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Crop stress monitoring in the semi-arid context of Doukkala (Morocco)

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Scientific background and objectives

EO AFRICA
Research and Development Facility

First call 2021

CrosMoD
(Crop Stress Monitoring in the semi-arid context of Doukkala, Morocco)

One of the crucial problems currently facing the Moroccan irrigated area of **Doukkala** is the **scarcity of water for irrigation**

Decrease in water resources

-Climate change and repetitive years of droughts
-Fluctuating rainfall with a decreasing trend

Increase in water demand

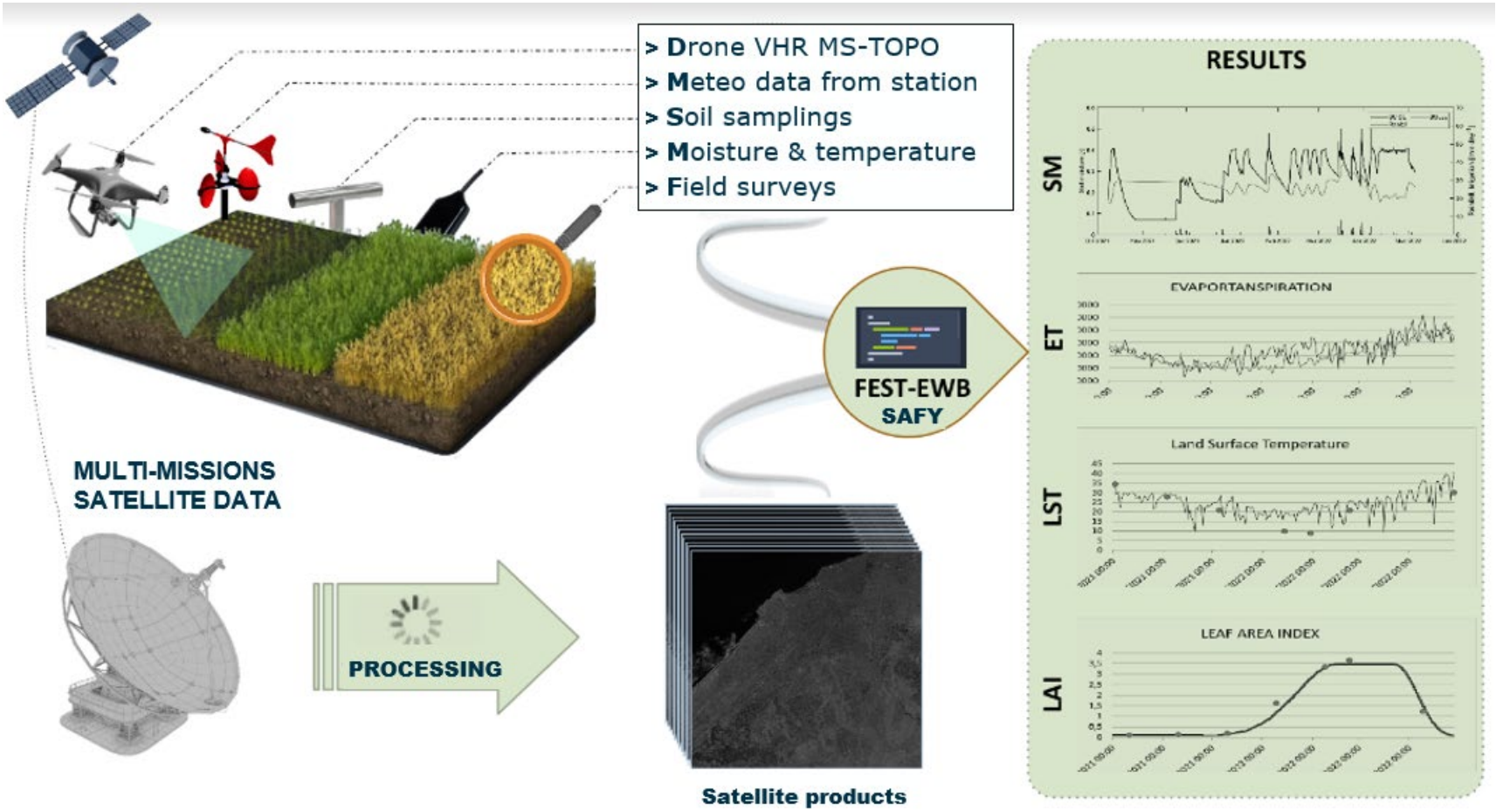
- Population growth
- Extension of irrigated agriculture
- Industrial Development
- Tourism development

Irrigation is the main consumer of water (more than 85% of water mobilized)

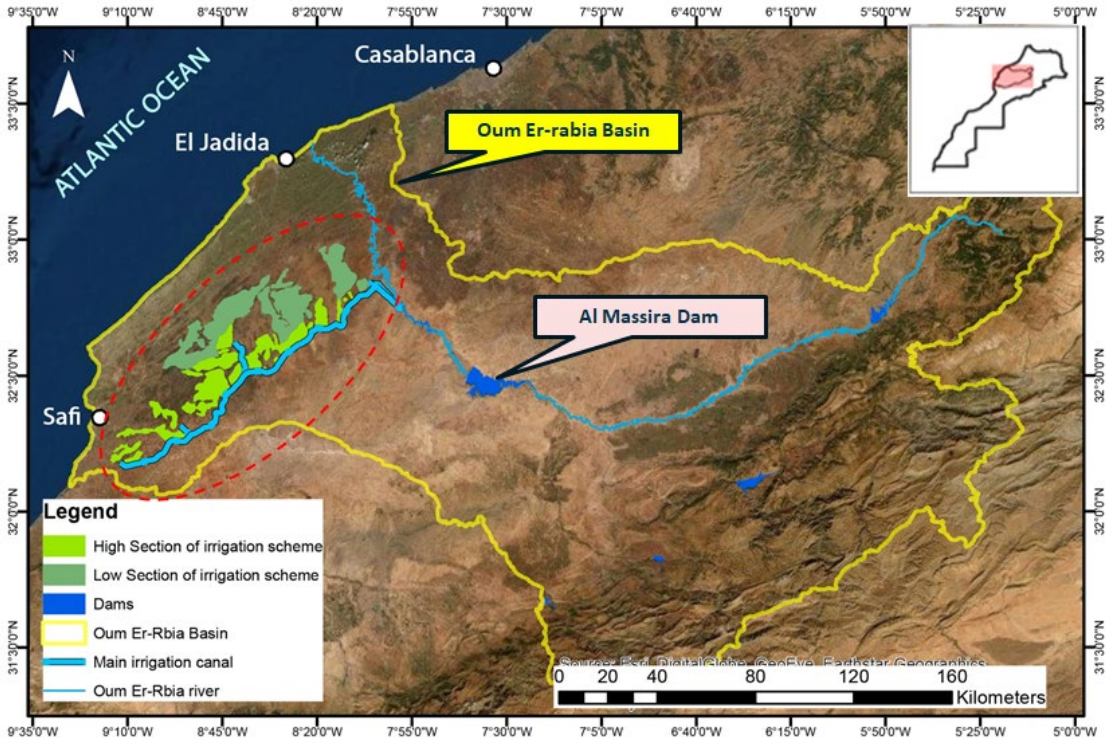
The project aims at developing a procedure for extreme events crops shocks monitoring (e.g. droughts) by integrating multiple satellite data and water-energy-crop modeling, able to support farmers precision agriculture.

Research outline

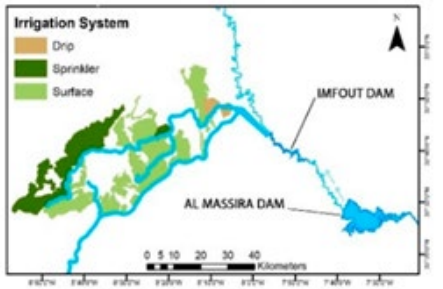
The project will develop an EO-service supporting precision agriculture for farmers and farms associations, tackling the issues of managing water scarcity and safeguarding food security in Africa.



