**Southern Bhutan Ecological Forecasting III**

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

**Project Team**

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**Project Overview**

***Project Synopsis:***

The DEVELOP Southern Bhutan Ecological Forecasting III team at NASA Goddard Space Flight Center assessed land use in southern Bhutan from 2010 to 2019 and forecasted habitat change for Asian elephants (*Elephas maximus*) to 2030. The team refined the Land Use and Land Cover (LULC) maps from the previous terms and generated LULC change maps to assess historical patterns in land use. These products will help the Bhutan Foundation, Bhutan Tiger Center, and Bhutan Ecological Society to incorporate NASA Earth observations into future conservation efforts.

***Abstract:***

 Habitat loss of the endangered Asian elephants (*Elephas maximus*) accompanied by rapid urbanization has contributed to the rising Human-Elephant Conflict (HEC) crisis in southern Bhutan. This poses a serious threat to the survival of Asian elephants, a keystone wildlife species essential for maintaining Bhutan’s forest ecosystems and rich biodiversity. With expanding urban areas, HECs present challenges to conservation efforts in the region. The team partnered with the Bhutan Foundation, the Bhutan Tiger Center, and Bhutan Ecological Society to help mitigate this issue using remote sensing technology and NASA Earth observations. The team refined Land Use and Land Cover (LULC) maps for 2010-2019 generated in previous terms and elephant corridor maps to include information on human settlements using Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) data. We generated LULC change maps and forecasted the LULC to 2030 using TerrSet Land Change Modeler, providing insights into future elephant habitat suitability in southern Bhutan. The results indicated that built-up areas increased approximately 688.9% from 2010 to 2019 and the forecasted 2030 LULC also predicted an increase in built-up areas compared to 2019. Suitable corridors in Gelephu intersect cultivated and built-up areas, indicating close proximity of elephants to humans and a need to research alternative corridor strategies. The end products from this project will aid partner organizations in decision-making processes in urban planning and future conservation strategies that include the refined placement of biological corridors to aid elephant movement and reduce the risk of HECs.

***Key Terms:***

satellite remote sensing, Asian elephant habitat suitability, Bhutan, LULC change and forecasting, corridor mapping, TerrSet Land Change Modeler, ArcGIS

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

***Study Location:*** Southern Bhutan

***Study Period:*** January 2010 - December 2019, Forecasting to 2030

***Community Concerns:***

* Asian elephants are integral to the functioning of Bhutan’s ecosystem.
* Elephants are culturally significant in Bhutan.
* Increased urbanization and habitat loss have led to more Human-Elephant Conflict (HEC) in southern Bhutan, threatening the survival of elephants in the region.
* A lack of research on land use and elephant habitat limits the ability of policymakers to respond.

***Project Objectives:***

* Refine Land Use and Land Cover (LULC) maps for 2010, 2015, and 2019 to include locations of human settlements throughout the southern region of Bhutan
* Produce land change maps displaying land change between 2010 and 2019
* Generate future LULC maps forecasted to 2030
* Update the potential biological corridor map for Asian elephants to incorporate information on built-up urban areas and rural human settlements

***Previous Terms:***

2020 Summer (GSFC) – Southern Bhutan Ecological Forecasting

2021 Spring (GSFC) – Southern Bhutan Ecological Forecasting II

**Partner Overview**

***Partner Organizations:***

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

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

The Bhutan Tiger Center’s work on tiger research, education, and outreach resources is relevant to Bhutan and other countries within the geographic range of tigers that includes elephant habitat. Although familiar with GIS vector-based data sets and remote sensing data products, the Tiger Center has limited experience and capacity to use Earth observations. To promote Gross National Happiness, of which environmental conservation is one of the four main pillars, the Bhutan Foundation supports various projects focused on climate change and conservation of endangered species such as snow leopards and mountain tigers. The Bhutan Ecological Society aims to build self-sufficient, resilient communities and functional landscapes while ensuring the functional integrity of the ecosystem. As non-profits, these organizations base their decisions on Bhutan’s 12th Five Year Plan, regional and international commitments, extensive board meetings, and field research.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Land surface reflectance | Land surface reflectance products were used to update LULC maps for 2015 and 2019. |
| **Landsat 5 TM** | Land surface reflectance | Land surface reflectance products were used to update LULC maps for 2010. |
| **SRTM** | Topography | SRTM was used to generate a Digital Elevation Model (DEM) of the study area. |
| **Terra MODIS** | Land surface temperature | Land surface temperature data were used in previous terms to generate an elephant habitat suitability model, which was used to create a resistance map of the study region. These end products were then used to model potential biological corridors and transition potential change in the spring 2021 and summer 2021 terms. |

***Ancillary Datasets:***

* Bhutan Protected Area Shapefile; received from Bhutan Foundation – Shapefiles of protected areas and land use and land cover maps
* Bhutan LULC map (2010); received from Bhutan Foundation – Aid in refinement and other evaluations of project-derived LULC maps
* LULC map (2016); received from Bhutan Ecological Society – Aid in refinement and other evaluations of project-derived LULC maps
* DIVA-GIS – Used to obtain GIS data layers for elevation, roads, rivers, and administrative units
* Socioeconomic Data and Application Center (SEDAC) – Population density and roads data to assess land use and identify areas of human settlement

***Modeling:***

* TerrSet Land Change Modeler (POC: Sean McCartney, Science Systems and Applications, Inc.) – Generate historical and future LULC change maps forecasted to 2030

***Software & Scripting:***

* Esri ArcGIS Pro Version 2.7.2 – Process raster and vector data and create map products for end users
* Google Earth Engine API – Script codes to obtain cloud-free satellite imagery
* TerrSet 2020 Version 19.0.5 – Model LULC change to 2030
* QGIS Version 3.18.2 – Visualize input and output GIS data sets

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| Refined LULC Maps | Landsat 5 TM, Landsat 8 OLI | LULC maps that include locations of human settlements will provide an understanding of historical land use trends, which will inform the partners of threats to elephant habitat in the region and enable them to plan conservation strategies accordingly. | I |
| LULC Change Maps | Landsat 5 TM, Landsat 8 OLI | Land change maps can provide an understanding of patterns in land change over time and will help partners assess changes in protected areas and overall development to inform future policy decisions.  | I |
| Future LULC Maps (Forecasted to 2030) | Landsat 5 TM, Landsat 8 OLI | LULC maps forecasted to 2030 will inform the partners on potential land cover over the next decade and on future threats to elephant habitat in southern Bhutan. | I |
| Refined Biological Corridor Map | Landsat 5 TM, Landsat 8 OLI | The refined corridor map will spatially demonstrate the potential biological corridors for Asian elephants in Bhutan, while considering human settlements in the region. These maps will inform partners’ decisions on conservation efforts. | I |

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

The refined current, historical, and forecasted LULC maps will allow the Bhutan Tiger Center, Bhutan Foundation, and Bhutan Ecological Society to spatially assess LULC trends over time and the impact of urbanization on elephant habitat and migratory routes. The maps of potential LULC forecasted to 2030 and the potential biological corridors for elephants will support the partners in their urban planning and conservation efforts in the southern region of Bhutan, especially in the Gelephu municipality.

**References**

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