

Department of Geography



AMAZING

Advancing MAiZe Information for Ghana

P Lewis (NCEO/UCL)

Contributions from GSSTI & Assimila, CAU, CAAS, UCL, NCEO teams



National Centre for
Earth Observation
NATIONAL ENVIRONMENT RESEARCH COUNCIL

Earth Observation promises and delivery for crop monitoring

Vital Early Warning Systems with EO: save money and lives

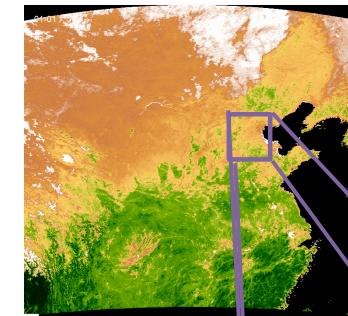
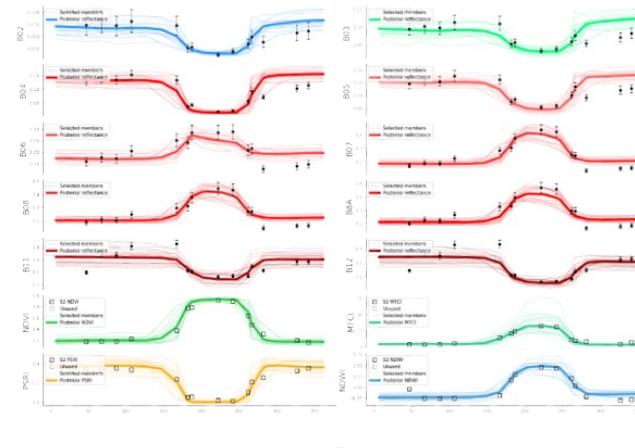
The top section shows a world map with color-coded crop conditions. A legend indicates conditions from Exceptional (blue) to Failure (red). Below is a graph titled 'Cropland NDVI for South Africa's North West Province' showing monthly NDVI from 2003 to 2010, with a red line for 'Crop Status' and a green line for 'Crop NDVI'. A small inset image shows a field of crops.

mars.jrc.ec.europa.eu/asap/cropmonitor.org; www.fao.org/giews; nasaharvest.org

Core global monitoring historically driven by weather and **coarse resolution** EO crop maps, indicators and anomalies, reporting from FAO, NASA, USGS, EU-MARS etc.

New capabilities: Denser time series at high spatial resolution

allows mapping of detailed crop status, where cloud cover permits



Developed new methods to deal with sparse samples

Within-field variation across North China Plain

Advances for practical global monitoring

Step change in last 5 years: Landsat + Sentinel
10-30m ~3-5 day revisit
more appropriate scales for many

+ national and commercial assets:
GF3, GF6, www.planet.com



GEOGLAM
Global Agricultural Monitoring

+ coordination / sharing

Maize in Ghana

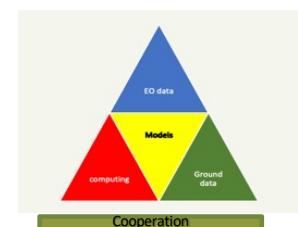
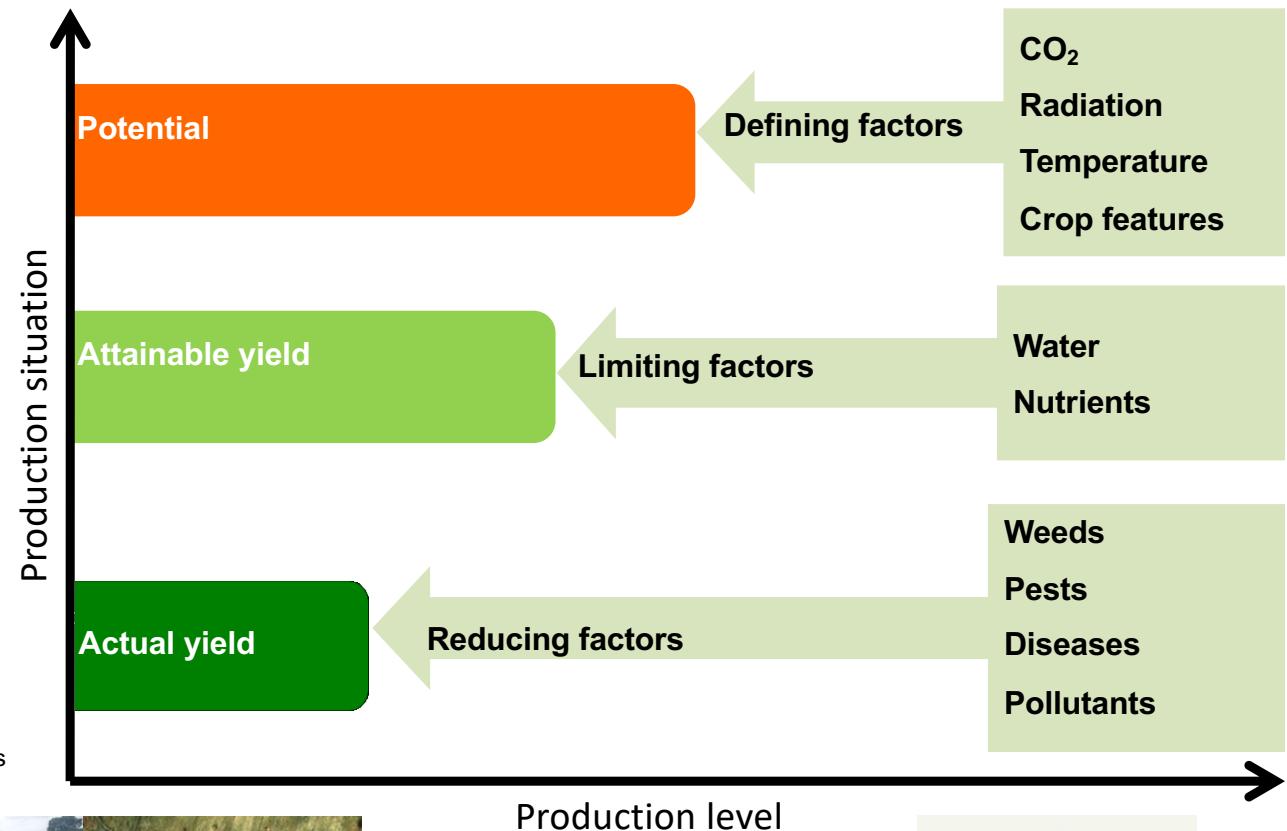


- Important cereal crop
- Many smallholder farms
 - Rainfed
- Yield gap
 - Soil fertility and water retention
 - Use of fertilizer
- **build towards smallholder maize information system for Ghana**



Develop from previous collaboration

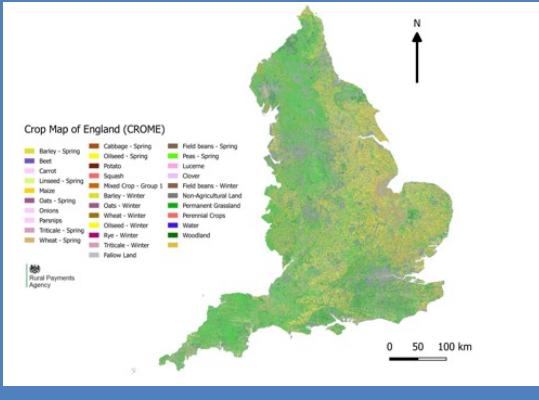
- 1-2 year projects
- Funded data collection & workshop
- Impacted by COVID and budget cuts



The building blocks for agriculture monitoring

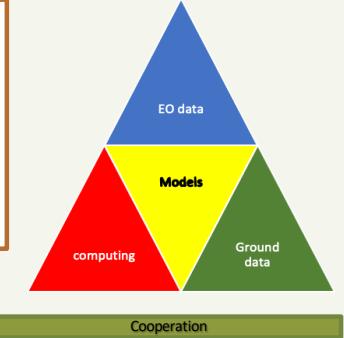
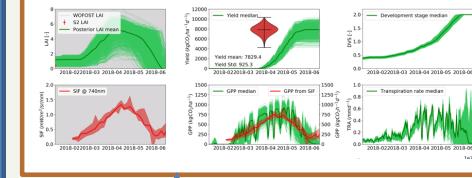
Earth Observation: Essential Agriculture Variables

Land use: Crop type maps



Crop status maps:
Leaf area, water, pigments

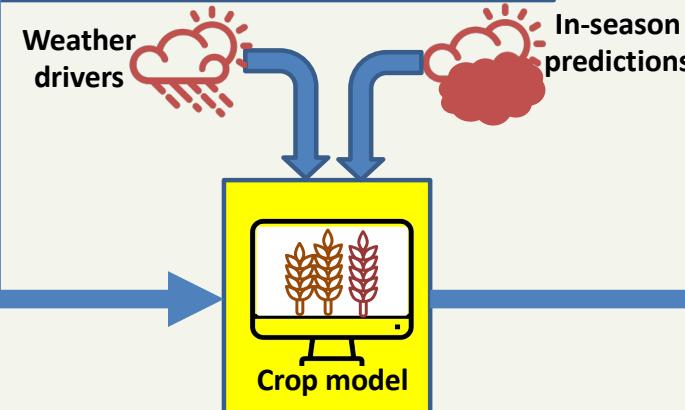
Productivity, yield, water use



Models connect satellite data of crop state to our knowledge of crop growth. Use these models to ask "what ifs" e.g. to optimise nitrogen inputs, irrigation, soil tillage.

Computing

Dissemination



calibration and validation



Cooperation

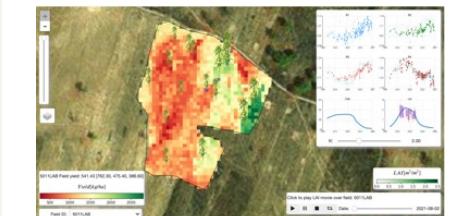
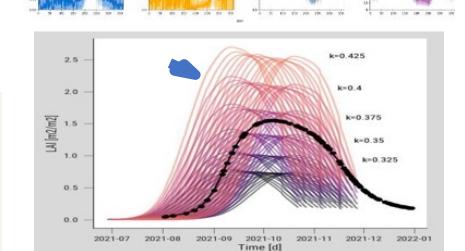
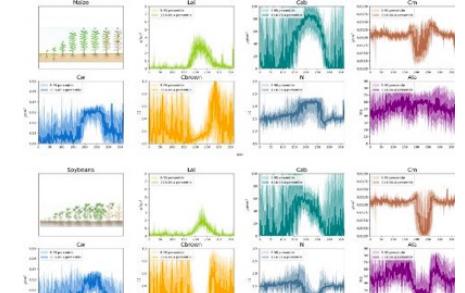
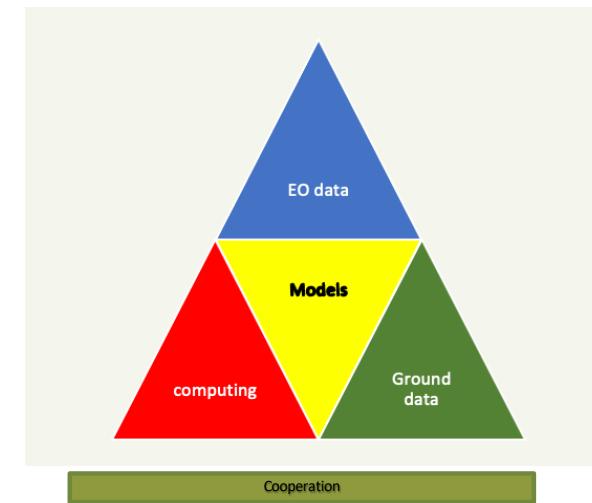
GEOGLAM
Global Agricultural Monitoring

CropWatch

AMAZING / Newton Prize: Achievements build towards smallholder maize information system for Ghana

Achievements

- Field data
- Method for biophysical parameters from EO in complex environment
- Prototype Data Assimilation: allows per-pixel yield prediction
 - Crop explorer
- Initial work on in-season forecast
- All dataset and codes open source (GEOGLAM)
- Workshops