Study area: Doukkala irrigation scheme



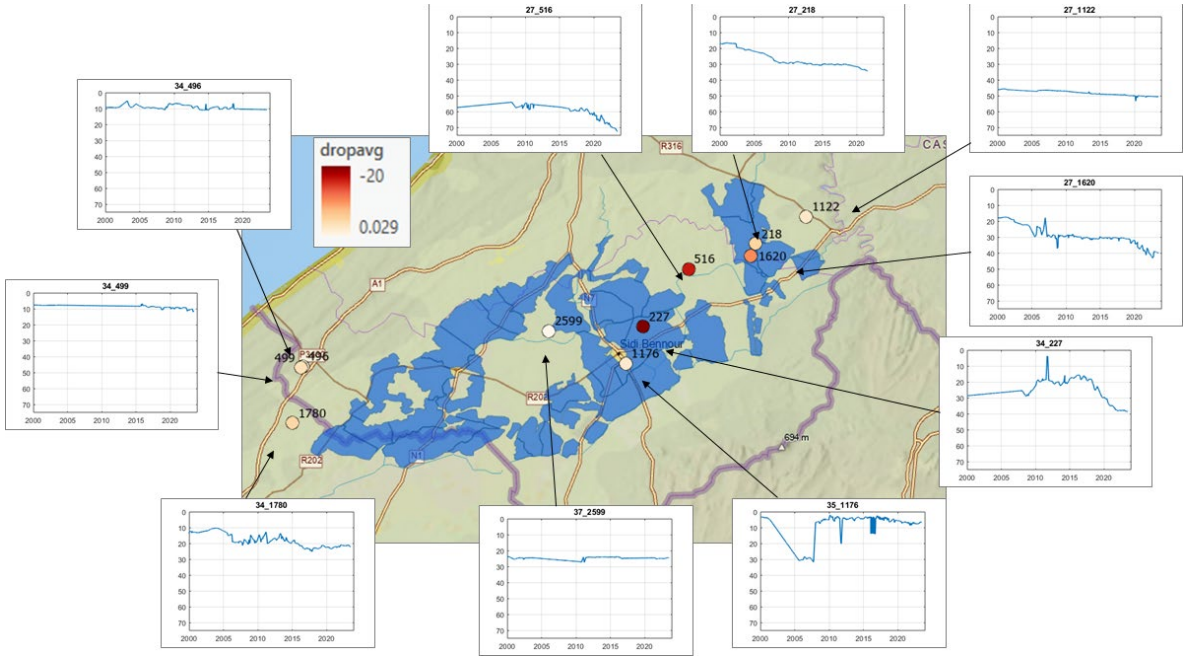
Almost 70% low efficiency surface irrigation



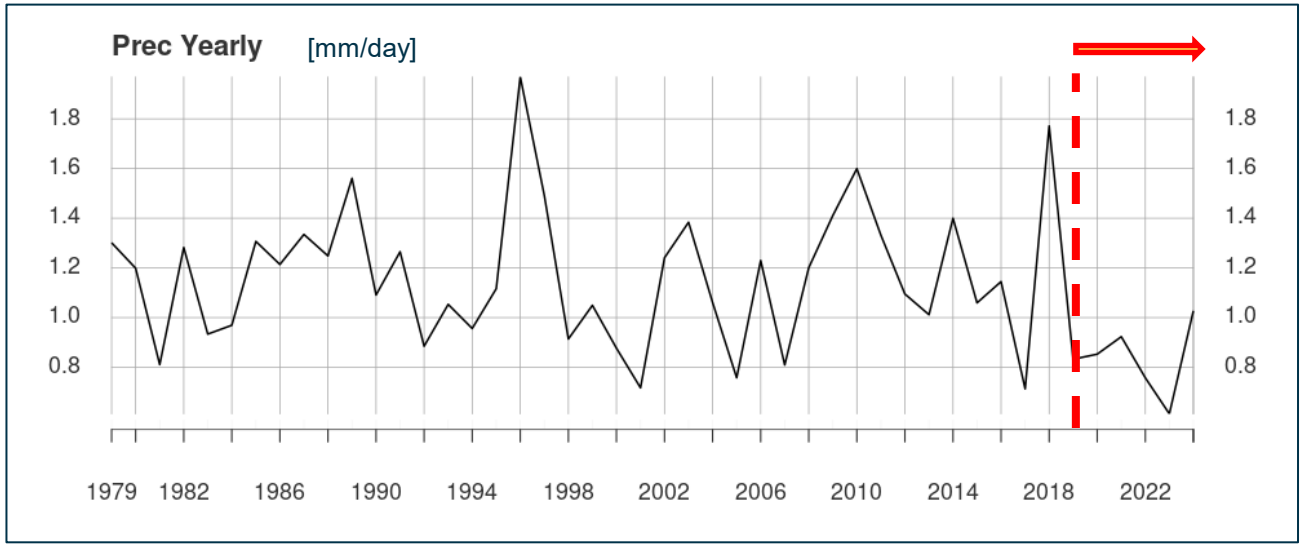
Main crops

Water scarcity

- many years of drought, **the ORMVAD office stopped supplying water** to farmers by the end of 2019.
- the agricultural technical commission **authorized farmers to use water from wells** to avoid any problems related to water scarcity.



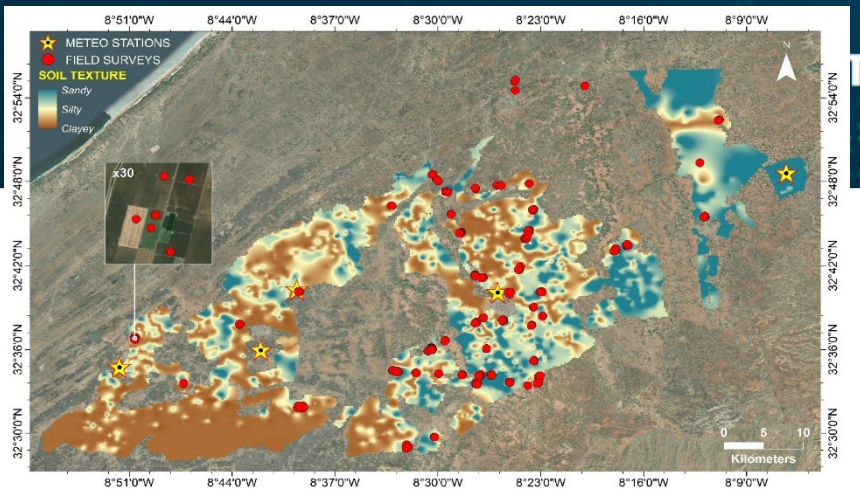
semi-arid climate



Sensible decrease of groundwater table depth in the last years (Faregh and Sidi Bennour

