



# EO for Africa Symposium 2024

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# Topsoil Organic Carbon Retrieval Using PRISMA Hyperspectral Imagery and Machine Learning Techniques

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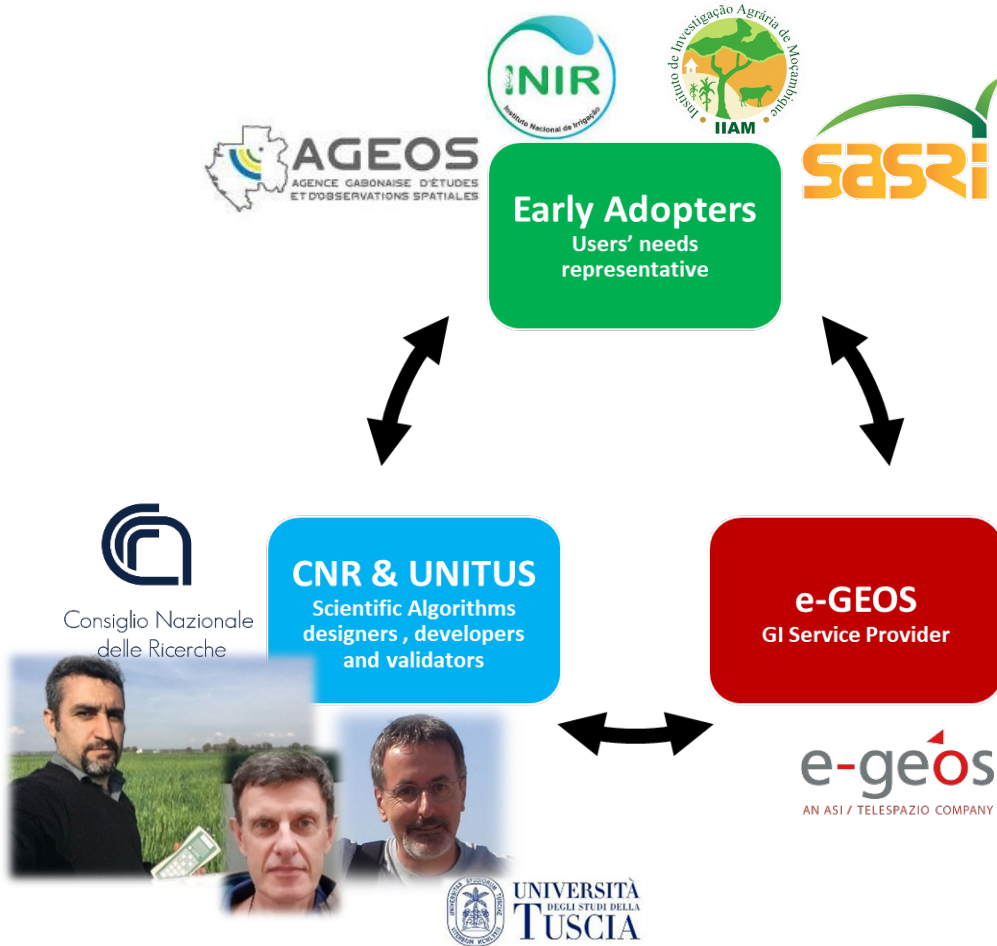
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# PRISMA 4 AFRICA - Overview



- Development and validation of analysis techniques (developed as open-source) exploiting satellite data as **hyperspectral** (e.g PRISMA) and **thermal** (e.g. ECOSTRESS) data for food security in **Gabon, Mozambique and South Africa**.



