HYPER-RESOLUTION SOIL MOISTURE & SURFACE TEMPERATURE FOR DROUGHT AND MAIZE YIELD PREDICTION

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Challenges in Satellite Monitoring of Drought Impacts on Agriculture

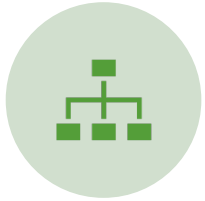
- The coarse spatiotemporal scale of drought indices with respect to farmer field size
- Most drought indexes are meteorologically-based which often neglects soil-plant-water interactions.
- Disconnection between drought indexes and impacts at the field-scale
- Limited information on field-scale agricultural yields and crop management.

How can surface temperature and soil moisture help to identify drought impact on agricultural yields across different scales?

ECOSTRESS observation's can leverage our capability to monitor drought and agricultural impacts at field scales.

OBJECTIVES

Use ECOSTRESS to calibrate hyper-resolution LSM to simulate **soil moisture and surface temperature** at field-scales (30-100m)



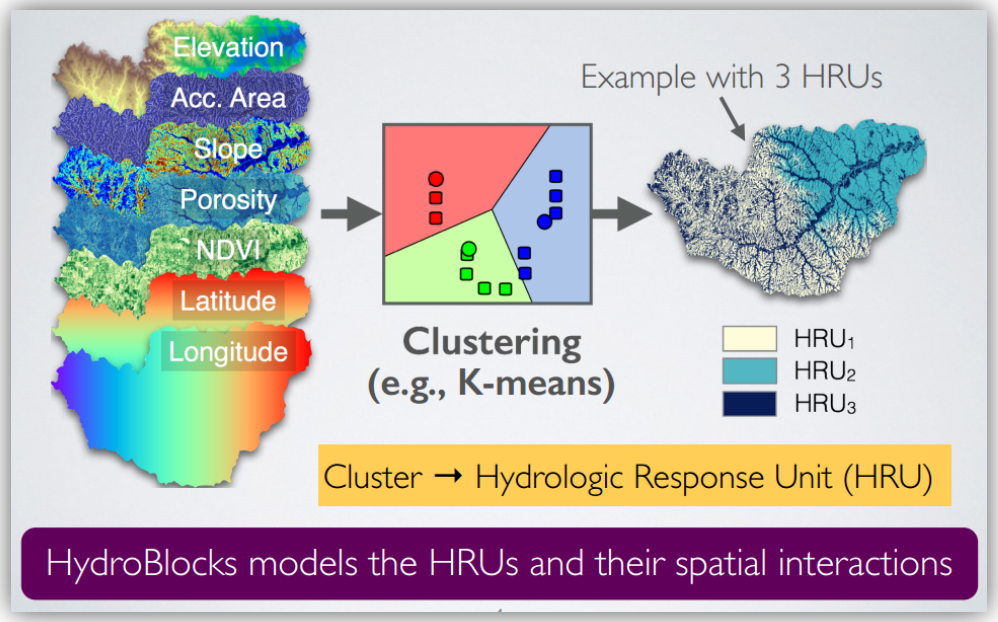
Train a random forest model with hydroclimate variables to predict **maize yields** at field-scales

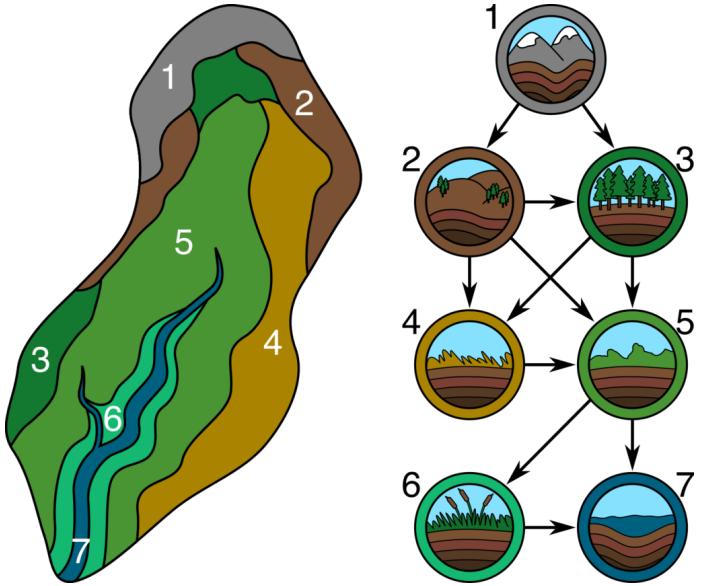
Identify the **most important predictors** of maize yield variability and their relationships

Identify the **drought thresholds** that lead to agricultural losses

Hyper-resolution Land Surface Model: HydroBlocks

- Field-scale resolving land surface model – 30 meters spatial resolution
- Represents spatial heterogeneity through discontinuous hydrologic response units (HRUs)
- Noah-MP LSM is run on each HRU to resolve the vertical land processes
- HRUs are connected via the subsurface lateral flow

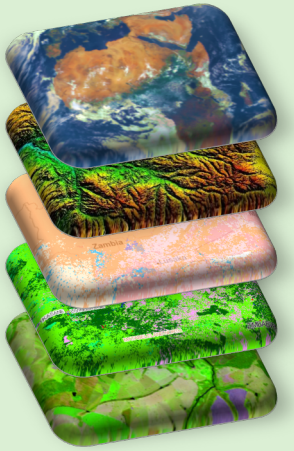




Chaney, N. W., Metcalfe, P., & Wood, E. F. (2016). HydroBlocks: A Field-scale Resolving Land Surface Model for Application Over Continental Extents. *Hydrological Processes*.