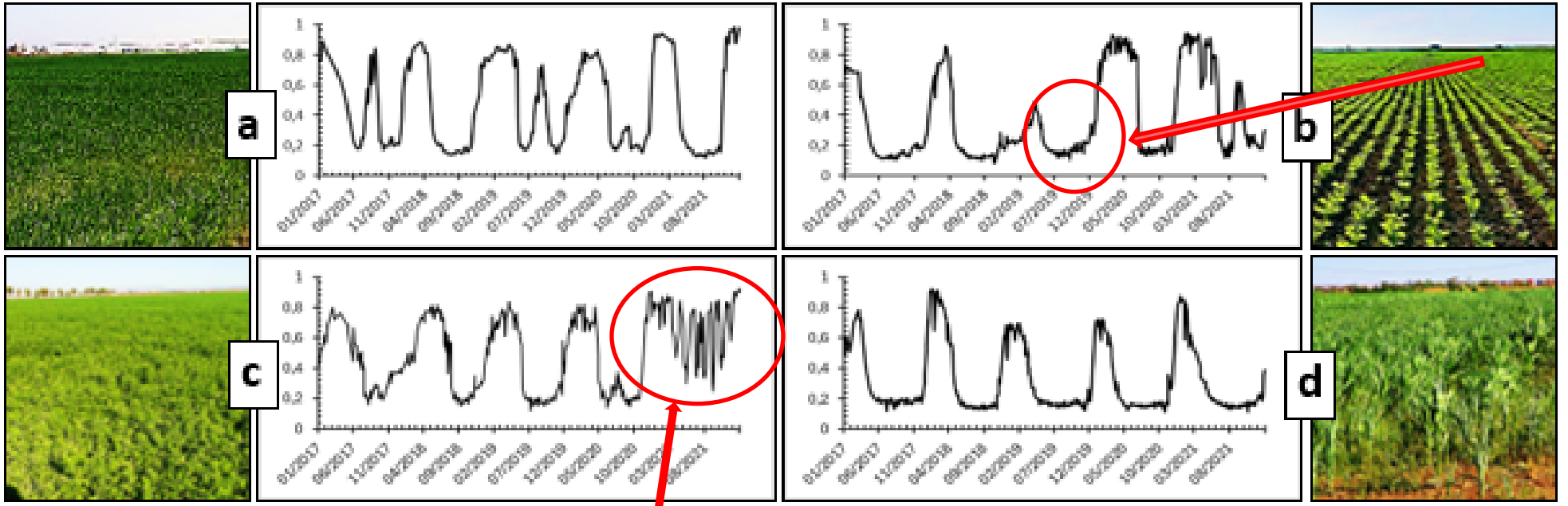
Selected fields

- different crop types
- different soil types
- different irrigation methods



NDVI evolution from Sentinel-2 2017-2021

20 Ha **winter wheat field** near Sidi Bennour with loamy soil and is irrigated with Pivot



6 Ha **sugar beet field** near Sebt Maarif with clay soil and is irrigated using gravity

During winter 2019, the ORMVAD stopped water allocations

3 Ha **alfalfa field** situated near Laakakcha with loamy soil and is irrigated using sprinkler from winter 2021 (before during winters wheat)

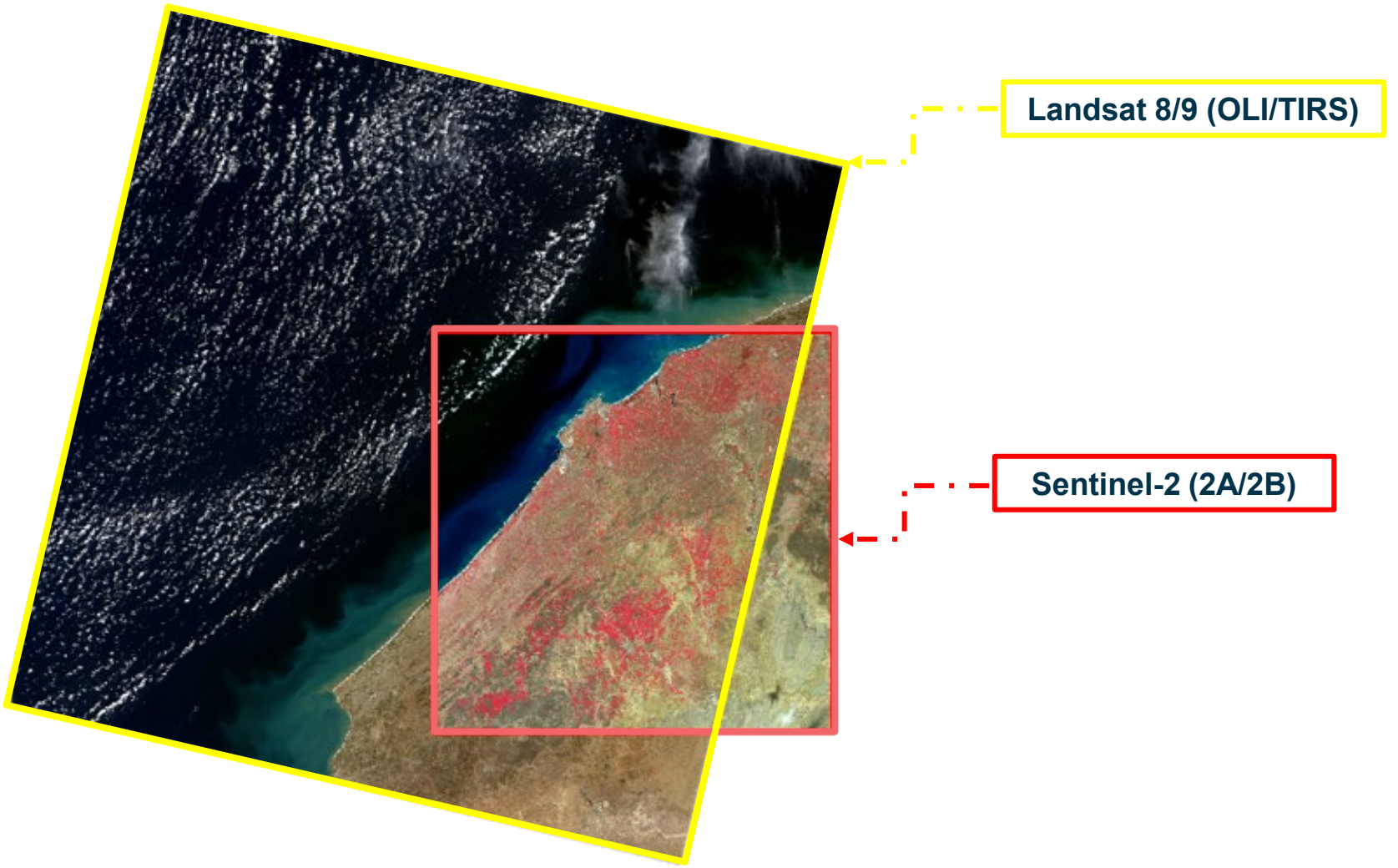
the short cycles (generally on a monthly base) starting from February 2021

2 Ha **maize field** near Larbaa Moghress with sandy soil and is irrigated using drip irrigation

SATELLITE DATA

For the implementation of ***FEST-EWB-SAFY*** model, five products have been prepared from satellite data along with other needed inputs:

- Leaf Area Index (LAI)
- Vegetation Index (NDVI),
- Vegetation Fraction (FV),
- Albedo,
- Land Surface Temperature (LST).



MODEL IMPLEMENTATION

FEST-EWB-SAFY

FEST-EWB: *Flash – flood Event – based Spatially – distributed rainfall – runoff Transformation – including Energy - Water Balance*

SAFY *: (Simple Algorithm For Yield Estimate)*

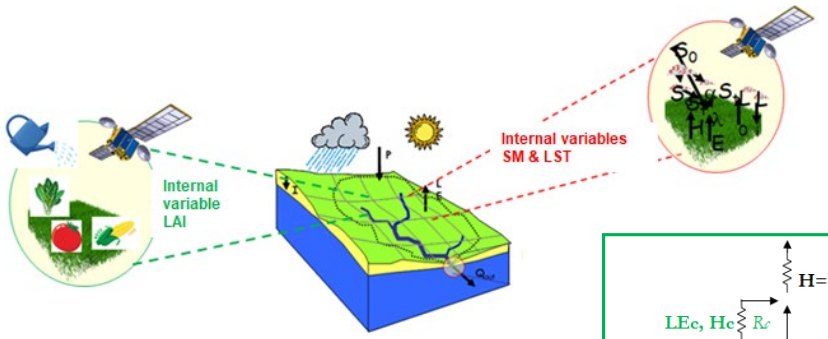
Soil water balance $P_{tot}=R+ET_{eff}+D+(\theta_{t+1}-\theta_t)*Z$

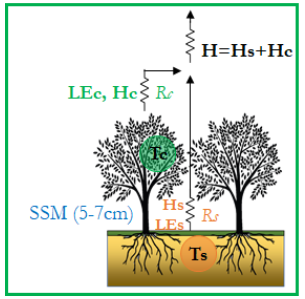
Energy balance $Rn-G-H-LE=\frac{dS}{dt}$

$ETeff=\frac{LE}{\rho Cp}$

Crop growth $\Delta DAM = APAR \cdot Pgro\_Lue \cdot F_T(Ta)K_s$

LAI, SM





Corbari et al., 2024, Corbari & Mancini 2022, (IRR); Corbari et al., 2022 (AWM); Corbari et al., 2011, (HSJ); Battude et al., 2018, Duchemin et al .2008

Methodology

After a preliminary calibration of the water and energy balances, the crop simulation will be both calibrated and performed via data assimilation of satellite LAI.