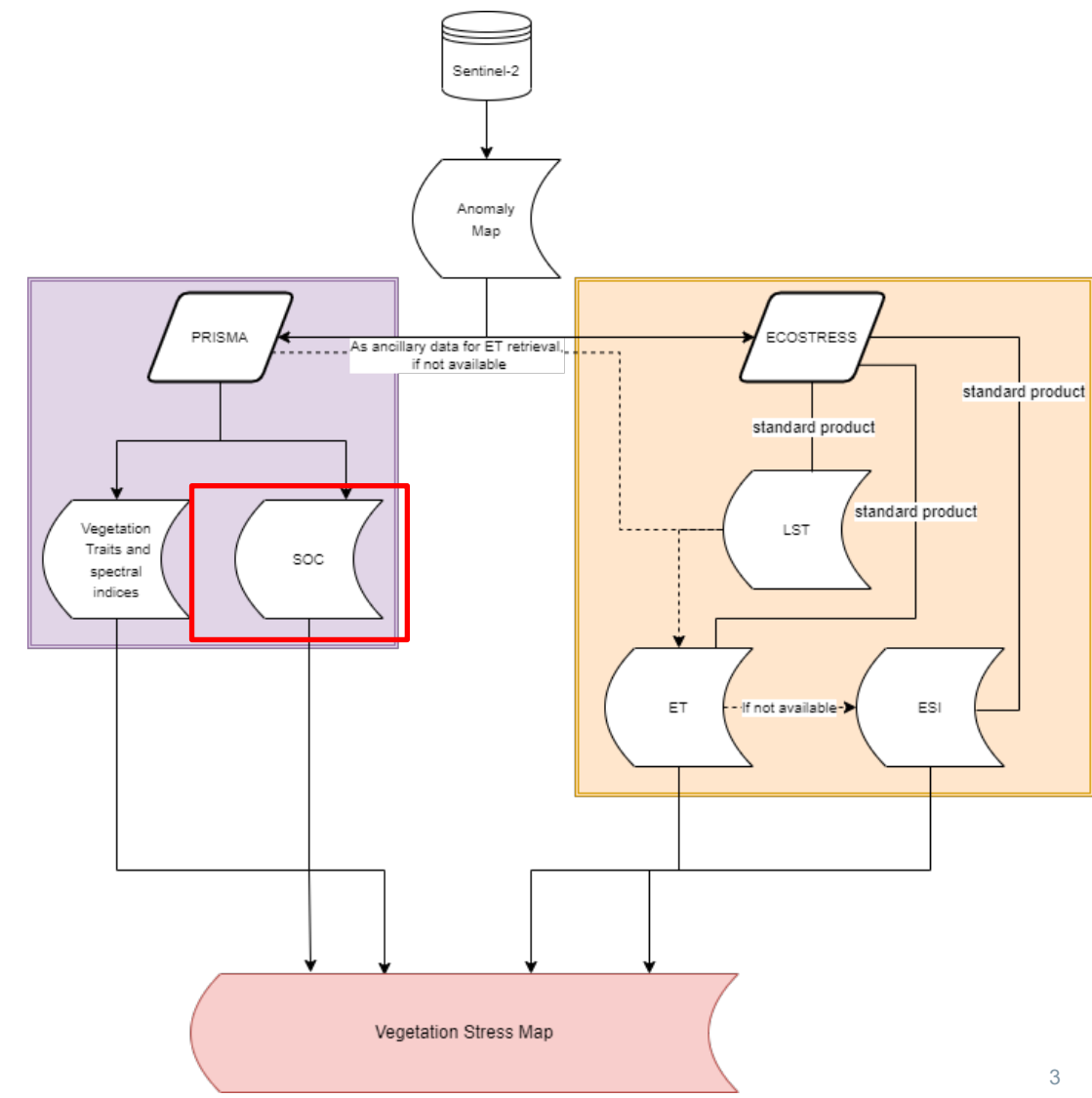


## Problem Statement

- Limitation of First-Hand In-Situ Data

## Goal

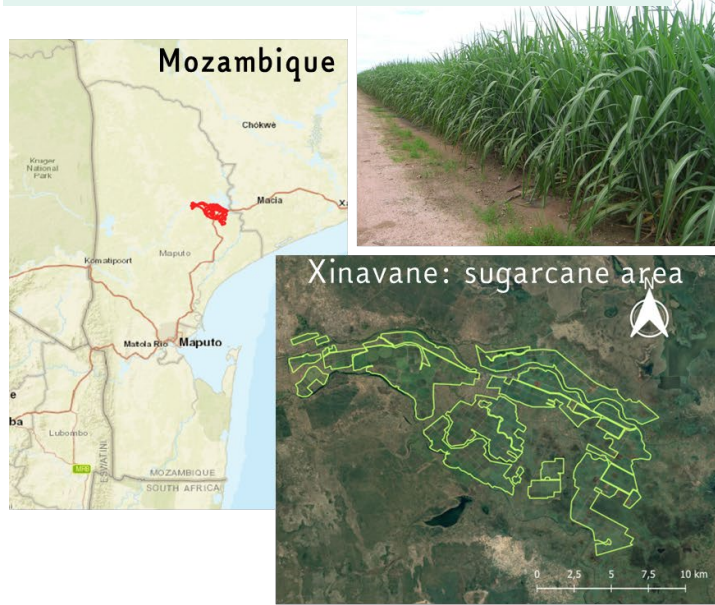
- Leverage the Global Free Available data along with PRISMA imaging and few Local data to produce high accuracy soil SOC map.



# Image Acquisition for Study Area



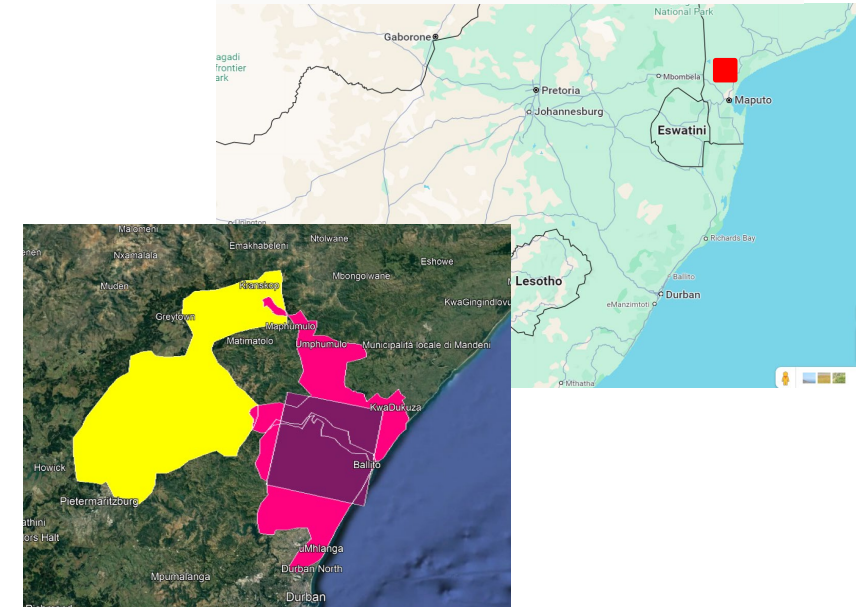
## Xinavane, Mozambique



## Boma, Gabon



## SASRI, South Africa



Site	Xinavane, Mozambique		Boma, Gabon		SASRI, South Africa	
Quality	Free Cloud	Cloudy	Free Cloud	Cloudy	Free Cloud	Cloudy
PRISMA	14	6	-	4	5	5
EnMAP	9	7	-	15	3	-
DESI	2	3	-	1	-	-



