regional and international commitments including the United Nations Sustainable Development Goals. Many projects supported by the Bhutan Foundation include stakeholder meetings and extensive background and field research to help collect relevant information for project planning.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
|  **Landsat 8 OLI** | Land surface reflectance, Vegetation indices | Land surface reflectance products were used for creating a land cover map for 2019. OLI data were also used to compute the NDVI (Normalized Difference Vegetation Index). |
|  **Landsat 5 TM** | Land surface reflectance, Vegetation indices | Land surface reflectance products were used for computing a land cover map for 1999. |
|  **SRTM** | Topography | SRTM was used to generate a Digital Elevation Model (DEM) of the study area to calculate slope and aspect. It was also used to gather rivers data which is a variable in the habitat suitability model. |
| **Terra MODIS** | Land surface temperature | MOD11A1.006 Terra Land Surface data were imported for image collection since it provided daily land surface temperature data. |

***Ancillary Datasets:***

* DIVA-GIS – used to acquire DEM to calculate slope and aspect
* Global Biodiversity Information Facility (GBIF) Elephant Occurrence Data – used to acquire presence data to train the habitat suitability model
* Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) – used to acquire annual precipitation data
* Socioeconomic Data and Application Center (SEDAC) – used for obtaining population density and roads data
* HydroRIVERS – used to collect rivers dataset

***Modeling:***

* Software for Assisted Habitat Modeling (SAHM) (POC: Kristen Dennis, Fort Collins Science Center, USGS) – used to run habitat suitability analysis for the present and future for Asian elephants in southern Bhutan
* Random Forests (POC: Leo Breiman, University of California, Berkley) – used to build a classifier of land use and land cover in and around elephant habitat

***Software & Scripting:***

* Esri ArcGIS Pro – used to process data and make land cover change analyses
* SAHM – utilized for elephant habitat suitability modeling
* Google Earth Engine – used to script codes to obtain NDVI, annual average land surface temperature and annual average precipitation data from MODIS and CHIRPS.

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Elephant Habitat****Suitability Map for****2019** | Landsat 8 OLITerra MODISSRTM | These maps spatiallydemonstrate the potential current and future ranges for Asian elephants in Bhutan, which can be used to inform decisions about wildlife corridors and transboundary conservation efforts.  | I |
| **Land Use Land****Cover Classification****Map for 1999 and 2019** | Landsat 5 TMLandsat 8 OLI  | These land classifications can serve as references for understanding historical land use trends, which will help the partners understand current threats to elephant habitat in the region. | I |

***Product Benefit to End User:***

Habitat suitability maps and land cover classifications will highlight potential wildlife corridors, enhancing the decision-making abilities of the Bhutan Tiger Foundation and other stakeholders. The land cover classification may also inform other related work supported by the Bhutan Tiger Foundation and Bhutan Foundation. In planning and supporting wildlife corridors, there is an opportunity to use satellite data to inform conservation decisions and generate information that contributes to the protection of entire ecosystems. This project will serve as a reference for the Bhutan Tiger Center’s future research involving habitat suitability modeling, especially pertaining to Asian Elephants in Southern Bhutan.

**References**

IUCN (2017). The IUCN Red List of Threatened Species. Version 2017-1. htps://www.iucnredlist.org

Jensen, J. R. (2014). Remote Sensing of the Environment. An earth resource perspective. Harlow, Essex: Pearson.

Meteobox. (2020). Weather statistics for Gelephu, Bhutan. Retrieved from https://meteobox.com/bhutan/gelephu/statistics/

Morisette, J., Jarnevich, C., Holcombe, T., Talbert, C., Ignizio, D., Talbert, M., . . . Young, N. (January 25, 2013). VisTrails SAHM: Visualization and workflow management for species habitat modeling. Retrieved from https://onlinelibrary.wiley.com/doi/full/10.1111/j.1600-0587.2012.07815.x

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.

Padalia, H., Ghosh, S., Reddy, C.S., Nandy, S., Singh, S., & Kumar, A. S. (2019) Assessment of historical forest cover loss and fragmentation in Asian Elephant ranges in India. *Environmental Monitoring and Assessment, 191*, 802. https://doi.org/10.1007/s10661-019-7696-5

Sharma, P., Adhikari, H., Tripathi,S., Ram, A.K., & Bhatarai, R. (2019). Habitat suitability modeling of Asian Elephant Elephas maximus (Mammalia: Proboscidea: *Elephantidae*) in Parsa National Park, Nepal and its buffer zone. *Journal of Threatened Taxa, 11*(13), 14643–14654. https://helda.helsinki.fi/bitstream/handle/10138/310445/4467\_Full\_article\_text\_with\_author\_details\_26032\_1\_10\_20191025.pdf?sequence=1&isAllowed=y

Sukumar, R. (2003). *The living elephants: Evolutionary ecology, behavior, and conservation*. Oxford University Press, New York, 478pp.

Yangchen, U., Thinley. U., & Wallentin, G. (2015). Land use land cover changes in Bhutan 2000-2013. College of Natural Resources, Royal University of Bhutan, Lobesa, Bhutan. Retrieved from https://www.researchgate.net/profile/Gudrun\_Wallentin/publication/288181926\_Land\_Use\_Land\_Cover\_Changes\_in\_Bhutan\_2000-2013/links/567ed87108ae051f9ae66aea.pdf