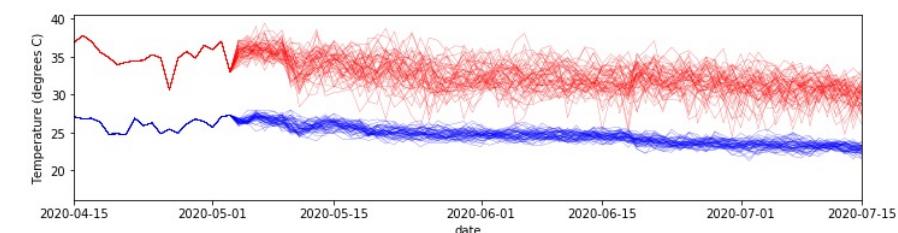
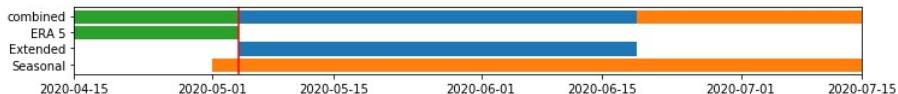
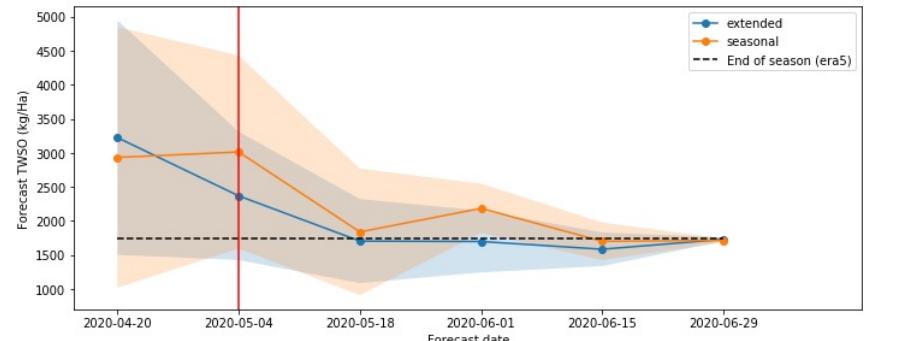
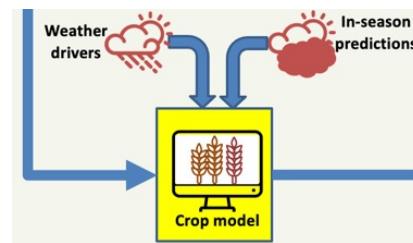


Mechanistic Crop Model at heart of system

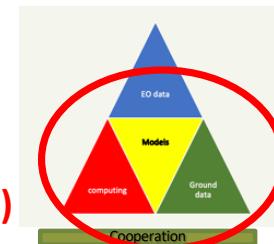


In Science and Agriculture

- Irrigation optimization
 - fertilization schedule optimization
 - **Impacts and responses to climate change**
 - Carbon cycle in ecosystem
 - Crop variety planning and environmental impact assessment
 - Crop variety modeling
-
- **Production forecasting**
 - Water and fertilizer management
 - Critical periods for use of agricultural machinery
 - Response and risk management for different meteorological scenarios
 - Targeted assistance and early warning for agricultural disasters
 - Agricultural commodity futures trading
 - Agricultural insurance



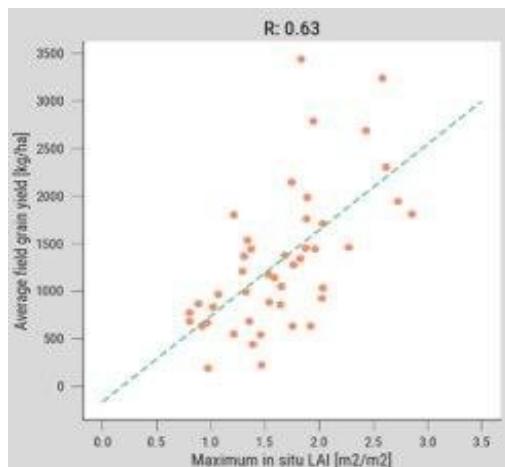
forecasting



WOFOST (WOrld FOod STudies)

Components of the system: Ground data

Ground data for calibration and validation



Very large range of LAI and Yield

Fieldwork

- Crop type survey 2020, 2021
- Equipment and training 2021: **Licor LAI, SPAD**
- **Extensive crop biophysical parameter campaign 2021** 50 km x 50 km area **Nr Tamale: LAI, Chlorophyll (Cab), yield**

Crop type

Once in season

Training and validation of crop type map

LAI

Weekly through season

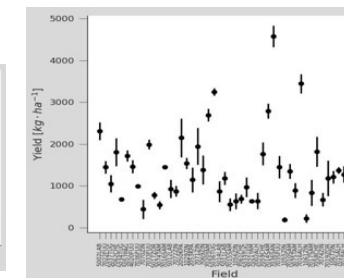
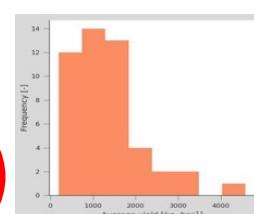
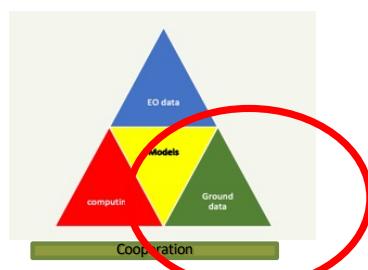
Validation of EO mapping of crop status

Chlorophyll

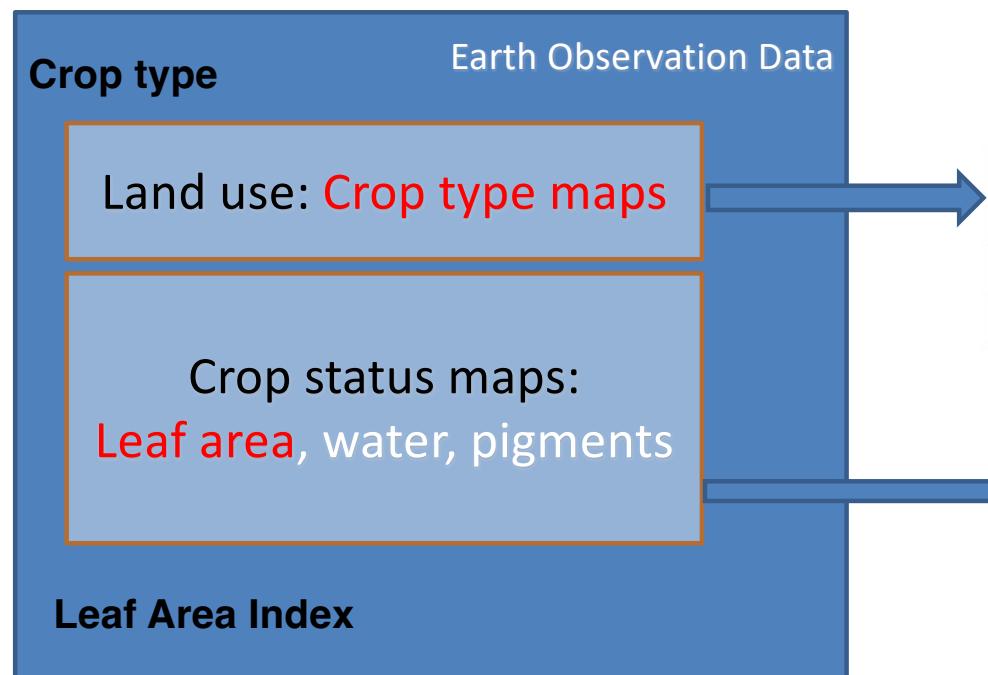
End of season

Training and Validation for model output

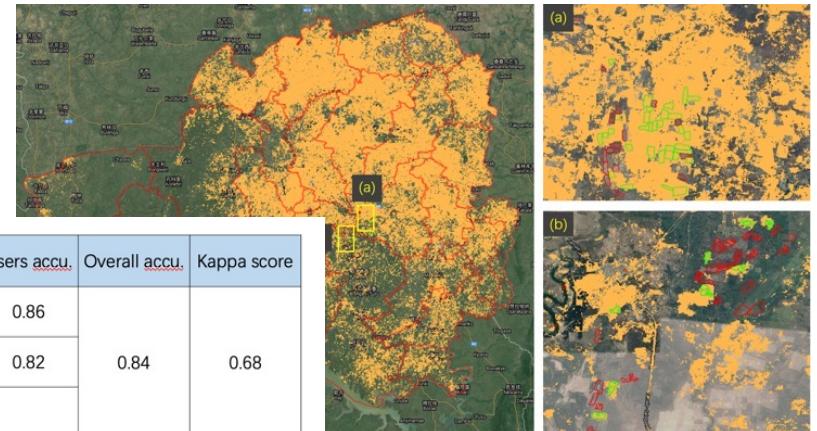
Yield



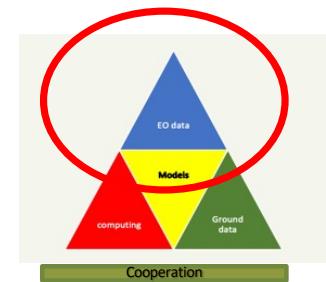
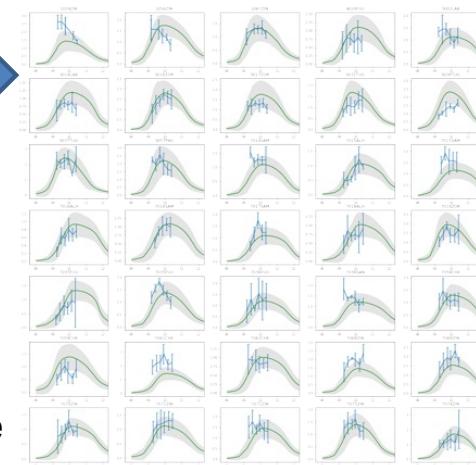
Components of the system: Earth Observation



Crop	others	maize	Users accu.	Overall accu.	Kappa score
others	7823	1234	0.86	0.84	0.68
maize	1800	7975	0.82		
Producers accu.	0.81	0.87			



Per-pixel Leaf Area Index as function of time

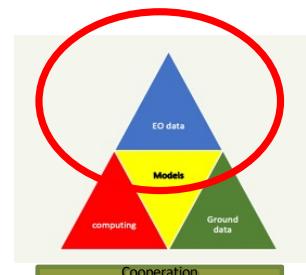
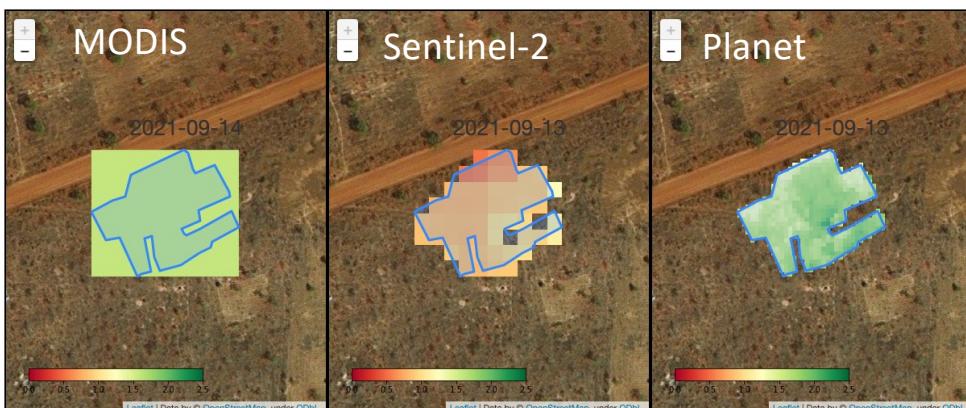
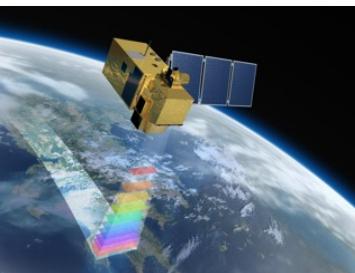
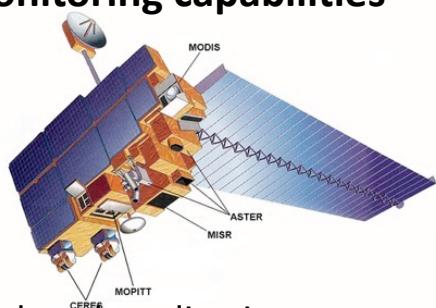


