**Bhutan Water Resources III**

*Analyzing Forest Disturbances and Climate Data in Bhutan to Create a Tool for Assisting the Himalayan Environment Rhythm Observation and Evaluation System (HEROES) Project*

**Project Team**

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**Project Overview**

***Project Synopsis:*** The Bhutan Water Resources III team developed the Forest Disturbances Detection Toolbox (FDDT) app in Google Earth Engine (GEE) by combining meteorological data derived from NASA Earth observations, along with the Landsat data to assess forest changes and other disturbances observed from 2000 to 2018. The results from this project will assist the Ugyen Wangchuck Institute for Conservation and Environmental Research (UWICER) to strengthen the efforts of the Himalayan Environmental Rhythm Observation and Evaluation System (HEROES) project to expand on educational outreach and help raise awareness for climate change mitigation.

***Abstract:***

Forest disturbances from bark beetle outbreaks are a major concern in Bhutan, sometimes causing extensive tree mortality to pine and spruce forests. The Bhutan Water Resources III team partnered with the Ugyen Wangchuck Institute of Conservation and Environmental Research (UWICER), the Bhutan Foundation, and the Karuna Foundation to assess forest changes for the focus districts of Bumthang and Haa from 2000-2018. The project used preprocessed meteorological data from the Climate Hazards Center Infrared Precipitation with Station (CHIRPS) and Famine Early Warning System Network Land Data Assimilation System (FLDAS), along with Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper (ETM)+, and 8 Operational Land Imager (OLI) to assess apparent forest disturbance occurrences and observe climate trends. Using the GEE LandTrendr code acquired from Dr. Robert Kennedy’s algorithm, along with the Landsat data, the team developed an app called Forest Disturbances Detection Toolbox (FDDT) to assess forest changes in Bhutan. The geocoordinates for known disturbances were provided to us by the end-users for comparing to LandTrendr disturbance detection products. The project's FDDT is being provided to project partners to aid forest management efforts in Bhutan. The project resulted in the FDDT, though additional work is needed in the future to validate the project end products from the FDDT.

***Key Terms:***

Forest disturbances, bark beetle infestations, climate variability, satellite remote sensing, Google Earth Engine, Landsat, LandTrendr.

***National Application Area(s) Addressed:*** Water Resources

***Study Location:*** Bumthang and Haa districts, Bhutan

***Study Period:*** 2000 – 2018 (October 31st - May 31st)

***Community Concerns:***

* Bhutan has experienced increased warming, with a decrease in annual rainfall and snowfall over the past decade, and faces high risk from glacial lake outburst floods.
* Changes in agricultural patterns due to climate change affect agricultural and forest productivity, which in turn impact national food and fiber security.
* Forest pests such as bark beetle infestations contribute to forest disturbances, resulting in tree mortality and increased action of felling.

***Project Objectives:***

* Identify forest disturbances in Bhutan from 2000 to 2018
* Assess maps of forest damage using the Forest Disturbances Detection Toolbox (FDDT)
* Analyze LandTrendr rate, magnitude, prevalence, duration, and year of detection output
* Produce a tutorial that describes the GEE FDDT tool that incorporates LandTrendr routines

***Previous Terms:***

2021 Spring (MSFC) – Bhutan Water Resources II

2020 Summer (MSFC) – Bhutan Water Resources

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Ugyen Wangchuck Institute for Conservation and Environmental Research (Bhutan)** | Changa Tshering, Head of Information Services | End User | No |
| **Karuna Foundation** | Lindsay Skog, Program Director | Collaborator | No |
| **Bhutan Foundation** | Tshewang Wangchuk, Executive Director | Collaborator | Yes |

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

UWICER bases its project support decisions around priorities outlined in the Bhutan 12th Five Year Plan. It strives to foster better stewardship of Bhutan’s natural heritage – land, water, air, and wildlife – through rigorous science-based research and transmission of science results to field practitioners, environmental leaders, and policymakers. The Karuna Foundation contributes to the pressing issues of climate mitigation and adaptation in the vulnerable Himalayan region including Bhutan. The Bhutan Foundation works and supports efforts to build Bhutanese capacity and serve the Bhutanese people in sharing the principles of Gross National Happiness. Since the Bhutan Foundation works extensively with Civil Society Organizations (CSOs) and government ministries, they can disseminate project results to many branches of government as well as CSOs operating in the country.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 5 TM** | Surface reflectance, NDVI | Surface reflectance and NDVI were used in the GEE tool to aid in land surface identification. |
| **Landsat 7 ETM +** | Surface reflectance, NDVI | Surface reflectance and NDVI were used in the GEE tool to aid in land surface identification. |
| **Landsat 8 OLI** | Surface reflectance, NDVI | Surface reflectance and NDVI were used in the GEE tool to aid in land surface identification. |
| **SRTM** | Elevation | SRTM was used to resolve variations in elevation and slope for mountainous regions.  |