HydroBlocks' 30-m Soil Moisture & Surface Temperature

The model was run at 3-hr 30-m resolution between 1980-2018 over Zambia



Modeling Inputs

10-km 3-hr meteorology from ERA5-Land

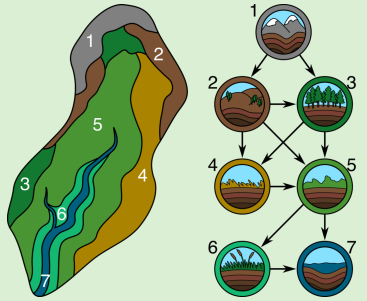
30-m topography from SRTM

250-m soil properties from SoilGrids

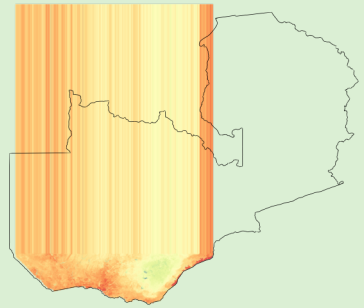
20-m land cover from ESA-CCI

30-m NDVI, water bodies,
and tree cover from Landsat

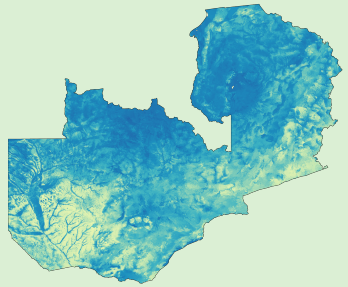
HydroBlocks



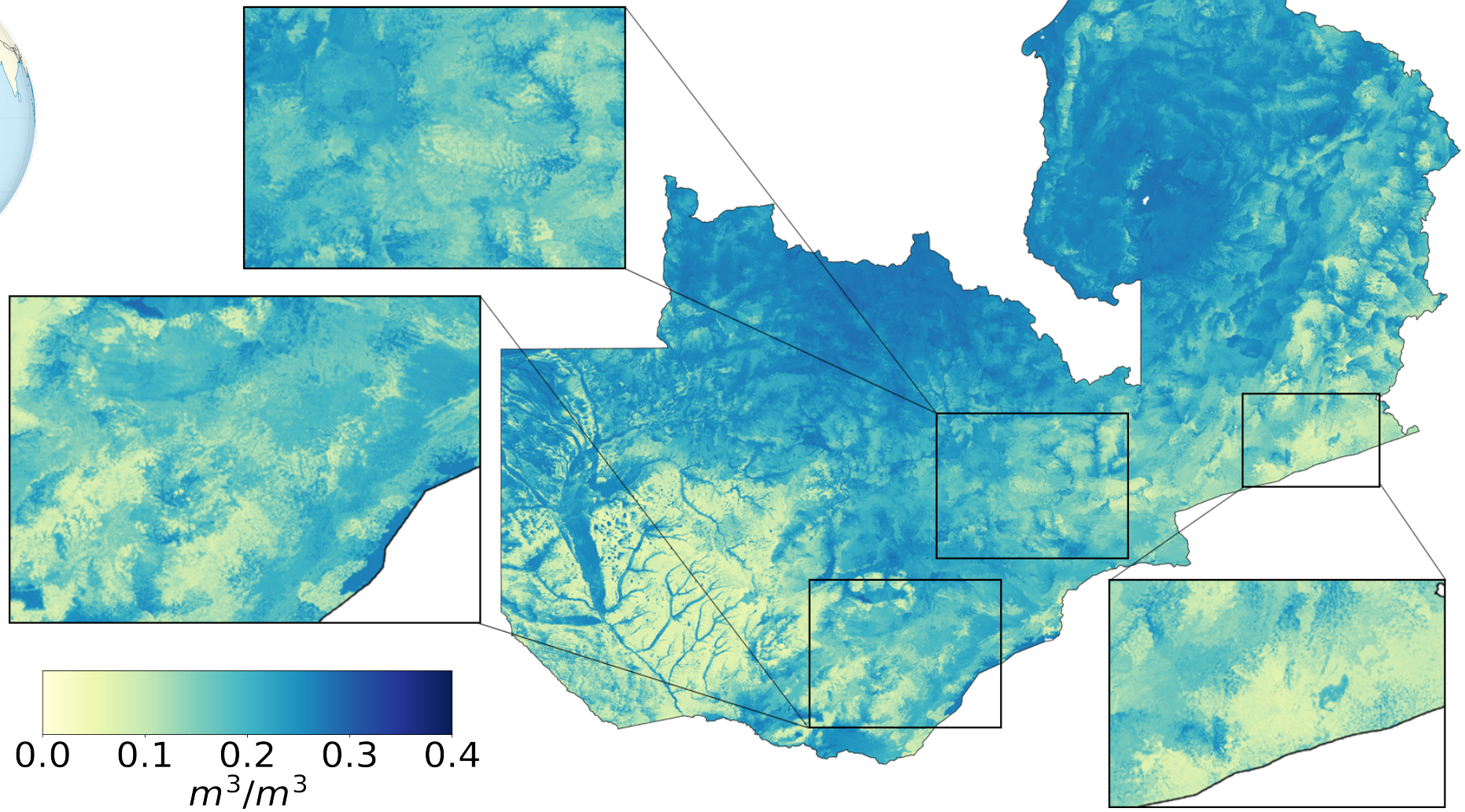
Soil Temperature



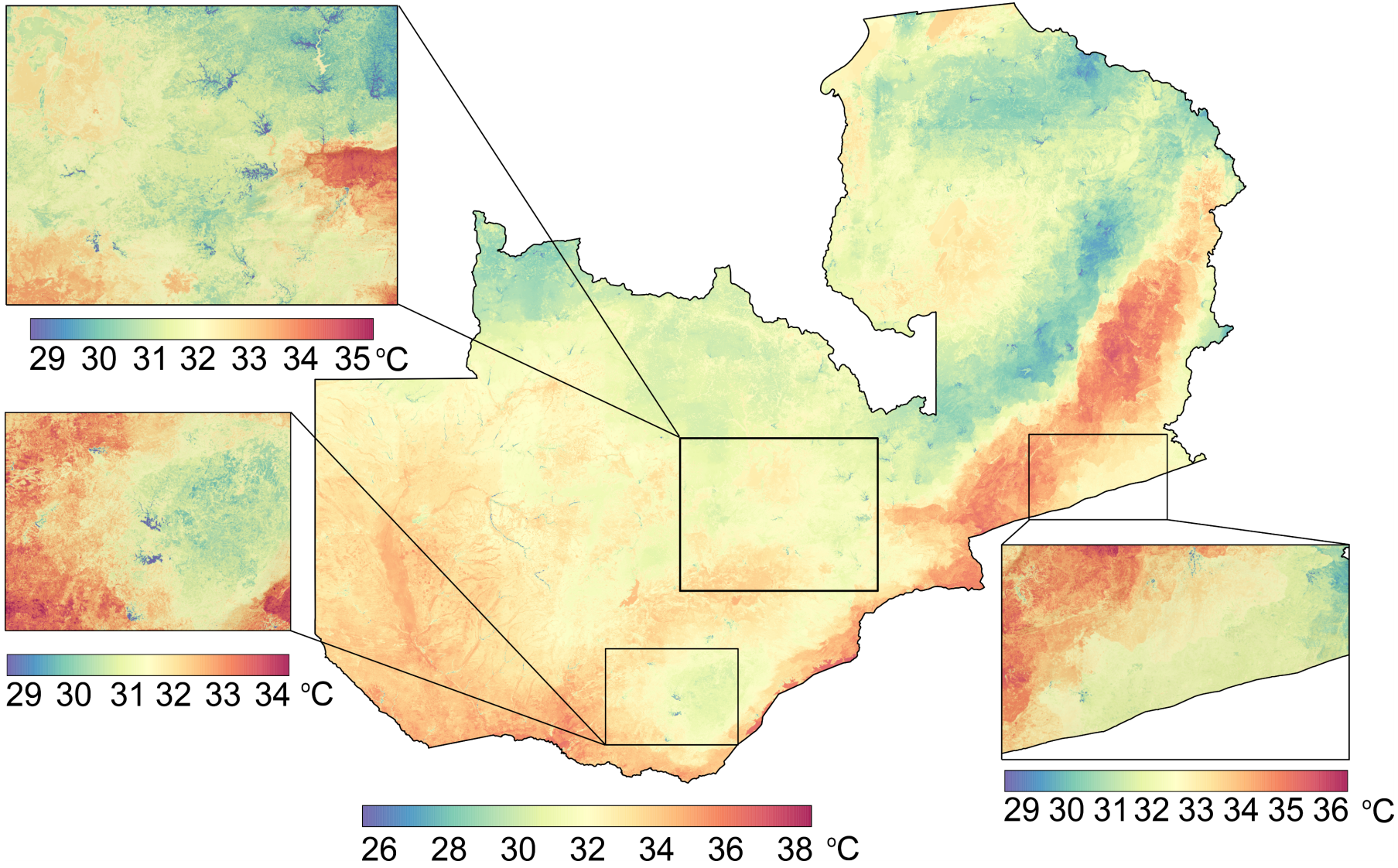
Soil Moisture



30-m root zone soil moisture for Zambia (2013)