Copernicus Sentinel-2 Data

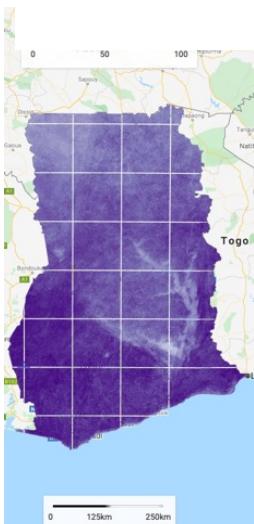
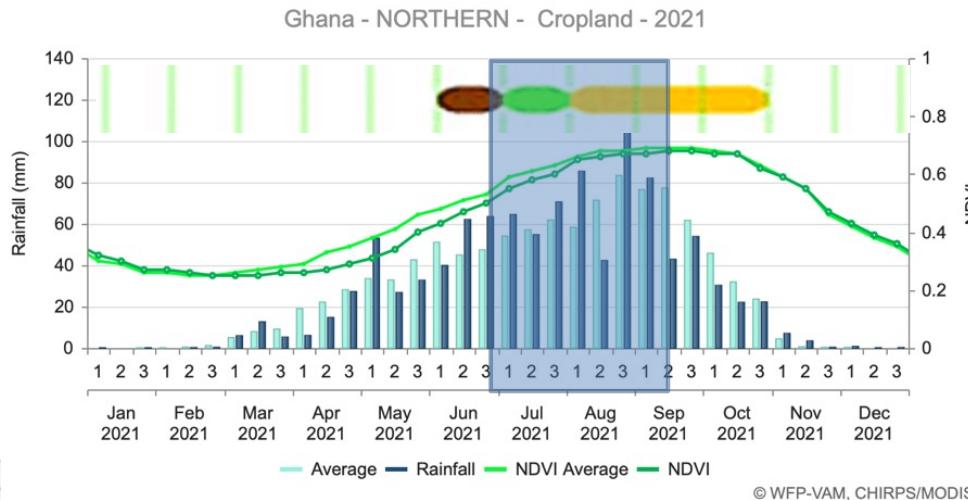


Step change in potential for Agriculture monitoring capabilities for smallholders in last 5 years

- 2000+: MODIS ~daily data, but 500m
- **Landsat + 2 x Sentinel-2 (2017+)**
 - 10-30m ~3-5 day revisit
 - more appropriate scales for many agricultural applications
 - **Free and open access**
 - Data processing and coordination
 - Digital Earth Africa



BUT Sentinel-2 ... not so good for N. Ghana



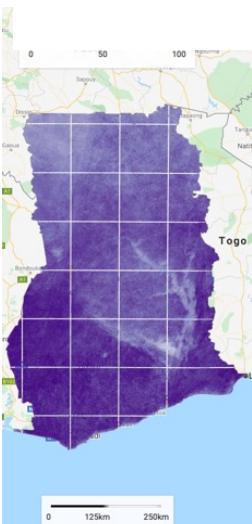
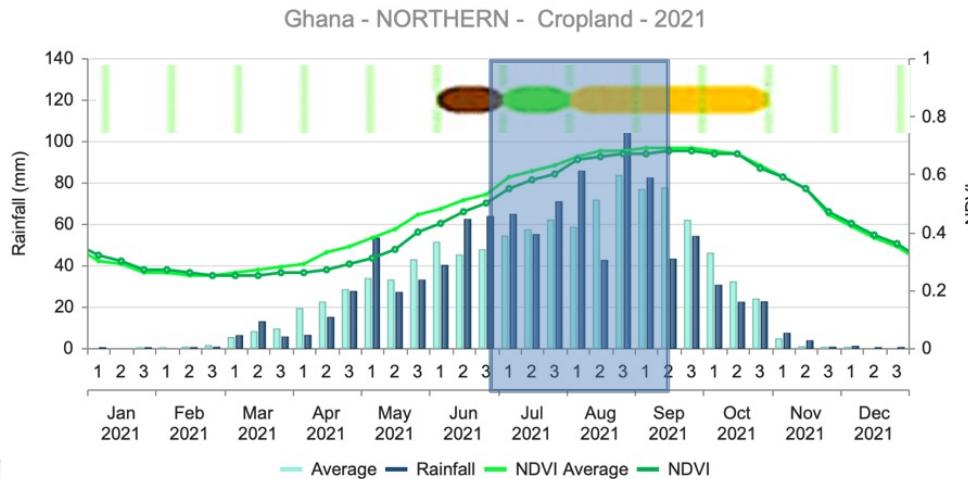
High cloud cover period at critical period

Most other areas we can use Sentinel-2 and/or MODIS LAI

- MODIS LAI product unreliable
- Single Sentinel-2 observation
- **Only Planet data sufficient to define early-mid season LAI**
- Information in Sentinel-1 RADAR data but harder to use

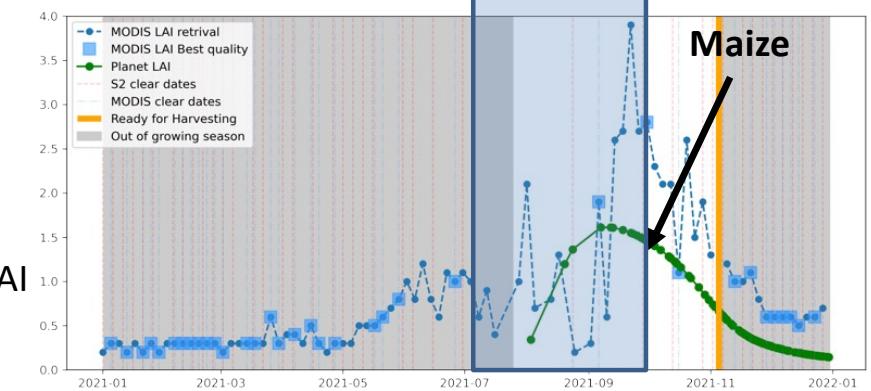
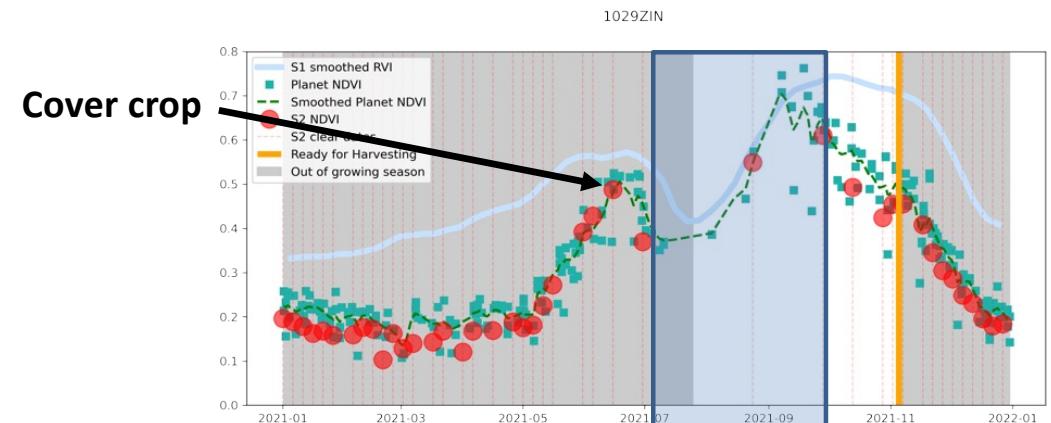


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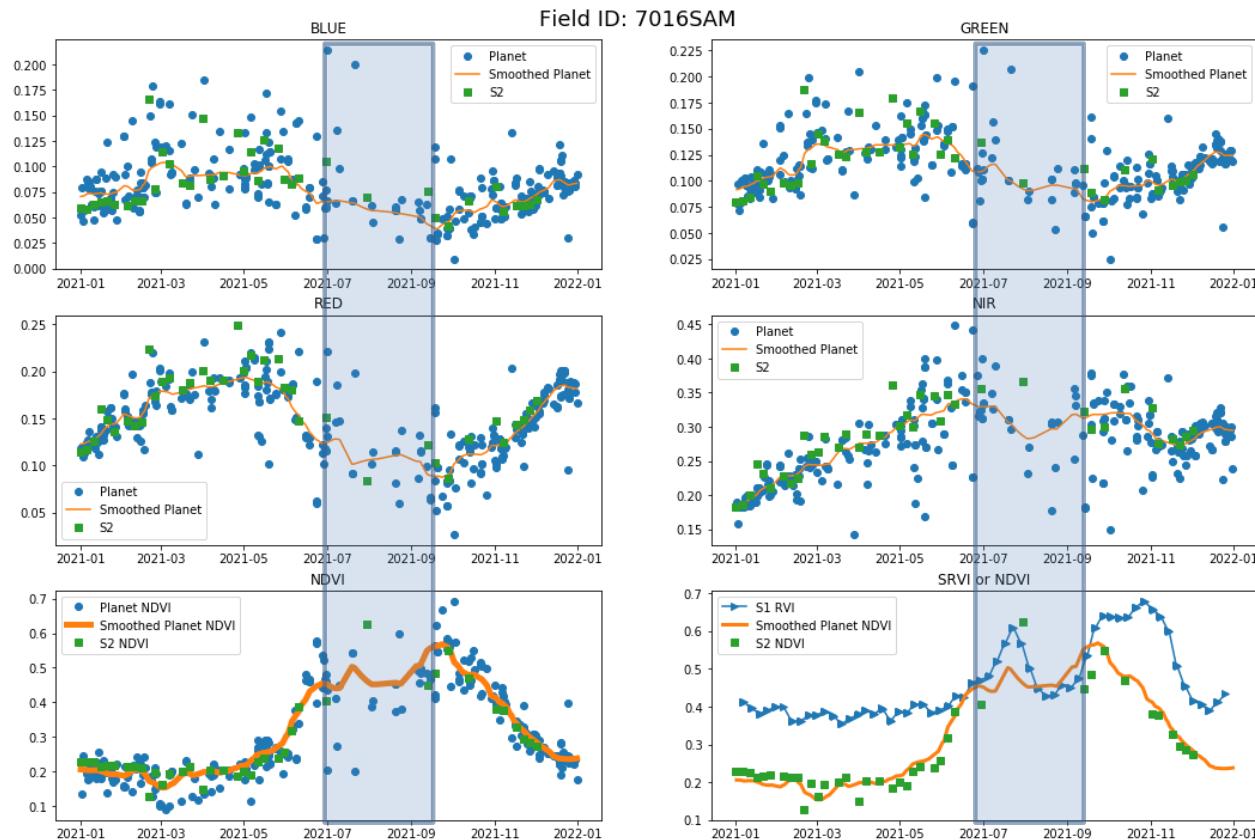


High cloud cover period at critical period

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Near-daily Planet data over critical period



planet.

