**Bhutan Agriculture**

*Developing a Crop Mask for Rice and Creating a Data Collection Protocol Utilizing Remotely Sensed Data in Bhutan*

**Project Team**

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**Project Overview**

***Project Synopsis:***

The Kingdom of Bhutan is a predominantly forested nation with a population heavily dependent on agricultural production. The team utilized NASA Earth observations and ancillary data to create a crop mask and sampling protocol for monitoring rice production in Bhutan. This project assisted partners at the Department of Agriculture of Bhutan, the Bhutan Foundation, and the Ugyen Wangchuck Institute of Conservation and Environmental Research (UWICER) in bolstering their agricultural decision-making and monitoring through the use of remotely sensed data.

***Abstract:***

Rice cultivation in Bhutan has been increasingly threatened by deteriorating soil health and outbreaks of diseases and pests associated with the global change in climate patterns. Field surveys, which the national government of Bhutan has relied on to monitor remote agricultural lands, are becoming increasingly overwhelmed by growing threats to agricultural health. To address these concerns, NASA DEVELOP partnered with the Department of Agriculture of Bhutan, the Bhutan Foundation, and the Ugyen Wangchuck Institute of Conservation and Environmental Research (UWICER) and worked to increase the government of Bhutan’s agricultural monitoring capacity. Utilizing Earth observations including Landsat 8 Operational Land Imager (OLI), Sentinel-1 C-band Synthetic Aperture Radar (C-SAR), Shuttle Radar Topography Mission (SRTM), and Planet imagery, the DEVELOP team worked with NASA SERVIR and created a sampling protocol to identify rice plantations and supplement field surveys for more efficient agriculture monitoring. The analysis focused on districts Paro, Punakha, Samtse, Sarpang, Trongsa, Zhemgang, Wangdue Phodrang, and Samdrup Jongkhar in the year 2020 during the period of transplantation (June) to harvesting of rice (November). The team provided the partners with a sampling protocol for integrating NASA Earth observations into their crop monitoring methods, as well as a crop mask for rice identification and to aid crop management. The crop mask for rice was developed using the Random Forest (RF) classifier for the eight districts of Bhutan. Visually, the random forest model has proved to be more accurate and precise than the classification and Regression Tree model. Statistically, the Random Forest model was 91.8% accurate in identifying rice in Bhutan.

***Key Terms:***

Google Earth Engine, Collect Earth Online, crop mask, rice plantation, Random Forest, Classification and Regression Trees (CART)

***National Application Area Addressed:*** Agriculture

***Study Location:*** Paro, Punakha, Samtse, Sarpang, Trongsa, Zhemgang, Wangdue Phodrang, and Samdrup Jongkhar districts, Bhutan

***Study Period:*** 2020 (June 1st – November 30th)

***Community Concerns:***

* With its mountainous topography, Bhutan experiences a series of climate change impacts. For example, low soil fertility and soil erosion lead to a lack of excess crop production and compel farmers to practice subsistence farming. This choice further leads to land fragmentation and nutrient loss, making farms more prone to natural disasters.
* Bhutan has experienced increased warming and decreased annual rainfall, which increases physiological activity that intensifies crop diseases and increases the metabolic rate of some insects, thus increasing the outbreak of certain pests. This threatens the national food security of Bhutan.
* As climate change continues to impact agriculture globally, farmers tend to shift cultivation and farming patterns, making field surveys less efficient as remote agricultural lands become increasingly inaccessible. Bhutan’s Department of Agriculture is left with a lack of crop monitoring options.