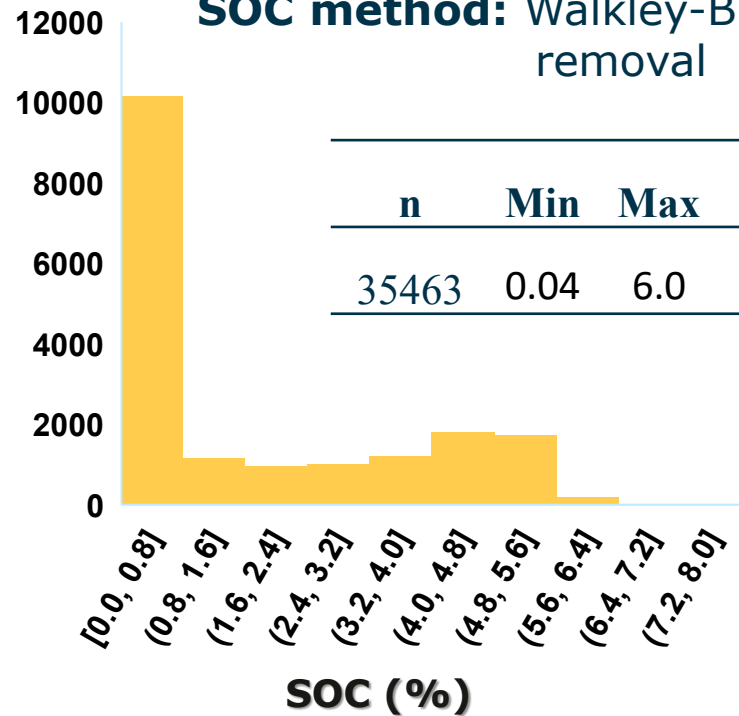
# Global SOC and PRISMA Dataset



<https://soilspectroscopy.org>

**Sampling depth: 0-20 cm**

**SOC method:** Walkley-Black oxidation after carbonates removal

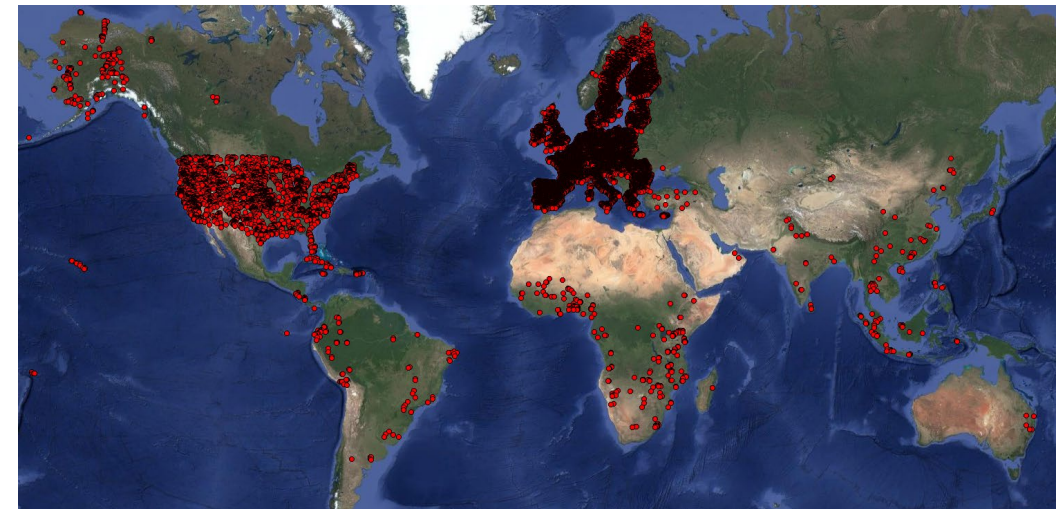


n	Min	Max	Mean	Std
35463	0.04	6.0	1.03	1.25

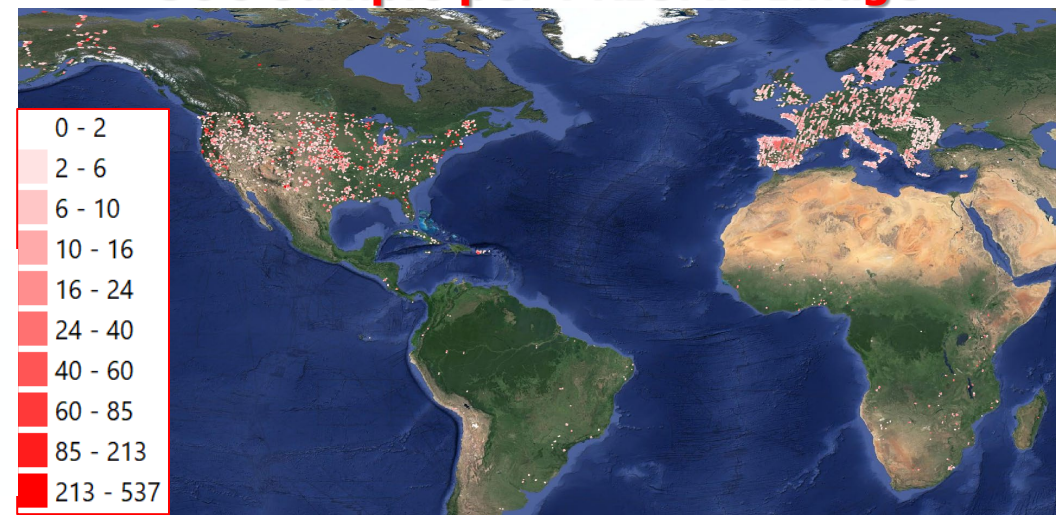
## Selected PRISMA Images

- ✓ Cloud Cover: < 1%
- ✓ pixel S-2:  $0 < NDVI < 0.20$

## Global SOC Dataset



## SOC Sample per-PRISMA Image



# South Africa SOC and PRISMA Dataset

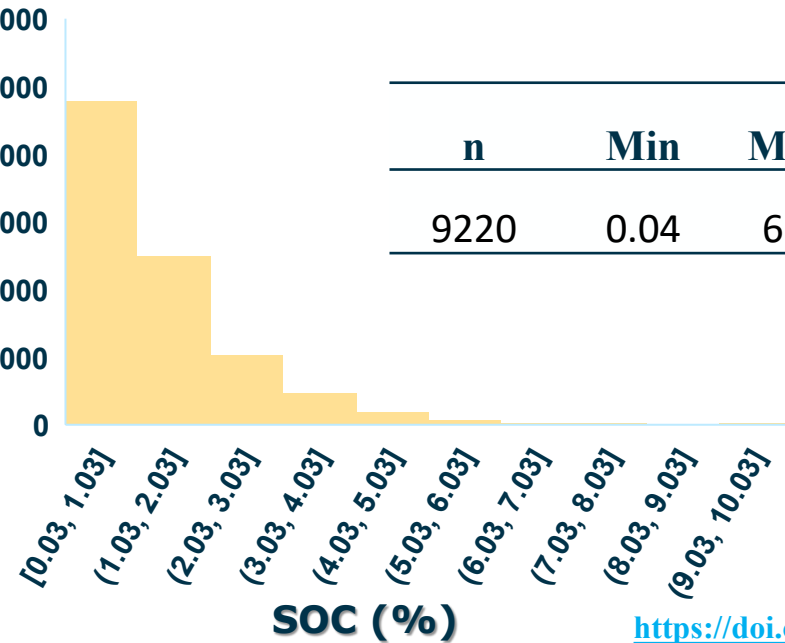


**Sampling depth: 0-20 cm**

## SOC Measurement Method:

Walkley-Black – dry oxidation after carbonates removal

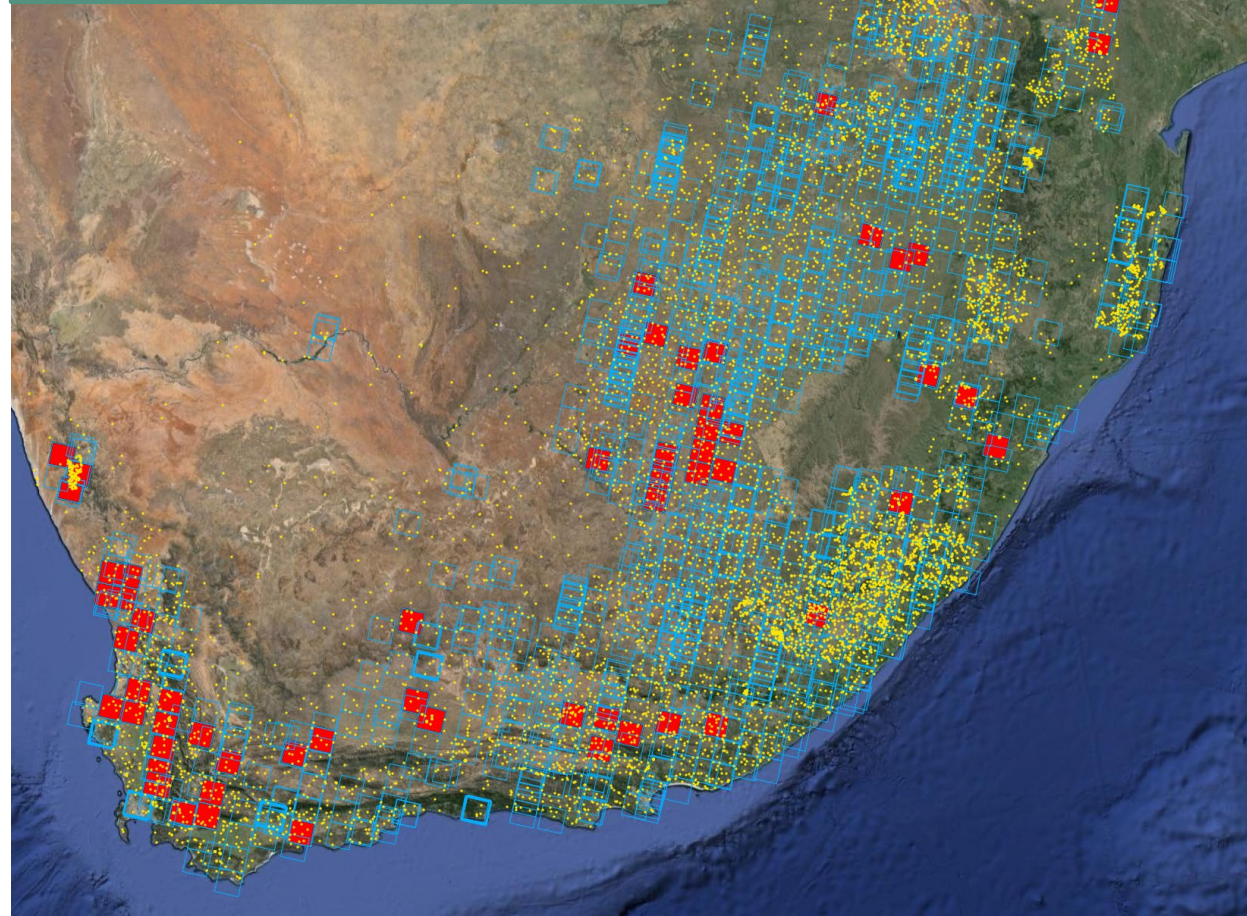
- International Soil Reference and Information Centre (ISRIC)
- Gamtoos Irrigation Board (GIB)
- Department of Environmental Affairs (DEA)
- Agricultural Research Institute (ARC)