www.planet.com

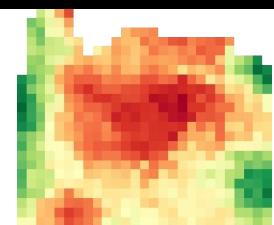


LAI

- Commercial data
- Noise
- 4m resolution, almost daily

Less information per sample

BUT Much more suitable coverage in time



Estimate LAI from EO reflectance

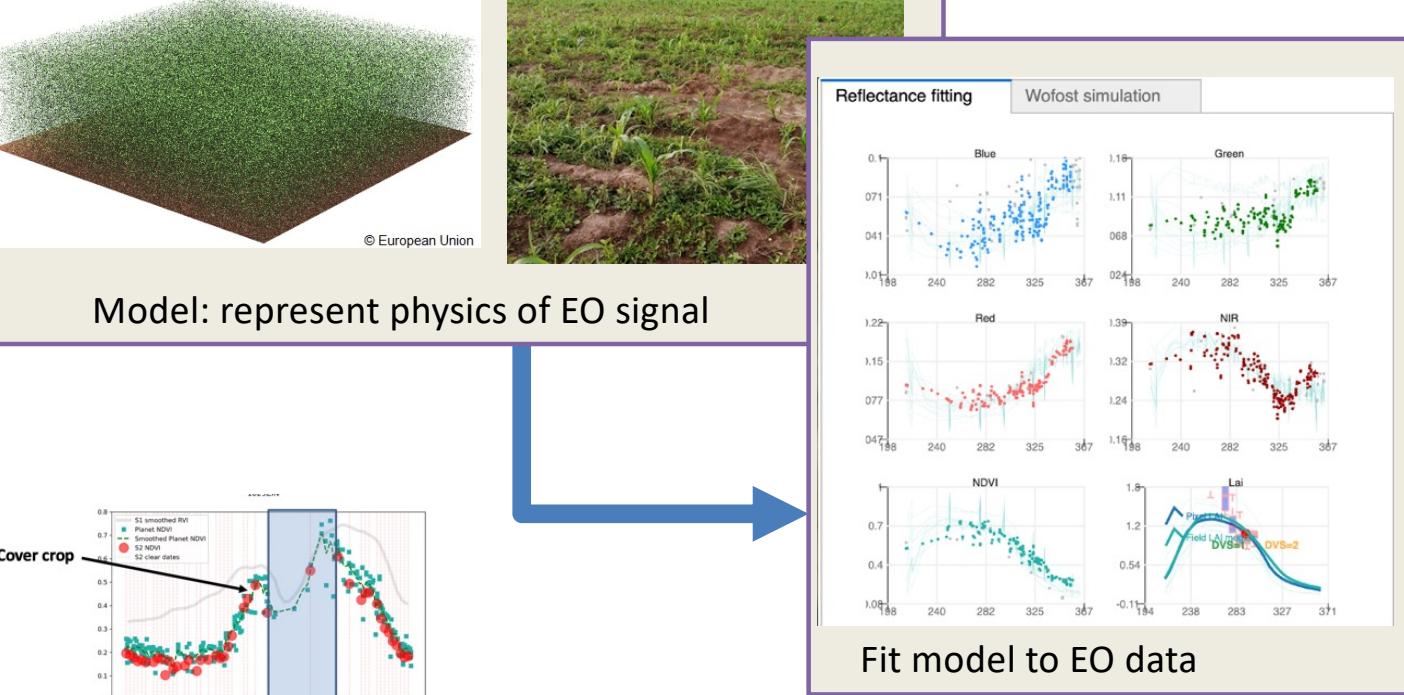
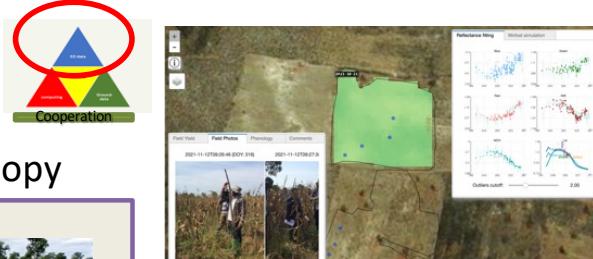
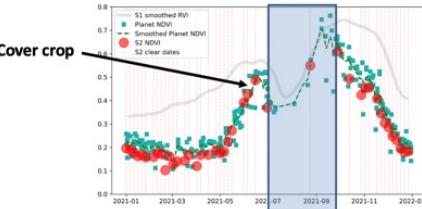


Models are abstractions of reality

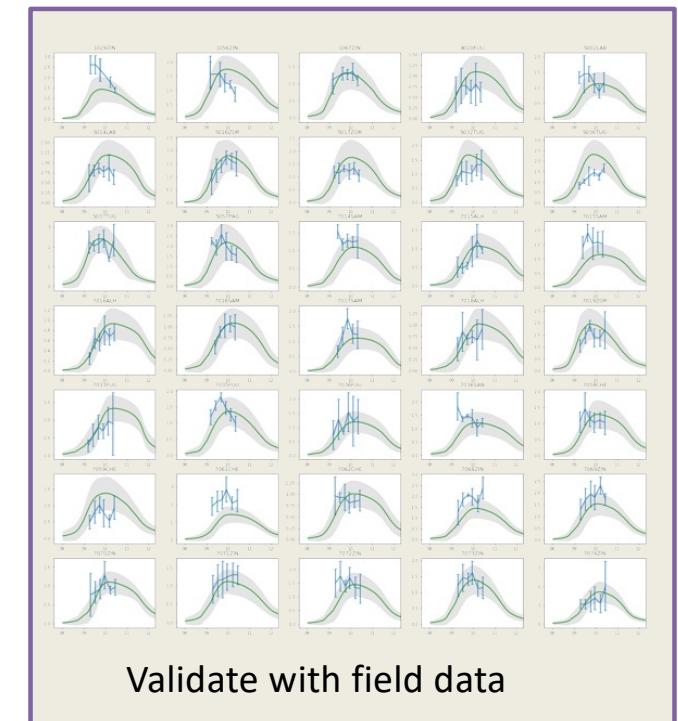
- Need models to interpret EO signals
- Make simple assumptions about nature of canopy



Model: represent physics of EO signal



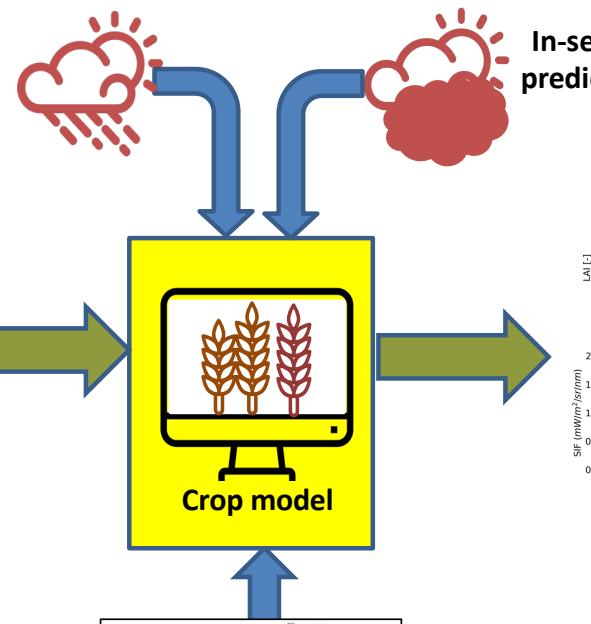
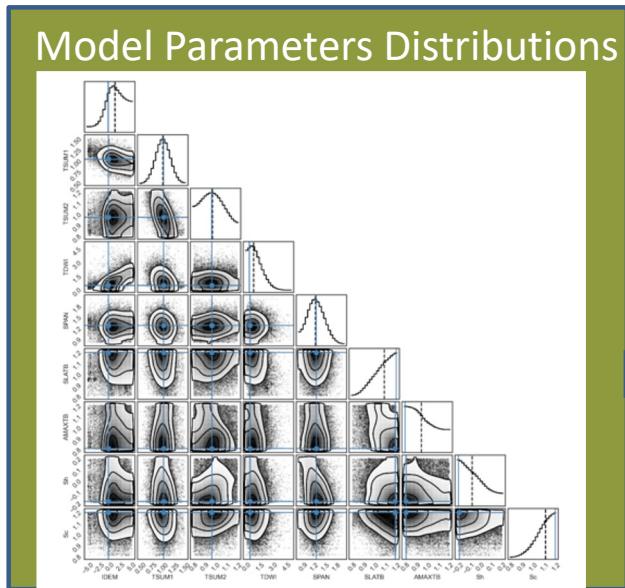
Critical to have ground validation data over range of conditions



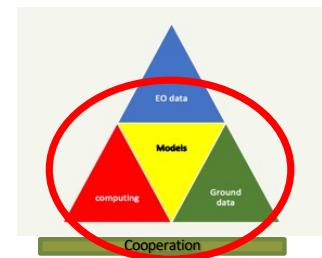
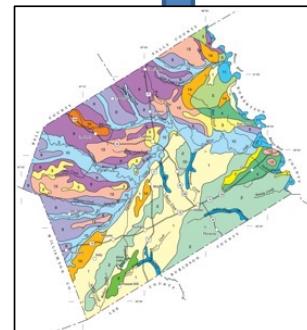
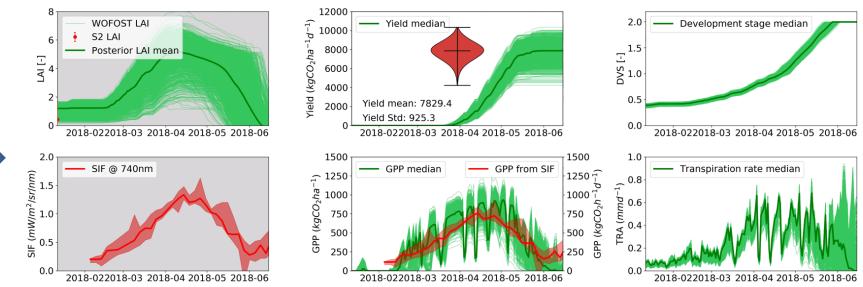
Components of the system: Crop Model



Tropical Maize

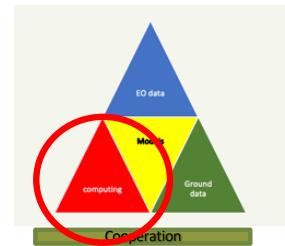
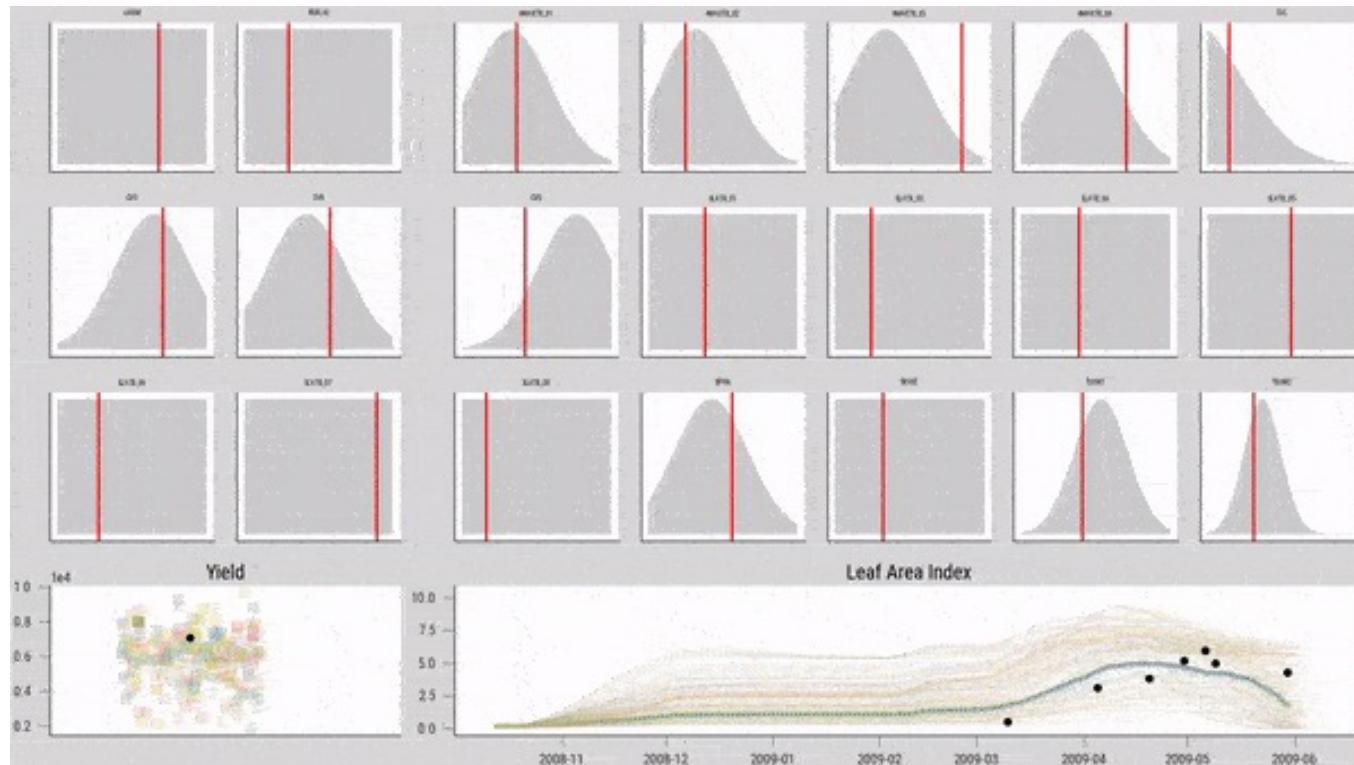


