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2025 DRAGON 6 SYMPOSIUM

14-18 JULY 2025

[PROJECT ID. 95424]

SATELLITE DATA APPLICABILITY AND ACCURACY AT DIFFERENT SPATIOTEMPORAL SCALES FOR SUSTAINABLE AGRICULTURAL WATER MANAGEMENT (SAA4WATER)







2025 Dragon 6 Symposium

<JULY 16TH, 2025>

ID. 95424

PROJECT TITLE: SATELLITE DATA APPLICABILITY AND ACCURACY AT DIFFERENT SPATIOTEMPORAL SCALES FOR SUSTAINABLE AGRICULTURAL WATER MANAGEMENT (SAA4WATER)

PRINCIPAL INVESTIGATORS:

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Project's objectives

FOSTER THE SYNERGIC USE OF E.O. DATA AND HYDROLOGICAL MODELLING, using multi-platform data (Sentinels, ESA, NASA and Chinese satellites) with the aim of establishing a multi-source modelling framework for a successful integration of EO data IN PRECISE **AGRICULTURAL WATER MANAGEMENT AT DIFFERENT SPATIAL SCALES (FIELD, REGIONAL)**

1) **assess water needs and water use efficiency**;
2) **how satellite observations accuracy at different spatial and temporal scales**;
3) **which extend the integration of EO and hydrological modelling can support the operational needs of agricultural water management.**

Aerospace Information Research Institute
Chinese Academy of Sciences

POLITECNICO MILANO 1863

Dragon 6 EO Data Delivery

Data access (list all missions and issues if any). NB. in the tables please insert cumulative figures (since June 2024) for no. of scenes of high bit rate data (e.g. S1 100 scenes). If data delivery is low bit rate by ftp, insert “ftp”

ESA /Copernicus Missions	No. Scenes
1. SMAP/Sentinel-1	164
2. Sentinel3/2	100
3.	
4.	
5.	
6.	
Total:	264
Issues:	

ESA Third Party Missions	No. Scenes
1. ESC CCI land cover	20
2.	
3.	
4.	
5.	
6.	
Total:	20
Issues:	

Chinese EO data	No. Scenes
1. ETMonitor ET data	>7300
2.	
3.	
4.	
5.	
6.	
Total:	>7300
Issues:	

European Young Scientists contributions in Dragon 6

Name	Institution	Poster title	Contribution including period of research
Nicola Paciolla	Politecnico di Milano	**Assimilation of satellite LST and SSM Retrievals For Irrigation Detection and evapotranspiration impact Over Heterogeneous Agricultural Areas**	Implementation of a previously developed methodology over a new case study – 2024-2025

Chinese Young Scientists contributions in Dragon 6

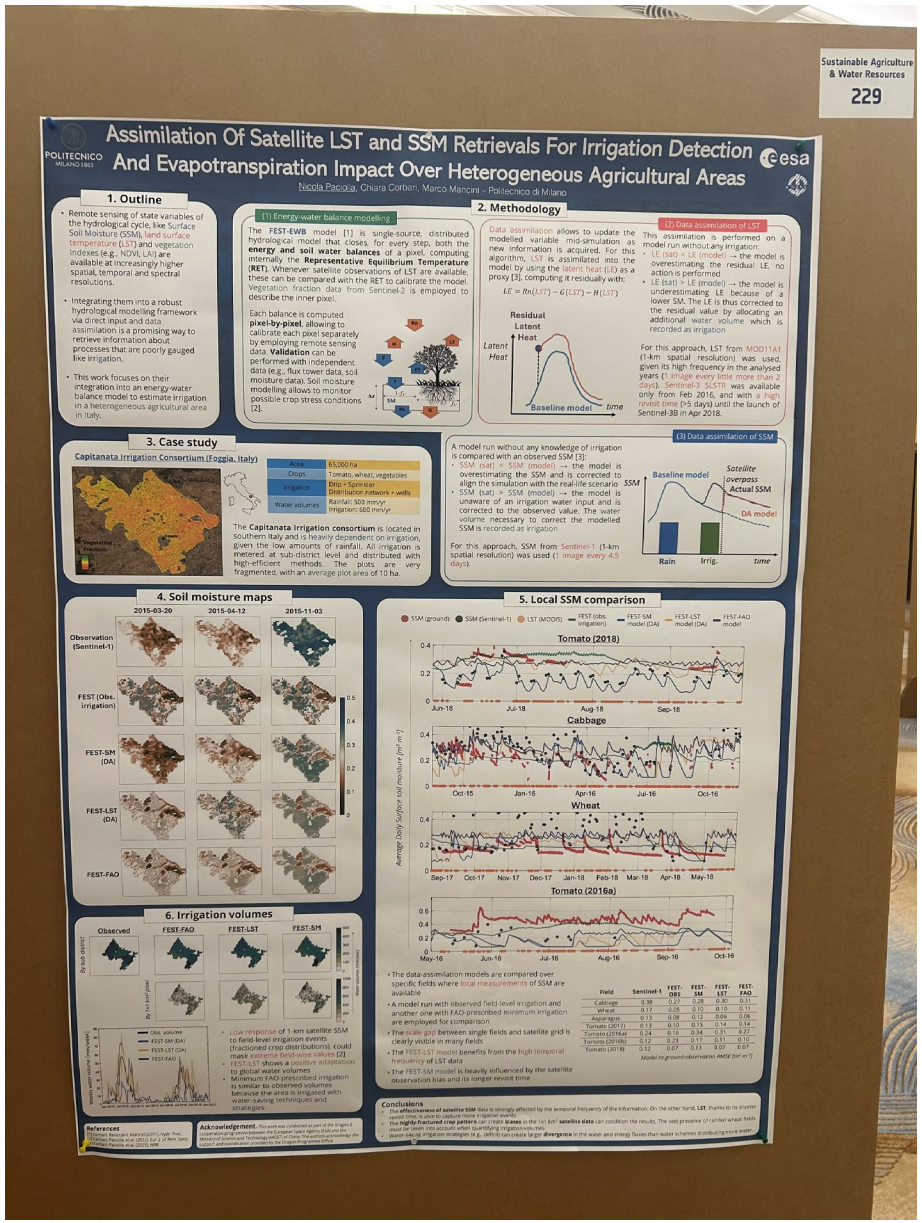
Name	Institution	Poster title	Contribution including period of research
Dingwang Zhou	AIR-CAS	Assessing Irrigation Performance Using Remote Sensing Data and the Budyko Hypothesis: A Case Study in Northwest China	Irrigation performance evaluation in Northwest China
Bingkui Wei	AIR-CAS	Monitoring Actual Irrigated Cropland Area in the Hexi Corridor Based on Blue/Green Evapotranspiration using Remote Sensing Observations	Monitoring irrigated cropland area based on blue ET and green GET obtained from multiple remote sensing datasets

Overview of European YSs research

Assimilation Of Satellite LST and SSM Retrievals For Irrigation Detection And Evapotranspiration Impact Over Heterogeneous Agricultural Areas

Nicola Paciolla, Chiara Corbari, Marco Mancini

- In this work, satellite LST and SSM retrievals over a heterogeneous agricultural area in Italy were assimilated into a hydrological model in order to estimate irrigation volumes and evapotranspiration changes.
- The employed hydrological model is the FEST-EWB (flash–Flood Event–based Spatially distributed rainfall–runoff Transformation – Energy Water Balance model), which is a distributed model that closes, at every time step, both the surface energy and water balances, computing LST as an internal variable. This allows the model to run on meteorological forcings and vegetation status information alone, and to use satellite observations of SSM and LST for other purposes, like calibration or data assimilation. In this work, irrigation will be derived from the model with three main strategies: (a) a volume equivalent to the Readily Available Water will be budgeted for every vegetated pixel whenever water stress conditions are met, following FAO guidelines and providing a baseline for unstressed irrigation management; (b) LST data from Sentinel-3 at 1 km spatial resolution and daily revisit time will be assimilated into the model, correcting the soil moisture status to match the thermodynamic conditions observed from satellite and budgeting irrigation water volumes for positive model LST biases; (c) SSM data from Sentinel-1 at 1 km spatial resolution and roughly 6 days of revisit time will be assimilated into the model, inducing a direct correction of the modelled soil moisture status and budgeting irrigation volumes for negative model SSM biases.
- The final results are contrasted with official irrigation volumes provided by the local consortium, and show good agreement. However, the spatial gap between satellite observations (1 km2) and average size of the local plots (on average, 7 ha, 14 times lower) is a major issue in capturing the field-scale differences, considering that the area is highly heterogeneous, with many neighbouring fields running on different yearly cultivation schedules (both in terms of

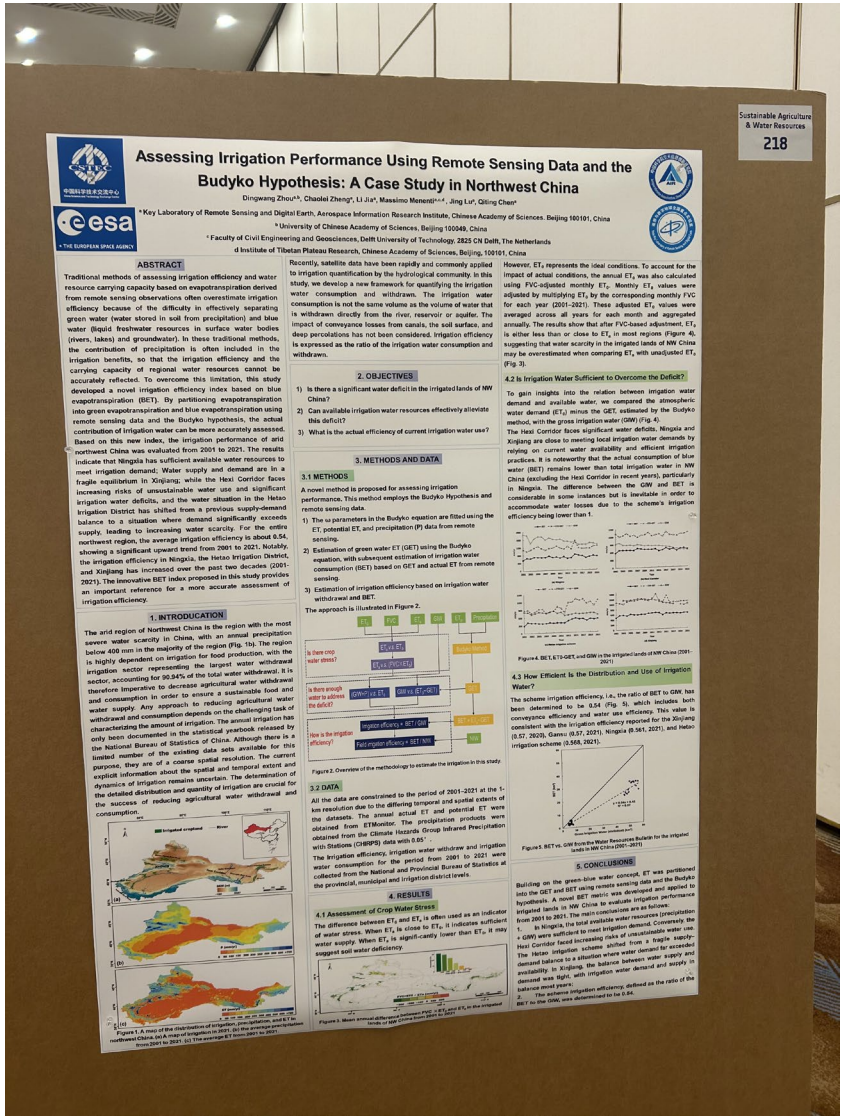


Overview of Chinese YSs research

Assessing Irrigation Performance Using Remote Sensing Data and the Budyko Hypothesis: A Case Study in Northwest China

Dingwang Zhou, Chaolei Zheng, Li Jia, Massimo Menenti, Jing Lu, Qiting Chen

- This study developed a novel irrigation efficiency index based on blue evapotranspiration (BET). By partitioning evapotranspiration into green evapotranspiration and blue evapotranspiration using remote sensing data and the Budyko hypothesis, the actual contribution of irrigation water can be more accurately assessed.
- Based on this new index, the irrigation performance of arid northwest China was evaluated from 2001 to 2021. The results indicate that Ningxia has sufficient total available water resources to meet irrigation demand; Xinjiang's water supply and demand are in a fragile equilibrium; while the Hexi Corridor faces increasing risks of unsustainable water use and significant irrigation water deficits, and the water situation in the Hetao Irrigation District has shifted from a previous supply-demand balance to a situation where demand significantly exceeds supply, leading to increasing water scarcity.
- For the entire northwest region, the average irrigation efficiency from 2001 to 2021 is about 0.54, showing a significant upward trend. Notably, the irrigation efficiency in Ningxia, the Hetao Irrigation District, and Xinjiang has increased over the past two decades (2001-2021).
- The innovative BET index proposed in this study provides an important reference for a more accurate assessment of irrigation efficiency.

