**Bhutan Agriculture II**

*Creating a Graphical User Interface, Crop Mask, and Data Collection Protocol for Analysis of Rice Crop in Bhutan using Remotely Sensed Data*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Building upon the previous DEVELOP team’s use of Earth observations data and sampling protocols for rice, the team expanded the crop mask for rice to the whole country of Bhutan. The project used different Earth Observations and built upon the first term’s sampling protocols for rice and provided an updated methodology assessment to partners. The end products will help increase the frequency of rice crop assessments conducted by the partners and aid in making informed decisions on how to prevent pests and diseases within crops. The project will also help end-users to better understand and identify rice in the country.

***Abstract:***

Agriculture is an important sector in Bhutan; accounting for 19.63% of Bhutan’s GDP in 2020 while also providing livelihoods for approximately 57% of the population. The Department of Agriculture (DoA) in Bhutan still relies on in-field reporting for crop monitoring which is time-consuming and labour intensive. To promote efficiency, the team partnered with the DoA, the Bhutan Foundation, and the Ugyen Wangchuck Institute of Conservation and Environmental Research (UWICER). The team, with the help of science advisors from NASA SERVIR, expanded the crop mask, created in the previous term, to the whole country of Bhutan for the time period of 2015-2020 (May-October) and streamlined the sampling protocols for applicability to any available crop data. The random forest model also had pre-processed rice points from Collect Earth Online for five heavy rice production dzongkhags: Paro, Samtse, Sarpang, Punakha and Wangdue Phodrang. The team also developed a graphical user interface (GUI) which provided a visual representation of current trends and rice distribution across Bhutan. The team utilized NASA Earth observations, including Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI), and Shuttle Radar Topography Mission (SRTM), as well as other Earth observations including Sentinel-1 C-band Synthetic Aperture Radar (C-SAR). This project refined the previous term’s methodology to help supplement crop monitoring and increase the frequency of data collected to aid the decision-making process with the use of remote sensing data. The accuracy and kappa score for the testing data were 85.9% and 71.8% respectively.

***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:*** May to October from 2015 to 2020

***Community Concerns:***

* Farming in Bhutan is difficult due to the mountainous terrain along with issues of low soil fertility, pests, short growing season, frequent weather swings and cold stress. Although Bhutan is mainly an agrarian society where majority of the population are farmers, due to the small-scale, subsistence farms with low productivity and limited processing capacity, the challenges mentioned above result in low crop yields and increased dependence on foreign imports which constrains Bhutan’s overall goal of ensuring food security.
* Along with the mountainous topography and climate variabilities, the task of boosting agricultural production becomes even harder if there are no efforts made in developing climate resilient farming technologies and the capacity of farmers to adopt new sustainable strategies instead of traditional farming techniques.
* Producing precise survey locations and coming up with an unbiased, reasonable sample size for field reporting is hard and not feasible because of the geographical location of the country. The farmers in Bhutan usually practice conventional mix farming, which makes it harder to determine a good sample size.
* The lack of modernization in the traditional farming methods and the limited amount of arable land forces individuals to pursue non-agriculture livelihoods with the advent of opportunities in other career fields, which also leads an increase to the external imports of food.

 ***Project Objectives:***

* Expand the overall research area in Bhutan to produce a more robust crop mask for rice
* Create a Graphical User Interface (GUI) for crop analysis
* Tune the Random Forest model parameters to yield optimal performance in creating the crop mask
* Streamline the previous term’s data collection protocol for ease of use and generalizability to any crop

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

2021 Fall (MSFC) – Bhutan Agriculture I

**Partner Overview**

***Partner Organizations:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Department of Agriculture (Bhutan)** | Tshering Wangchen, Deputy Chief Agriculture Officer | End User |
| **Bhutan Foundation** | Tshewang Wangchuk, Executive Director | Collaborator |
| **Ugyen Wangchuck Institute for Conservation and Environmental Research (Bhutan)** | Changa Tshering, Head of Information Services | Collaborator |

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

The DoA under the Ministry of Agriculture in Bhutan, depends on field reporting and surveys of different crops for the development of yearly national statistics and land-use decision-making. To get the yearly statistics, surveys are done by using a set of questionnaires that are given to the rural households (samples) in all 205 Gewogs of the 20 districts of the country. The decision-making processes for DoA rely heavily on surveys and field reports with no integration of any earth observations or remote sensing data and a lack of human resources. With only 2.93% of the total land area under agricultural production (Tenzin et al., 2019), DoA aims to increase agricultural awareness, and economic livelihood of the farmers. For the agricultural land use, the DoA has to decide accordingly to the policies listed in the Constitution of Bhutan, which is to maintain at least 60% of geographical land under forest cover, currently at 71% forest cover (Tenzin et al., 2019).