In-season
predictions



Data Assimilation

In essence, **calibrate relationship between LAI and yield for given weather**

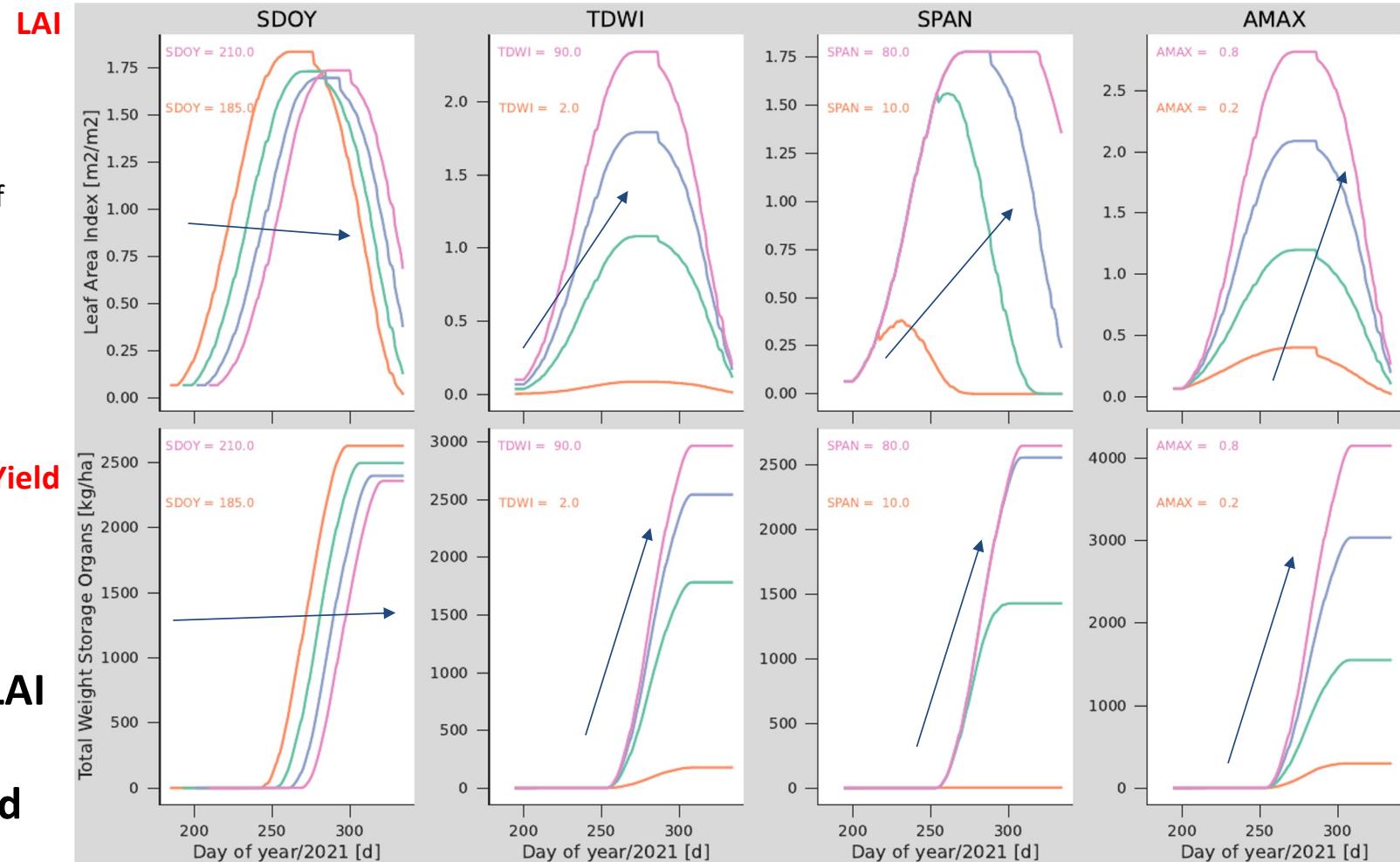


Effect of parameters on LAI and yield

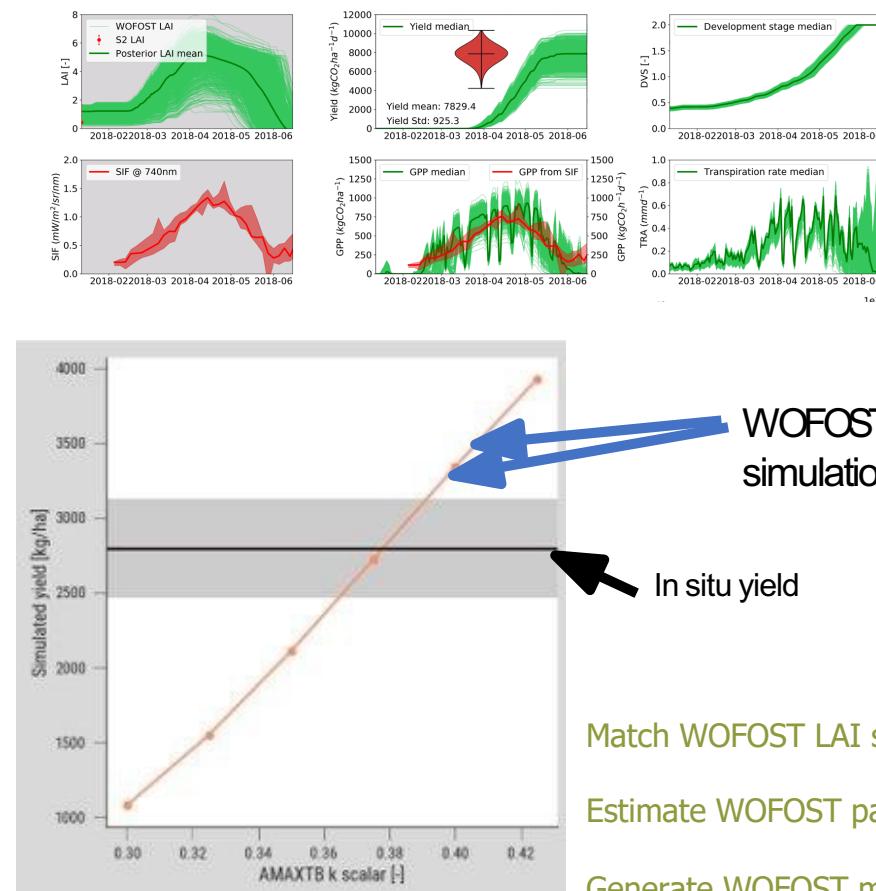
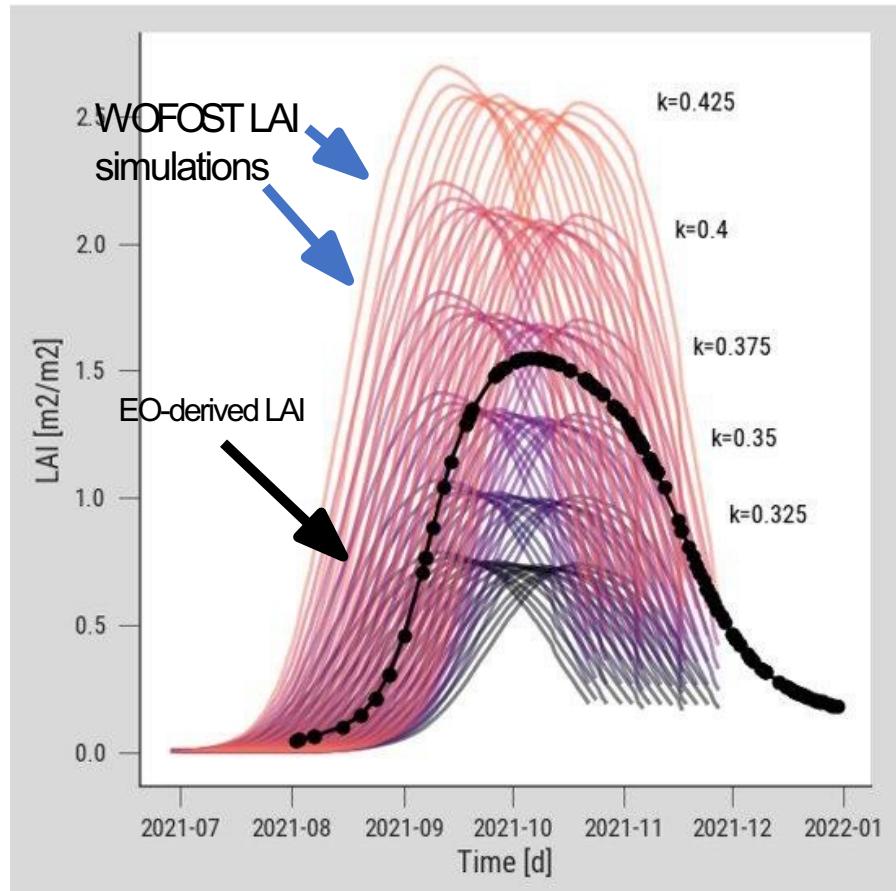
- **Planting date**
 - **SDOY:** Shift in time/weather
- **Seed mass**
 - **TDWI:** Initial build up of LAI, max LAI
- **Leaf life span**
 - **SPAN:** length of LAI arc, max LAI
- **Photosynthesis rate**
 - **AMAX:** max LAI & yield



**Localise model so LAI
is an effective
constraint for yield**



Data Assimilation

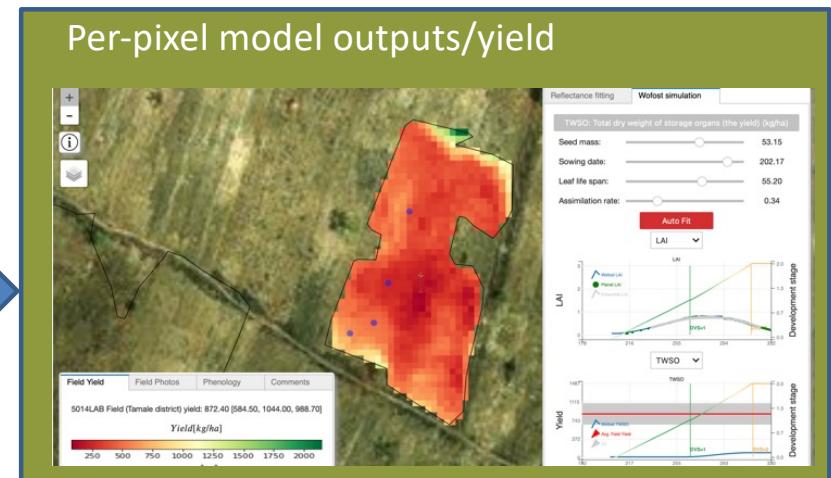
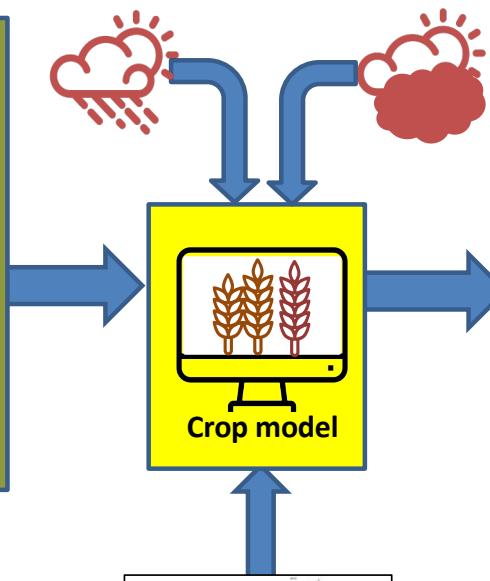
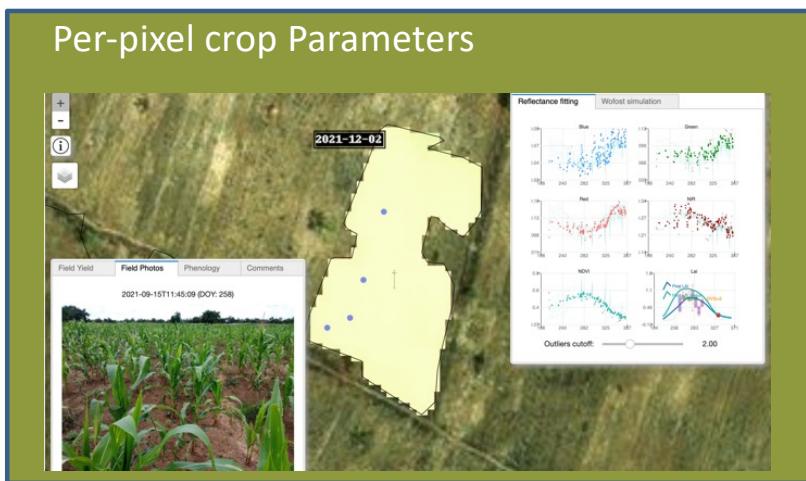