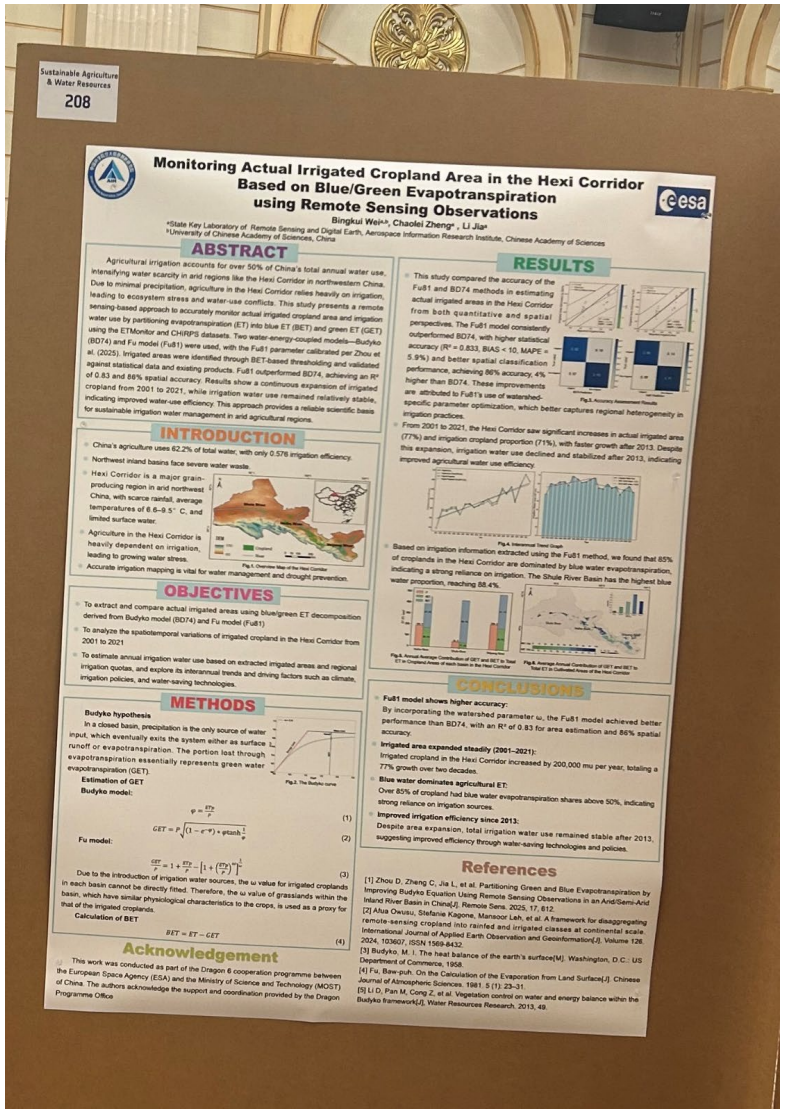


Overview of Chinese YSs research

Monitoring Actual Irrigated Cropland Area in the Hexi Corridor Based on Blue/Green Evapotranspiration using Remote Sensing Observations

Bingkui Wei, Chaolei Zheng, Dingwang Zhou, Li Jia

- We have developed a remote sensing-based method to obtain the actual irrigated cropland area based on blue evapotranspiration (BET) and green evapotranspiration (GET) obtained from multiple remote sensing datasets, e.g., ETMonitor evapotranspiration (ET) data and CHIRPS precipitation data. The proposed approach uses the water-energy-coupled model to partition actual evapotranspiration into BET and GET, and then identifies irrigated areas using a thresholding method after analyzing the differences in BET between rainfed and irrigated croplands.
- Two water-energy-coupled models were tested in this study: the original parameter-free Budyko model (BD74) and the single-parameter Fu's model (Fu81), and the parameter ω in the Fu81 model was calibrated following Zhou et al. (2025). The irrigated areas extracted based on the two models were compared and validated against statistical data from water resource bulletins, which shows that the irrigated area based on the Fu81's result has higher accuracy.
- The actual volume of irrigated water was also obtained by multiplying the irrigated cropland area by the irrigation quota. On this basis, we analyzed the inter-annual characteristics variations of irrigated cropland area and actual irrigation water use across the Hexi Corridor.



1st year results (2024~2025)

For the 1st years during Dragon6, we focus:

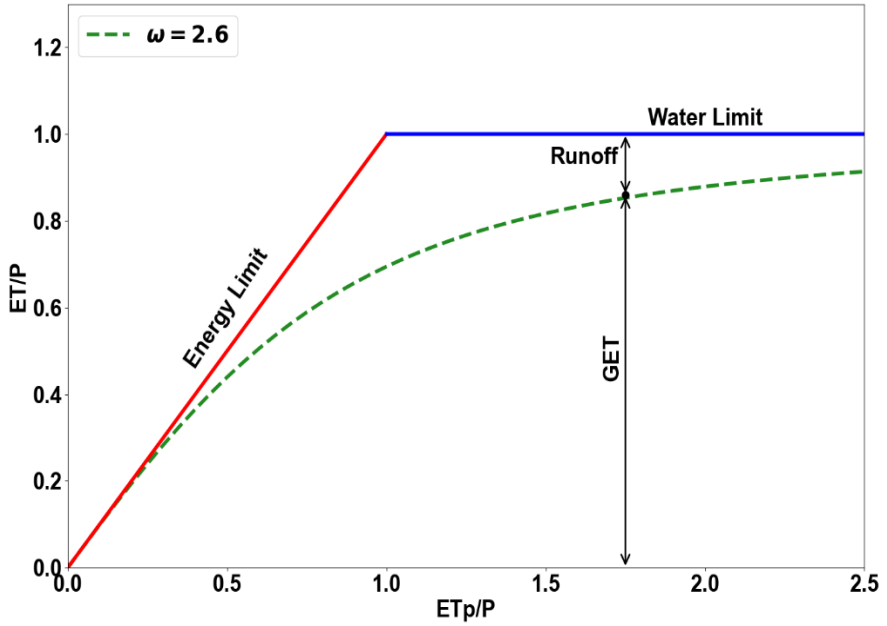
- Irrigation water assessment in the arid and semi-arid land of Northwestern China (YSs research)
- Global cropland water use efficiency assessment
- WaterMap: Cloud-based Platform for Monitoring and Assess Water Resources & Agricultural Water Use
- Evapotranspiration fluxes estimates using several satellites, ground data and hydrological modelling at different spatial and time resolution.
- Precise irrigation supported by satellite information will be analysed providing a discussion on the satellite spatial resolution and temporal frequency required.
- Irrigation volume monitoring by assimilating satellite land surface temperature and soil moisture(YSs research)
- Impact of satellite vegetation (LAI) on flood routing

Irrigation water assessment in Northwestern China

YSs research

Irrigation is the key to sustain the development of agriculture in the arid and semi-arid land. Details on the distribution of irrigation cropland and the water consumptions are crucial for utilizing the limited freshwater resources in agricultural sections.

--> A novel framework to quantify the irrigation area, irrigation water consumption, irrigation efficiency is proposed by utilizing the EO data and hydrological modelling.



Budyko hypothesis diagram

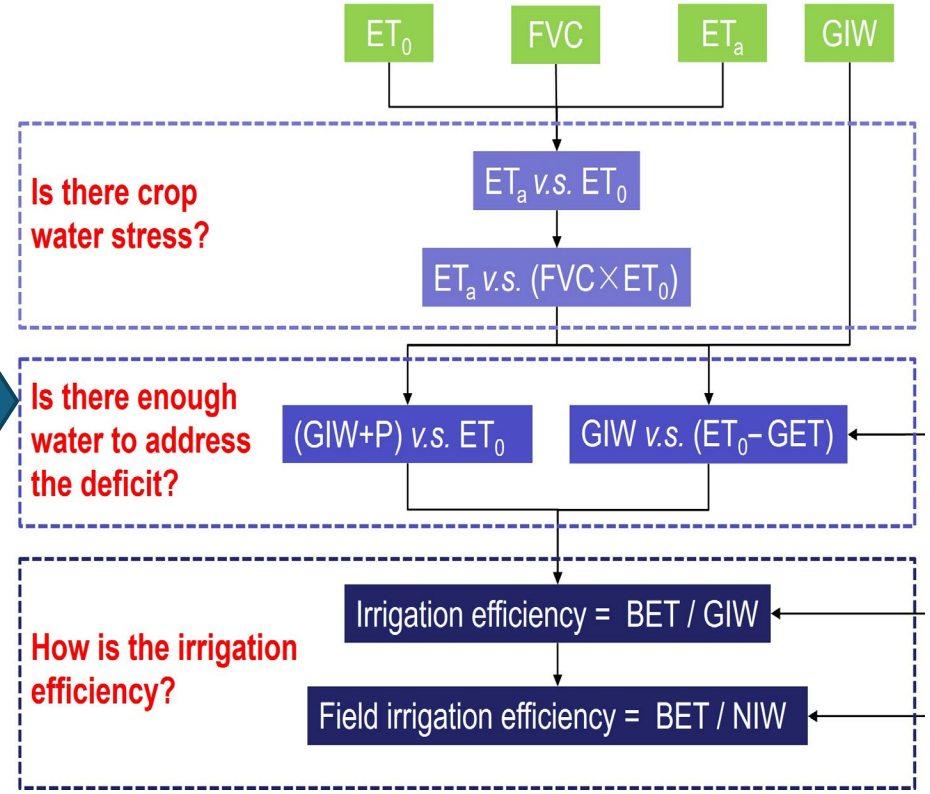
GET: ET from green water source (e.g., P)

BET: ET from blue water source (e.g., I)

Irrigation area

Irrigation water volume

Irrigation efficiency



Irrigation water assessment in Northwestern China

Dataset Name	Main Information	Time Range	Spatial Resolution	Data Source
ETMonitor	Actual evapotranspiration Potential evapotranspiration Reference evapotranspiration	2001-2021	1km	Zheng, Jia, & Hu (2022)
CHIRPS	Precipitation data	2001-2021	5km	Climate Hazards Group (CHG), USA
ESA CCI	Land cover types (Including rainfed irrigation classification)	1992-2021	300m	European Space Agency (ESA)
IrriMap_CN	Irrigated cropland distribution	2000-2019	500m	National Ecosystem Science Data Center
National bulletins	Irrigation area, irrigation water volume, at province level	2000 ~	-	MWR of P. R. China

The **ESA_CCI** land cover data and **IrriMap_CN** dataset were jointly used to construct the validation dataset for irrigated farmland.

Irrigation water assessment: GET/BET partitioning

Partitioning BET/GET using Budyko hypothesis

- Remote Sensing can provide actual ET (ET = GET + BET)
- In a closed basin, **precipitation** is the only source of water input, which eventually exits the system either as **surface runoff** or **evapotranspiration**. The portion lost through evapotranspiration essentially represents green water evapotranspiration (GET).