MODEL IMPLEMENTATION

$$\Delta T(.) = Min(RET(.) - LST(.))$$

Observed Satellite (Sentinel2) **LAI**

(1) Model calibration

Crop development (SAFY)

Model outputs (LST, SM, LAI, Yield)

Observed Satellite (Landsat 8) **Land surface temperature**

Meteorological inputs

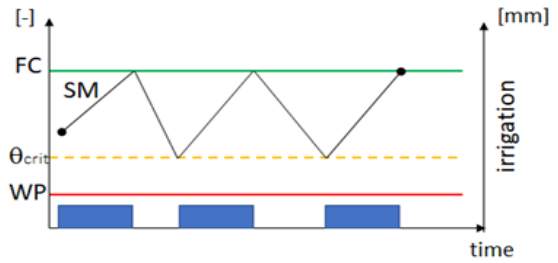
Soil and vegetation ancillary data

FEST-EWB-SAFY model

Calibration

Calibrated water-energy balance (FEST-EWB)

Irrigation strategy



$$\theta_{crit} = FC - p(FC - WP)$$

Observed Satellite (Sentinel2) **LAI**

LAI Model state

Crop development (SAFY)

Ensemble Kalman Filter (DA)

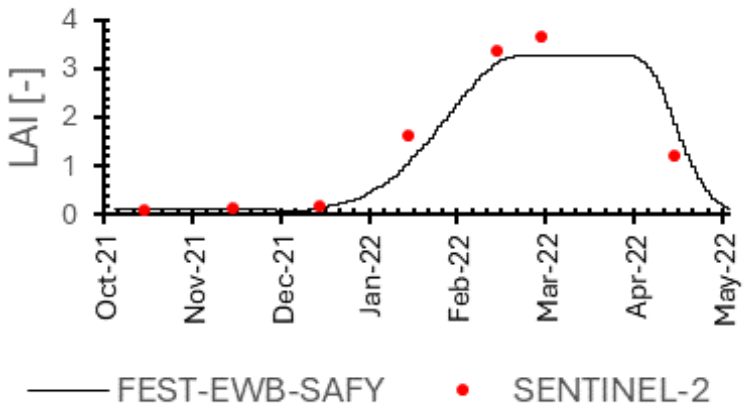
Model outputs (LST, SM, LAI, Yield)