- Match WOFOST LAI simulations to EO LAI
- Estimate WOFOST parameters
- Generate WOFOST model outputs

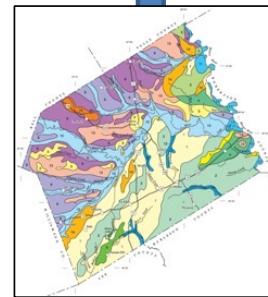
develop spatial input and output maps



Tropical Maize



Need to estimate per-pixel crop model parameters
To predict per-pixel yield



Use method called **Data Assimilation (DA)**
To estimate per-pixel crop Parameters

DA takes prior model parameter estimate
And updates with information from observations

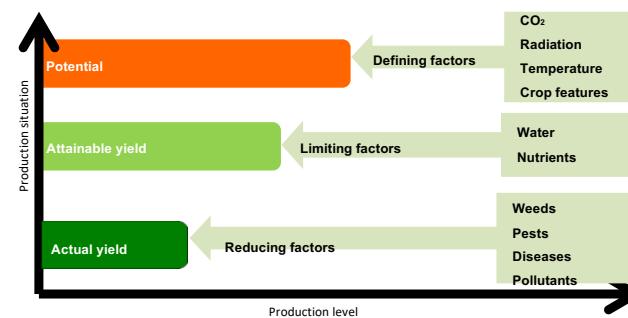
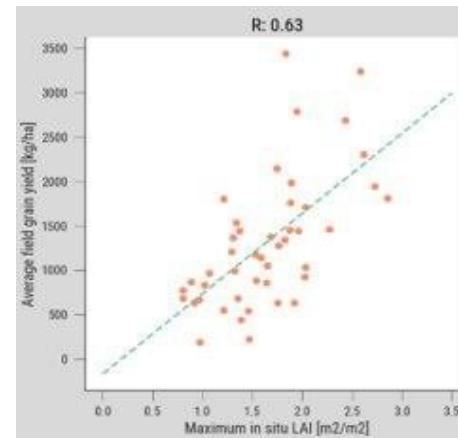
Complex environment for crop models



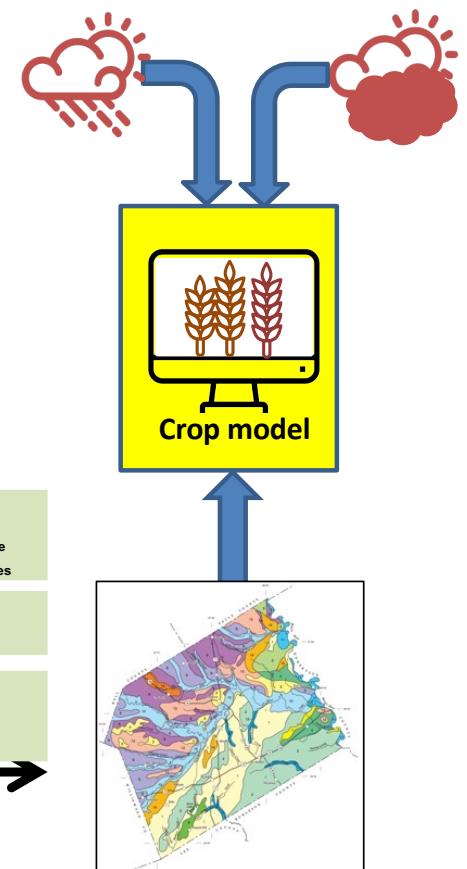
Only tested under limited conditions

Strength of crop models is response to weather variations

- Only data for a single year here (2021)
- Only data for limited region (Tamale 50 km x 50 km)
- Spatial resolution of driving data from crop models
 - 10s of km
 - Essentially same weather/drivers for all fields
 - in-field variations significant
 - **Underlying broad relationship from LAI to yield**
 - Reliant on this for mapping



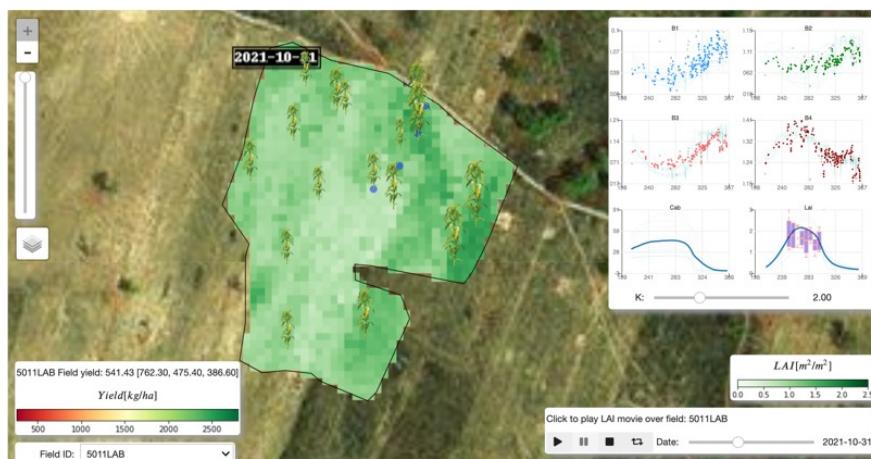
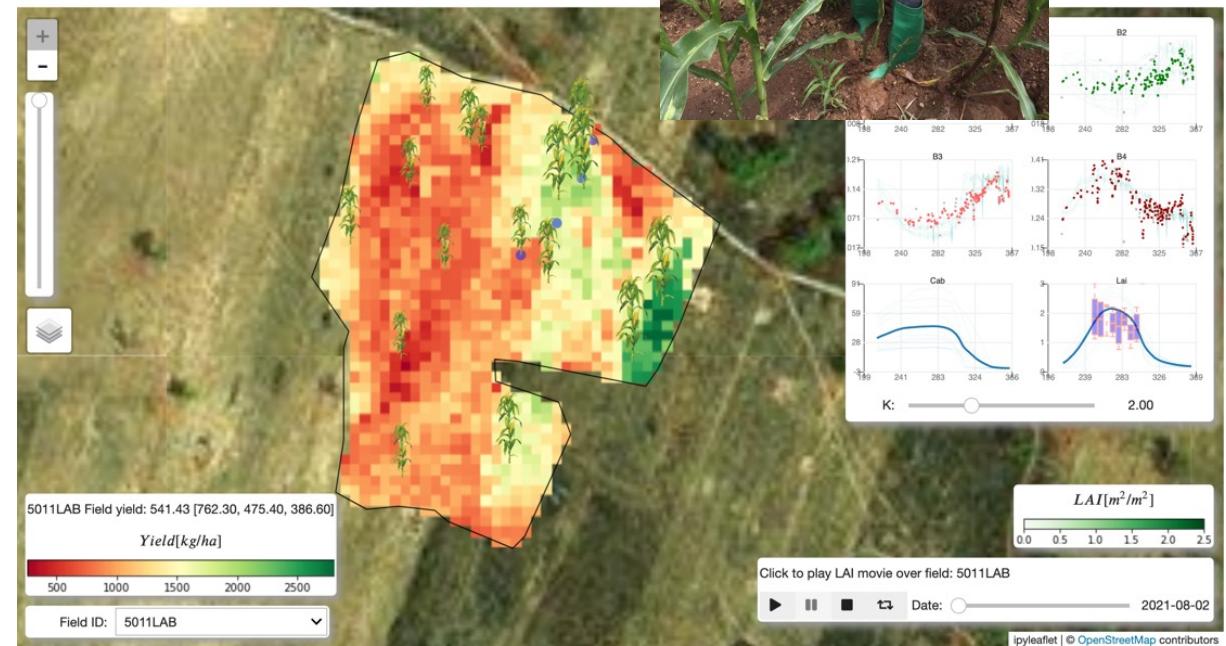
Critical to have validation data



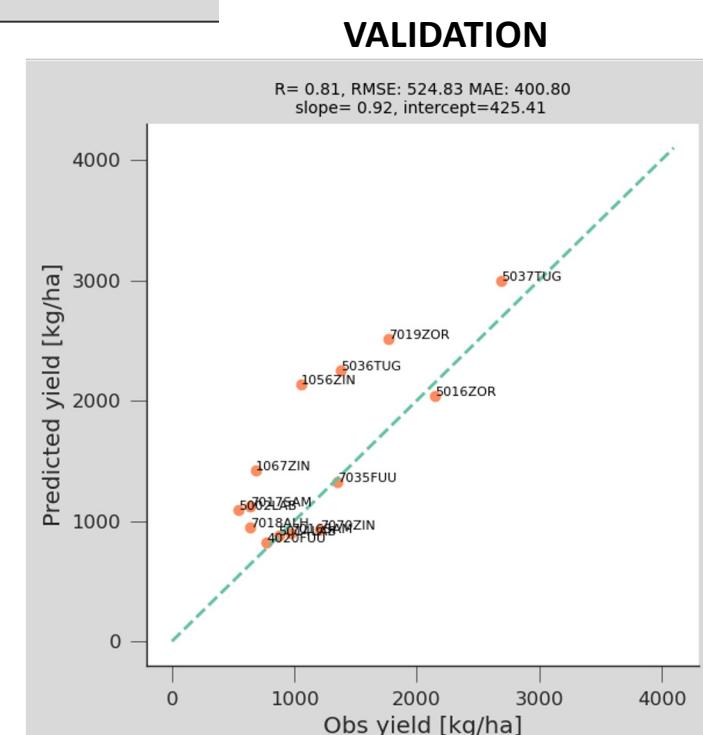
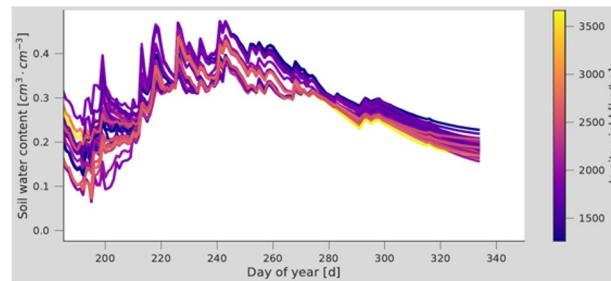
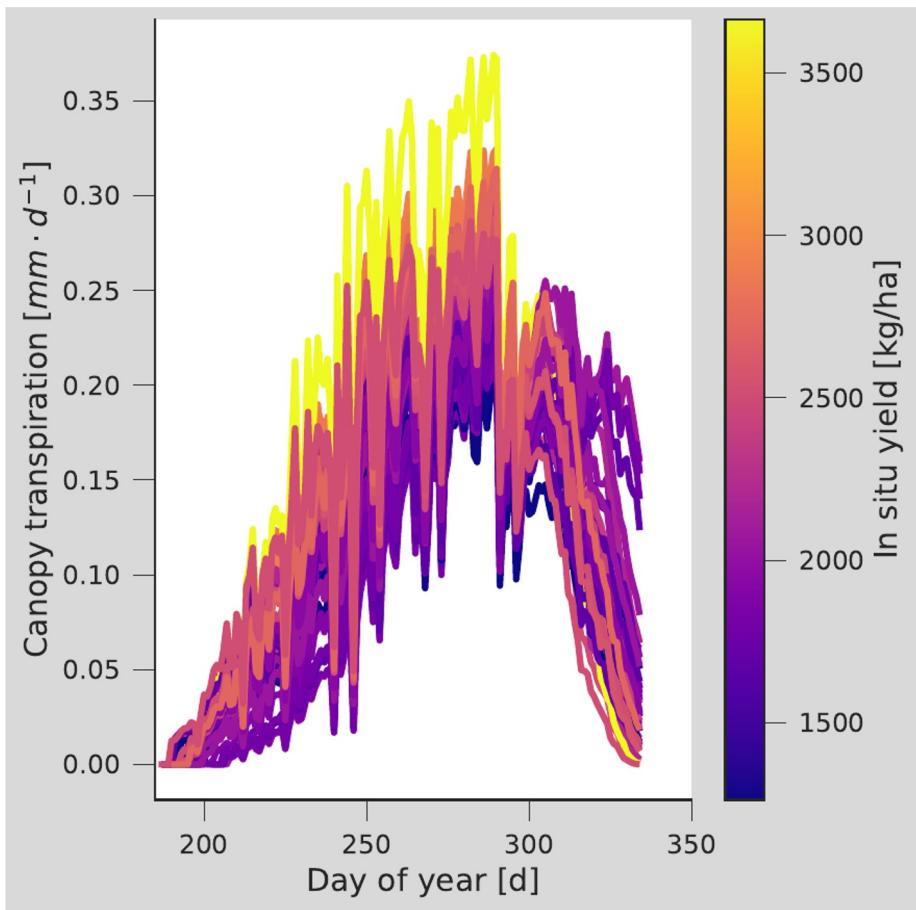
Implemented Crop Explorer

