



## Bhutan Agriculture III

Monitoring Cropland Changes in Bhutan Using Remote Sensing to  
Bolster Food Security and Support Crop Monitoring

Sonam S. Tshering • Ugyen T. Dorji • Tenzin Lhaden • Sangay Choden • Garab K. Dorji

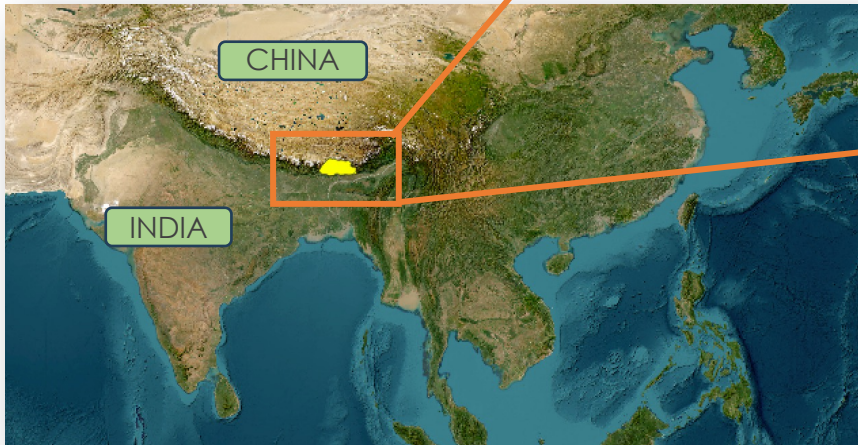
25<sup>TH</sup> DEVELOP

ANNIVERSARY



# Study Area and Period

- Bhutan is a mountainous country
- Dependence on agriculture
- June – September
- 2015 – 2022



Basemap Credit: Esri, Maxar, Earthstar Geographics, CNES/Airbus DS, and the GIS User Community



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0 75 150 km

■ Highest rice production dzongkhags  
■ Bhutan



# Project Overview

**Fall  
2021**



Generated crop mask for 8 districts in Bhutan for the year 2020



Created a sampling protocol for crop monitoring methods

**Summer  
2022**



Expanded the crop mask to all 20 districts in Bhutan



Created a Graphical User Interface (GUI) for crop analysis



# Objectives

**Optimize**

Annual rice crop masks

**Enhance**

Data sampling accuracy

**Identify**

Farmland area change



Image Credit: Kandukuru Nagarjun



# Partners

## End User

Department of Agriculture (DoA)



National Plant  
Protection  
Centre (NPPC)



Agriculture Research  
and Development  
Centre (ARDC)



## Collaborators

National Statistics Bureau (NSB)



Ugyen Wangchuck Institute  
for Conservation and Environment  
Research (UWICER)



Bhutan Foundation



# Community Concerns

**Complex** geophysical location

**Impact** on crop yields

**Difficulty** in surveying and reporting

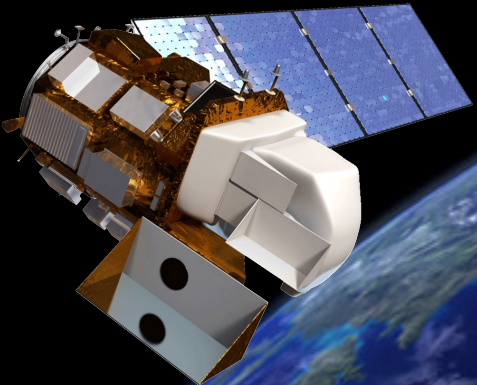
**Shift** towards non-agriculture lifestyles



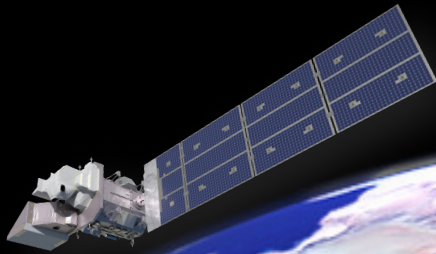


# Earth Observations

Landsat 8  
Operational Land  
Imager (OLI)



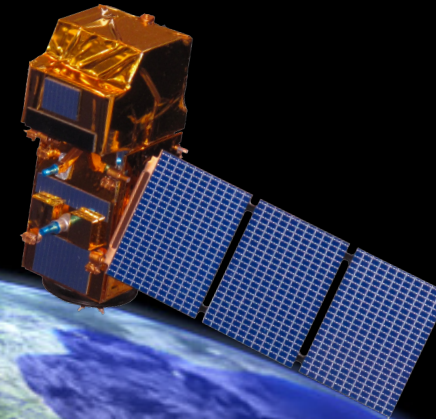
Landsat 9  
Operational Land  
Imager-2 (OLI-2)



Sentinel-1 C-Band  
Synthetic  
Aperture Radar  
(C-SAR)



Sentinel-2 MultiSpectral  
Instrument (MSI)



Shuttle Radar  
Topography Mission  
(SRTM)



# Agriculture Classification and Estimation Service (ACES)

Employing the agricultural classification and estimation service (ACES) for mapping smallholder rice farms in Bhutan

Timothy Mayer<sup>1,2\*</sup>, Biplov Bhandari<sup>1,2</sup>, Filoteo Gómez Martínez<sup>1,2</sup>, Kaitlin Walker<sup>1,2</sup>, Stephanie A. Jiménez<sup>1,2</sup>, Meryl Kruskopf<sup>1,2</sup>, Micky Maganini<sup>1,2</sup>, Aparna Phalke<sup>1,2</sup>, Tshering Wangchen<sup>3</sup>, Loday Phuntsho<sup>4</sup>, Nidup Dorji<sup>5</sup>, Changa Tshering<sup>6</sup> and Wangdrak Dorji<sup>7</sup>