n	Min	Max	Mean	Std
9220	0.04	6.0	1.03	1.25

<https://doi.org/10.1016/j.scitotenv.2021.145384>

● **SOC Sample**  
■ **Selected PRISMA Image**  
  **Archive PRISMA Image**



# Methods for SOC Retrieval Using EO Data



## ✓ Parametric Methods

$$SOC1 = \frac{1}{\sum_{i=464}^{699} R_i}$$

$$SOC2 = \frac{1}{slope(R_{464:699})}$$

$$SOC3 = \frac{1}{area(R_{2053:2199})}$$

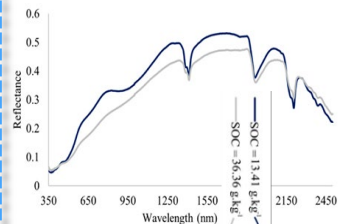
$$SOC4 = \frac{1}{slope(R_{2135:2199})}$$

$$SOC5 = \frac{R_{478}}{R_{546} * R_{660}}$$

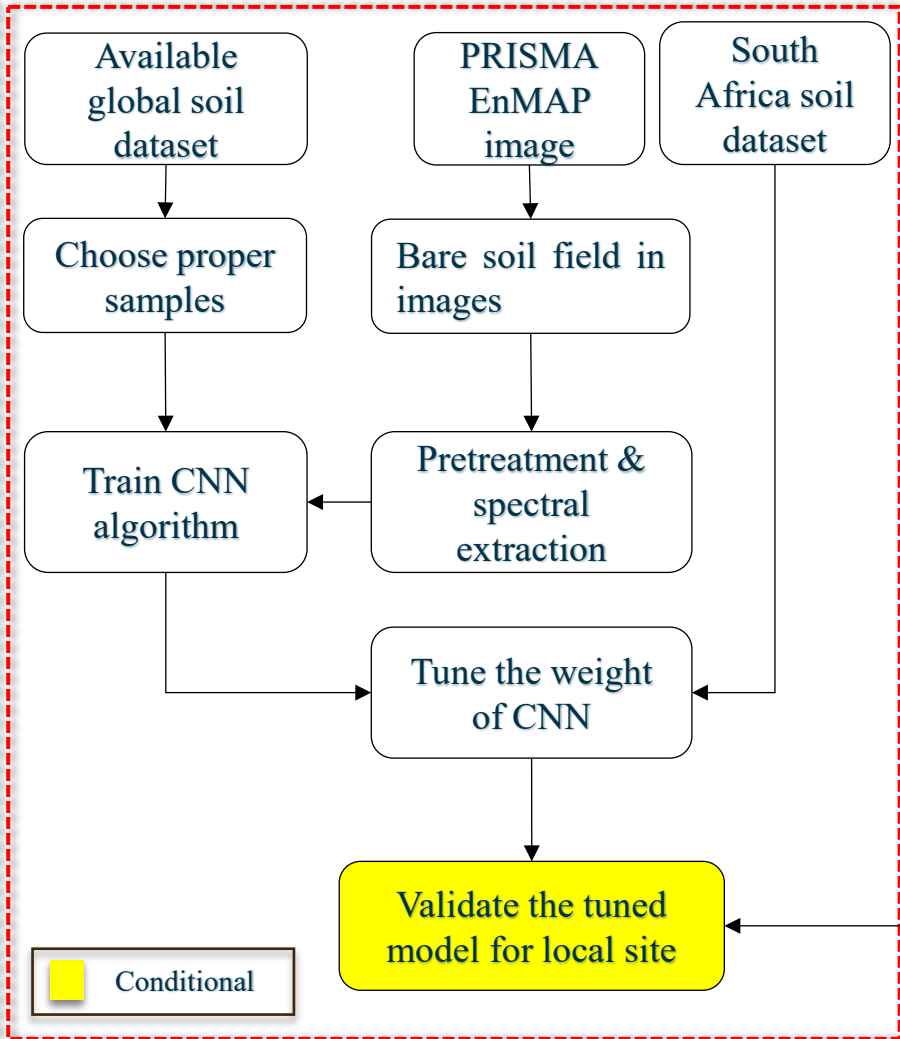
$$SOC6 = \frac{R_{1606}}{R_{834}}$$

$$SOC7 = \frac{R_{998} - R_{679}}{R_{998} + R_{679}}$$

(Bartholomeus et al., 2008)