Relate smallholder & extension worker experience of crop to information from EO

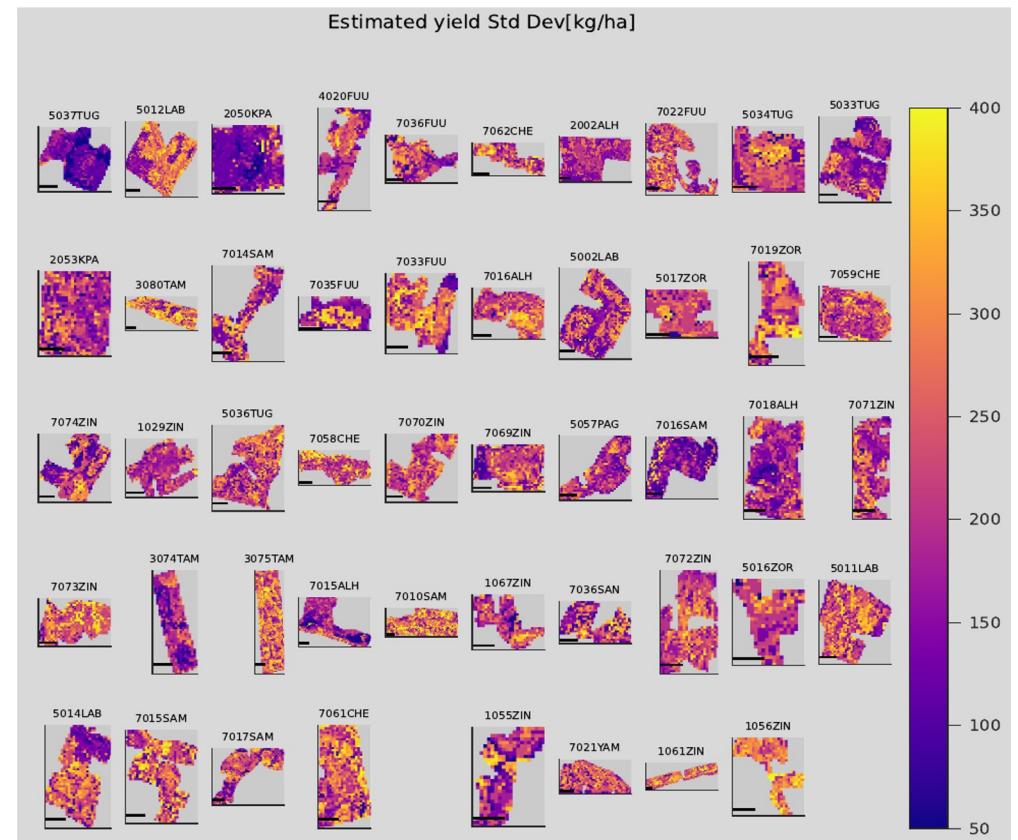
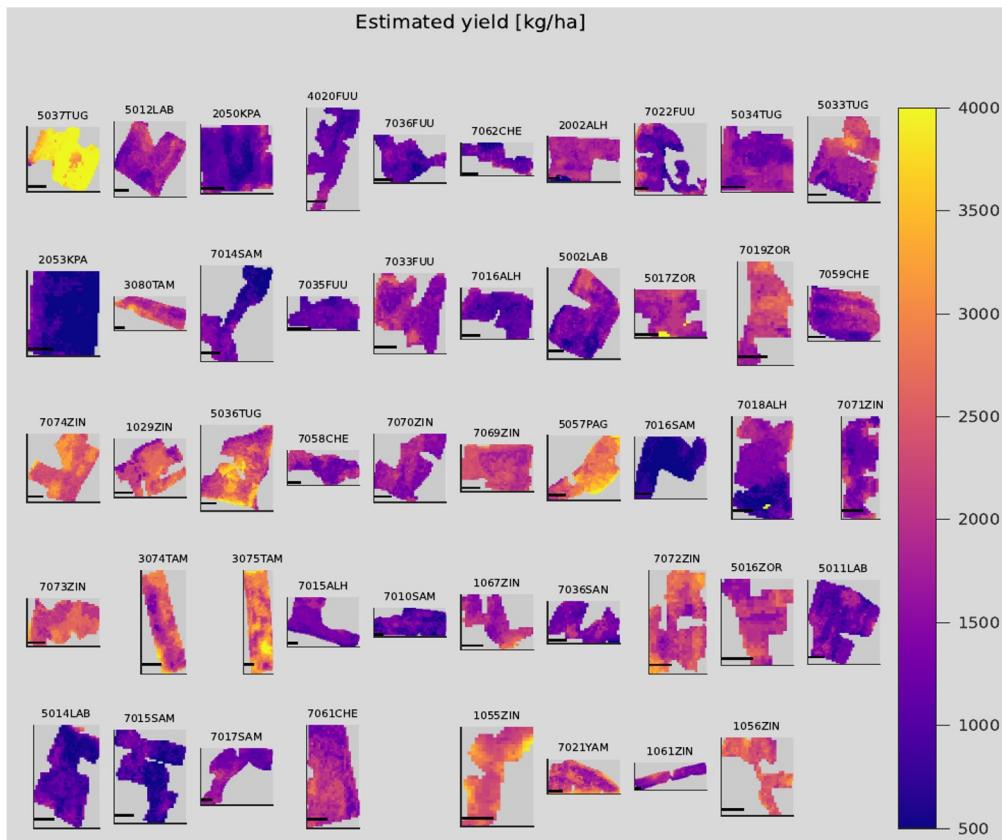
- EO reflectance data from Planet
 - Solve for LAI and compare to field measures
 - Data assimilation of LAI in WOFOST to solve for yield
 - Use to:
 - explain method (EO and modelling)
 - Explore and explain results



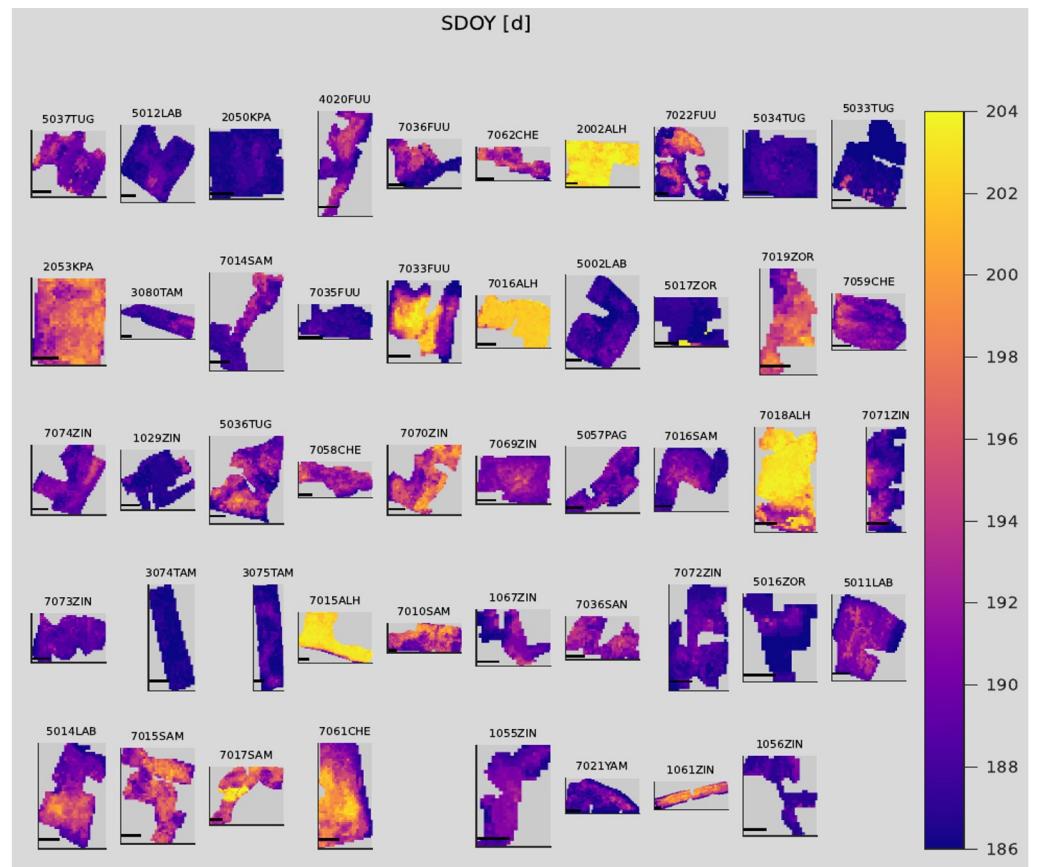
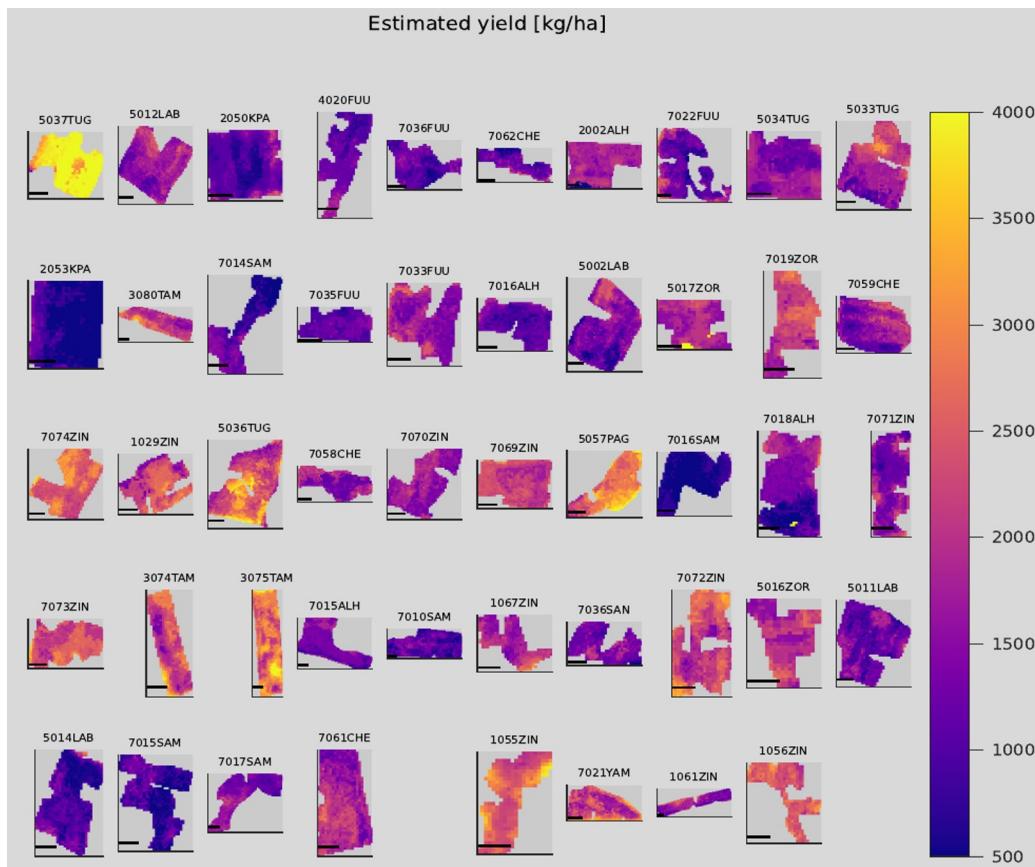
Model outputs and Results