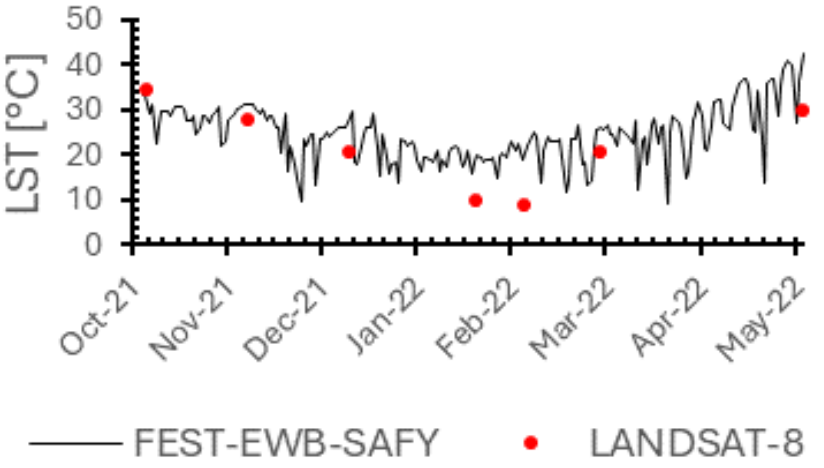
LAI state update

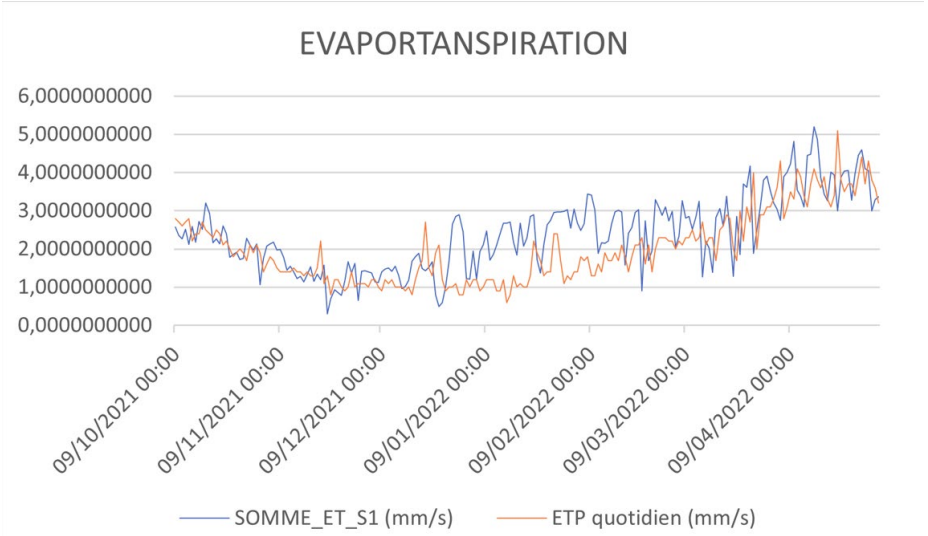
(2) Data assimilation

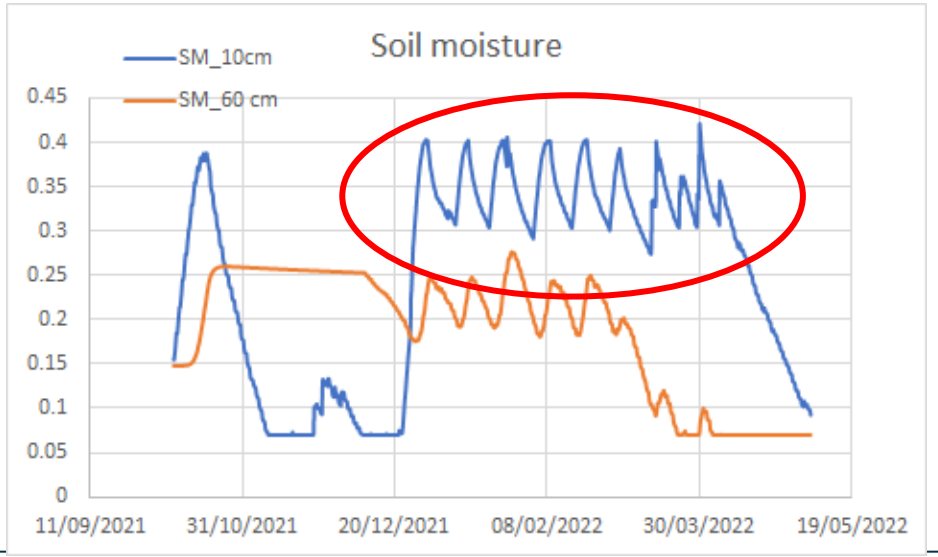
Satellite LST and LAI based calibration

wheat field







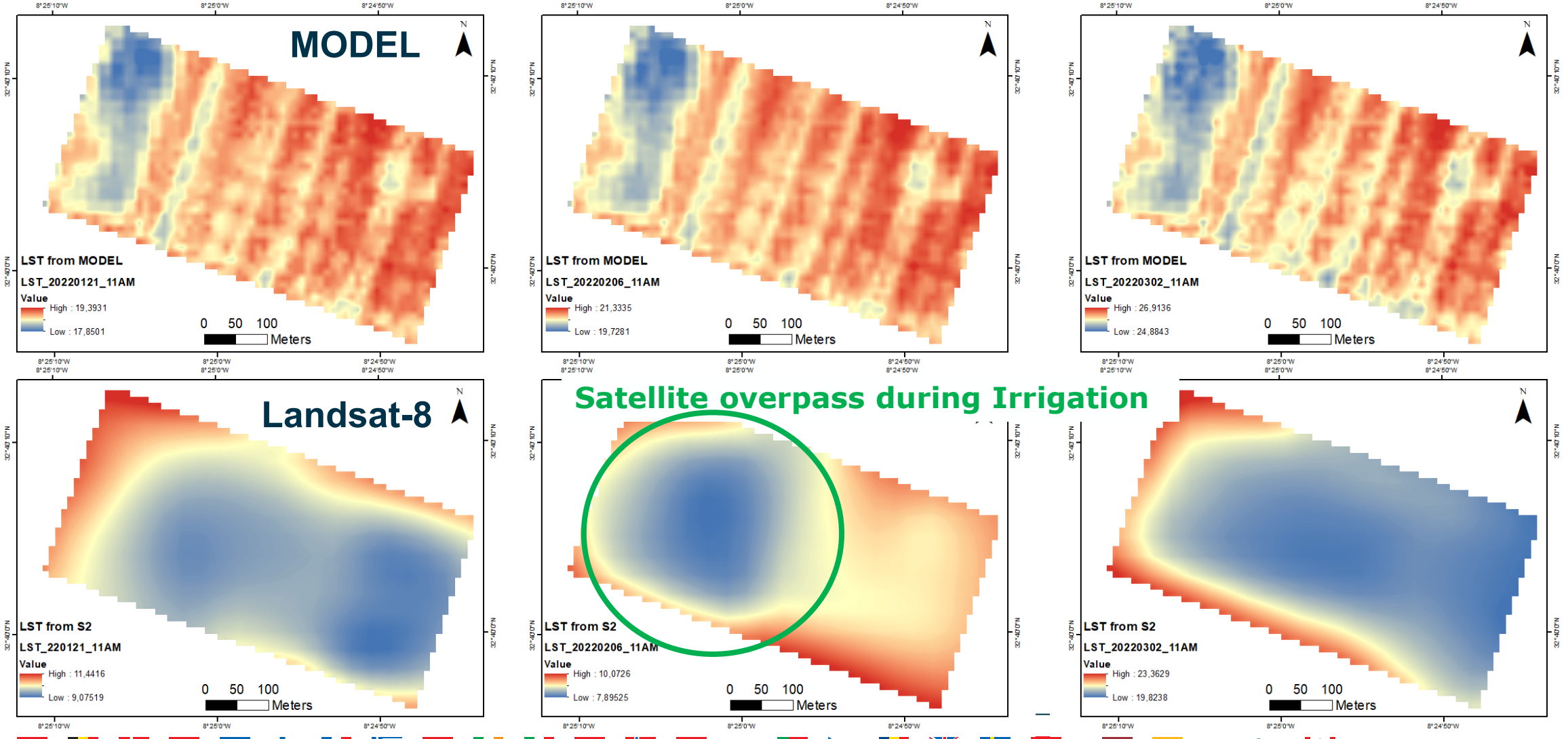


Calibration procedure based on a pixel by pixel scale comparison on LAI and on LST

Satellite LST and LAI based calibration

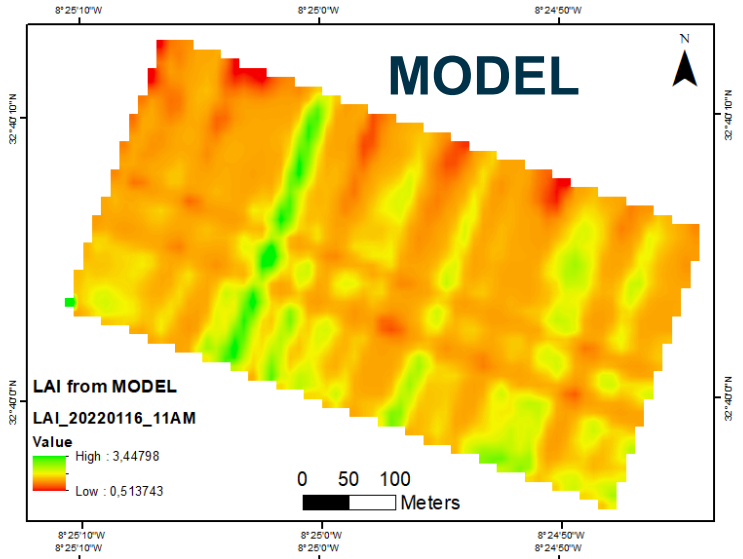
wheat field

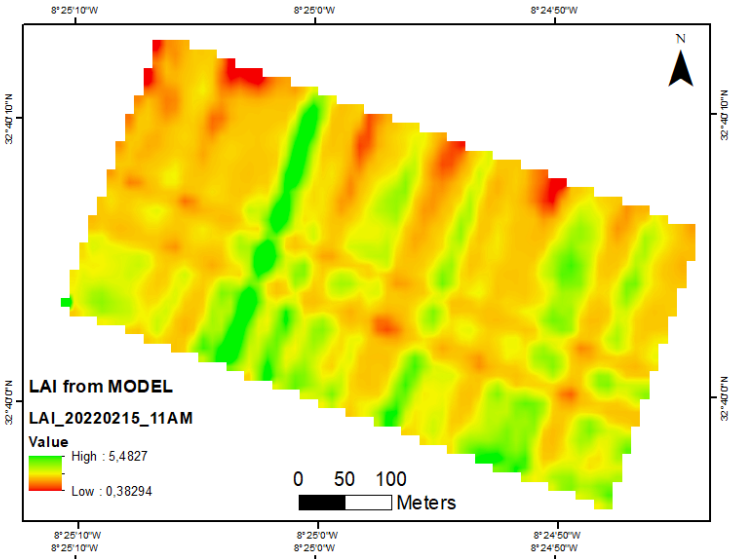
Need to set the correct timing of irrigation