Guided Bhutan Agriculture III with model and ACES workflow

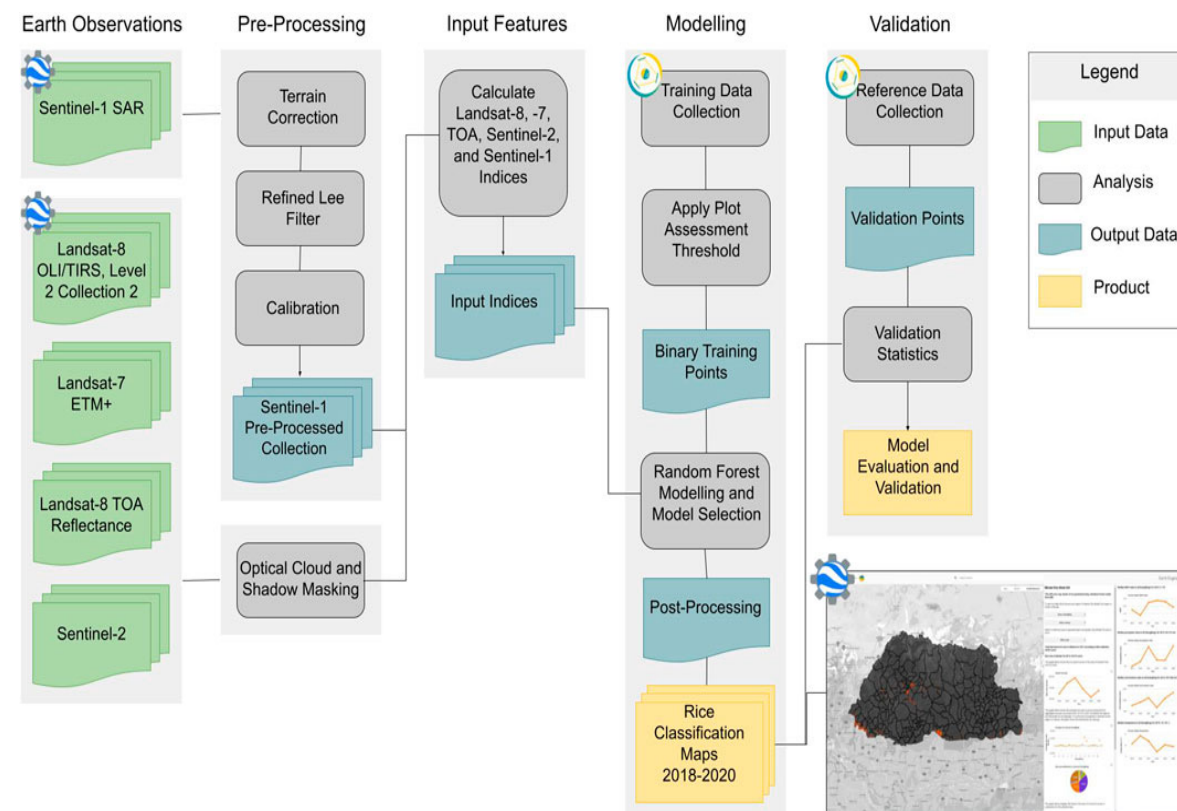


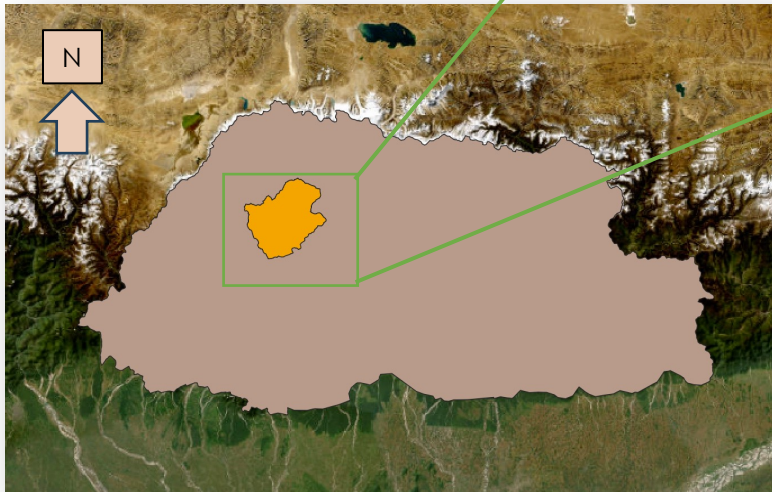
Image credit: Mayer et al., 2023



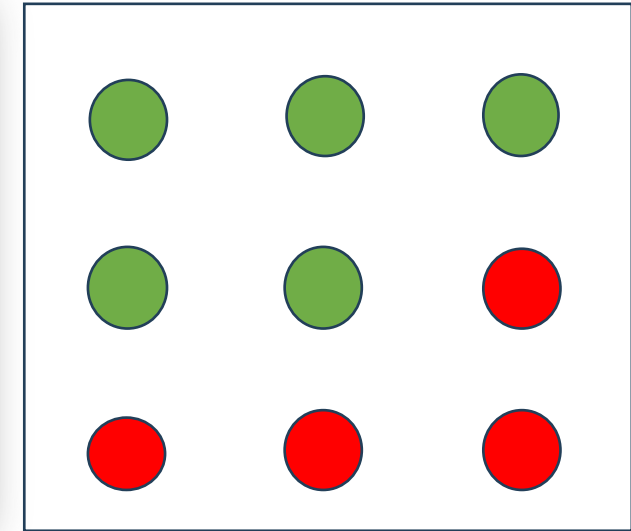
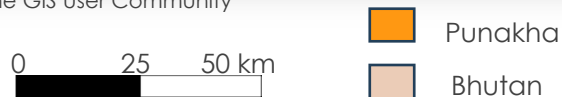


# Methodology: Input

- Sampling rice and non-rice points using Collect Earth Engine (CEO)
- Data points from GeoFairy provided by DoA for validation.