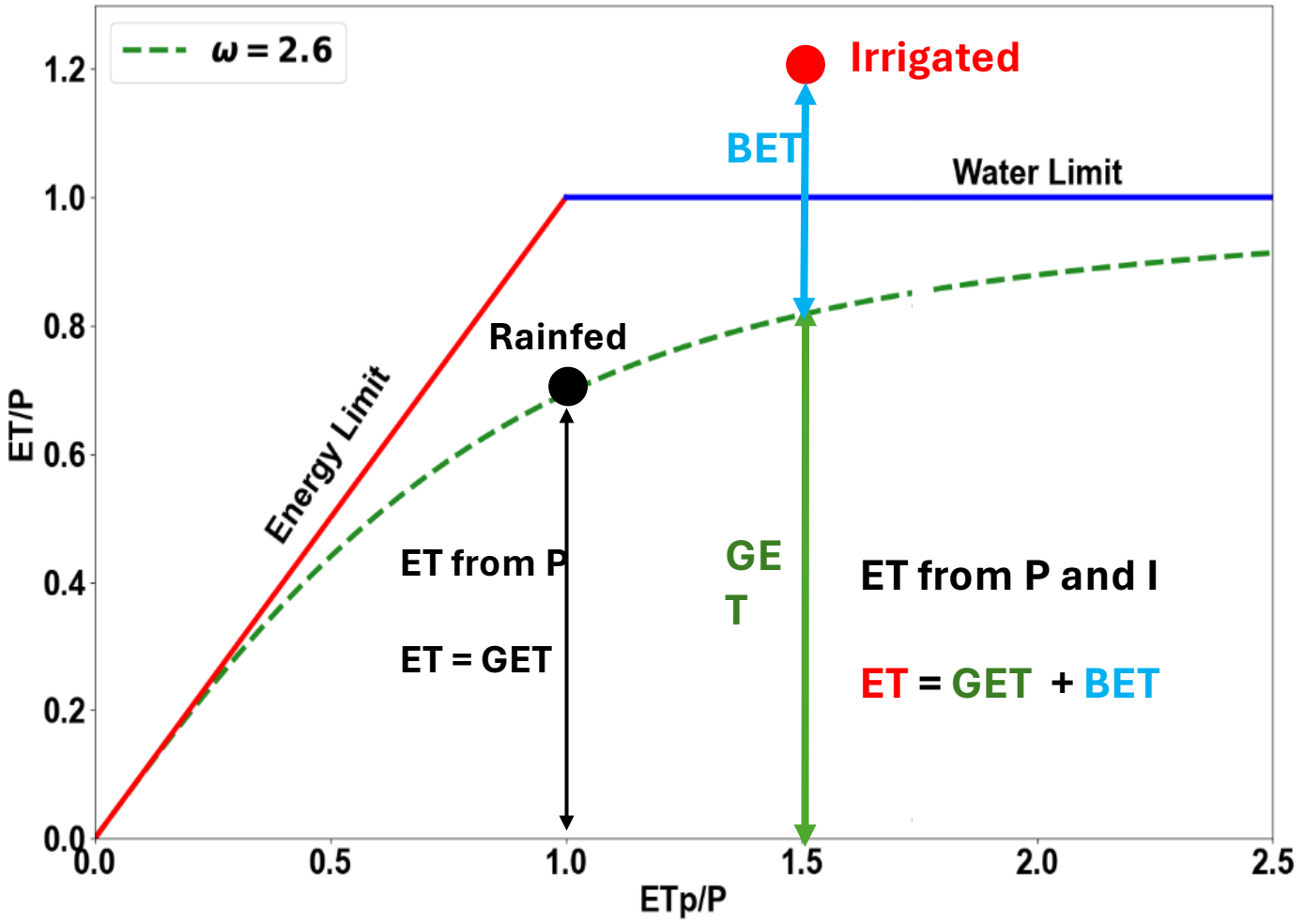
Budyko original model (parameter-free):

$$GET = P\sqrt{(1 - e^{-\varphi}) * \varphi \tanh\frac{1}{\varphi}} \qquad (\varphi = \frac{ETp}{P})$$

Fu's model (single parameter, ω):

$$\frac{GET}{P} = 1 + \frac{ETp}{P} - \left[1 + \left(\frac{ETp}{P}\right)^{\omega}\right]^{\frac{1}{\omega}}$$

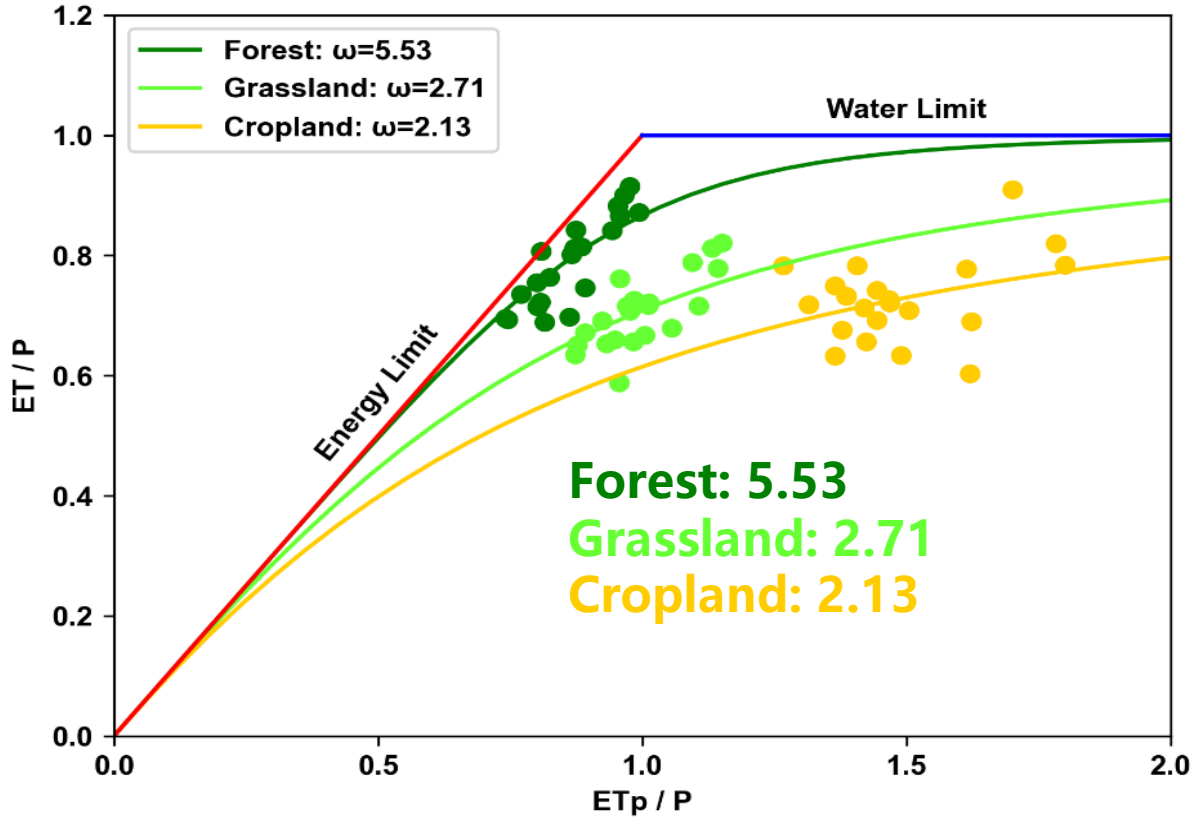
Budyko hypothesis diagram



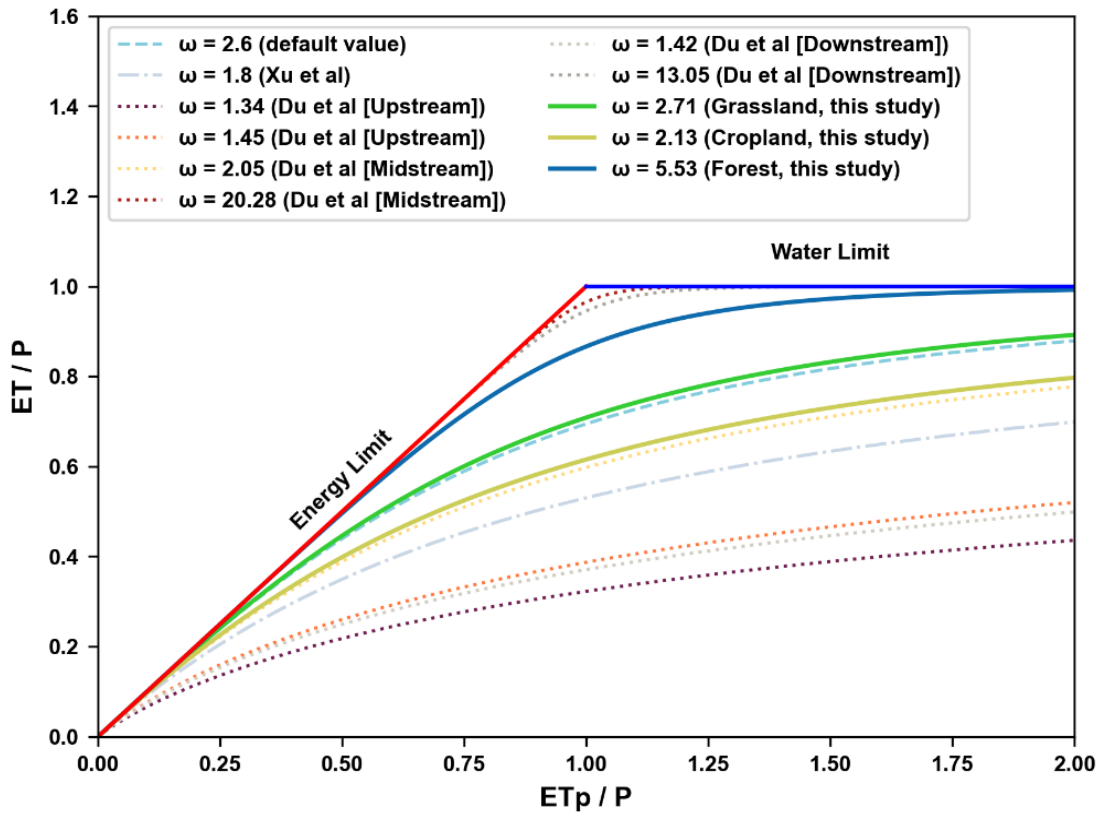
Irrigation water assessment: GET/BET partitioning

The single parameter (ω) in Fu's model is calibrated for differnet land cover types in the basin.
→ ω varied with differnet vegetation, climate regimes, etc.

Optimized ω_v in Heihe river basin



Optimized ω_v VS. literature ω values



Zhou et al., 2025, RS

Irrigation water assessment : GET/BET partitioning

Compare Budyko method (BD) with orther methods, e.g., Precipitation Deficit Method (PD), SoilWater Balance Method (WB): **BD showed higher accuracy.**

Complexity

PD

$$BET = max(ET - P_e, 0)$$

$$GET = ET - BET$$

BD

$$\frac{GET_v}{P_v} = 1 + \frac{ET_{p_v}}{P_v} - \left[1 + \left(\frac{ET_{p_v}}{P_v}\right)^{\omega_v}\right]^{\frac{1}{\omega_v}}$$