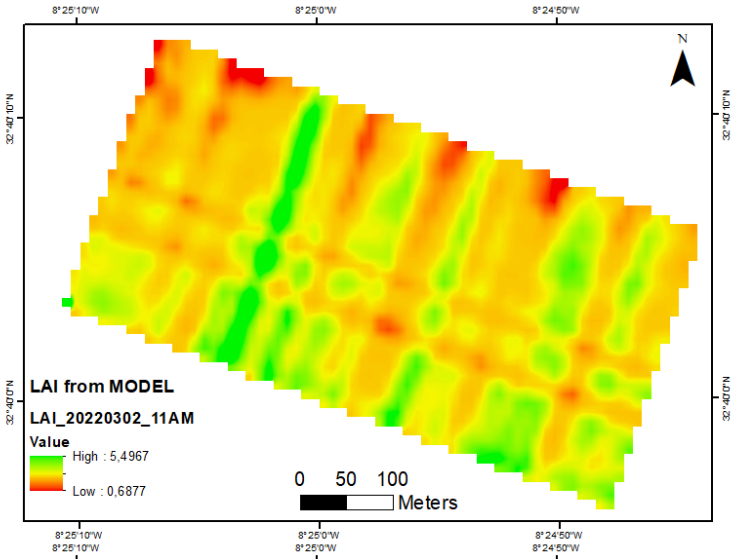


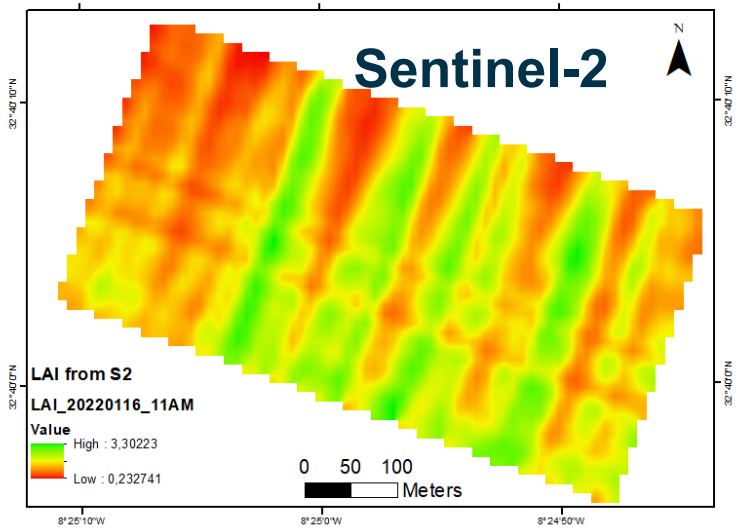
Satellite LST and LAI based calibration

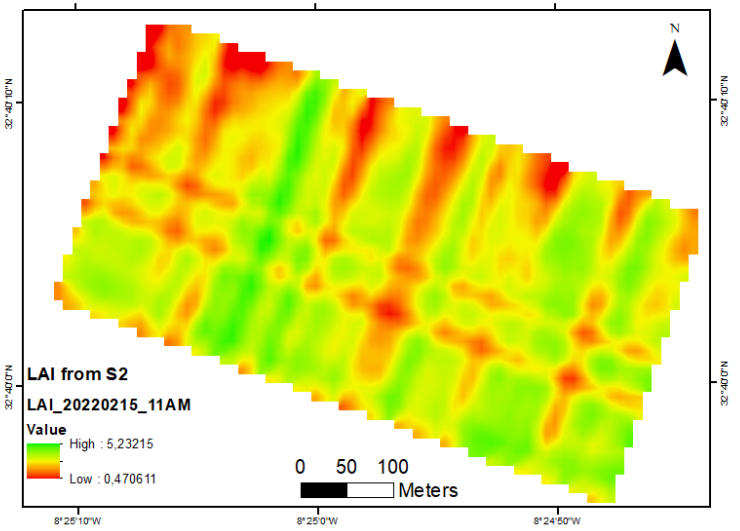
wheat field

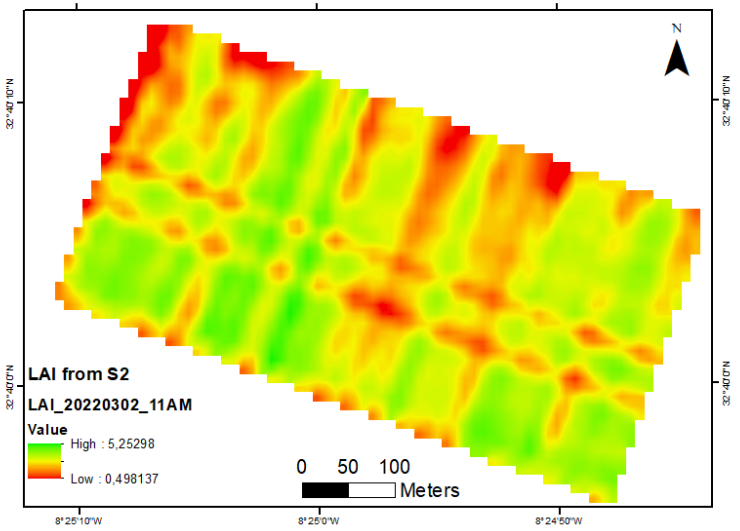






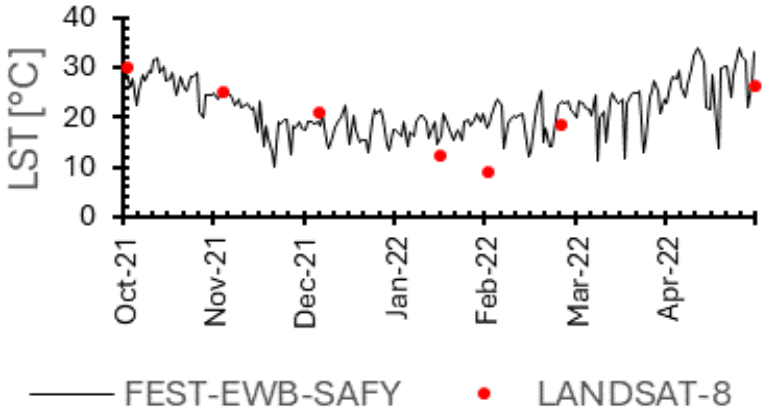


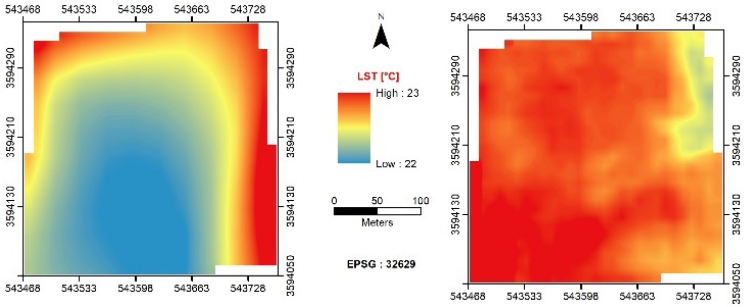




Satellite LST based calibration

sugar beet field on December 12, 2021

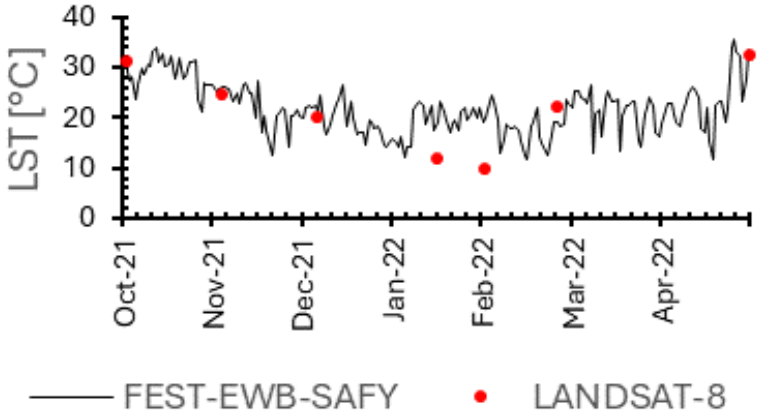


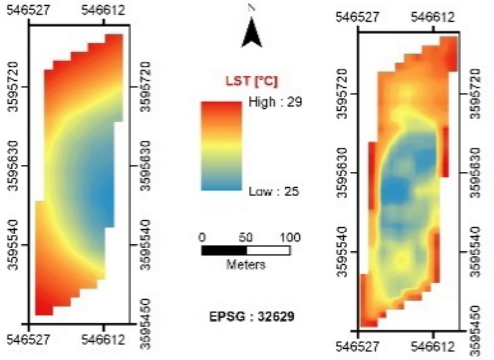


Crop type / field	LST		
	MBE [°C]	AMBE [°C]	RMSE [°C]
Wheat/field1	6,67	7,04	8,04
Sugar beet/field 2	5,28	6,04	7,4
Alfalfa/field 3	2,52	3,41	4,86
Maize/field 4	-1,08	4,07	4,45

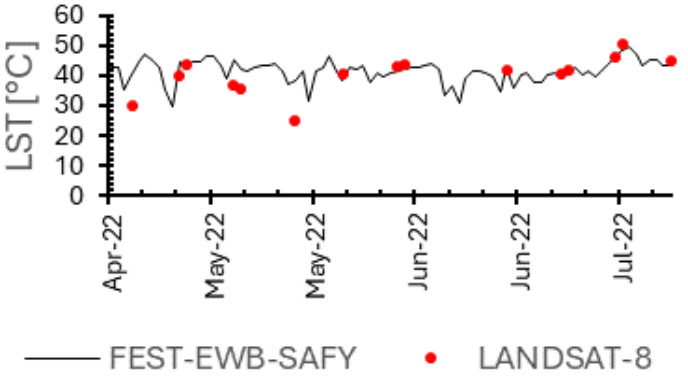
The not Knowldege of the perfomrmed irrigation has a strong impact on LST (ET, SM)

