**Bhutan Agriculture III**

*Monitoring Cropland Changes in Bhutan using Remote Sensing to Bolster Food Security and Support Crop Monitoring.*

**Project Team**

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**Project Overview**

***Project Synopsis:***

This final iteration of the DEVELOP Bhutan projects will build upon the previous team’s data sampling protocol by comparing the accuracy of different learning methods in Google Earth Engine. This project will also introduce a cropland change analysis, which will provide local and regional information about how cropland areas are changing across Bhutan. This project will utilize Landsat, Sentinel, and Planet data to create end products that support the future of farming in Bhutan. The end products will be used by the Department of Agriculture, National Plant Protection Center, Agriculture Research and Development Centre in Wengkhar, Ugyen Wangchuck Institute for Conservation and Environment, and National Statistics Bureau to inform agricultural decisions within the country, improve the efficiency of farming, and support future research.

***Abstract:***

The Bhutan Agriculture III team aimed to improve agricultural efficiency in Bhutan, a nation heavily reliant on agriculture but faces challenges such as geophysical limitations and lack of scientific agricultural practice, in collaboration with the end partner; Bhutan’s Department of Agriculture (DoA), and with the collaborators; the Bhutan Foundation, National Plant Protection Centre (NPPC), Agricultural Research Department Centre (ARDC), National Statistics Bureau (NSB), and the Ugyen Wangchuck Institute for Conservation and Environment Research (UWICER). Advised by NASA SERVIR, the team developed crop masks and monitored rice distribution from 2015 to 2022 utilizing Earth observations such as Landsat 8 Operational Land Imager (OLI), Landsat 9 OLI-2, Sentinel-1 C-Band Synthetic Aperture Radar (C-SAR), Sentinel-2 MultiSpectral Instrument (MSI) and Shuttle Radar Topography Mission (SRTM). The team gathered 5000 points from the five dzongkhags that yield the most rice in Bhutan (Paro, Punakha, Samtse, Sarpang and Wangue Phodrang) using Collect Earth Online (CEO). With the data collected, the team trained and split the data into training and validation data on Google Earth Engine (GEE) for a random forest (RF) classifier for rice and non-rice classification. After running the data on the Random Forest (RF) model, the team got an accuracy score of 81.48%, a kappa score of 55.75% and an F1 score of 86.11%. This data supports better agricultural decision-making for the governing body of Bhutan, helps enhance farming efficiency and foster sustainable practices, assists in overcoming data inaccuracy and bolsters food security in the country.

***Key Terms:***

Remote Sensing, Earth observations, Google Earth Engine, Collect Earth Online, crop mask, rice plantation, Random Forest, graphical user interface

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

***Study Location:*** Bhutan

***Study Period:*** 2015-2022 (June-September)

***Community Concerns:***

* Due to Bhutan's complex geophysical location, there are multiple agricultural issues such as low soil fertility, pests, frequent changes in climate and weather, short growing seasons, and cold stress.
* Even though Bhutan is primarily an agrarian society, the challenges mentioned above result in low crop yields and increased reliance on imports, limiting Bhutan's overall goal of ensuring food security.
* Moreover, with the emergence of urbanization, there are options in other jobs and a lack of modernity in traditional farming practices, individuals are forced to pursue non-agriculture lifestyles, which leads to a rise in food imports
* Lastly, because of the country's geographical position, it is difficult to generate precise survey locations and get an unbiased and reasonable sample size for field reporting. Farmers in Bhutan typically utilize conventional mix farming, making determining a reasonable sample size more difficult.

***Project Objectives:***

* Optimize annual rice crop mask for better food security and crop monitoring
* Enhance the accuracy of data samples
* Identity farmland area change

***Previous Term(s):***

2021 Fall (MSFC) – Bhutan Agriculture I

2022 Summer (MSFC) - Bhutan Agriculture II

**Partner Overview**

***Partner Organization(s):***

|  |  |  |
| --- | --- | --- |
| **Organization(s)** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Department of Agriculture (Bhutan)** | Tshering Wangchen, Deputy Chief Agriculture Officer | End User |
| **National Plant Protection Centre, Department of Agriculture (Bhutan)** | Nidup Dorji, Plant Protection Supervisor | Collaborator |
| **National Statistics Bureau (Bhutan)** | Tobden Tobden, Deputy Chief Statistical Officer | Collaborator |
| **Ugyen Wangchuck Institute for Conservation and Environment (Bhutan)** | Changa Tshering, Dy. Chief Forestry Officer Collaborator | Collaborator |
| **Agriculture Research and Development Centre, Wengkhar, Department of Agriculture (Bhutan)** | Loday Phuntsho, Horticulturist | Collaborator |
| **Bhutan Foundation** | Tshewang Wangchuk, Executive Director | Collaborator |