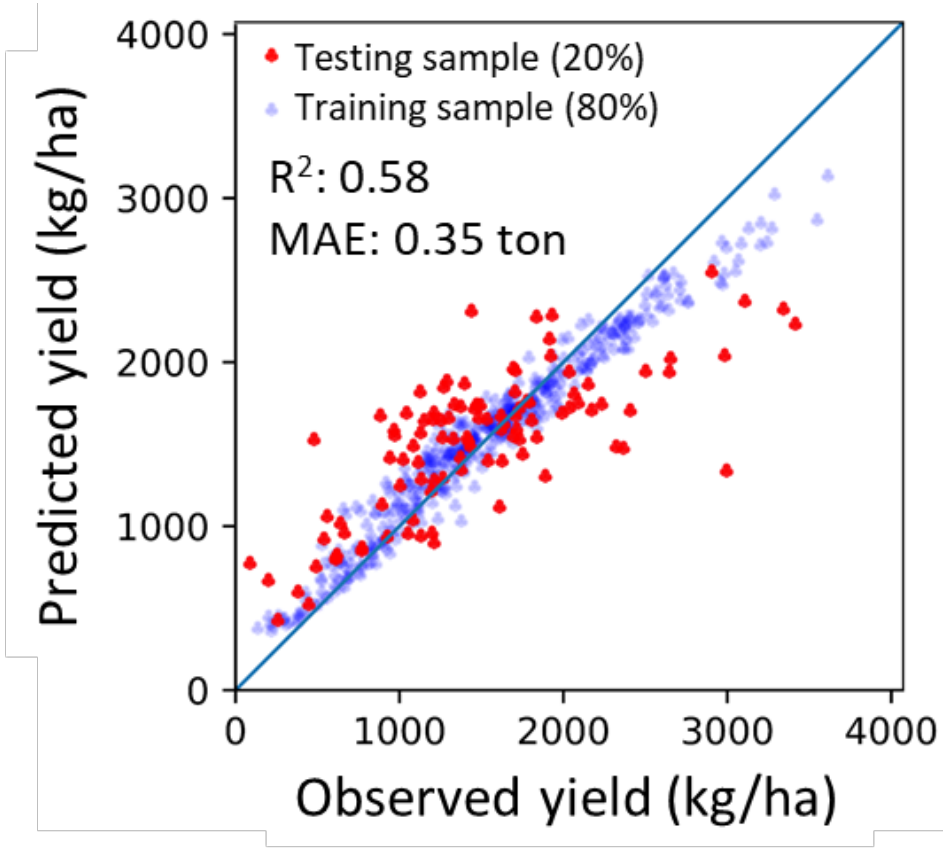
30-m root zone soil temperature for Zambia (2013)



Mapping maize yields at 250-m between 2000-2018

- **Model Prediction:** Random forest model to predict annual maize yields at 250-m in Zambia
- **In-situ training data**: 527 data observations between 2002-2012 of harvested maize at district level from the Zambian Post-Harvest Survey (PHS)
- **For each 250-m grid**: 124 predictors from MODIS NDVI vegetation index, soil properties, soil-hydraulic properties, land cover, topography, air temperature, rainfall and root zone soil moisture, soil temperature