Basemap Credit: Esri, Maxar, Earthstar Geographics, CNES/Airbus DS, and the GIS User Community



| Rice or Not-Rice |   |
|------------------|---|
|                  | 1 |
|                  | 1 |
|                  | 0 |
|                  | 0 |
|                  | 1 |

Is this agriculture plot  
rice crop?

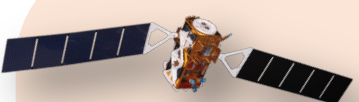
Yes

No

# Methodology: Processing

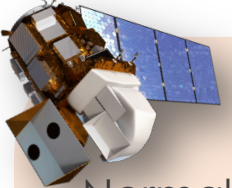
Train and test split data into Google Earth Engine

Variables

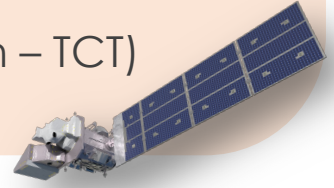


Vertical Horizontal ratio (VH),  
Vertical Vertical ratio (VV), normalized difference between VV and VH

Slope, Elevation

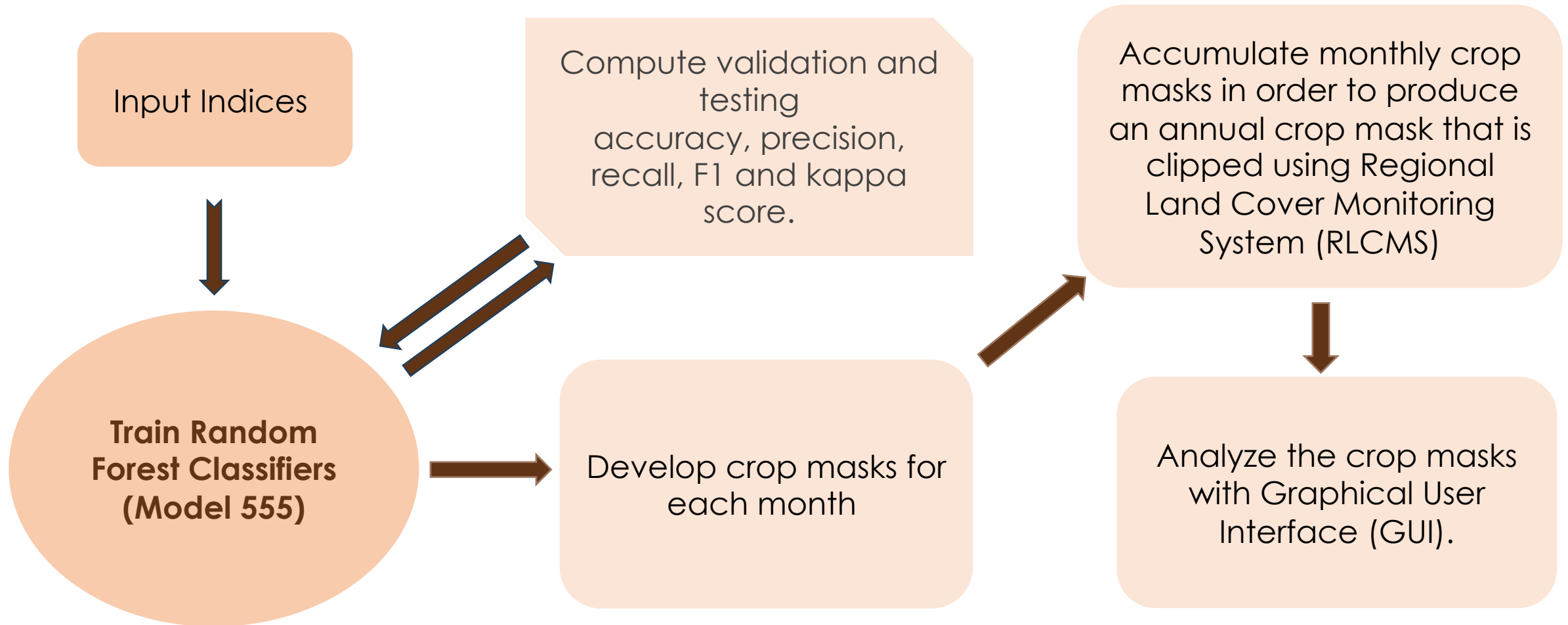


**Optical Indices:**  
Normalized difference vegetation index (NDVI)  
Soil-Adjusted Vegetation Index (SAVI)  
Normalized difference moisture index (NDMI)  
Normalized Difference Water Index (NDWI)  
Modified Normalized Difference Water Index (MNDWI)  
Normalized Difference Built-up Index (NDBI)  
Brightness, Greenness, Wetness, Fourth, Fifth, and Sixth (Landsat 8)  
Tasselled Cap Transformation – TCT