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

The Bhutan Department of Agriculture currently conducts in-field crop and land-use assessments rotating over multiple years. The Department of Agriculture is heavily dependent on field reporting for developing national statistics and crop reporting. Integrating more diverse remote sensing approaches within the Department’s methodology for reporting and developing planning efforts will increase the rate of assessments (multi-year to annual). The end user is not familiar with NASA Earth observations data. This project will build the Department’s capacity to use NASA Earth observations data and provide them with valuable information about remote sensing techniques.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 8 OLI** | Vegetation Index (NDVI), Soil-Adjusted Vegetation Index (SAVI), Modified Normalized Difference Water Index (MNDWI), Normalized Difference Water Index (NDWI), Normalized Difference Moisture Index (NDMI), Normalized Difference Built-up Index (NDBI)  surface reflectance, tasseled cap brightness, greenness, and wetness | NDVI, SAVI, surface reflectance, tasseled cap brightness, greenness, and wetness will be used to analyze and delineate rice paddy fields. |
| **Landsat 9 OLI-2** | NDVI, SAVI, surface reflectance, tasseled cap brightness, greenness, and wetness | NDVI, SAVI, surface reflectance, tasseled cap brightness, greenness, and wetness will be used to analyze new crop varieties. |
| **Sentinel-1 C-SAR** | VH Ascending, VV Ascending, VH Descending, VV Descending, Normalized Difference Ratio Ascending, Normalized Difference Ratio Descending | These data will provide high temporal resolution imagery to analyze crop distribution over a larger area. |
| **Sentinel-2 MSI** | MNDWI, NDVI, SAVI, NDWI, NDMI, NDBI | These data will provide high spatial resolution data to differentiate between different crop species. |
| **SRTM** | Slope, elevation | Slope and elevation will be used as features in the classification of different crops, showing their relation to different elevation. |

***Ancillary Datasets:***

* Department of Agriculture (Bhutan) Rice Crop Surveys- Identify initial crop locations and validate results.
* World Settlement Footprint 2015- Outline human settlements within Bhutan

***Modeling:***

* Agriculture Classification and Estimation Services (ACES)- geospatial application for identifying and mapping rice farms in Bhutan (POC: Timothy Mayer, timothy.j.mayer@nasa.gov)

***Software & Scripting:***

* Collect Earth Online- Data sampling protocol
* Google Earth Engine API- Data collection, visualization and implementation of Random Forest and CART

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

|  |  |  |
| --- | --- | --- |
| **End Product(s)** | **Earth Observations Used** | **Partner Benefit & Use** |
| **Crop Mask for Rice** | Landsat 8 OLI, Sentinel-1 C-SAR, Sentinel-2 MSI, SRTM | Based on Earth observation data, this mask will assist in identifying the distribution of rice. To help their efforts to improve food security in Bhutan, the partners can better identify where rice is grown. |
| **Rice Crop Mask**  **Graphical User Interface** | Landsat 8 OLI, Landsat 9 OLI, Sentinel-1 C-SAR, SRTM, Sentinel-2 MSI | This GUI will assist in highlighting pertinent data from the crop mask, such as the proportion of regions designated as rice, and in visualizing trends over a specified time. For regionally tailored visualizations, end users will define districts or subdistricts. Additionally, end users can pinpoint changes in the rice growing season and areas that could require additional assistance with agricultural development and monitoring. |
| **Methodology tutorial** | Landsat 8 OLI, Landsat 9 OLI, Sentinel-1 C-SAR, SRTM, Sentinel-2 MSI | This tutorial will round out the project by creating a replicable process for the partners to follow. It will outline the various methodologies used throughout the Bhutan Agriculture projects and demonstrate how to use remote sensing to create rice crop masks. |

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

The end users of this project will greatly benefit from its implementation. The project provides a way to precisely identify and monitor rice distribution in various locations using cutting-edge Earth observation data from sources like Landsat 8 OLI, Sentinel-1 C-SAR, and SRTM. By empowering stakeholders to make data-driven decisions about resource allocation and food security, they may successfully plan strategies to improve agricultural practices. By injecting data-driven accuracy into decision-making processes, the project's results have the potential to alter practices and regulations. This change to focused actions and informed policies can greatly improve efforts to secure food, manage resources more effectively, and guarantee sustainable agricultural growth.

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