Performance of the predicted maize yields using a random forest model

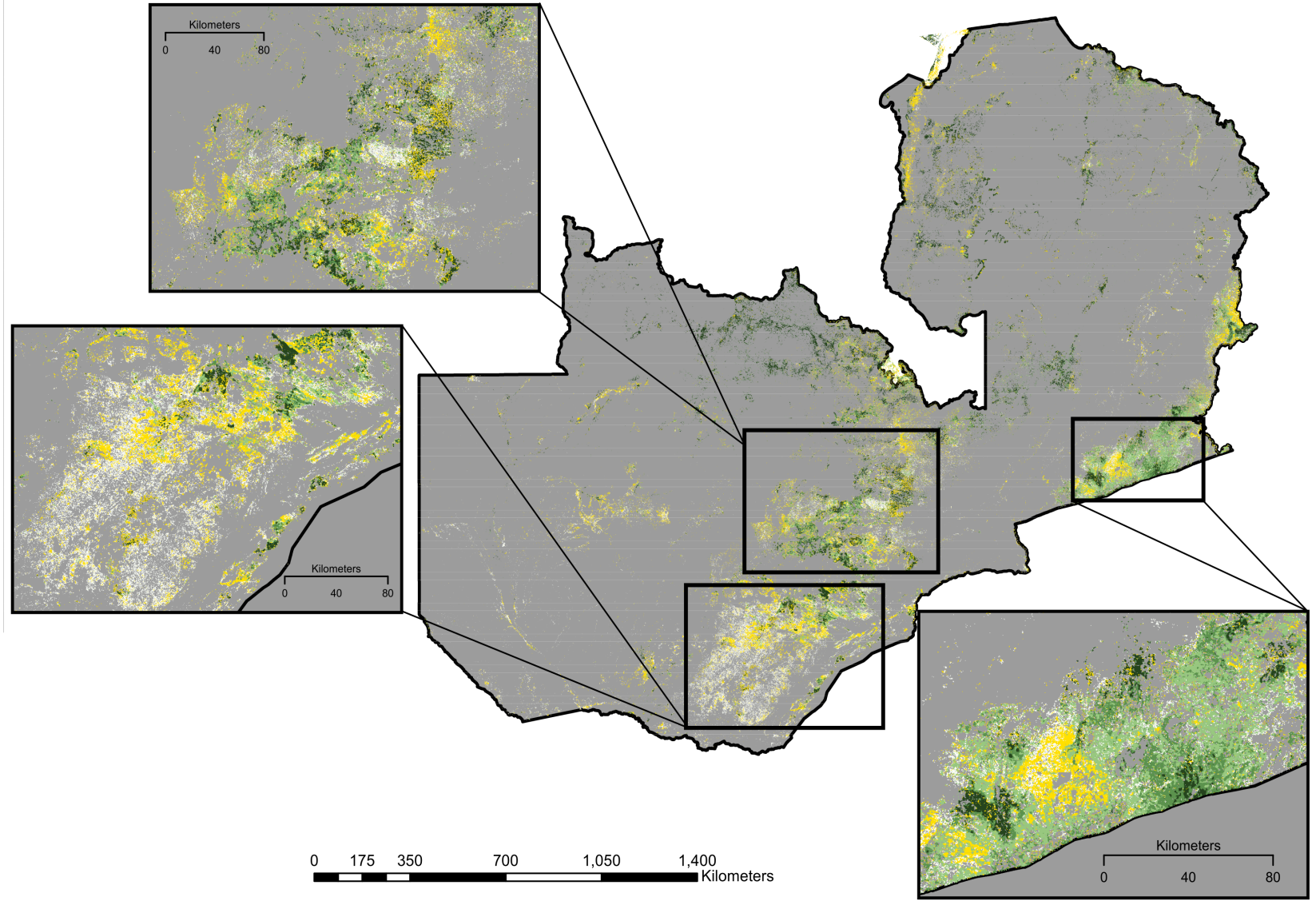


250-m maize yields as predicted by random forest model (2013)