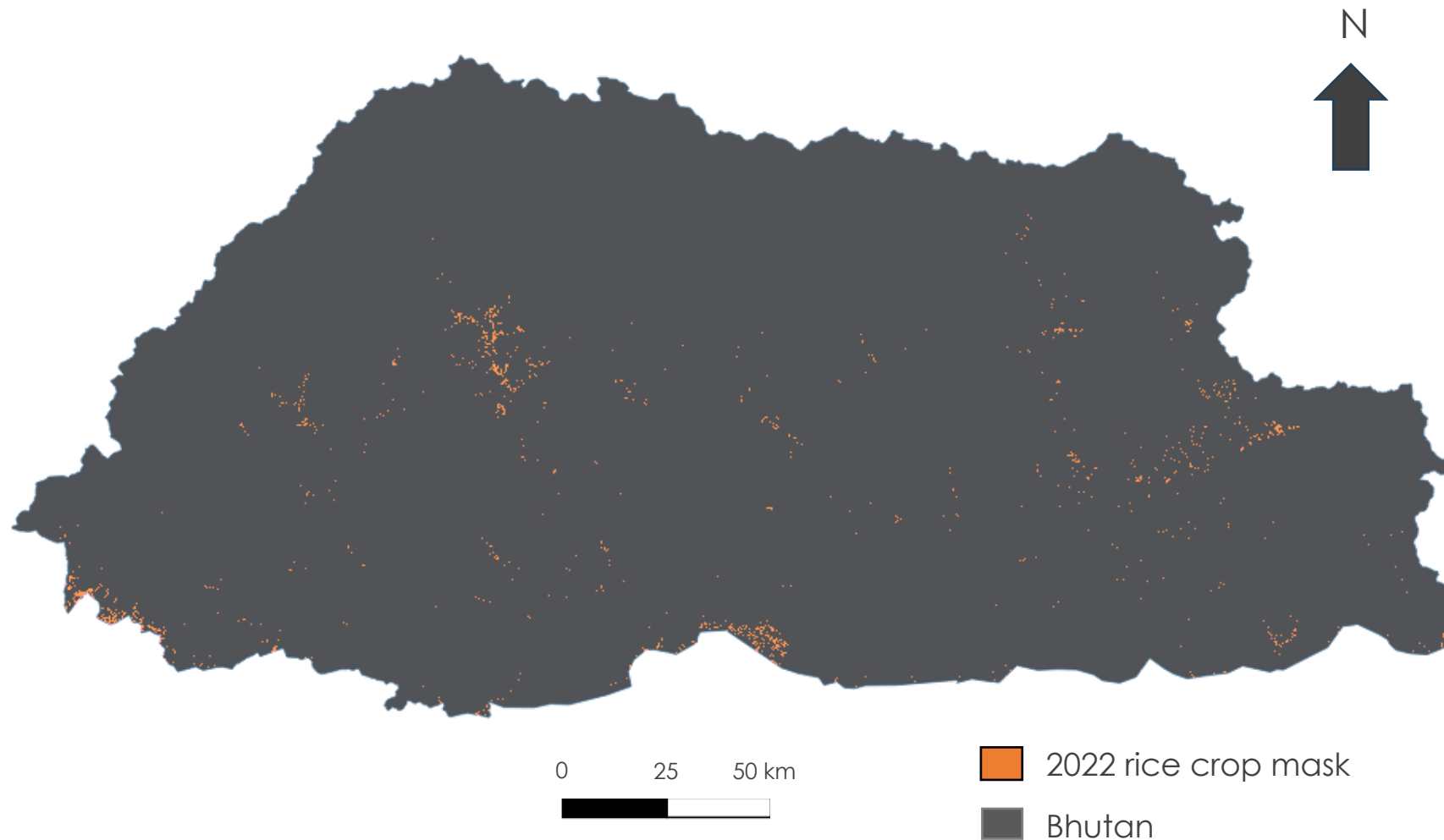




# Methodology: Analysis



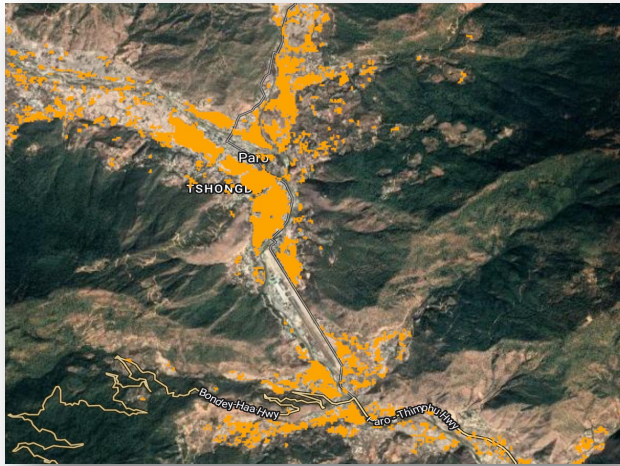
# Results: 2022 Rice Crop Mask



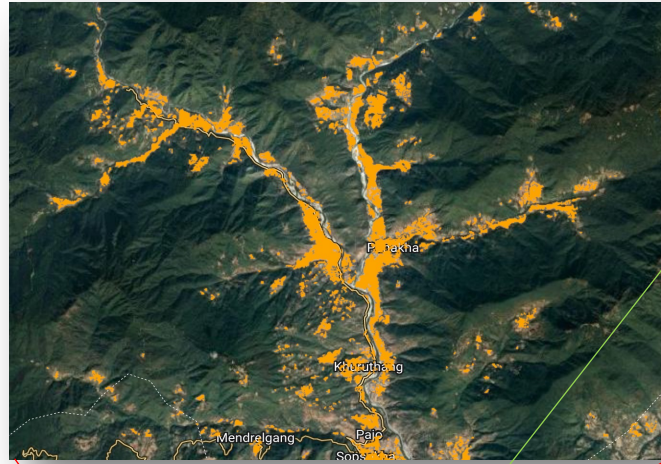