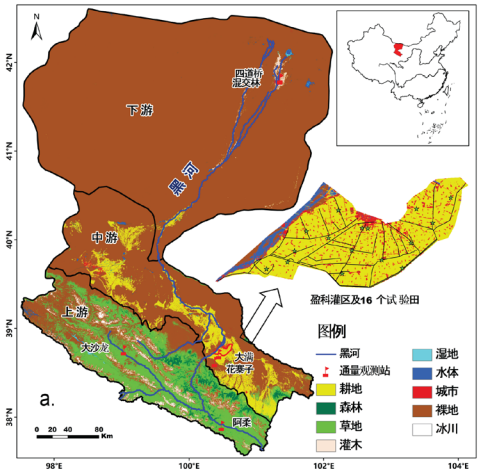
$$BET = ET - GET$$

WB

$$GET_t = min(W_t, ET_t)$$

$$BET_t = max(ET_t - W_t, 0)$$

$$W_t = SM_{t-1} + P_t - I_t - Q_t - Q_{prec,t}$$



Zhou et al., 2025, RS

Accuracy of partitioned GET by comparing with in-situ observations

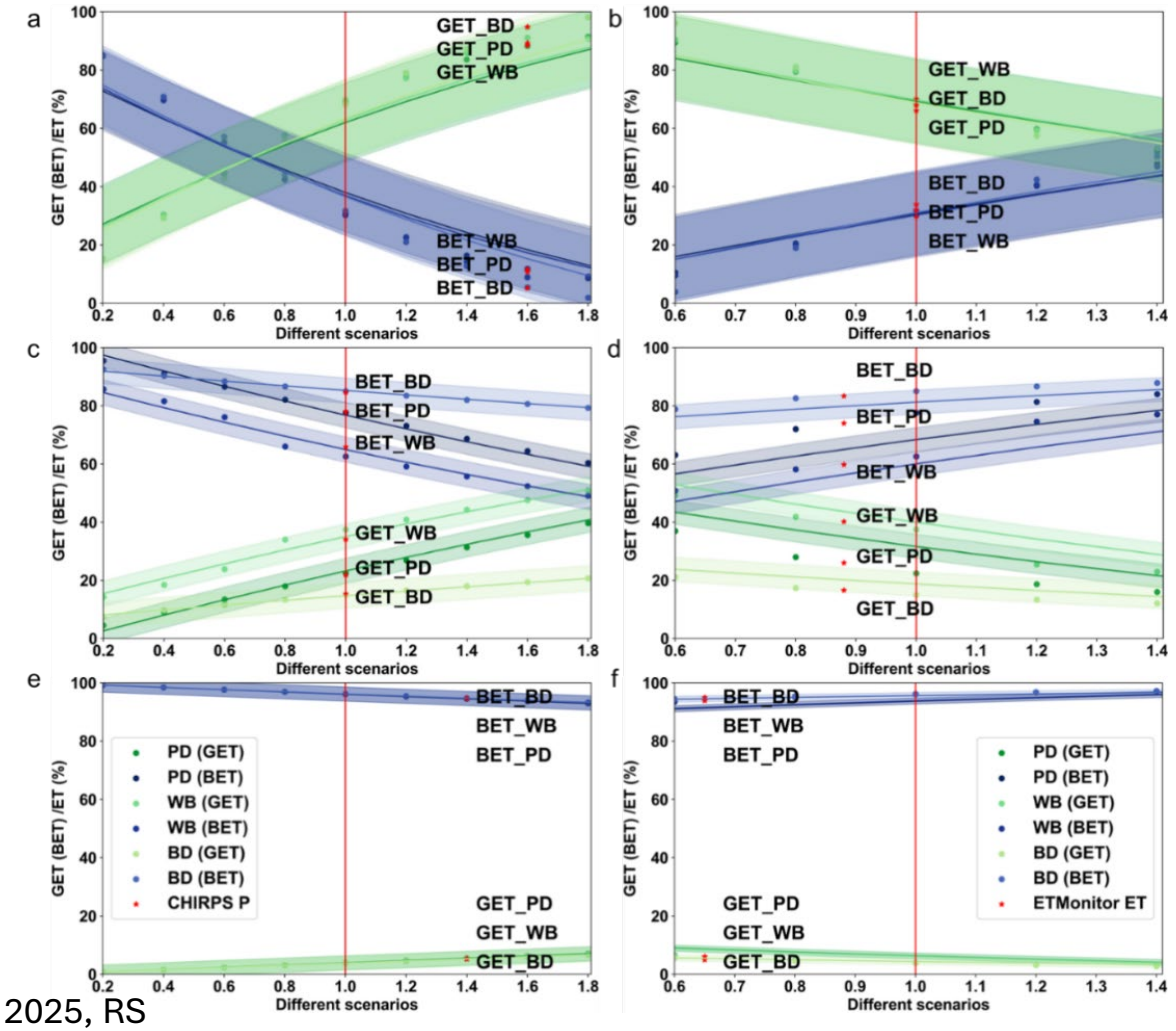
year	in-situ obs.	BET (mm/yr)			PBIAS (%)			RMSE (mm/yr)		
		BH	WB	PD	BH	WB	PD	BH	WB	PD
2012	308.3±90.1	373.8±103	381.8±102	380.0±103	23.8	26.9	25.8	84.8	90.8	89.5
2013	249.4±62.0	346.2±107	348.3±106	352.9±107	37.4	38.3	39.9	113	115	119

Irrigation water assessment: GET/BET partitioning

Sensivity analysis was also conducted to assess the uncertainty associated with the Input data, hence reveal the potential impact of errors of RS-based on P and ET.

Wet condition

Dry condition



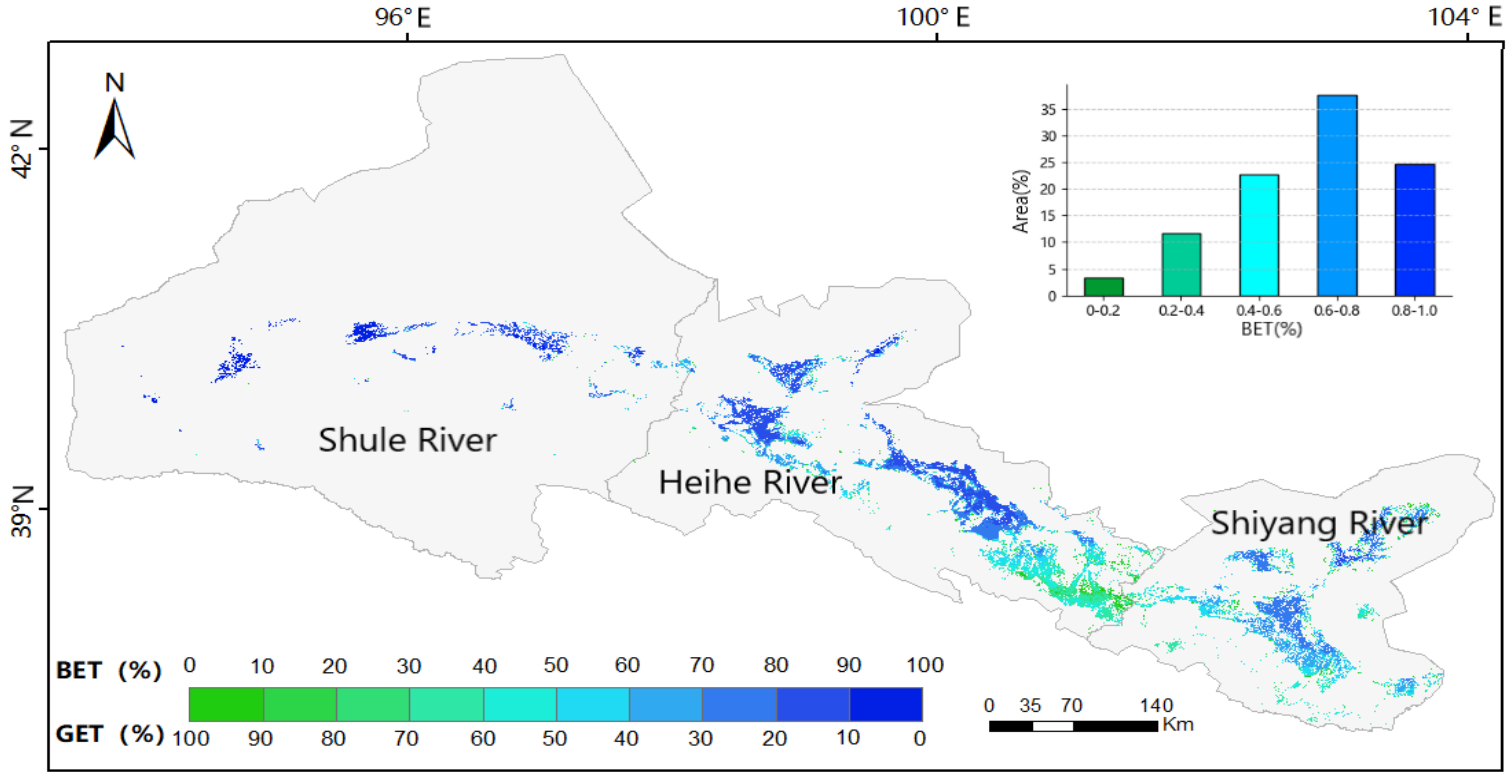
Zhou et al., 2025, RS

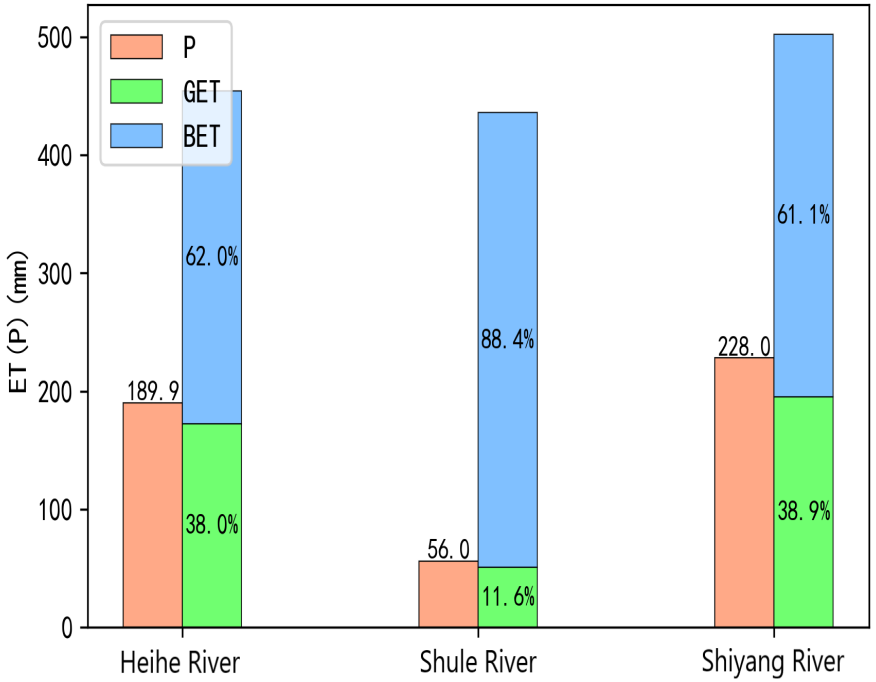
In both wet and dry climate regimes, three methods showed similar partitioning results and similar sensitive to the uncertainty of input data.

Different results occurs in the wet-to-dry transition regions (e.g., oasis in the middle reach of Heihe basin). Budyko method showed less sensitivity to the uncertainty of the RS-based P and ET data, hence is more robust.

Irrigation water assessment: GET/BET partitioning

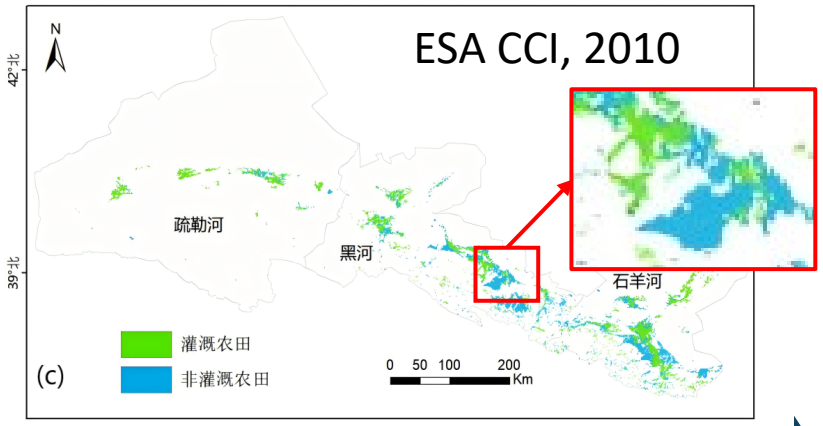
- Most croplands in the Hexi Corridor heavily rely on blue water, with **over 40%** of evapotranspiration from blue water in **85%** of the region, highlighting **strong dependence on irrigation**.