***Ancillary Datasets:***

* Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS) – Gridded rainfall estimates from rain gauge and satellite observations used to assess trends in precipitation from 1981-2020
* Famine Early Warning Systems Network (FEWS NET) Land Data Assimilation System
(FLDAS) – Gridded temperature data used to assess trends in surface temperature from 1981-2020
* UWICER i*n-situ* bark beetle infestation data – used for conducting visual qualitative analysis

***Software & Scripting:***

* Google Earth Engine API – data visualization and raster manipulation
* ArcGIS ArcMap 10.6 – data visualization, raster analysis, and zonal statistics
* LandTrendr – package of algorithms for change detection
* QGIS – data visualization and shapefile creation
* Microsoft Excel 365 – graphing and preliminary analysis

***End Product(s):***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **FDDT Tool using GEE and LandTrendr** | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, SRTM | This tool will be provided to partners to help visualize and assess changes in forest disturbance for aiding forest health monitoring in the country. It will provide an interactive mapper to work with forest disturbance data in Bhutan. | IV |
| **Case Study for Assessing Bark Beetle Damage to Coniferous Forests in Bhutan** | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, SRTM | This analysis will be provided to UWICER with an initial investigation into data on forest change in areas with known bark beetle infestations for the districts of Haa and Bumthang in Bhutan. This case study will be used as a starting point to further develop, assess, and demonstrate the FDDT. | N/A |

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

The project’s FDDT app will be provided to project partners to aid forest management efforts in Bhutan. The FDDT app will help to assess forest changes over time and investigate what may have caused the disturbances for the two focus districts addressed in our study. The project results will be of use in future research by project partners (potentially including other projects being done by NASA SERVIR in support of Bhutan) in identifying forests with tree dieback, measuring the extent of forest damage, and monitoring to see if bark beetle outbreaks are taking place over time. Overall, project results showed how NASA Earth observations can be used with software tools to aid studies of Bhutan climate change trends and related impacts to Bhutan vegetation (e.g., to phenology and forest health conditions). Any future related projects could also look at additional areas with coniferous forest disturbances in western and central Bhutan.

**References**

Bajracharya, S., Maharjan, S., Shrestha, F., & Uddin, K. (2016). Application of remote sensing and GIS in environmental monitoring in the Hindu Kush Himalayan region. *AIMS Environmental Science, 3*(4), 646-662. doi: 10.3934/environsci.2016.4.646

Kennedy, R. E., Yang, Z., Gorelick, N., Braaten, J., Cavalcante, L., Cohen, W. B., & Healey, S. (2018). Implementation of the LandTrendr algorithm on Google Earth Engine. *Remote Sensing, 10*(5), 691. https://doi.org/10.3390/rs10050691

Meddens, A.H., Hicke, J. A., Vierling, L. A., & Hudak, A. T. (2013). Evaluating methods to detect bark beetle-caused tree mortality using single-date and multi-date Landsat imagery. R*emote Sensing of Environment, 132*, 49-58. https://doi.org/10.1016/j.rse.2013.01.002

The World Bank. (2019). *Pathways for sustainable forest management and Socio-equitable economic development*. https://documents1.worldbank.org/curated/en/118821562700584327/pdf/Bhutan-Forest-Note-Pathways-for-Sustainable-Forest-Management-and-Socio-equitable-Economic-Development.pdf

Tshering K. & Tshering C. (2018). *Predicting bark beetle outbreaks using GIS, climate & phenology data*. http://www.uwice.gov.bt/admin\_uwice/publications/publication\_files/Reports/2018/Predicting%20Bark%20Beetle%20Outbreaks%20using%20GIS,%20Climate%20and%20Phenology%20Data\_UWICER%20Technical%20Note%202018.pdf