# Results: Dzongkhag Rice Crop Masks

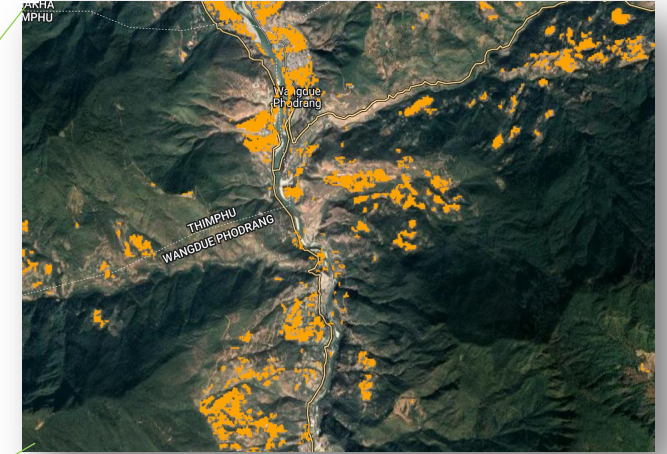
Paro



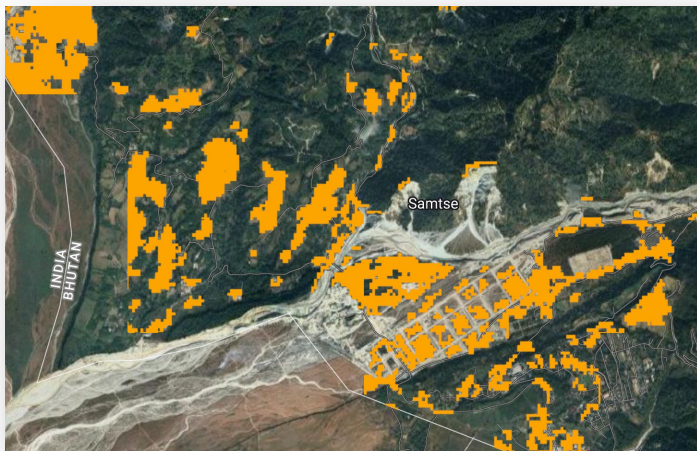
Punakha



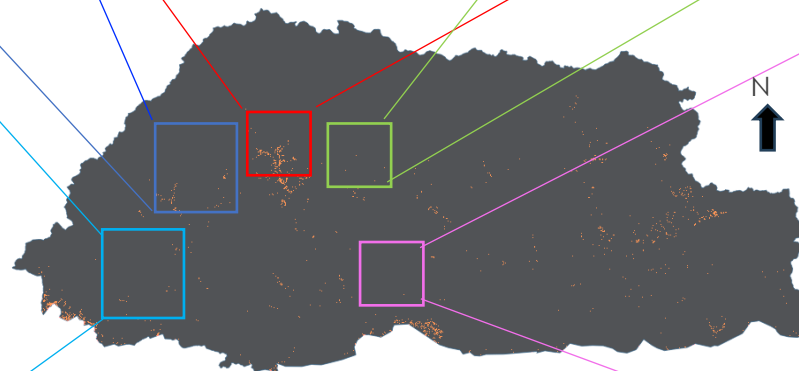
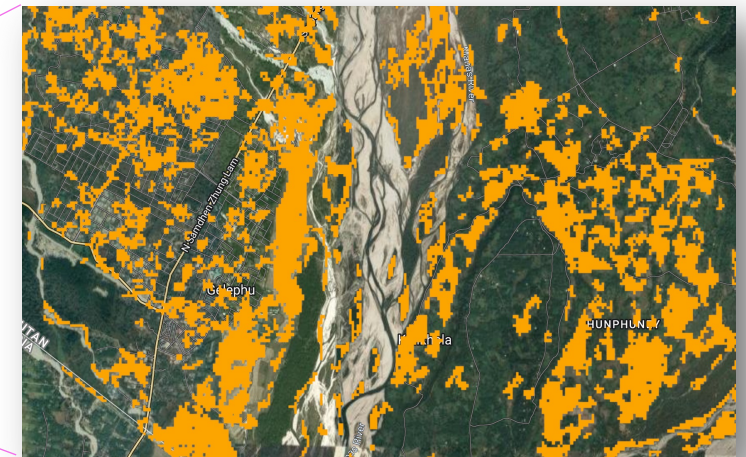
Wangdue Phodrang