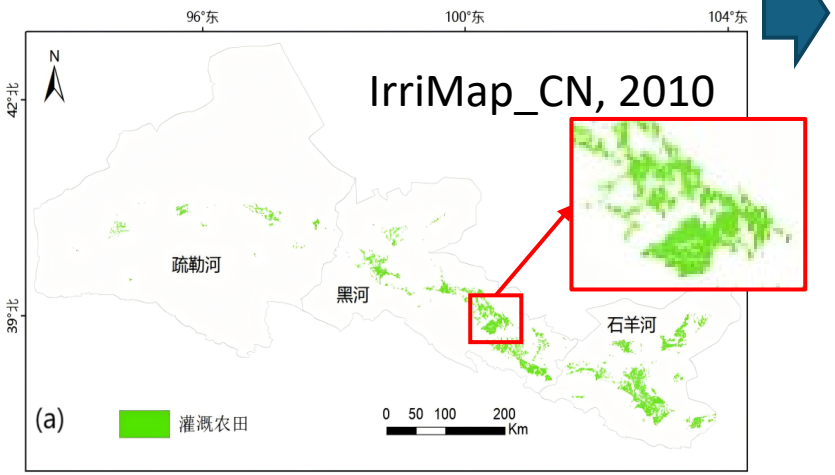


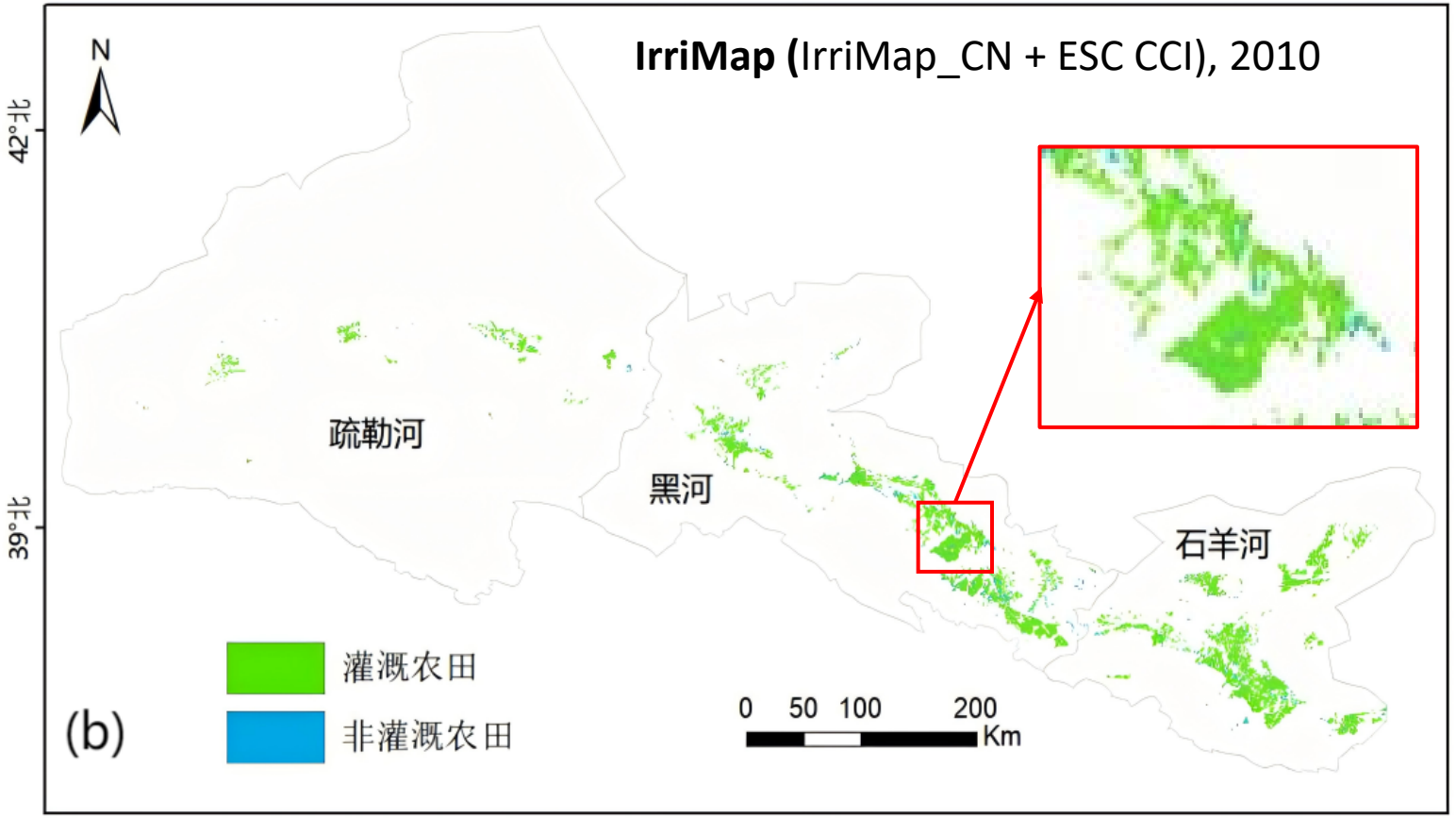


Irrigation water assessment: Irrigation area

Actual Irrigation map for validation is obtained by fusing IrriMap_CN data (only irrigated cropland) and ESA CCI land cover (irrigated and non-irrigated cropland, but with limited accuracy in China) products.







Irrigation water assessment: Irrigation Area

GET/BET for irrigation mapping (BET > threshold)

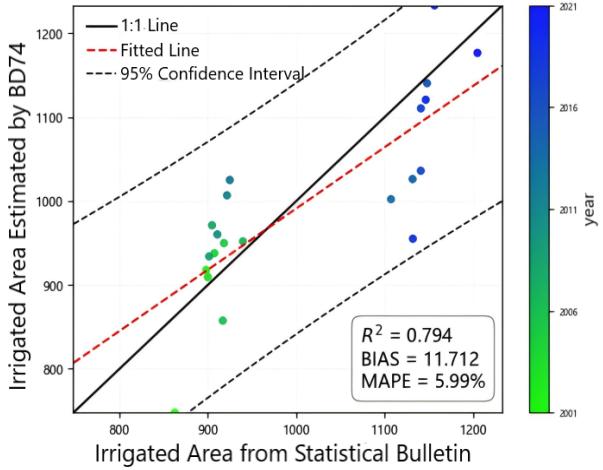
Singe-parameter Fu81 outperformed parameter-free BD74

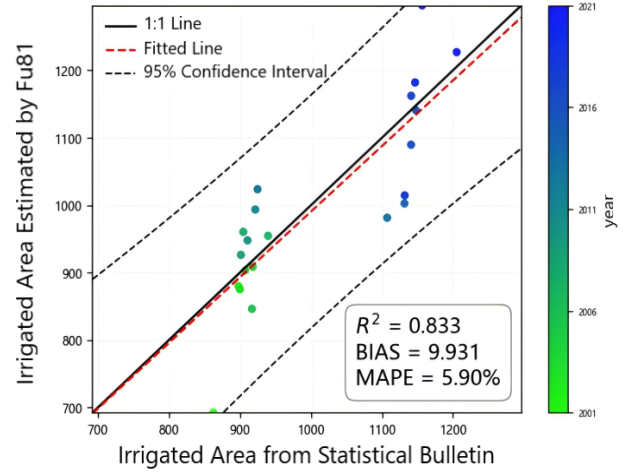
- **Quantitative Accuracy (vs. bulletin):**

R^2 = 0.833(Fu81) > R^2 = 0.794(BD74)

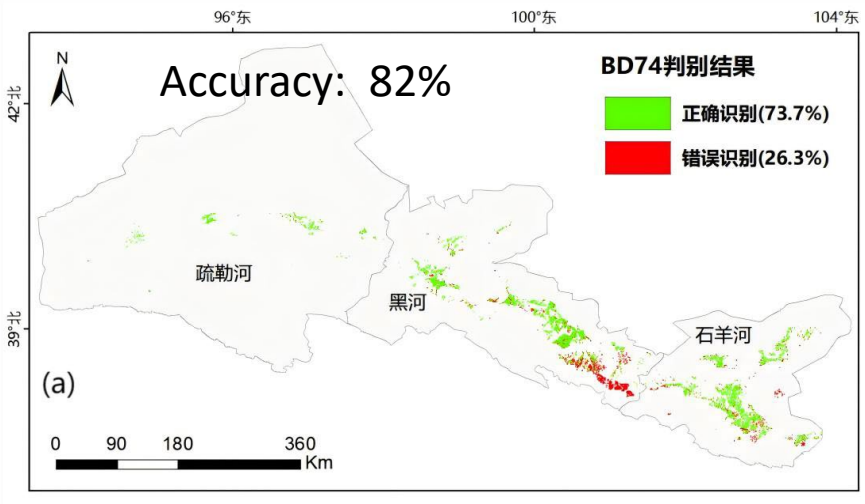
BIAS = 9.931(Fu81) < BIAS = 11.712(BD74)

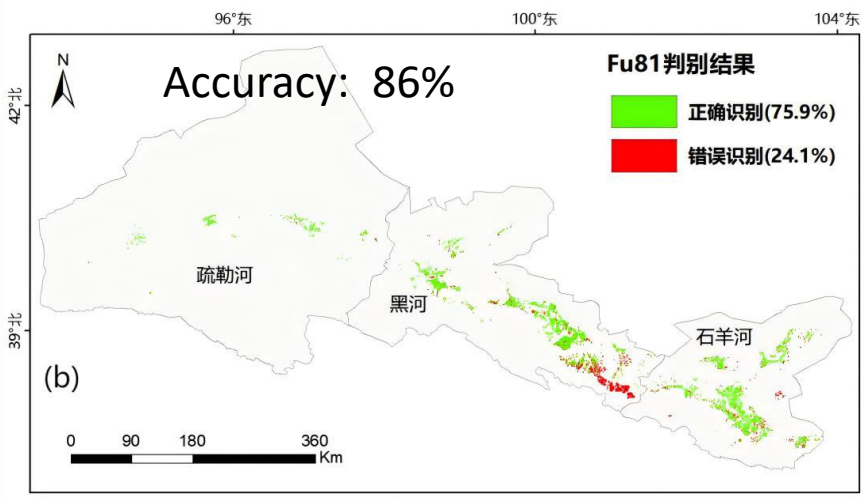
MAPE = 5.9%(Fu81) < MAPE = 5.99%(BD74)

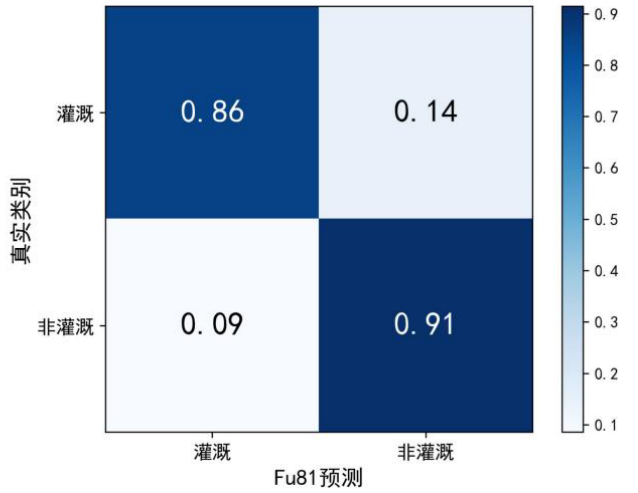




- **Classification accuracy (vs. IrriMap products):**



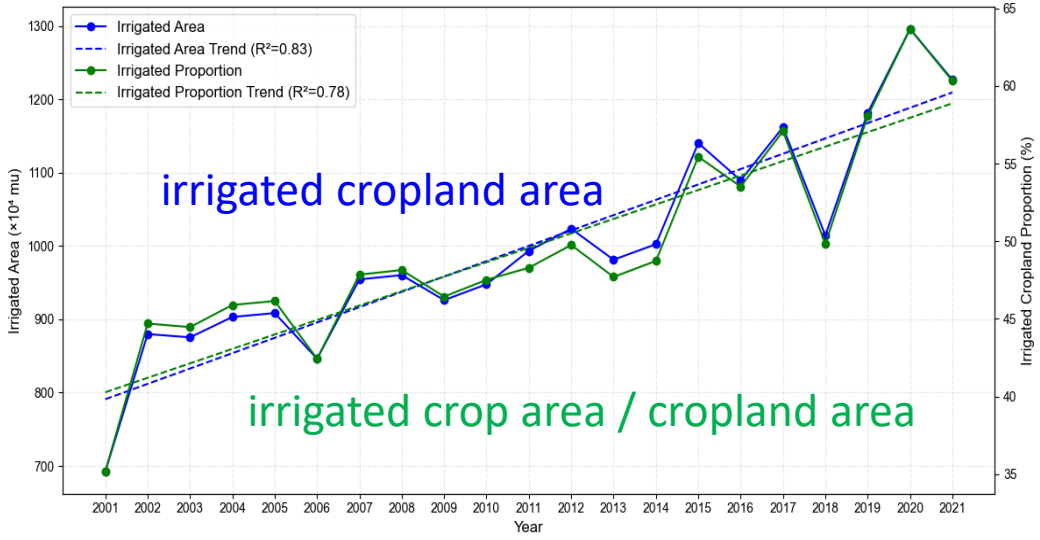




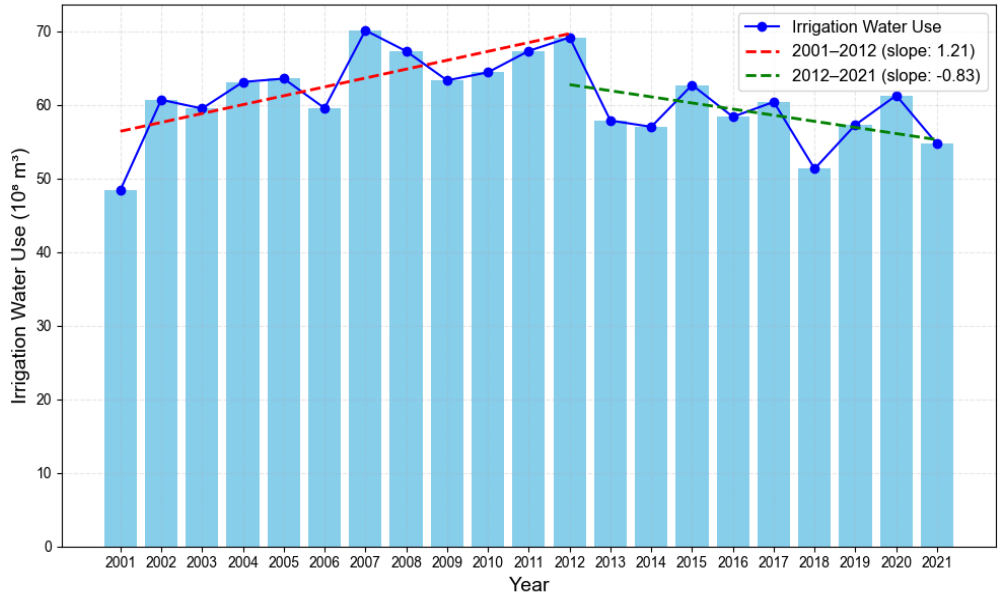
Irrigation water assessment: Irrigation Area