maize yield

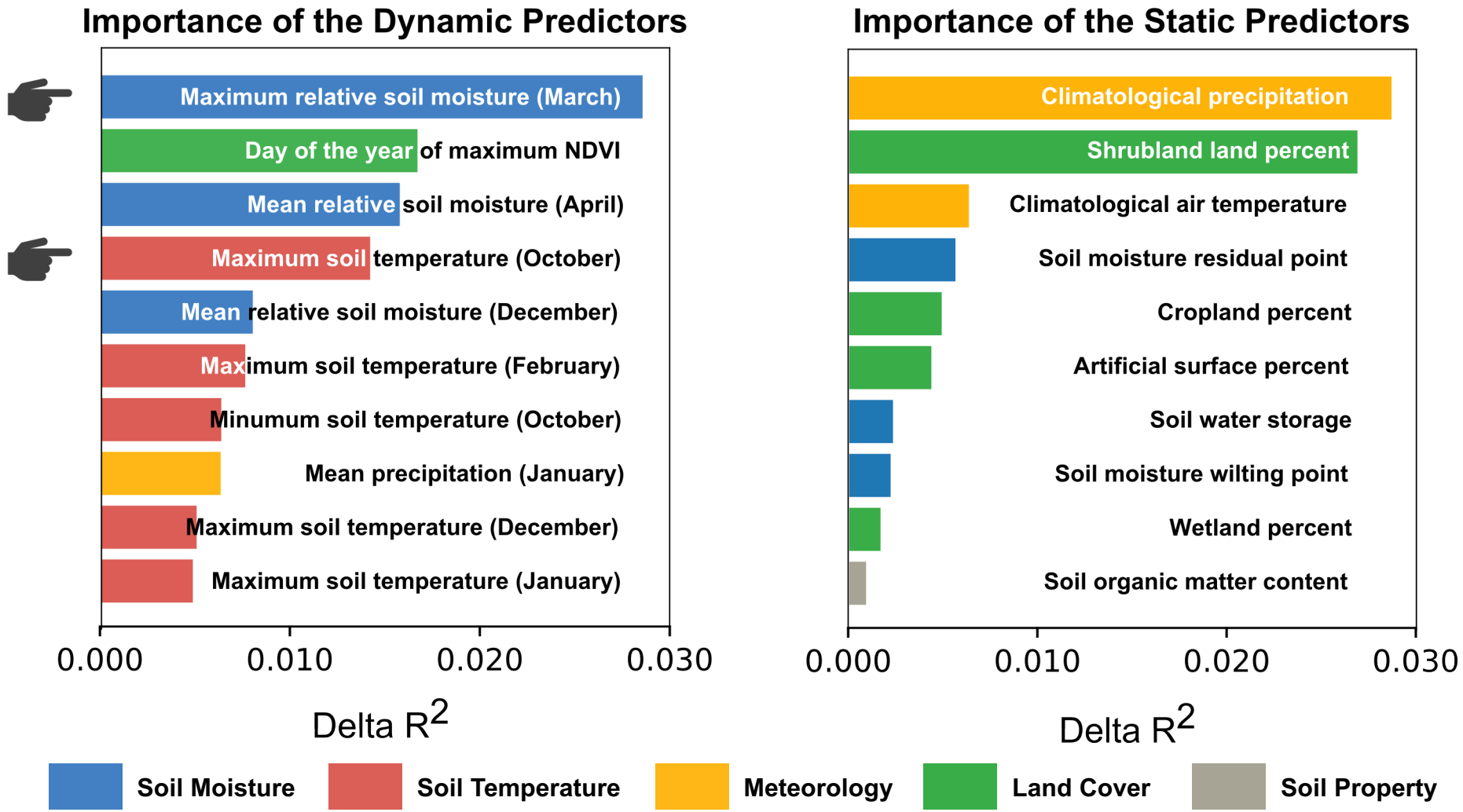
kg/ha

- 0 - 750
- 750 - 1500
- 1500 - 2250
- 2250 - 3000
- 3000 - 4940

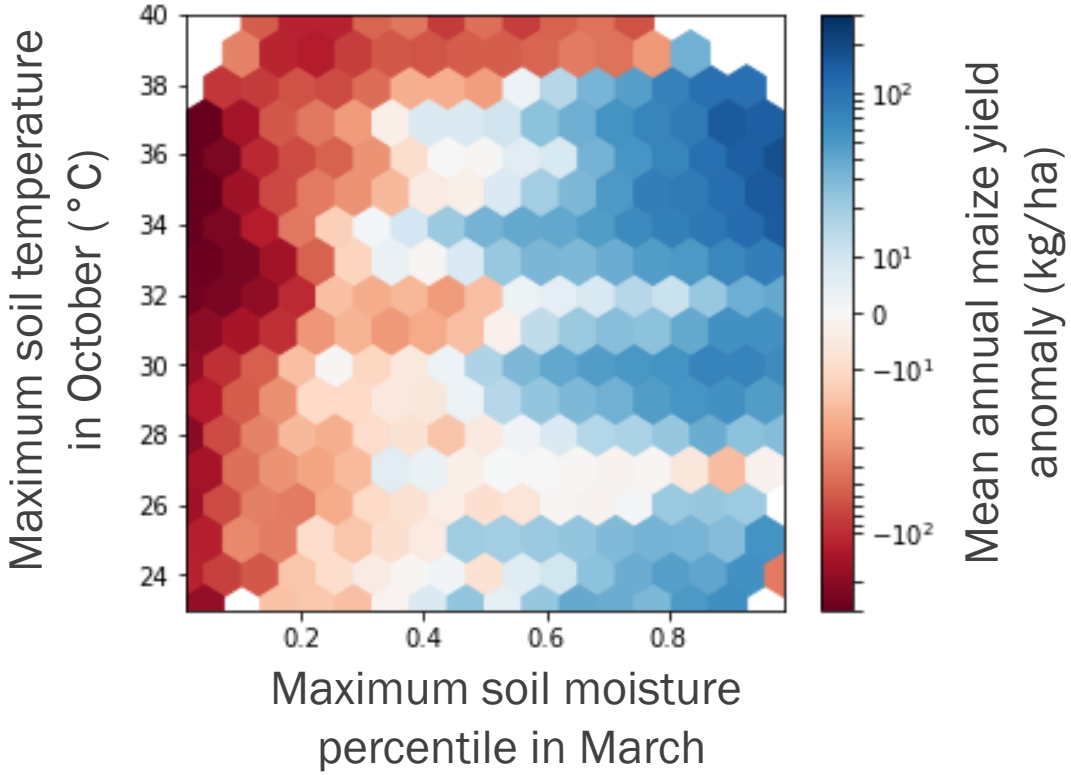


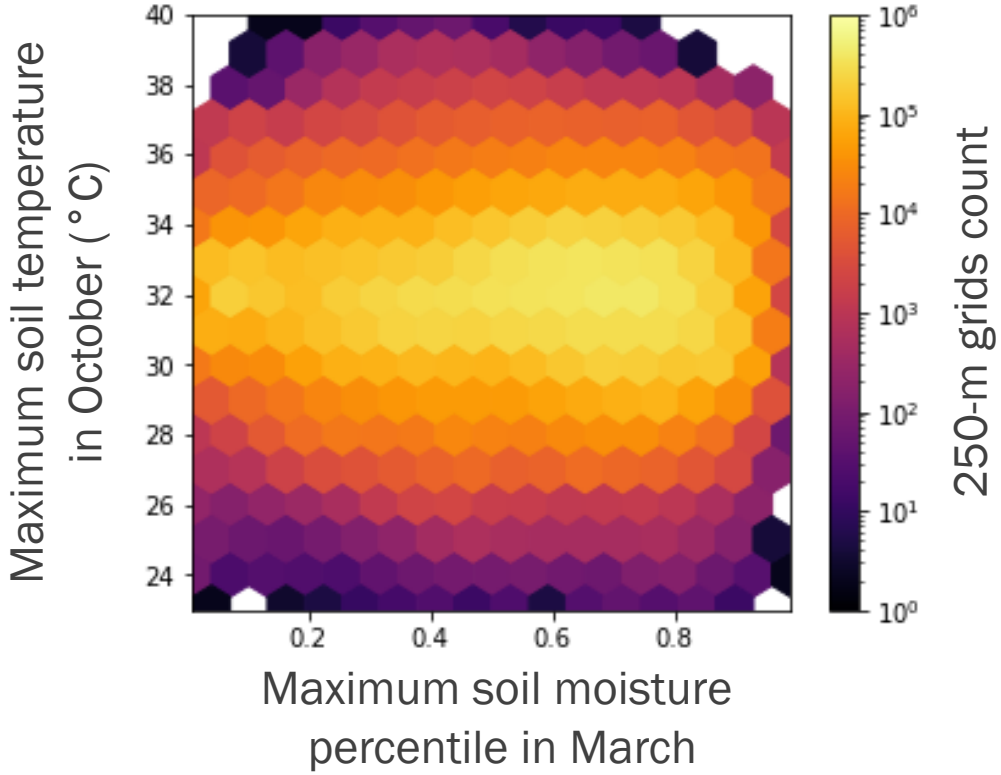
Predictor importance using random permutation