Samtse



Sarpang



0 75 150 km

2022 Rice crop masks  
Bhutan



# Applying Random Forest Model



# Confusion Matrix Results

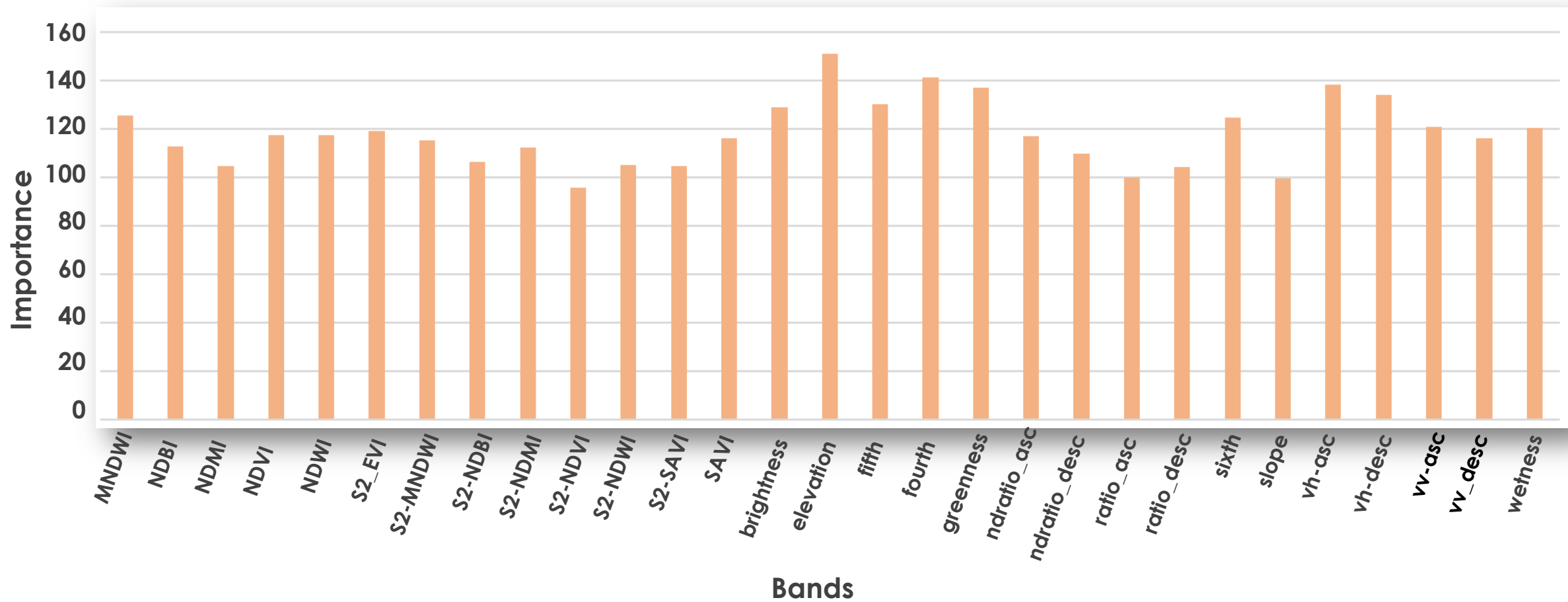
|            |          | Model's Predicted Label |                |
|------------|----------|-------------------------|----------------|
|            |          | Rice                    | Non-Rice       |
| True Label | Rice     | True Positive           | False Positive |
|            | Non-Rice | False Negative          | True Negative  |

|            |          | Model's Predicted Label |          |
|------------|----------|-------------------------|----------|
|            |          | Rice                    | Non-Rice |
| True Label | Rice     | 255                     | 126      |
|            | Non-Rice | 104                     | 757      |