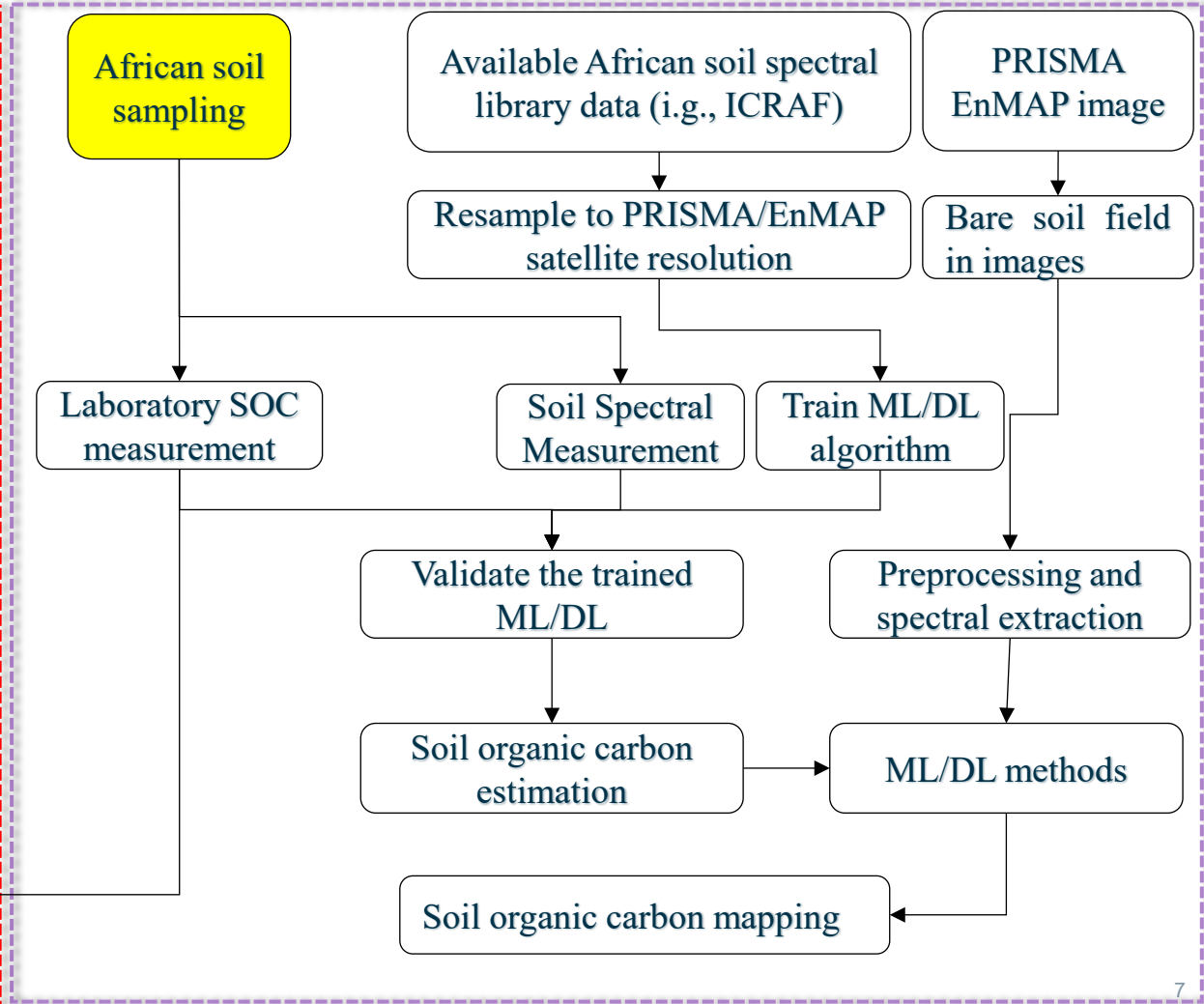


## ✓ Transfer Learning



Conditional

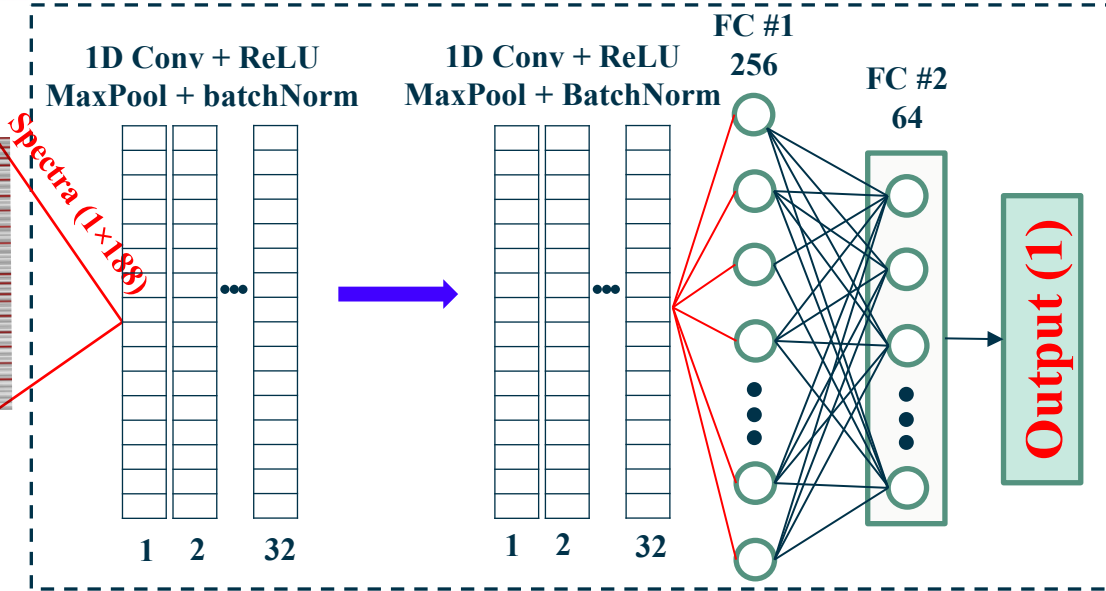
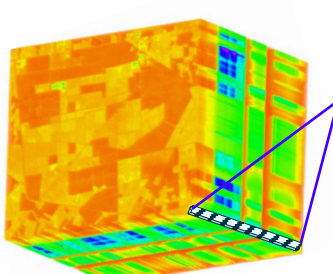
## × Bottom-up



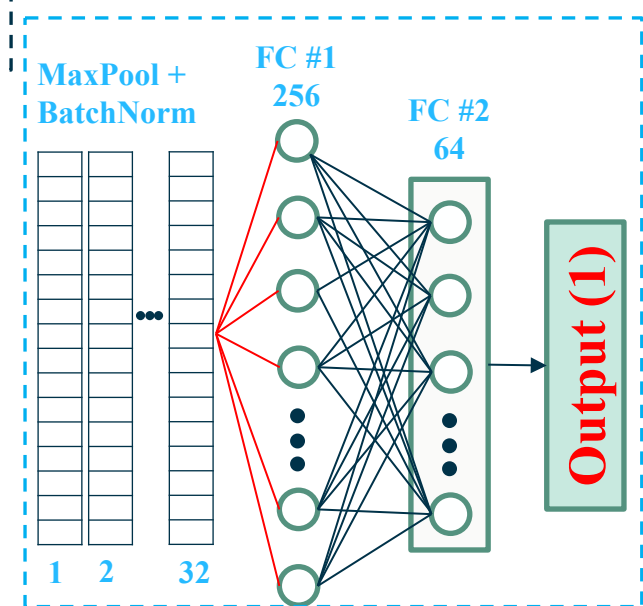
# Deep Transfer Learning for Local SOC Retrieval