Annual Trends of Irrigation Indicators in the Hexi Corridor(2001–2021)

- Actual irrigated area increased by 77%, irrigated cropland proportion increased by 71%
- Irrigation water consumption declined after 2013, may indicating improved agricultural irrigation water use efficiency



irrigated water consumption

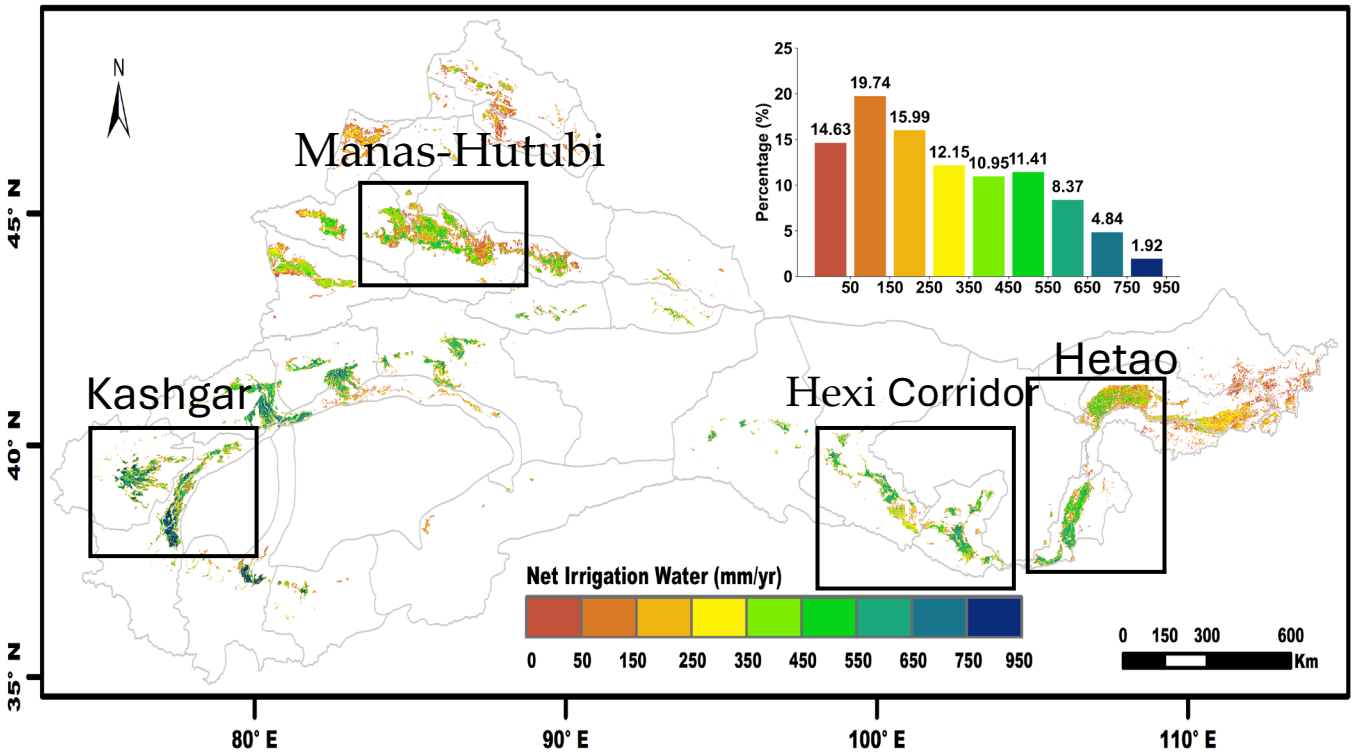


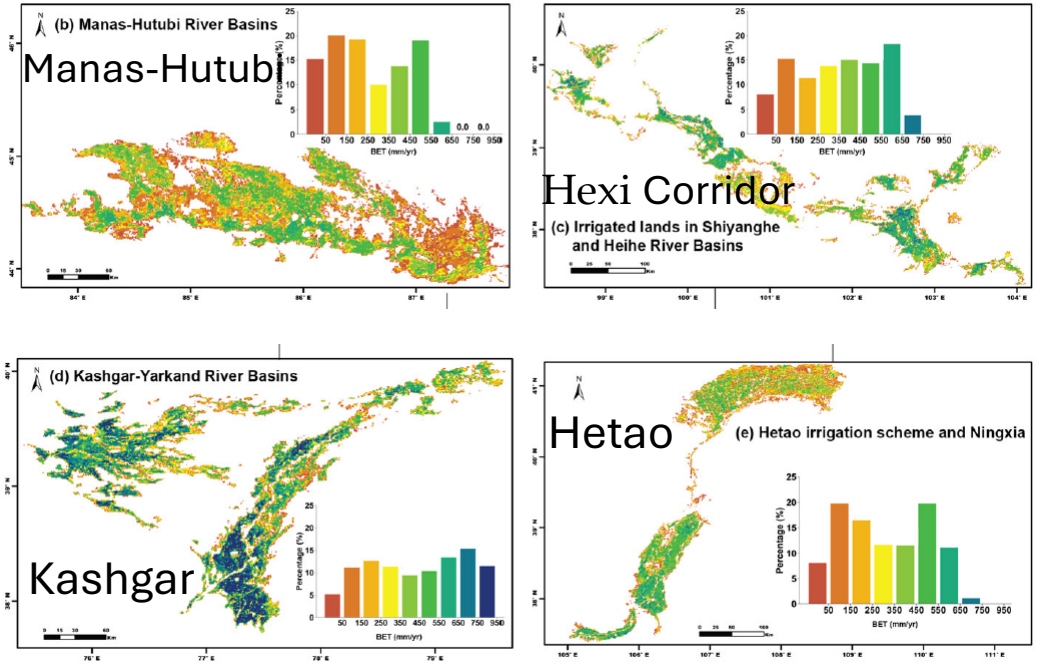
irrigated water volume = area (ha) * quota (L water/ha)

Irrigation water assessment: Irrigation efficiency

The BET metric of consumptive irrigation water use was applied to the irrigated lands in northwest China to evaluate the performance of irrigation from 2001 to 2021.

Average BET from 2001 to 2021



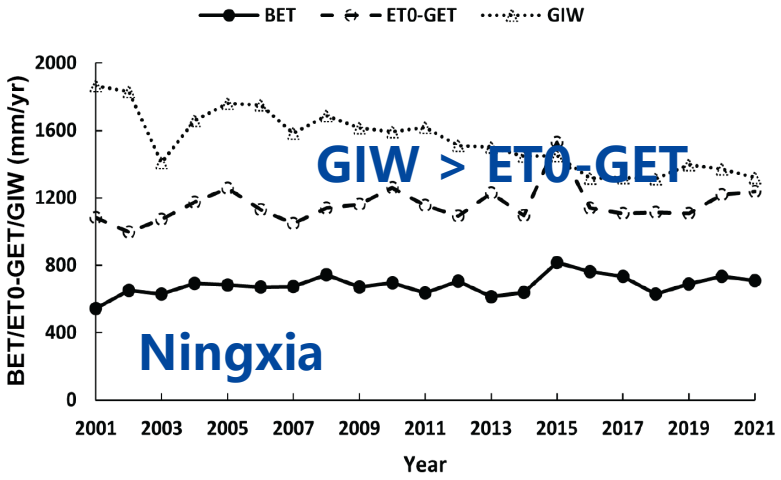


Zhou et al., 2025, RS

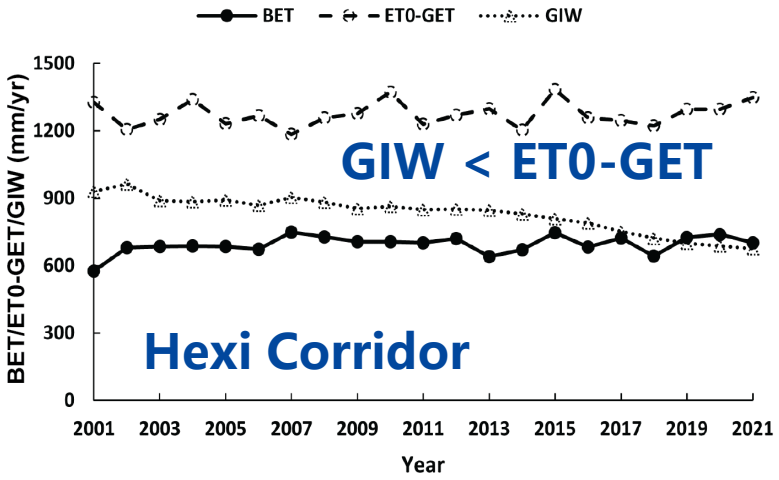
Irrigation water assessment: Irrigation efficiency

Is Irrigation Water Sufficient to Overcome the Deficit?

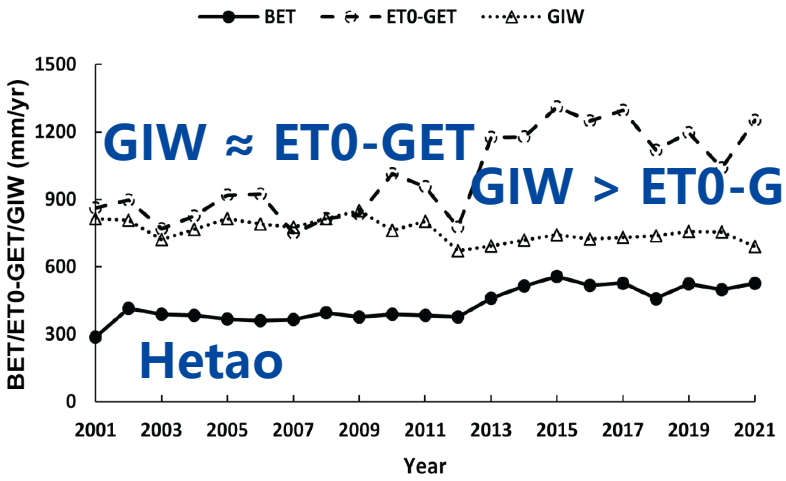
→ Blue water: supply (GIW from bulletin) vs. demand (ET0-GET)



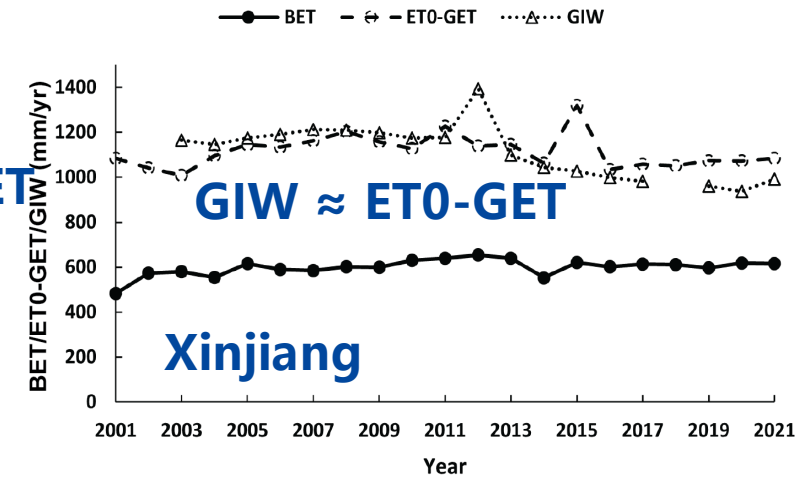
(a) Ningxia



(b) Hexi Corridor



(c) Hetao irrigation scheme

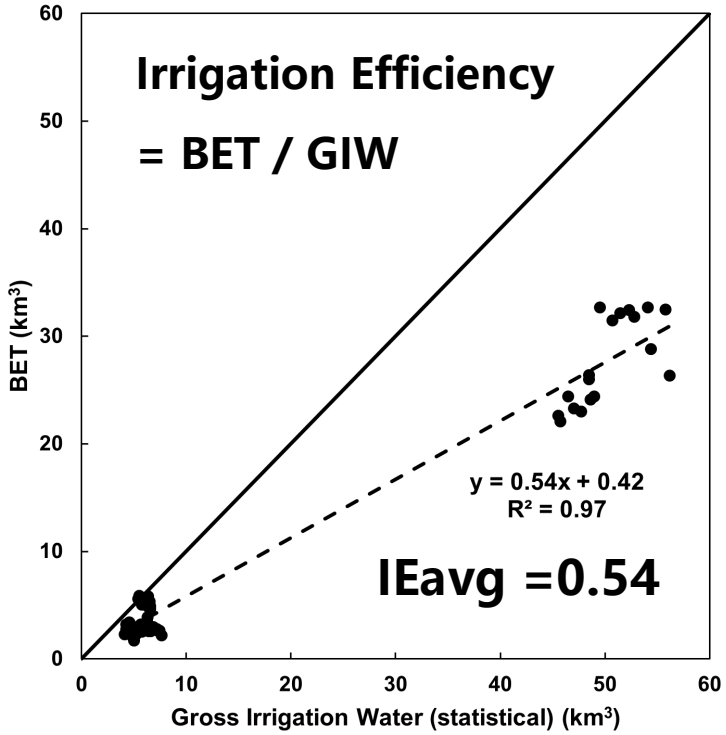


(d) Xinjiang

Zhou et al., 2025, RS

How Efficient Is the Distribution and Use of Irrigation Water?