Model Baseline: R^2 = 0.58



Soil moisture and soil temperature impact on maize yields (250-m resolution)





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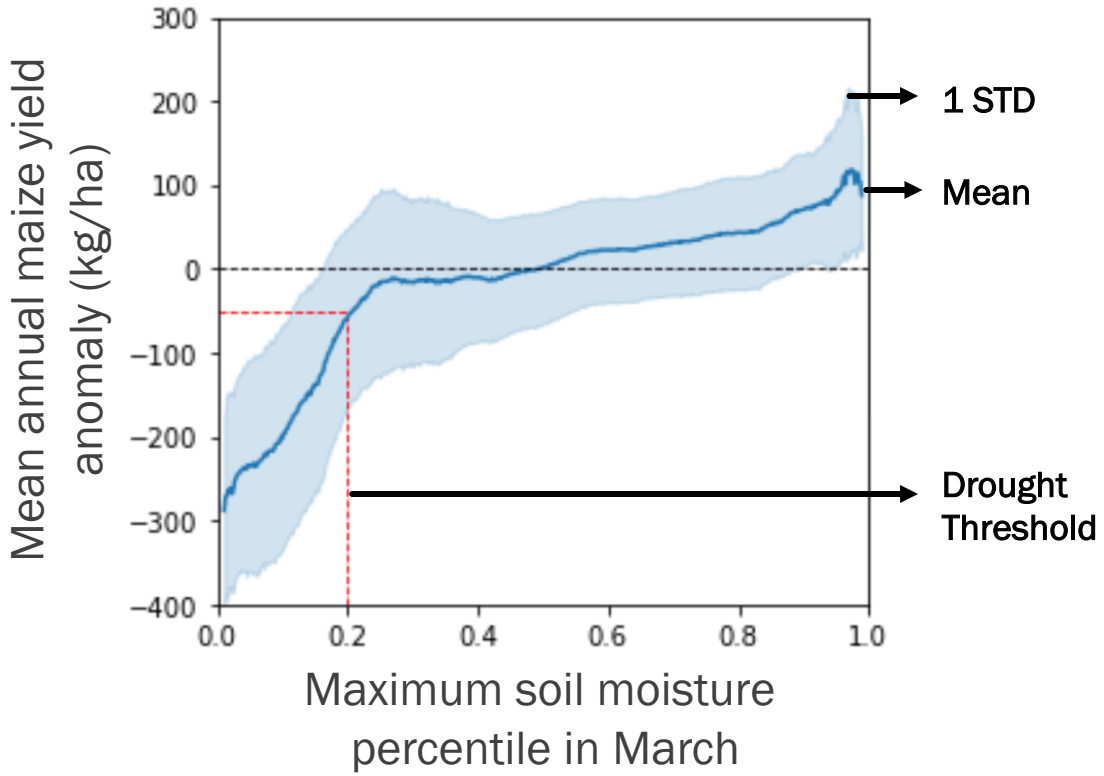
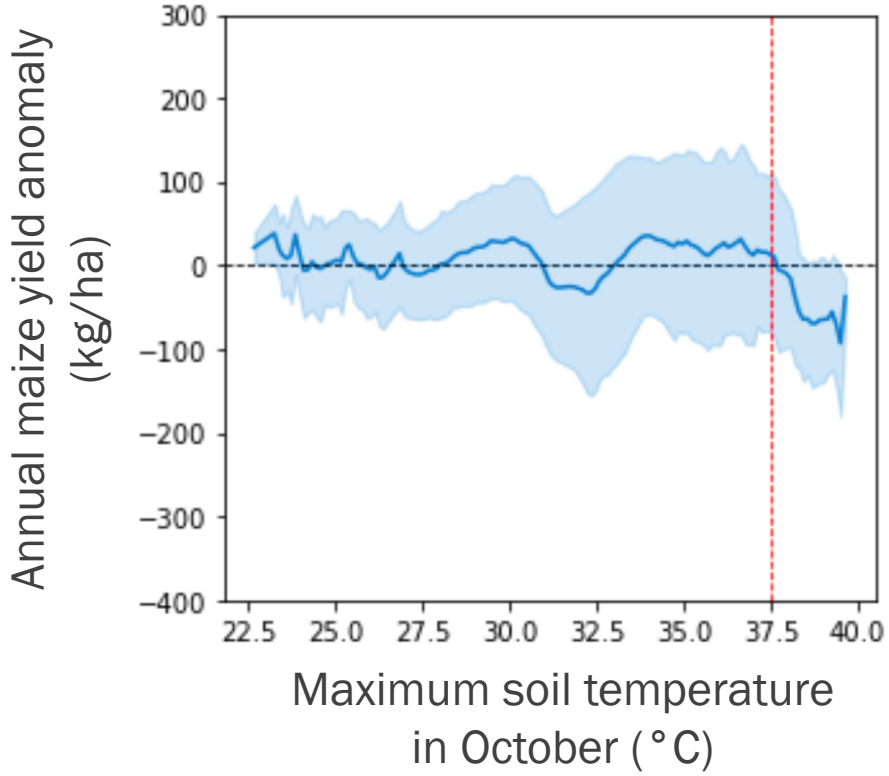