Global SOC data & corresponding PRISMA spectra



Fine-tuning the pre-trained model



South Africa SOC data and corresponding PRISMA spectra

Structure and parameters keep fixed

Validate the tuned model



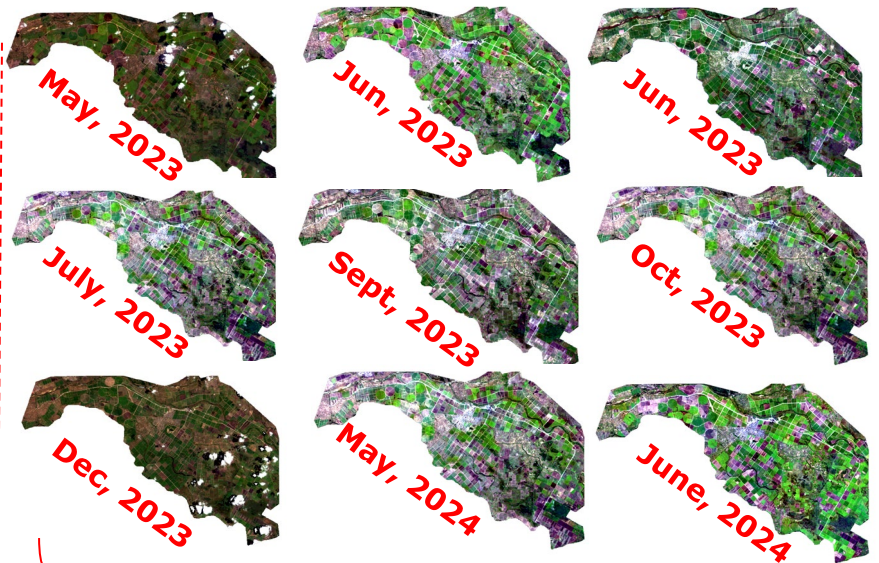
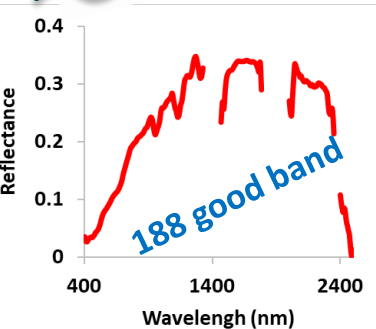
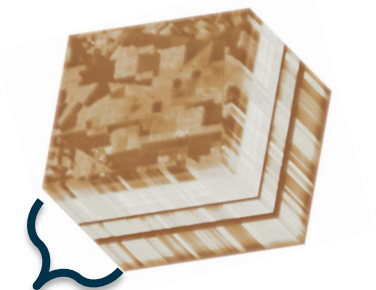


# Apply Tuned CNN Model to Xinavane SOC Retrieval



## 1- Pre-Processing

PRISMA images co-registration using a S2

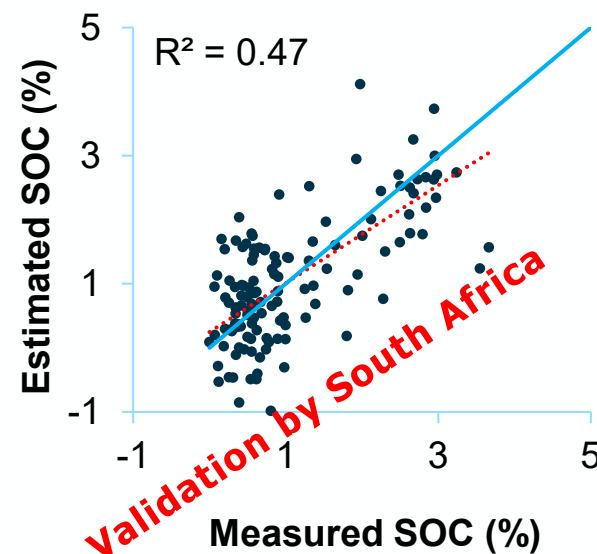
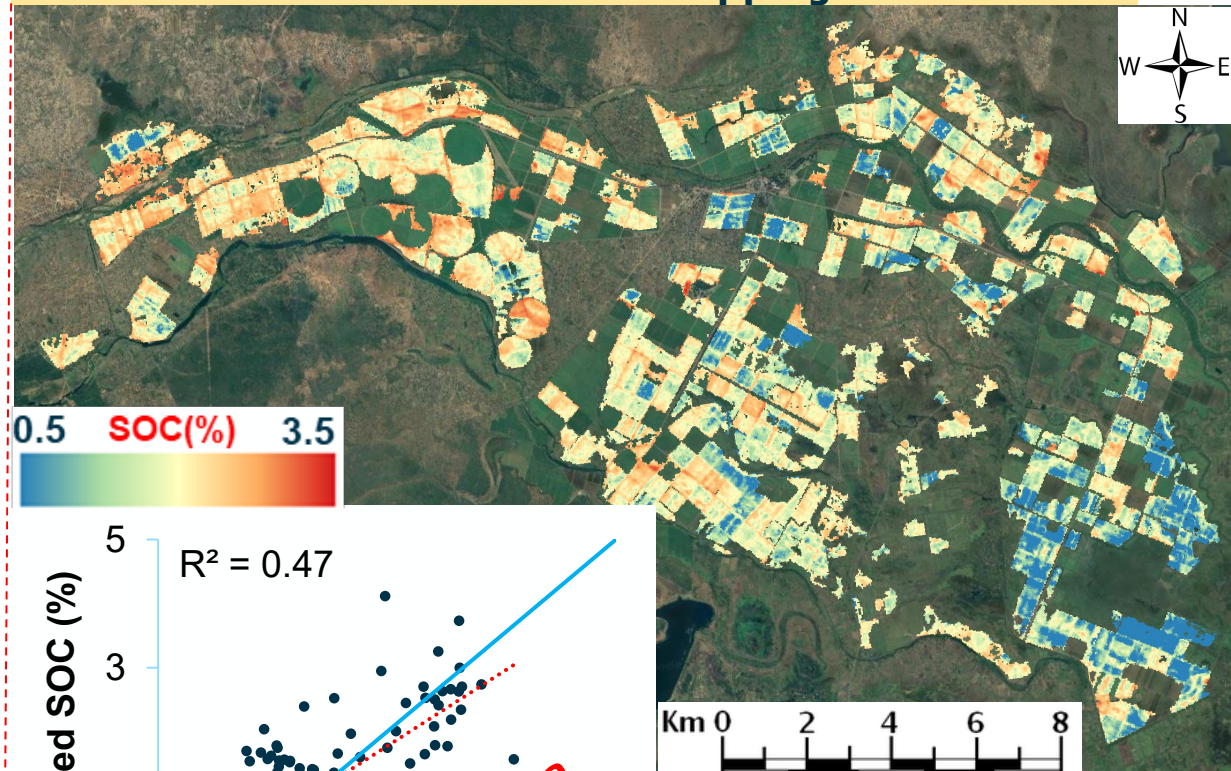