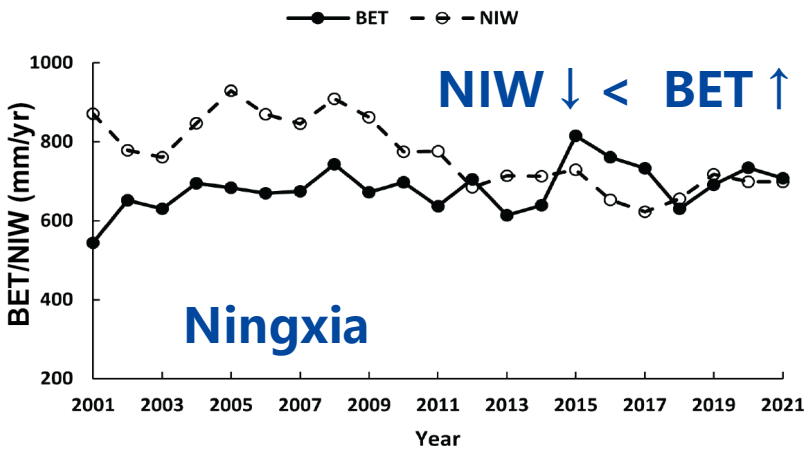
→ supply (GIW) vs. actual use (BET)



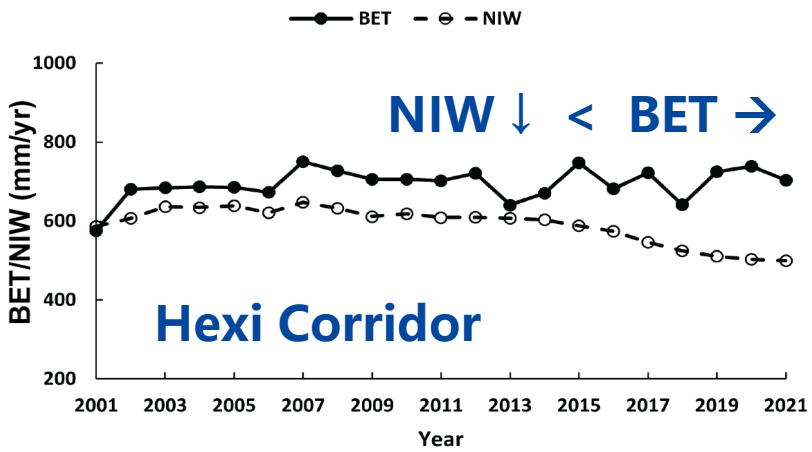
FAO: IE between 50% to 60% is considered good

Irrigation water assessment: Irrigation efficiency

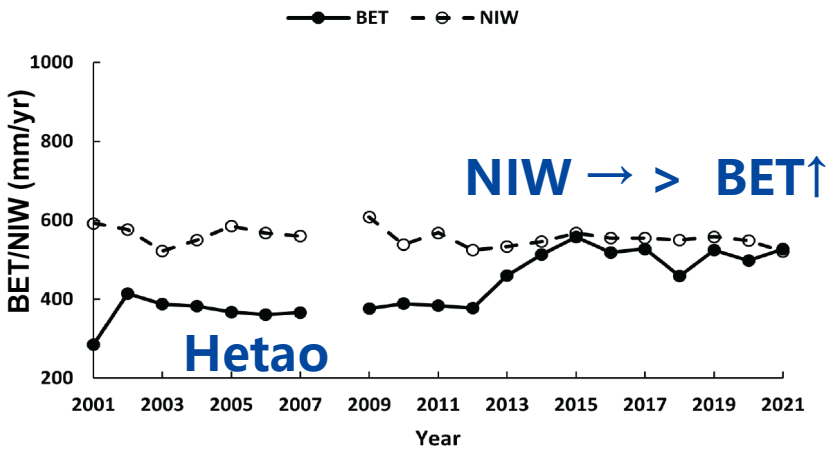
Is Irrigation Water Used Efficiently by Crops? → BET vs. NIW (NIW from bulletin)



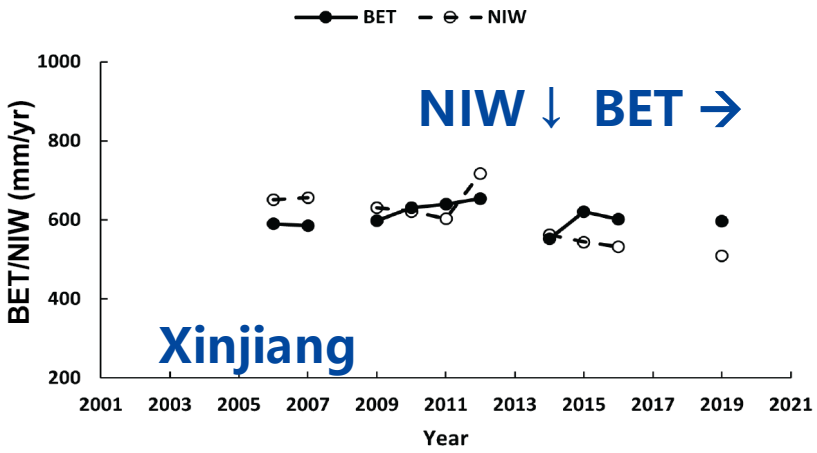
(a) Ningxia



(b) Hexi Corridor



(c) Hetao irrigation scheme



(d) Xinjiang

Zhou et al., 2025, RS

Global cropland water use efficiency assessment

- **Improving WUE across various sectors can alleviate pressure on water resources and is closely linked to human well-being and the achievement SDGs.**
- ✓ **We developed an integrated framework for WUE estimation**

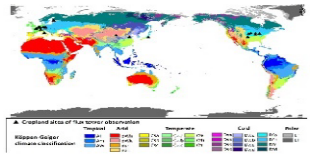
Water-carbon coupled WUE integrated model

$$WUE = \frac{GPP/NPP}{ET}$$

Advance in parameter calibration



Flux tower data

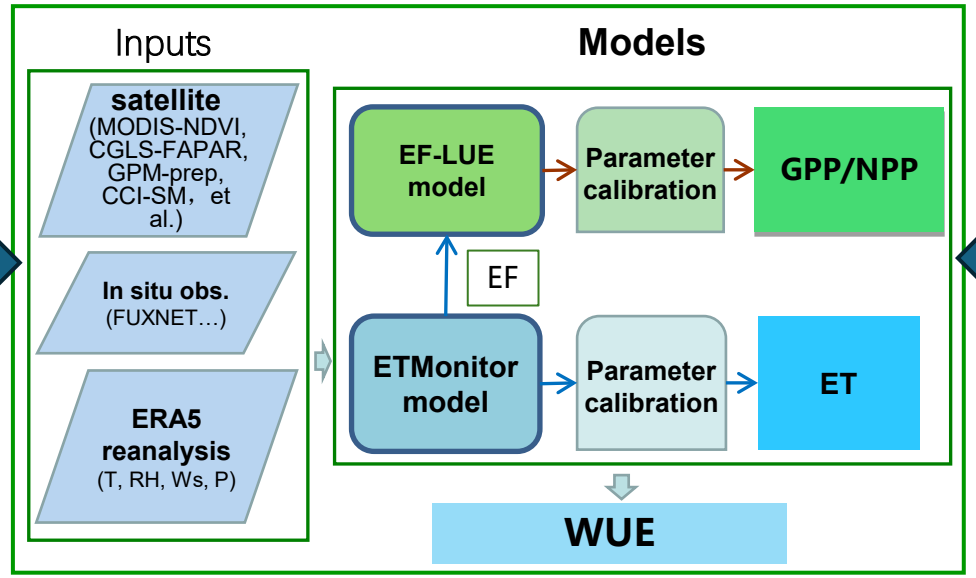


Climate zone

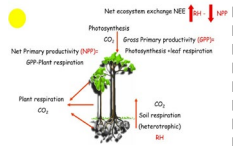
Parameters are optimized for each climate zone, improving the accuracy of estimation

Same forcing datasets

the same forcing datasets for ETMonitor and the EF-LUE model, reducing the uncertainties in WUE estimation caused by different forcing data



Advance in model



ETMonitor ET ➡ $F_{EF} = ET/(Rn - G)$

Carbon-water coupled

$$GPP = APAR \times \varepsilon_{max} \times F_{VPD} \times F_T \times F_{EF}$$

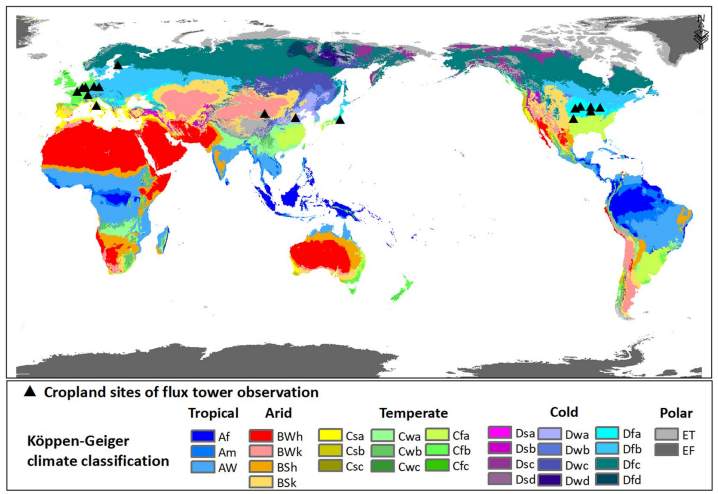
- ➢ Use EF in LUE model, improves the accuracy of GPP estimation, especially in arid soil condition
- ➢ reflect the carbon-water coupled relationship