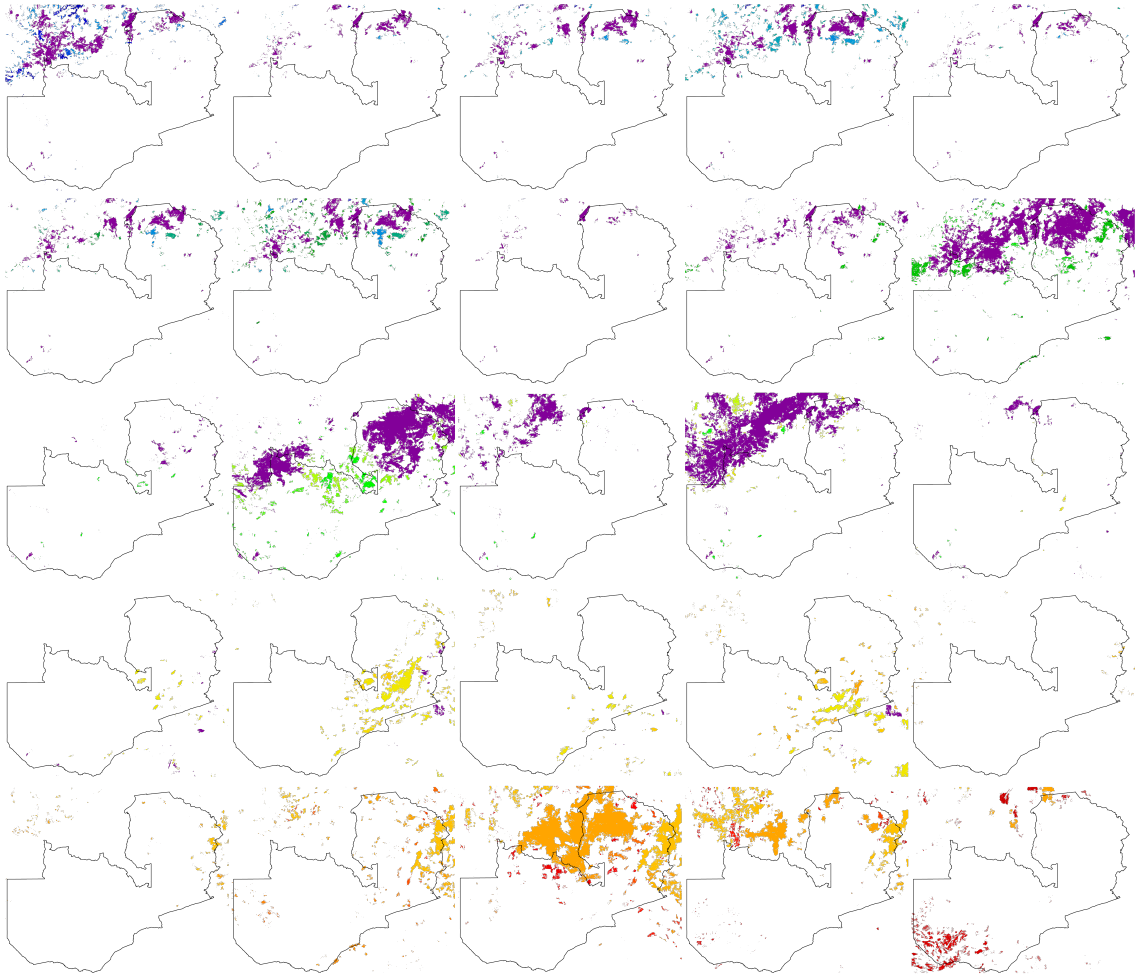
Summary and Conclusions

- ECOSTRESS will provide the surface temperature data required for agriculture and water management – for example, soil moisture and soil temperature are the main drivers of maize yield variability;
- Soil moisture-based drought index captures the impacts of droughts on agricultural yields, while losses in maize yield happens only for extreme temperatures above 37.5 °C;
- Hydrology and crop yield prediction can be improved by merging ECOSTRESS with hyper-resolution Land Surface Models at field scales.

Opportunity to use ECOSTRESS measurements within an assimilation framework will help to understand the uncertainty in the measurements and to improve LSM thermal parameterizations

Identification of drought events at weekly 250-m resolution (1980-2018)

- Identify droughts with weekly soil moisture percentile < 20 % (1980-2018).
- Use a machine learning Density-Based Spatial Clustering of Applications with Noise (DBSCAN) to identify clusters of pixel under drought as drought events
- Retrieve drought characteristics: duration, maximum area, drought intensity



The drought events identified using DBSCAN clustering algorithm. Each drought event is tracked on time based on its spatial overlap with future and previous clusters. Each color identify different a cluster.