**Southern Bhutan Ecological Forecasting II**

*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 II team at NASA Goddard Space Flight Center produced a potential biological corridor map for elephants connecting protected areas in southern Bhutan. This work was conducted in partnership with the Bhutan Foundation, the Bhutan Tiger Center, and Bhutan Ecological Society. The project’s second term included generation of land use and land cover (LULC) maps for 2010 and 2015, leveraging the methods and products created in the first term. These results encourage integration of NASA Earth observations for future studies and project planning for conservation efforts in Bhutan.

***Abstract:***

The diverse landscapes of Bhutan host a rich biodiversity of animal and plant species. Asian elephants (*Elephas maximus*) are a flagship keystone wildlife species whose conservation is essential for the functioning of Bhutan’s forest ecosystems. Despite this, increasing habitat loss and human-elephant conflict continue to be detrimental to the survival of Asian elephants. The lack of information on Bhutan’s elephants and land use and land cover (LULC) trends present major challenges for Bhutan in modeling locations with suitable habitat and biological corridors for elephants. The DEVELOP team at NASA Goddard Space Flight Center partnered with the Bhutan Foundation, Bhutan Tiger Center, and Bhutan Ecological Society to help address this problem. The team mapped LULC in Bhutan for 2010 and 2015 by utilizing NASA Earth observations, including Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) to acquire information on historical LULC patterns and view apparent land cover change. The team used the Linkage Pathways Tool of the Linkage Mapper Toolbox in ArcMap to derive biological corridor maps from habitat suitability model outputs of the previous term and known locations of protected areas in Bhutan. The corridor maps were used to view and assess corridor suitability and connectivity between protected parks. Project results are being provided to partners to help make informed decisions on the placement and conservation of elephant movement corridors.

***Key Terms:***

Asian elephant conservation, remote sensing, habitat modeling, biological corridor mapping, habitat loss, ArcGIS Pro, Linkage Mapper

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

***Study Location:*** Southern Bhutan

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

***Community Concerns:***

* Elephants are a flagship species and environmental engineers that holds cultural significance in Bhutan. Since 1986, the Asian elephant has been listed as Endangered on the International Union for Conservation of Nature (IUCN) Red List. Loss of the Asian elephant species would be detrimental to the functioning of the ecosystem, as well as a loss of the cultural significance it holds.
* Increasing habitat loss and fragmentation has led to an increase in human-elephant conflicts in the southern foothills of Bhutan.

***Project Objectives:***

* Assess LULC type occurrence in southern Bhutan for 2010 and 2015
* Develop biological corridor maps connecting protected areas within Bhutan for migrating elephant populations

***Previous Term:***

2020 Summer (GSFC) – Southern Bhutan Ecological Forecasting

**Partner Overview**

***Partner Organizations:***

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

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

As a leader in environmental and wildlife conservation, Bhutan Tiger Center’s work on tiger research, education, and outreach is relevant to the people of Bhutan and other countries within the geographic range of tigers. With the goal of promoting Gross National Happiness, of which environmental conservation is one of the four main pillars, Bhutan Foundation supports various projects focused on climate change and conservation of endangered species such as snow leopards and mountain tigers. Bhutan Ecological Society aims to build self-sufficient and resilient communities and functional landscapes while ensuring the functional integrity of the ecosystem. As non-profit organizations, these organizations base their decisions on the Bhutan 12th Five Year Plan, regional and international commitments, extensive board meetings, and field research. These organizations currently do not use NASA Earth observations to inform their decisions.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 8 OLI** | Land surface reflectance | Land surface reflectance products were used for updating LULC maps for 2015 and 2020 and as inputs to the corridor path modelling. |
| **Landsat 5 TM** | Land surface reflectance | Land surface reflectance products were used for creating LULC maps for 2010. |

***Ancillary Datasets:***

* Bhutan Foundation Protected Areas and Land Cover maps – shapefiles of protected areas and existing land use and land cover maps, occurrence data for Asian elephants
* Google Earth Pro – High resolution Landsat mosaic satellite imagery of Bhutan for 2010 and 2015

***Modeling:***

* Linkage Mapper Version 2.0.0 (in conjunction with ArcGIS Desktop Version 10.8.1) – used to map linkages using least cost path between protected areas to map potential biological corridors

***Software & Scripting:***

* ESRI ArcGIS Pro Version 2.7.0 – used to process data and make land cover change analyses.
* Google Earth Engine API – used to obtain cloud-free satellite imagery.

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Multispectral Data Stacks for 2010, 2015, and 2020** |  Landsat 5 TM, Landsat 8 OLI  | True color composites serve as references of cloud-free imagery coinciding with each LULC map which can be used for future analyses on landscape use and trends. | I |
| **Elephant Biological Corridor Maps** | Landsat 8 OLI | This map spatially demonstrates the potential migratory corridors for Asian elephants in Bhutan, which can be used to inform decisions about transboundary conservation efforts. | I |
| **Land Use Land Cover Classification Maps for 2010 and 2015** | Landsat 5 TM, Landsat 8 OLI  | These maps complement the previous term’s LULC maps for 1999 and 2019 to 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:***

Land cover classifications and biological corridor maps can enhance the decision-making abilities of Bhutan Tiger Center, Bhutan Foundation, and Bhutan Ecological Society. 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. Land cover classifications may also inform other related work supported by the project partners. In planning and managing biological corridors, there is an opportunity to use satellite data to generate information that contributes to potential placement of biological corridors.

***Project Continuation Plan:***

The next term of the project could build upon previous work to further assess historic habitat change and forecast future habitat change for the Asian elephants in Bhutan. To address the land use conflict in southern Bhutan, the project could also implement the Land Use Conflict Identification Strategy (LUCIS) model. The results, along with other findings and knowledge from the three-term project, will be transferred to the partners during a virtual workshop. This will encourage Bhutan Foundation, Bhutan Tiger Center, and Bhutan Ecological Society to incorporate NASA Earth observations into future conservation efforts.

**References**

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