Clouds mask & water & built-up mask, NDVI < 0.35 & nCai < 0.03



## 2- Bare Soil Masking

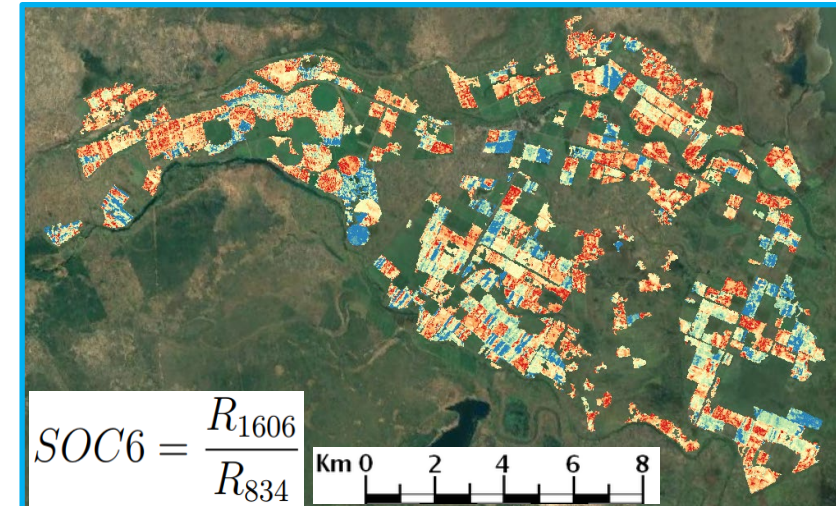
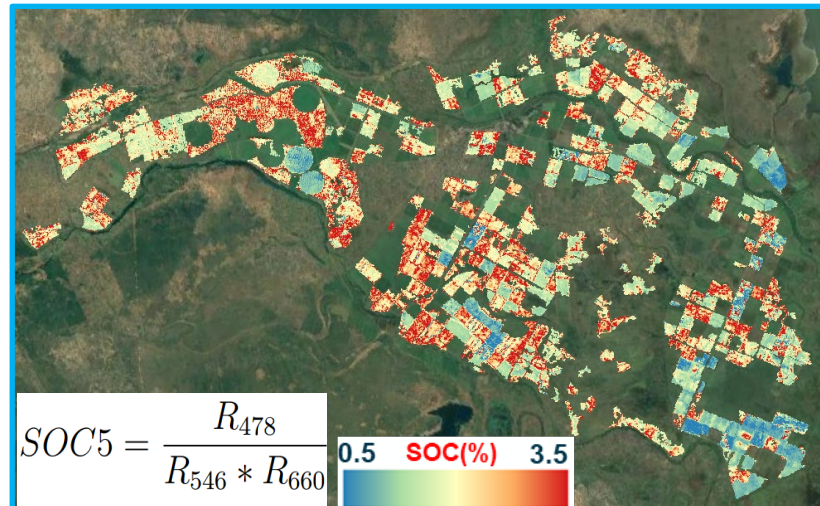
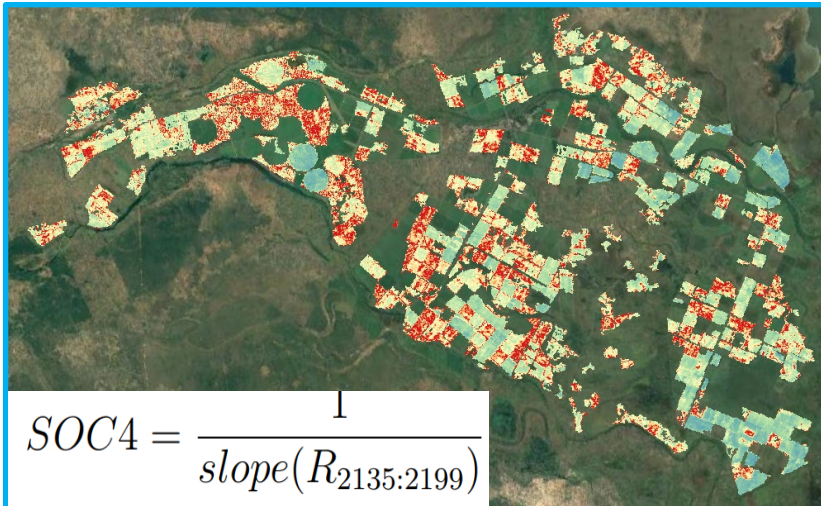
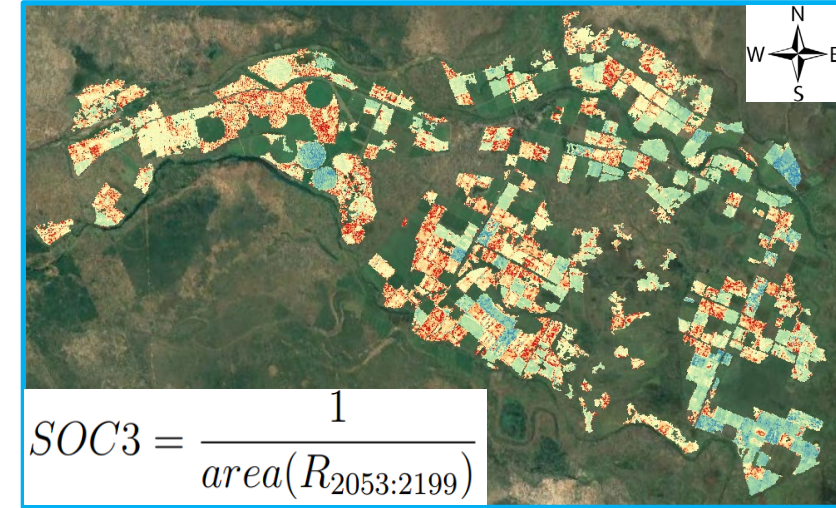
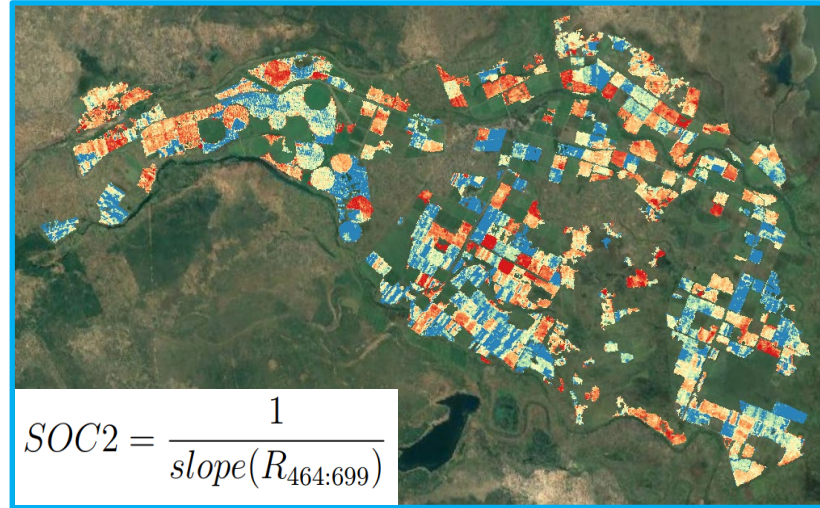
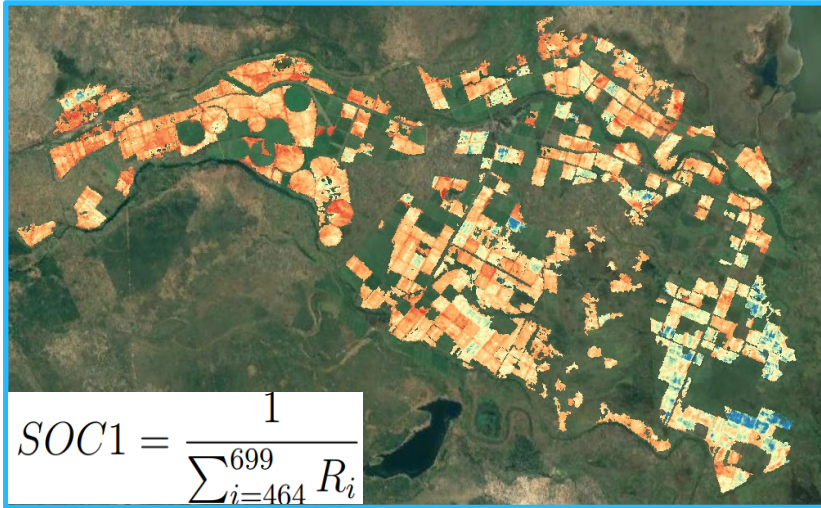
## 3- Validation & Mapping