# RF Model Variable Importance Graph

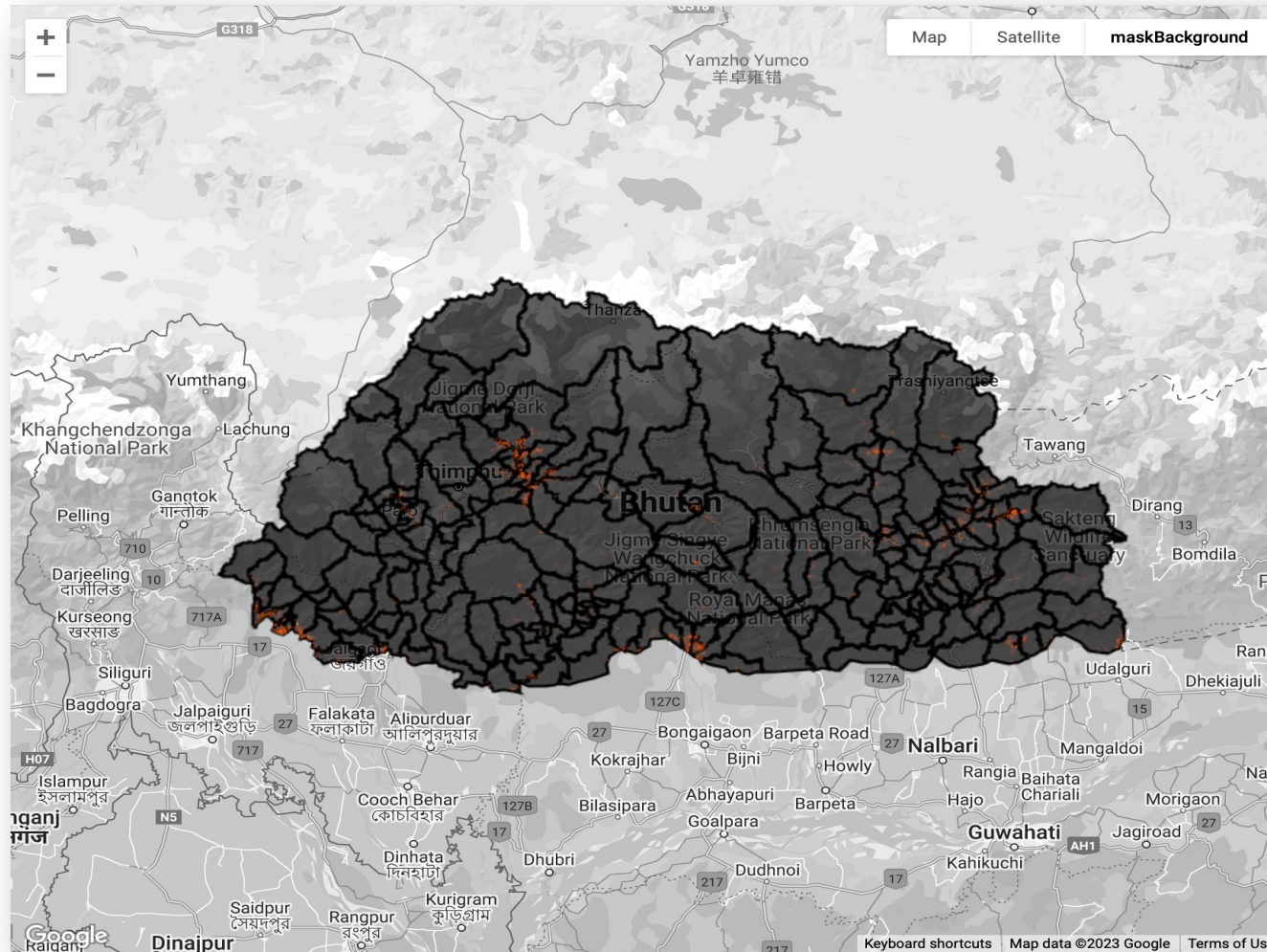
Random Forest Variable Importance



# Statistical Measurements for Testing Data

| Statistical Method | Score |
|--------------------|-------|
| Accuracy           | 81.48 |
| Kappa              | 55.75 |
| Recall             | 87.92 |
| Precision          | 85.73 |
| F1                 | 86.11 |

# Graphical User Interface



## ACES: Agricultural Classification and Estimation Service

This GUI visualizes annual rice crop masks generated using a Random Forest model from GEE.

To get rice stats, first choose your region of interest. By default, the region is whole of Bhutan.

Select a Dzongkhag

Select a Gewog

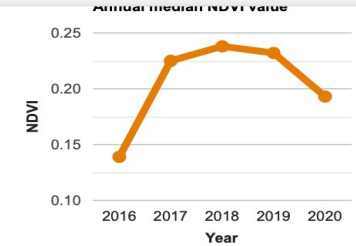
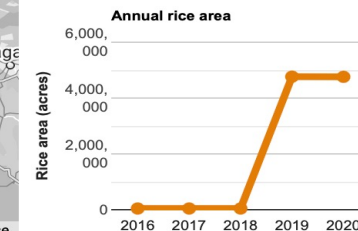
Select a reference year to generate layers and graphs. By default, the year is 2016.

Select a year

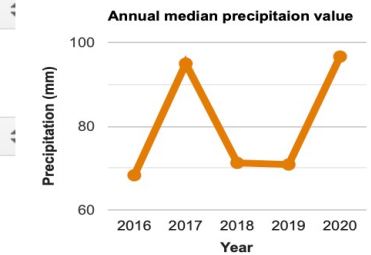
Total harvested rice area in Bhutan for 2016 according to DOA statistics: 54881 acres

Rice area in Bhutan for 2016: 43307 acres

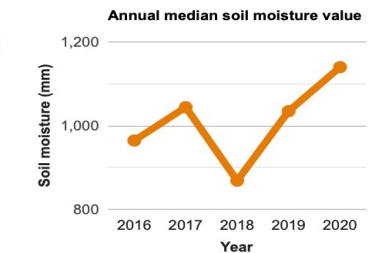
The graph below shows the rice area in acres in the area of interest from 2016 to 2020.