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 8 OLI** | Top of Atmosphere reflectance (TOA), NDVI, MNDWI, SAVI, NDWI, NDBI and NDMI  | Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Modified Normalized Difference Water Index (MNDWI), Soil-Adjusted Vegetation Index (SAVI), Normalized Difference Moisture Index (NDMI), Normalized Difference Built-up Index (NDBI), Brightness, Greenness, Wetness, Fourth, Fifth and Sixth were used as features in the classification of rice and creating the rice mask. |
| **Landsat 7 ETM+** | True color | Sample rice and non-rice points were collected from Landsat 7 imagery. |
| **Landsat 5 TM** | True color | Sample rice and non-rice points were collected from Landsat 5 imagery. |
| **Aqua MODIS** | True color | Sample rice and non-rice points were collected from Aqua MODIS imagery. |
| **Terra MODIS** | True color | Sample rice and non-rice points were collected from Terra MODIS imagery. |
| **Sentinel-1 C-SAR** | Synthetic Aperture Radar (SAR) VH and VV  | VH (cross-polarization), VV (co-polarization), VV and VH ratio, normalized difference between VV and VH for both descending and ascending orbiting orientations were used as features in the classification of rice and creating the rice mask. |
| **SRTM** | Slope, elevation | Slope and elevation were used as features in the classification of rice and creating the rice mask. |

***Ancillary Datasets:***

* Department of Agriculture (Bhutan) Crop Surveys – identify initial crop locations and validate results.
* The crop layer from Regional Land Cover Monitoring System (RLCMS) by the SERVIR team was imported within GEE to help filter out noise from land features such as glaciers and barren soil in the final crop mask.
* The Height Above Nearest Drainage (HAND) computed by Donchyts et al was imported within GEE as additional indices for crop classification.
* Precipitation from TerraClimate dataset was imported within GEE as additional indices for crop classification.
* Temperature from ECMWF Reanalysis 5th Generation-Land (ERA5-Land) dataset was imported within GEE as additional indices for crop classification.
* Canopy Interception from Penman-Monteith-Leuning Evapotranspiration (PML) dataset was imported within GEE as additional indices for crop classification.

***Software & Scripting:***

* Collect Earth Online – data sampling protocol
* Google Earth Engine API – data collection, visualization, Random Forest implementation and graphical user interface creation

***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  | This mask will help identify rice distribution based on Earth observations data. Thus, allowing the partners to gain a better understanding of where rice is located to support their efforts to strengthen food security in Bhutan. |  I |
| **Rice Crop Mask****Graphical User Interface** | Landsat 8 OLI, Sentinel-1 C-SAR, SRTM  | This GUI will help to highlight relevant information from the crop mask, such as the number of regions classified as rice, and visualize trends based on a custom time range. End users will specify districts or subdistricts for visualizations specific to that region. End users can also identify rice growing season change and regions that may need more support in terms of agriculture monitoring and development. |     I |
| **Sampling Protocol** | Landsat 5 TM, Landsat ETM+, Terra MODIS and Aqua MODIS | This sampling protocol will build upon the previous term’s sampling protocol to be more streamlined and easier to follow. This protocol will provide a reference procedure for crop points collection and help partners to replicate the methodology for future analysis of remote sensing data applied to any crop type. |   I |

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

The end products will help the project partners to have an improved and streamlined approach to creating a crop mask that will supplement field reporting. Data collected throughout the years can be easily compiled together and accessed with the help of the GUI, providing a visual representation of current trends and rice distribution across Bhutan. Such vital data can aid the decision-making process of project partners to identify regions requiring more investigation in terms of crop data or a region whose trends in rice production have changed significantly due to an underlying phenomenon which can be studied further. The methodology described can be generalized to any available crop data and will help partner organizations in Bhutan to learn how to leverage NASA Earth observations for land-use planning.

**References**

Renewable Natural Resources Statistics Division (RSD) Directorate Services (2021). *Agricultural statistics 2020*. Royal Government of Bhutan, Ministry of Agriculture and Forests. <https://www.doa.gov.bt/wp-content/uploads/2021/08/Agriculture-Statistics-2020.pdf>

Chhogyel, & Kumar, L. (2018). Climate change and potential impacts on agriculture in Bhutan: a discussion of pertinent issues. *Agriculture & Food Security, 7(1),*, Article 79. <https://doi.org/10.1186/s40066-018-0229-6>

CIAT; World Bank. (2017). Climate-Smart Agriculture in Bhutan. CSA Country Profiles for Asia Series. International Center for Tropical Agriculture (CIAT); The World Bank. Washington, D.C. 26p. <https://climateknowledgeportal.worldbank.org/sites/default/files/2019-06/CSA-in-Bhutan.pdf>

Tenzin, J., Phuntsho, L., & Lakey, L. (2019). Climate Smart Agriculture: Adaptation and Mitigation Strategies to Climate Change in Bhutan. In *Climate Smart Agriculture: Strategies to Respond to Climate Change in South Asia* (pp. 37–61). essay, SAARC Agriculture Centre (SAC), Dhaka, Bangladesh.

Tshewang, S., Park, R., Chauhan, B., & Joshi, A. (2018). Challenges and prospects of wheat production in Bhutan: A review. *Experimental Agriculture, 54(*3*),* 428–442. https://doi.org/10.1017/S001447971700014X