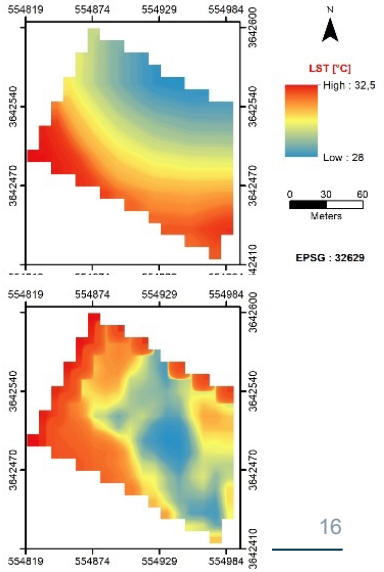
alfalfa field on November 10, 2021





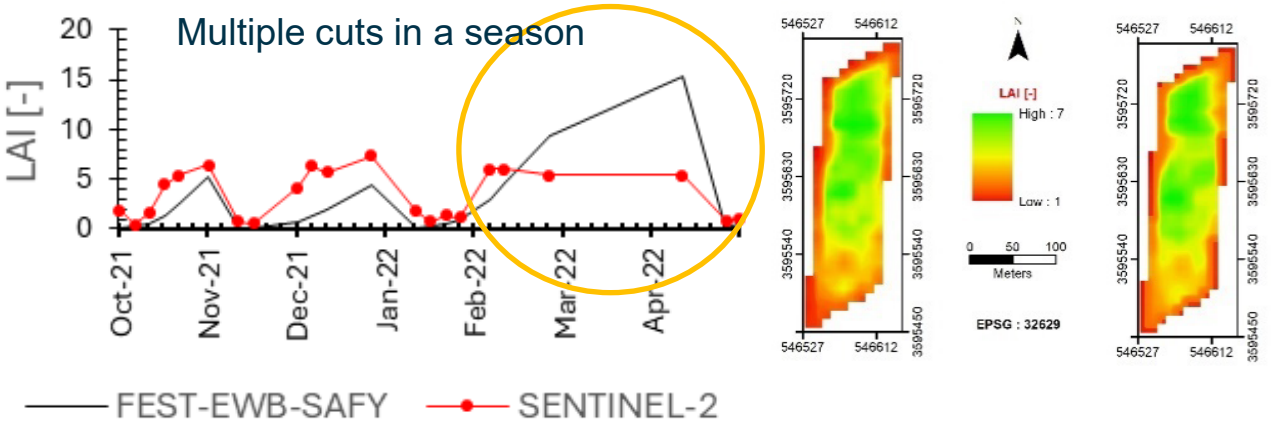
maize field on April 28, 2022



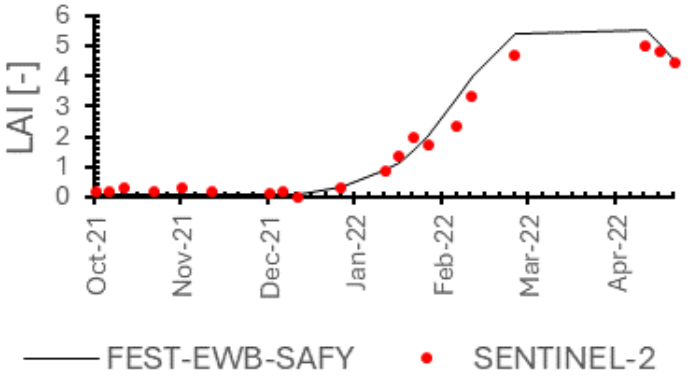


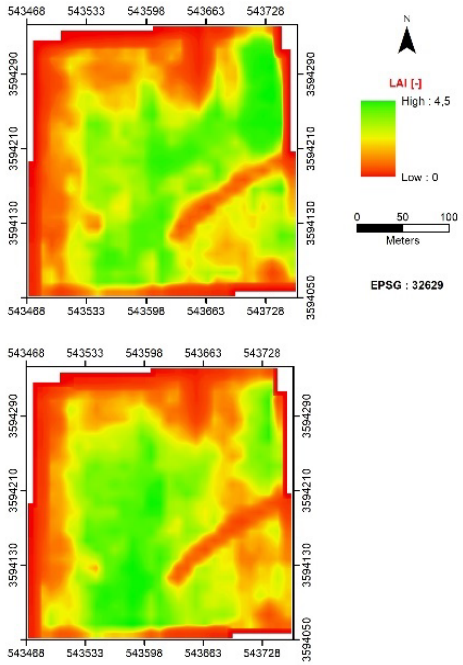
Satellite LAI based calibration

alfalfa field on February 15, 2022

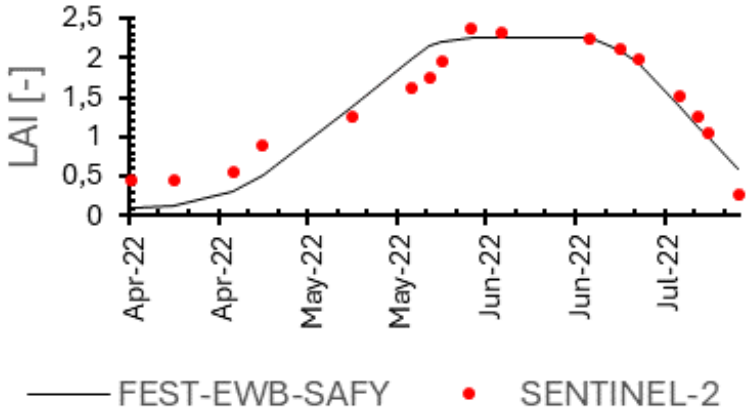


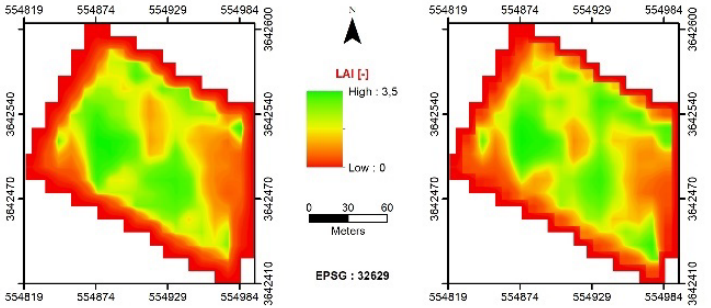
sugar beet field on February 15, 2022





maize field on June 30, 2022



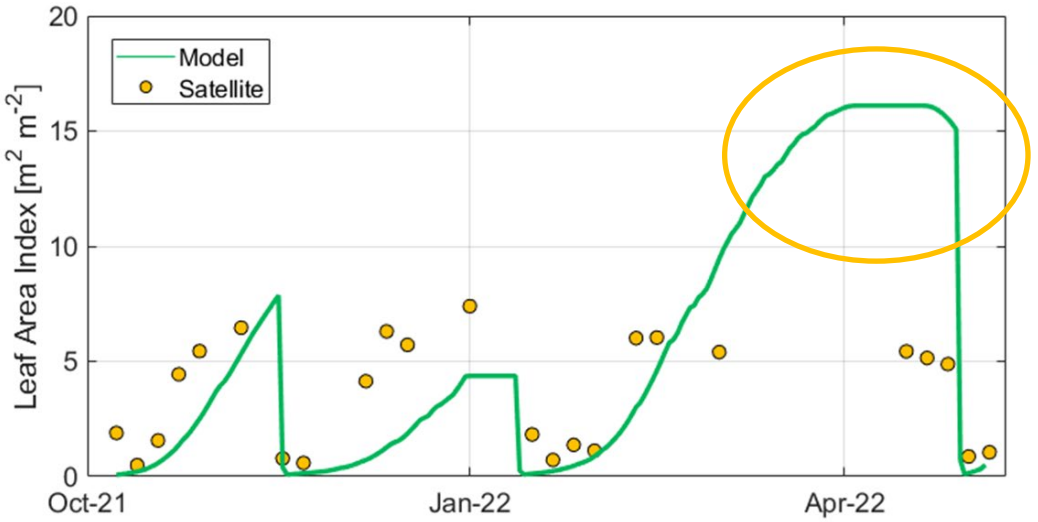


Crop type / field	LAI		
	MBE [-]	AMBE [-]	RMSE [-]
Wheat/field1	-0,08	0,26	0,35
Sugar beet/field 2	0,27	0,23	0,37
Alfalfa/field 3	-0,98	2,25	3,13
Maize/field 4	-0,04	0,11	0,13