✓ Validation for local site in ongoing



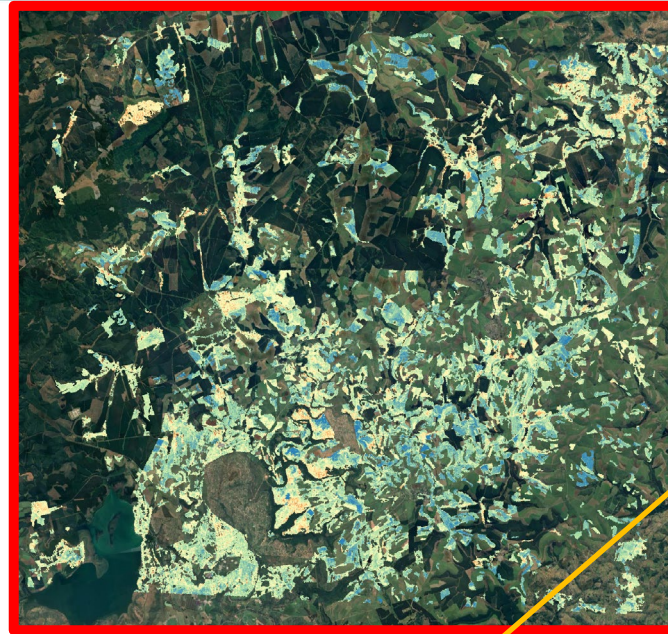
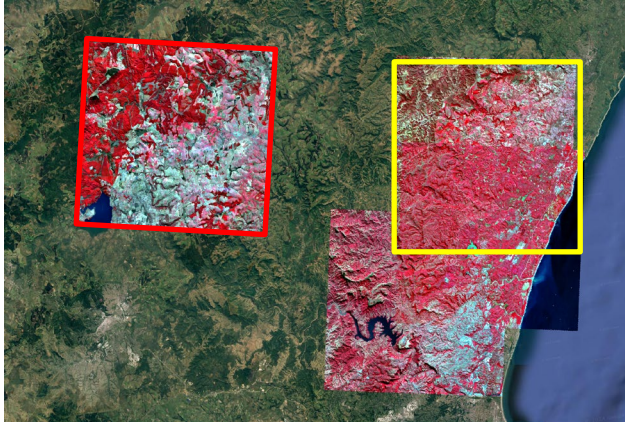
# Primarily SOC Map of Xinavane using Already developed Indices



# Apply the Tuned CNN Model to SASRI Test Areas SOC Retrieval



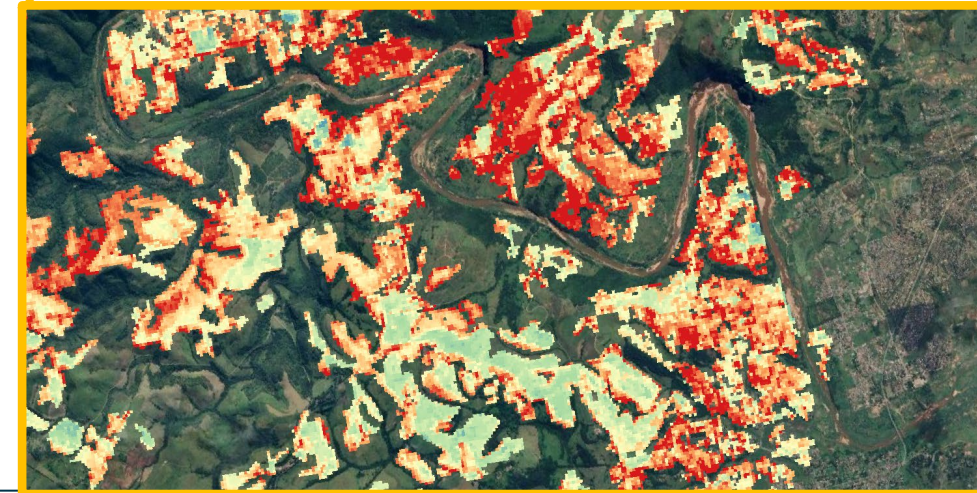
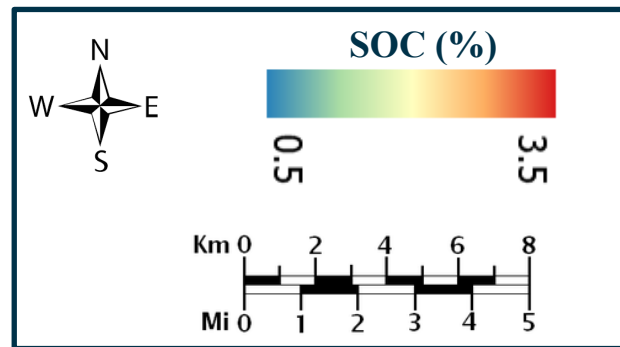
PRISMA Time-Serie Images



Clouds, Water & Built-up Mask & NDVI < 0.35 & nCAI < 0.03



Bare Soil Pixels Masking



## Conclusion

- The developed CNN is working properly in the test areas pointing out that the data set is close to being wide enough. At the same time, validation and testing should be improved.

## Challenging

- × Availability of a sufficient large independent data set for the test.
- × Explore the CNN transferability robustness in different soil ecosystems.

## Future Work

- Provide local SOC samples to validate tuned CNN model at local scale.
- Increasing the number of SOC samples to improve the accuracy of transferred CNN model by covering more diverse soil samples in this region, including a wider range of SOC.
- Investigate the capability of other Hyperspectral sensors (e.g. EnMAP and DESIS) for SOC retrieval.
- The ongoing work, applying the button-up approach, is devoted to up-scaling this methodology to the African agricultural PRISMA4AFRICA test sites by the Gabon, Mozambique, and South Africa Early Adopters