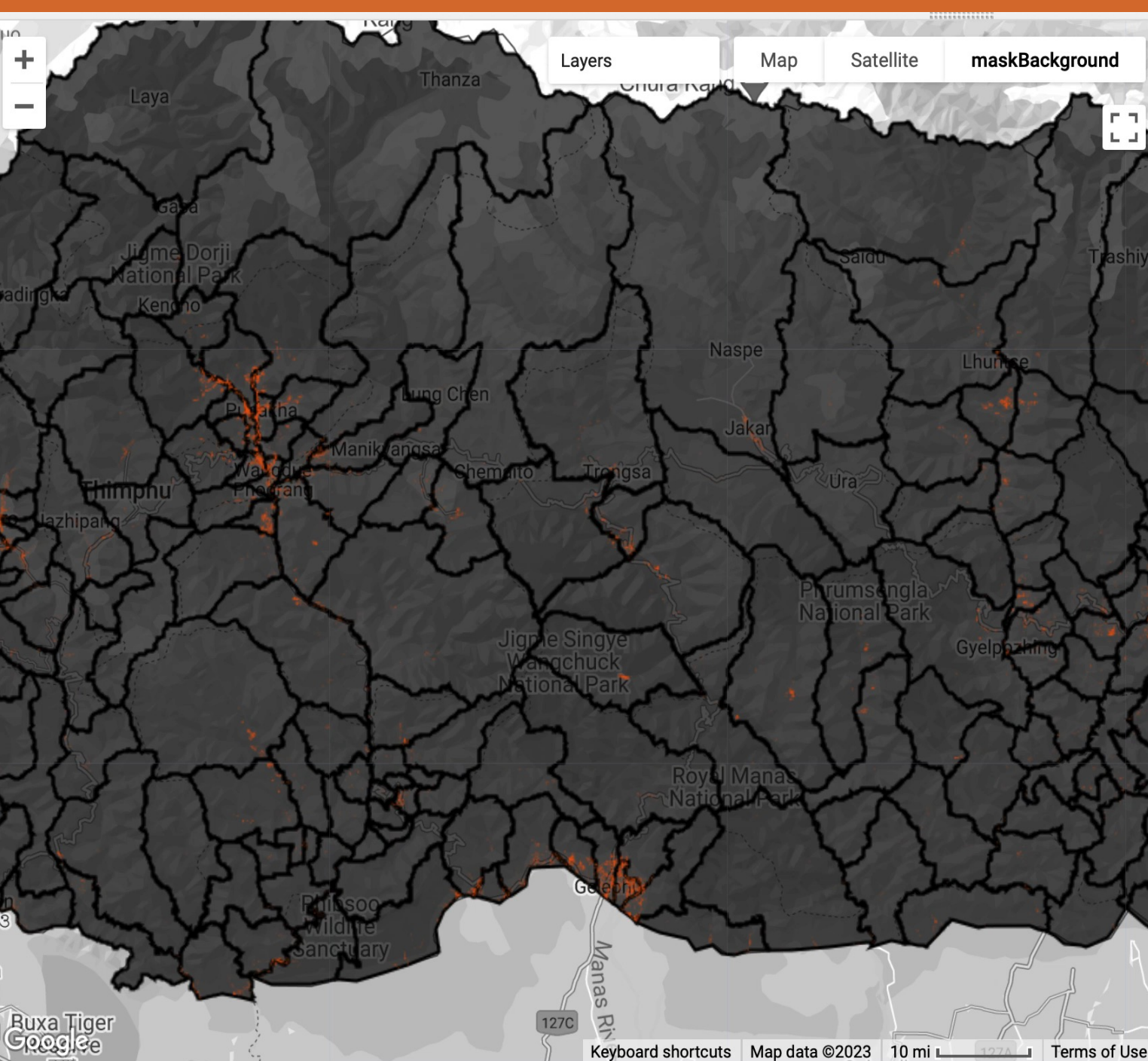
Median precipitation value in all Dzongkhags for 2016: 68.281 mm



Median soil moisture value in all Dzongkhags for 2016: 964.469 mm







## ACES: Agricultural Classification and Estimation Service

This GUI visualizes annual rice crop masks generated using a Random Forest model from GEE.

To get rice stats, first choose your region of interest. By default, the region is whole of Bhutan.

All Dzongkhags

Bumthang

Chhukha

Dagana

Gasa

Haa

Lhuntse

Mongar

Paro

Pema Gatshel

Pena Gatshel

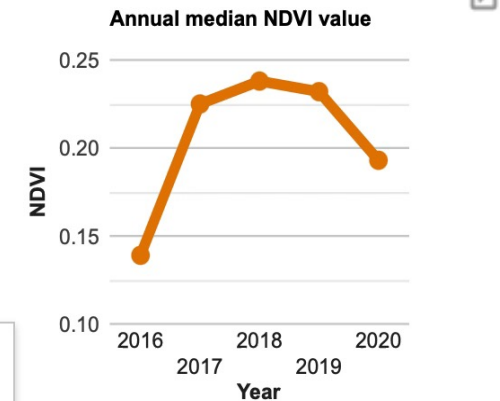
Punakha

Samdrup Jongkhar

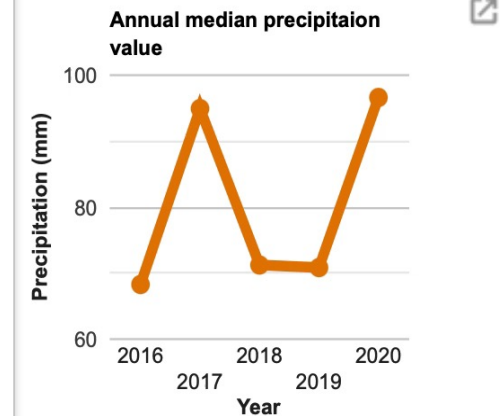
Samtse

Sarpang

Median NDVI value in all Dzongkhags for 2017: 0.225



Median precipitation value in all Dzongkhags for 2017: 94.929 mm



Median soil moisture value in all Dzongkhag for 2017: 1044.117 mm



# Conclusions

This methodology along with the support from NASA SERVIR created an accurate aggregate crop mask for each individual year from 2016 to 2022 using Random Forest classifier.

The team observed from the partner's report and our classification that there is an overall decrease in planted rice areas from 2016 to 2022.

Image credit: Abhishek Hajela



# Error and uncertainties

Diversity in  
Satellite  
Imagery

Temporal  
Constraints

Data  
Quantity and  
Variation

Difficulty in  
Interpretation

Assumption of  
Single Rice  
Variety

Human Errors  
in Reference  
Data

Randomness  
in Model  
Training





# Future Work

**Include**

Additional crop types into the crop mask protocol

**Expand**

Functionalities on the GUI

**Support**

Agricultural decision-making



# Acknowledgments

## Partners

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- Nidup Dorji (NPPC)
- Loday Phuntsho (ARDC)
- Tbden Tobden (NSB)
- Tshewang Wangchuk (Bhutan Foundation)
- Tshering Yangzom (Bhutan Foundation)
- Changa Tshering (UWICER)

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