External factors impacts: a data assimilation scheme

1st cycle	2nd cycle	3rd cycle	Overall
1.98	3.21	6.15	**4.49**

RMSE

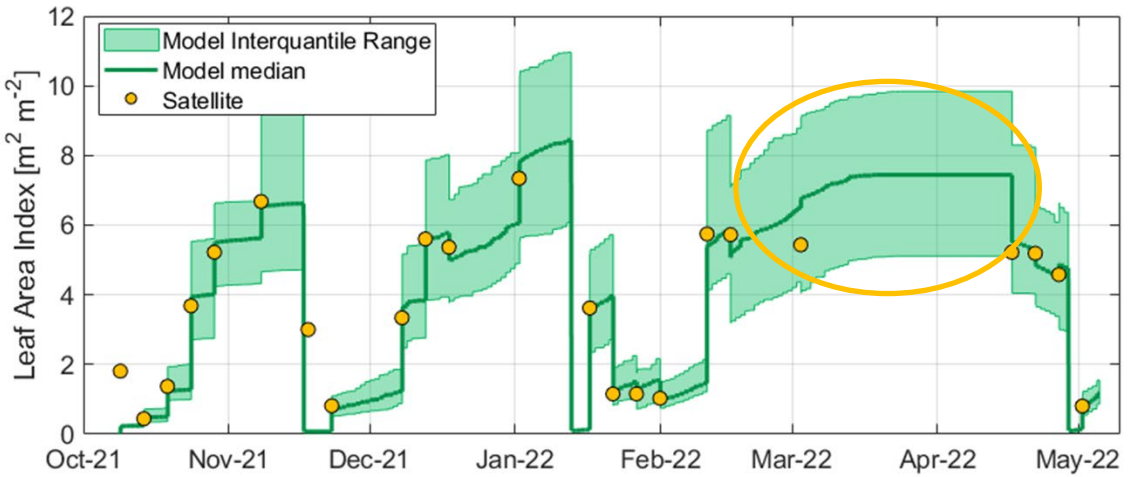


(1) Calibration

(2) Data assimilation

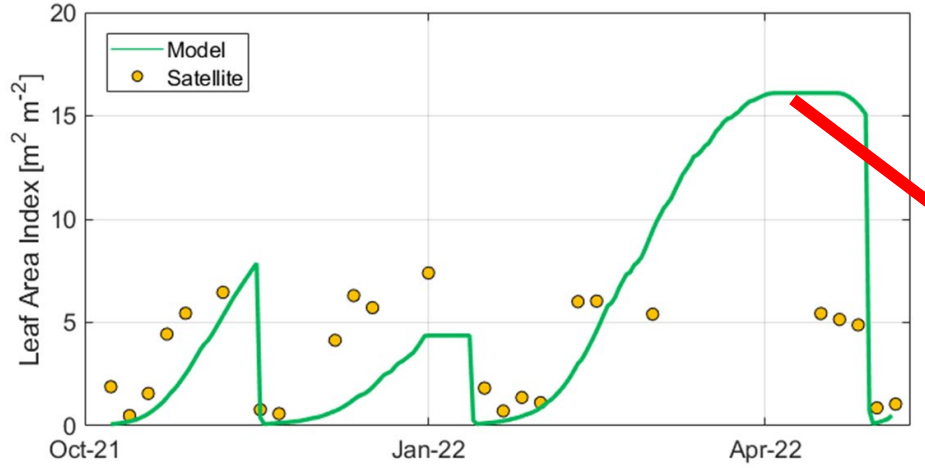
1st cycle	2nd cycle	3rd cycle	Overall
0.67	1.22	0.51	**0.79**

RMSE

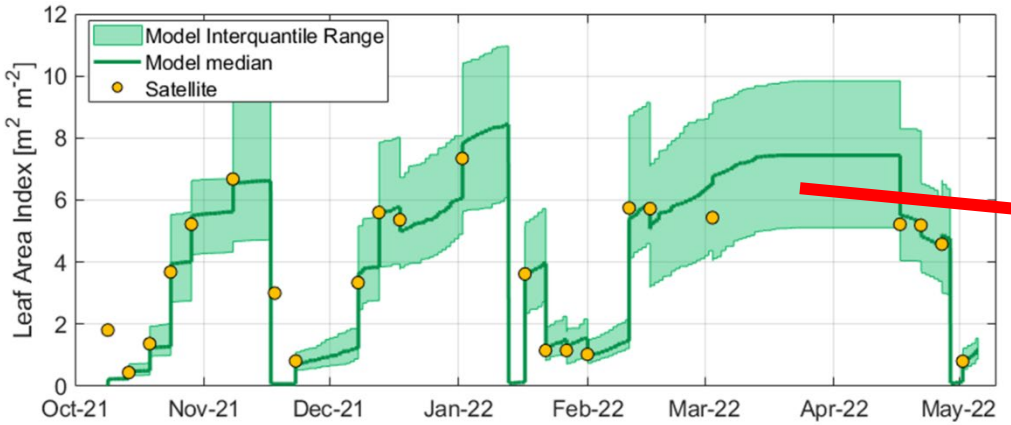


External factors impacts: a data assimilation scheme

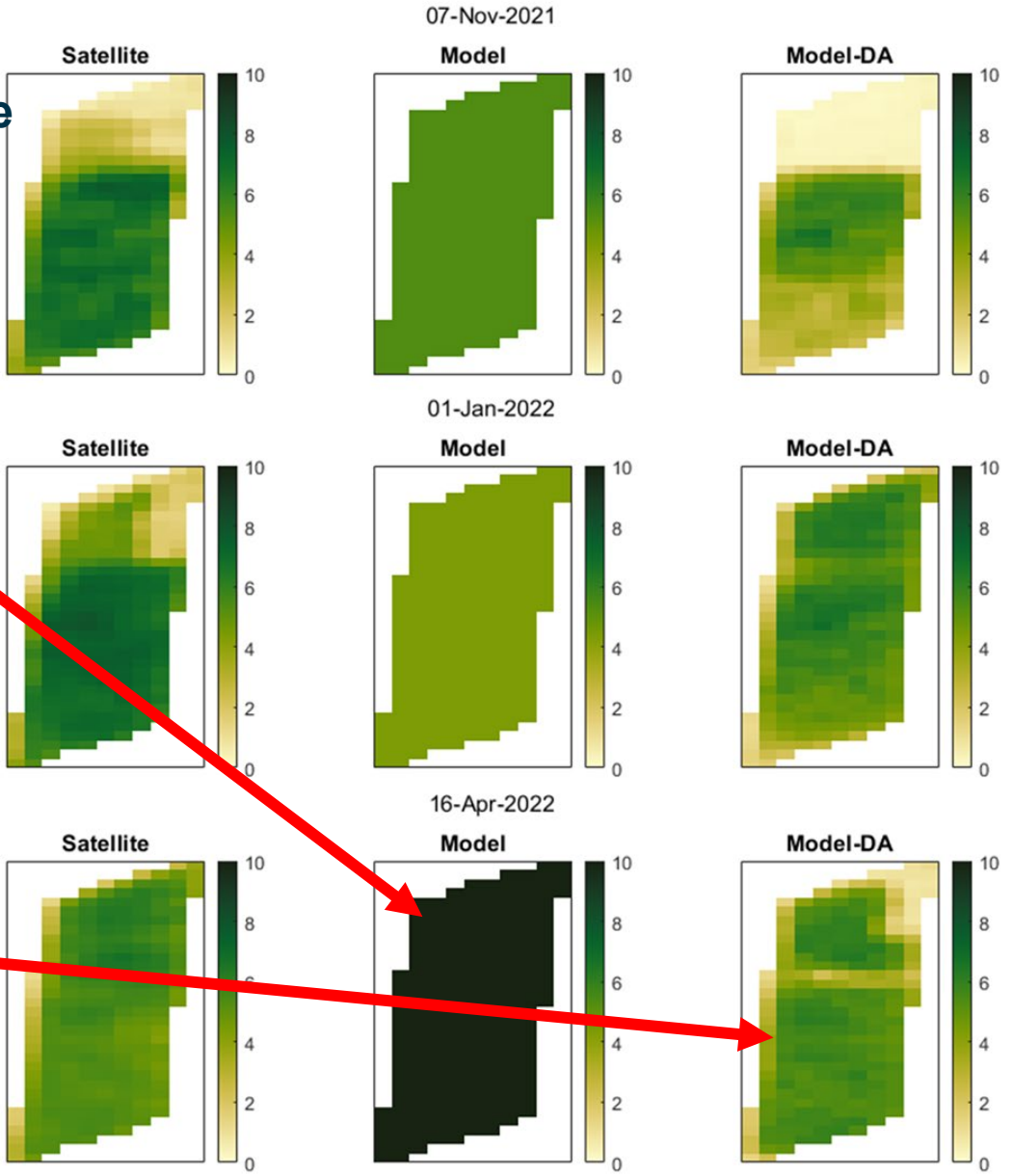
(1) Calibration



(2) Data assimilation



LAI at maximum stage



CONCLUSION

- integrating multiple satellite data and water-energy-crop modeling is able to support farmers precision agriculture providing estimates of water use and crop productivity under different irrigation schemes, crop and soil types

- LST is reproduced in good agreement against satellite data (useful for crop water use estimates) but the lack of water allocation and irrigation data has a strong impacts on the model accuracy.

- LAI (future crop productivity) is greatly reproduced from the model even through a simple calibration approach
- Data Assimilation approach of satellite LAI is fundamental when external factors are impacting the crops