***Project Objectives:***

* Investigate the distribution of rice in 2020 by developing a crop mask for identifying rice agriculture using Landsat 8 OLI, Sentinel-1 C-SAR, the Shuttle Radar Topography Mission (SRTM), and PlanetScope imagery
* Generate a remote sensing-oriented data collection protocol and methods tutorial for Collect Earth Online (CEO) and Google Earth Engine (GEE) to enable partners to use NASA Earth observations for land-use planning

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Department of Agriculture (Bhutan)** | Tshering Wangchen, Deputy Chief Agriculture Officer | End User | Yes |
| **Bhutan Foundation** | Tshewang Wangchuk, Executive Director | Collaborator | No |
| **Ugyen Wangchuck Institute for Conservation and Environmental Research (UWICER)** | Changa Tshering, Head of Information Services | Collaborator | No |

***Decision-Making Practice & Policies:***

The Department of Agriculture of Bhutan conducts *in situ* crop and land-use assessments in cycles over multiple years. The Department of Agriculture depends primarily on field reports for national statistics and land use decision-making. The partners currently do not integrate NASA Earth observations into their decision-making processes. Integration of more diverse remote sensing approaches within their methodology will help to increase the frequency of assessments.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Normalized Difference Vegetation Index (NDVI), Soil-Adjusted Vegetation Index (SAVI), Normalized Difference Water Index (NDWI), Normalized Difference Moisture Index (NDMI), Kauth-Thomas Tasseled Cap Transformation | NDVI, SAVI, NDWI, and NDMI were used in the classification of rice and creating the rice mask. Landsat imagery was also used in collecting sample points for training data. The Kauth-Thomas Transformation was calculated using Landsat 8 Top of Atmosphere spectral data to calculate greenness, brightness, and wetness of Bhutan’s agricultural vegetation. |
| **Sentinel-1 C-SAR** | Synthetic Aperture Radar (SAR) Polarization | Synthetic Aperture Radar (SAR) polarization indices were used in the classification of rice and creating the rice mask. |
| **SRTM** | Slope,  Elevation | Slope and elevation indices were used in the classification of rice and creating the rice mask. |
| **PlanetScope** | RGB Imagery | This 3- to 5-meter resolution RGB imagery was used in the sampling protocol to identify testing data. |

***Ancillary Datasets:***

* Department of Agriculture (Bhutan) Crop Survey Coordinates – Identification of initial crop locations and validation of results
* SERVIR Mekong Regional Land Cover Monitoring System – Identification of agricultural presence and crop mask development
* SERVIR Mekong Bhutan Administrative Boundaries – Mapping crop mask results in Bhutan districts of interest

***Software & Scripting:***

* Collect Earth Online – Data sampling protocol
* Google Earth Engine API – Data collection, visualization, and implementation of Random Forest and CART
* Esri ArcGIS ArcMap 10.6 – Data visualization
* Google Colab TensorFlow 2.x – Statistical analysis and independent validation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Crop Mask for Rice** | Landsat 8 OLI  Sentinel-1 C-SAR  SRTM | The crop mask will be used by partners to identify and monitor areas of rice agriculture in Bhutan, allowing more robust crop management and reducing the need for field surveys. | N/A |
| **Sampling Protocol** | Landsat 8 OLI  PlanetScope | The partners will use the standardized approach for collecting statistically valid land cover training data created by the remote sensing-oriented sampling protocol to replicate the methodology for future analysis. | N/A |
| **Methods and Remote Sensing Capacity Building Tutorial** | Landsat 8 OLI  Sentinel-1 C-SAR  SRTM  PlanetScope | This tutorial will help partners in Bhutan gain the skills and knowledge of the DEVELOP team to replicate methodologies and further engage with NASA data. It will be used to better understand how to leverage NASA Earth observations for land-use planning. | N/A |

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

The project’s end products will provide partners with a crop mask to better identify rice in the country and a remote sensing-oriented data collection protocol and methods tutorial to aid crop management efforts in Bhutan. Project partners will use the crop mask in future research to study rice distribution in the country and monitor efforts to prevent crop diseases and pests. These end products will help partner organizations in Bhutan to better understand how to leverage NASA Earth observations for land-use planning.

***Project Continuation Plan:***

The second term of this project will build upon the first term’s sampling methodology and crop mask to expand the overall area assessed in Bhutan. It will also incorporate additional crop types into the crop mask protocol and attempt to determine the healthiness of crop varieties within the region. The continuation project will also provide a video tutorial so partners can replicate these sampling methods and utilize NASA Earth observations in the future. These end products will help partners meet their goal of remotely monitoring agricultural regions in Bhutan.

**References**

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