Pixel-scale estimation: yield and uncertainty

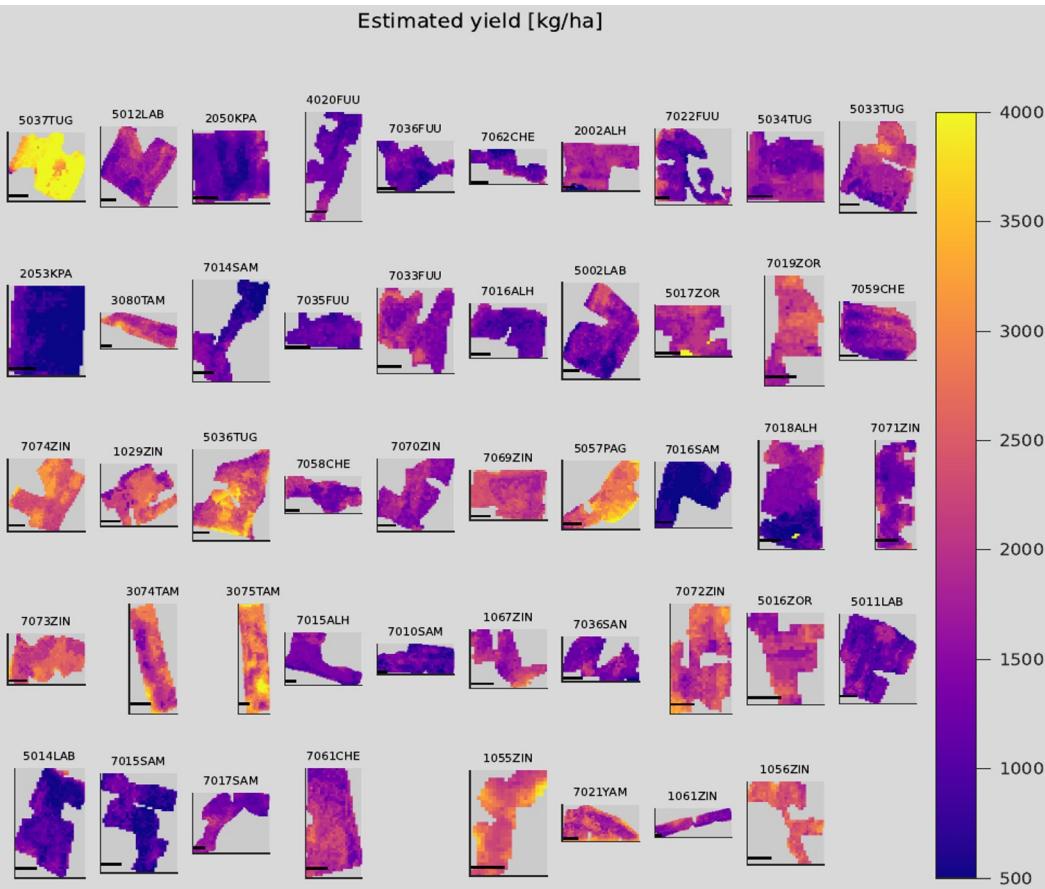


Yield and Sowing date

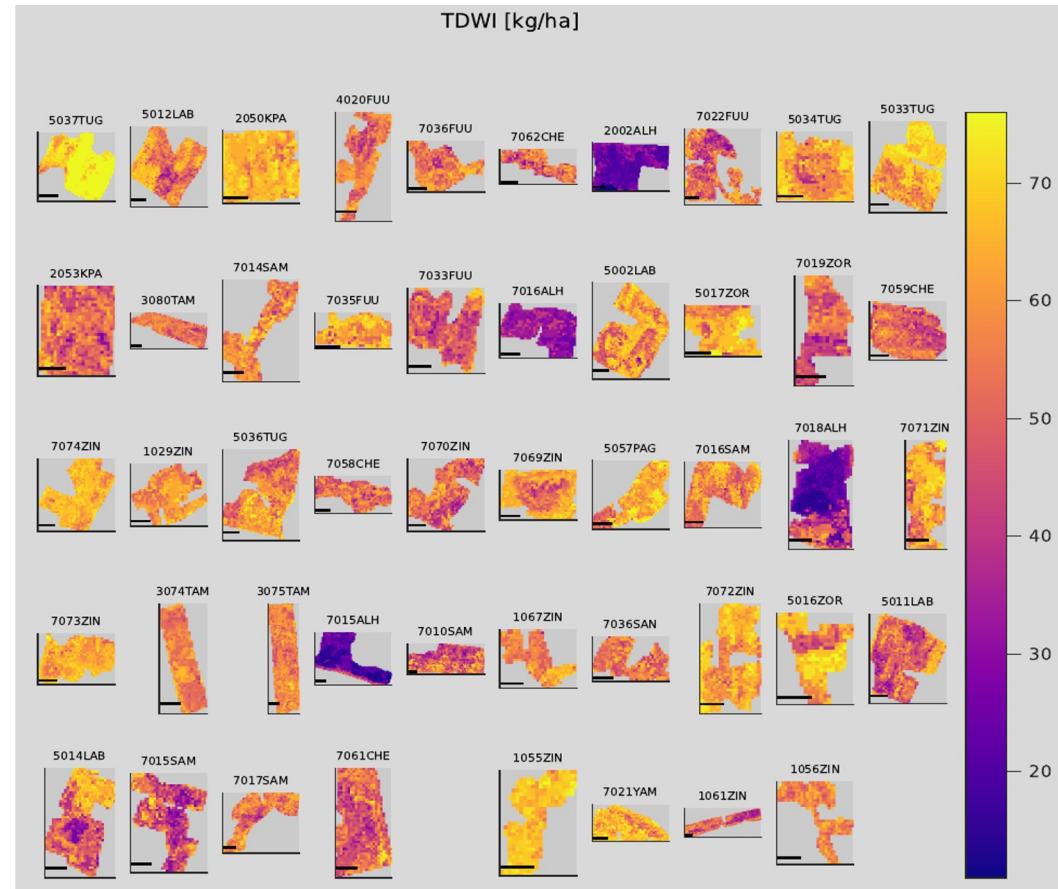


Yield and Seed mass

Estimated yield [kg/ha]



TDWI [kg/ha]



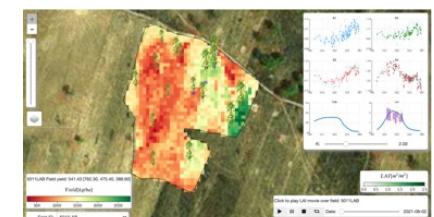
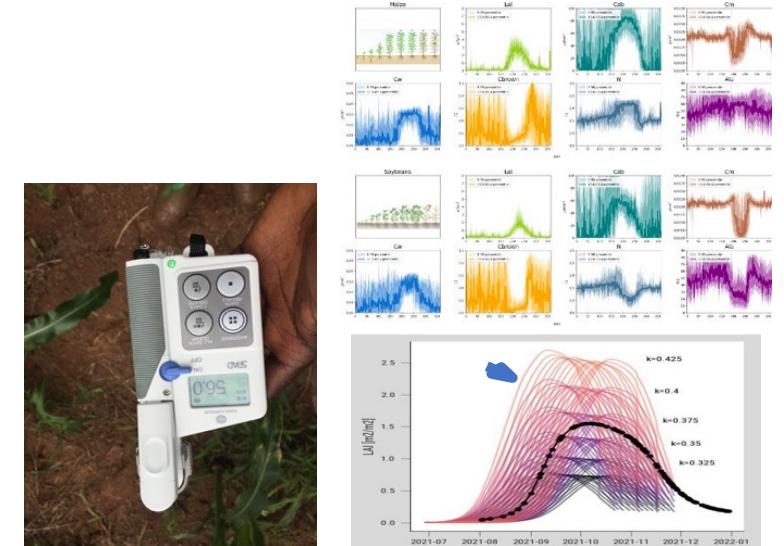
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Achievements

- Method for biophysical parameters from EO in complex environment
- Prototype Data Assimilation: per-pixel yield prediction
- Crop explorer
- Initial work on in-season forecast
- All dataset and codes open source (GEOGLAM)
- Workshops

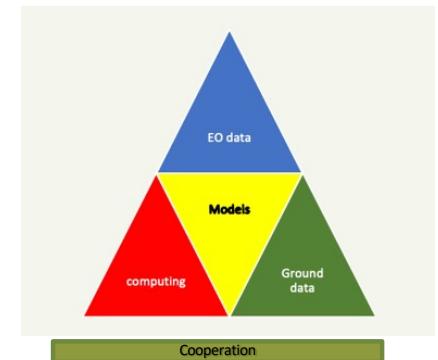
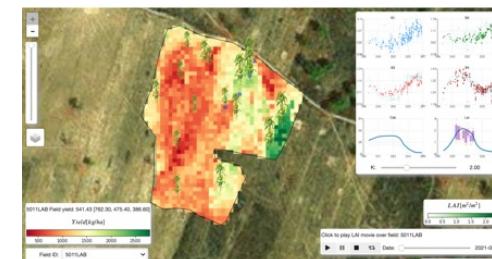
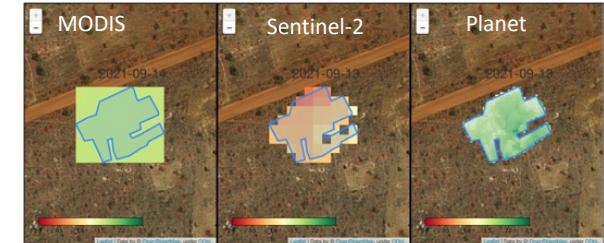
Fieldwork

- Crop type survey 2020, 2021
- Equipment and training 2021: **Licor LAI, SPAD**
- Extensive crop biophysical parameter campaign 2021
 - Nr Tamale: LAI, Chlorophyll (Cab), yield



Remarks

- **Towards smallholder maize information system for Ghana**
- **Built components:** **Earth Observation data, Crop models, ground data, DA**
 - Complex environment for use of crop models
 - Crop mask and LAI EO
 - Complex environment for EO interpretation
 - Spatial and temporal resolution at critical period
 - But **solution with Sentinel-2 and Planet data**
- **Engagement & legacy**
 - Affected by Covid-19
 - **Workshops and crop explorer**
 - Field equipment and training
 - **Model parameters for smallholder**
 - Explore factors, link to in-season predictions
- **Limited testing data**
 - Need to extend in space and time
 - Learn from 2021
 - Yield location



Thank You