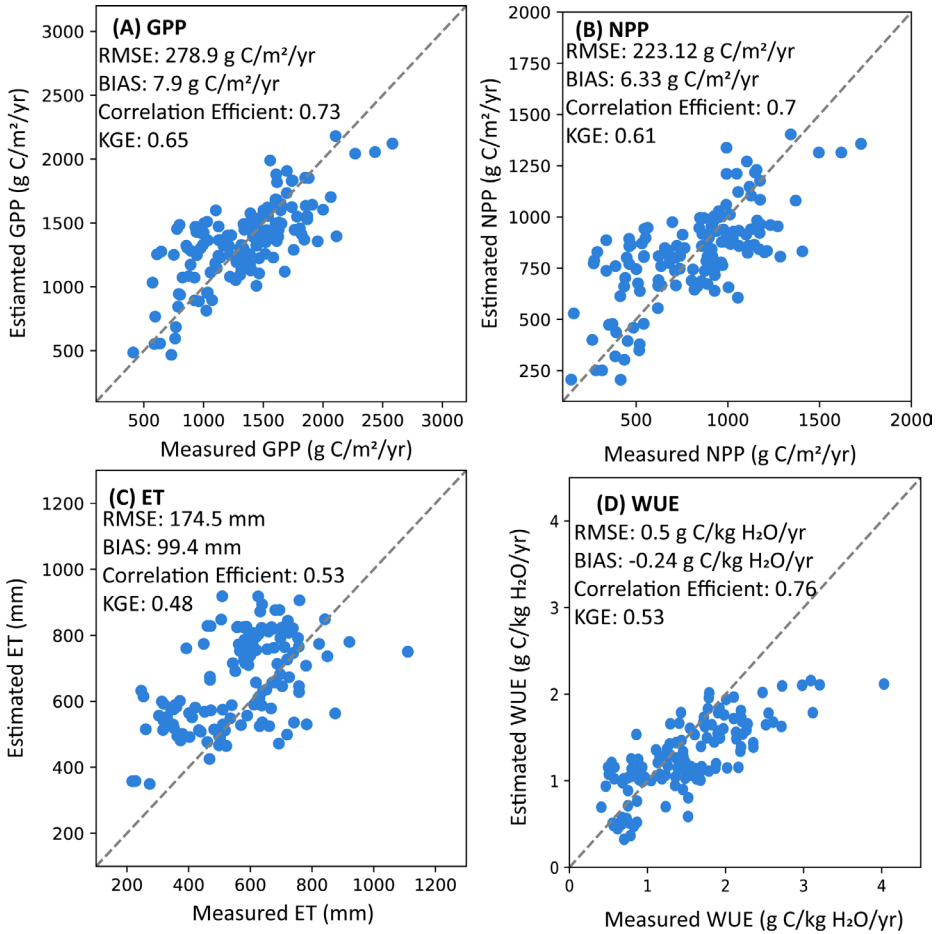
(Jiang. M., Zheng. C., Jia. L., et al,2025, *Scientific Data*)

Global cropland water use efficiency assessment

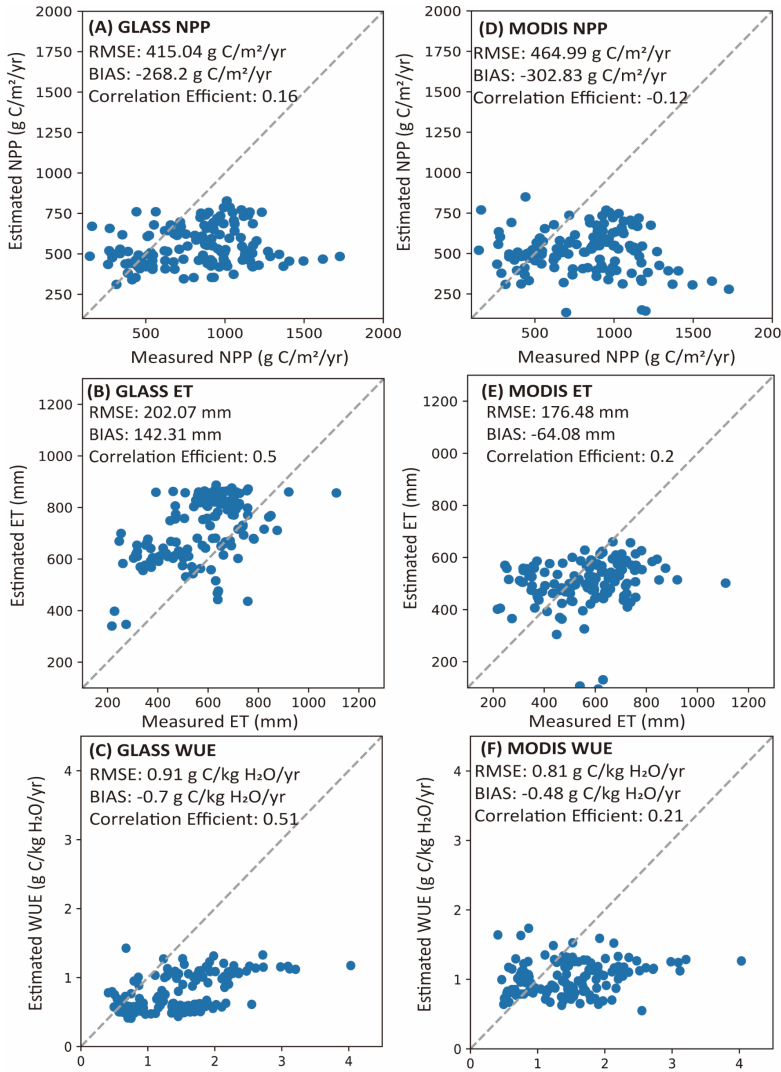
Accuracy by comparing to 21 in-situ observations globally

- GPP, NPP, and WUE (referred to GCWUE) all have a good performance
- The GCWUE generated by our study outperforms the MODIS WUE and GLASS WUE, with low RMSE , higher correlation efficiency





Comparisons between the estimates from the models in this study and ground measurements

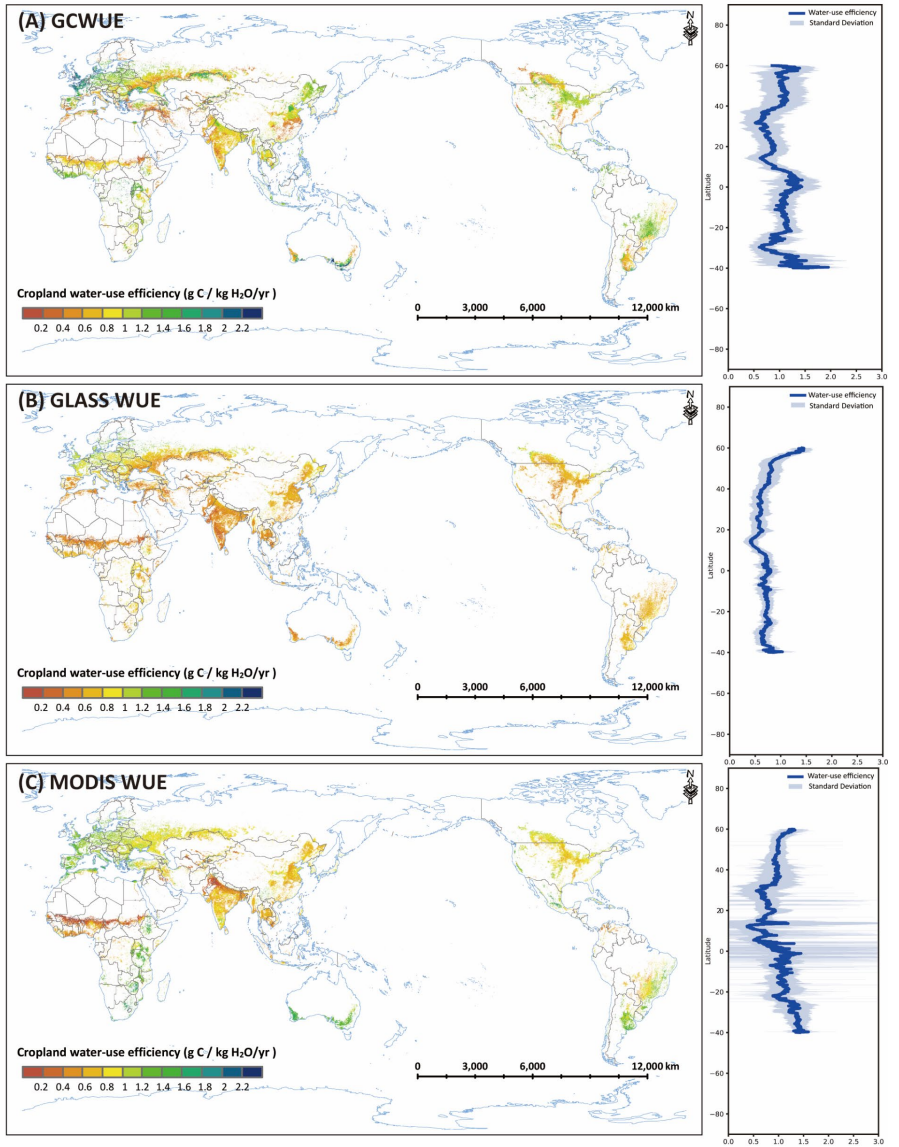


Comparisons between the MODIS and GLASS and ground measurements

Global cropland water use efficiency assessment

Intercomparing with other products: spatial pattern

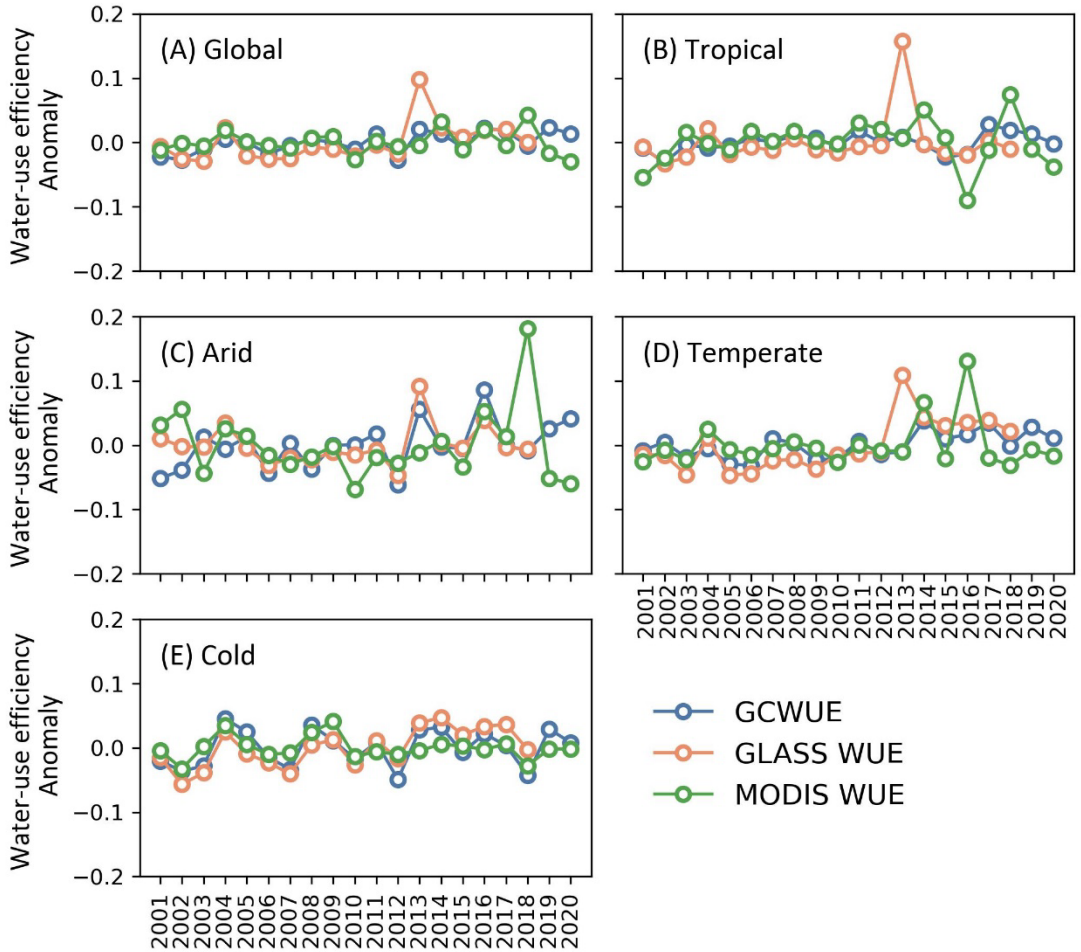
- GCWUE, MOD17 WUE, and GLASS WUE show similar spatial patterns. The areas with high WUE are mainly located in the tropical, northern Europe; the areas with low WUE are mainly located in the Sahel region and India.
- the MODIS WUE is generally lower than GCWUE, especially in India and the North China Plain with large irrigated cropland, because the MODIS dataset has been shown to underestimate NPP, especially for irrigated crops
- GLASS WUE is generally lower than GCWUE and MODIS WUE, especially in India, Russia, and Australia, because the GLASS NPP is underestimated and the GLASS ET is overestimated



Global cropland water use efficiency assessment

Intercomparing with other products: temporal pattern

- The WUE change pattern of the three products (GCWUE, MODIS, GLASS) are similar at the global and different climate zone scales
- The fluctuation of GCWUE is significantly smaller than that of MODIS and GLASS, and GCWUE is more robust in time series.



Global cropland water use efficiency assessment

Freely accessible via CASEarth Data Sharing Portal :

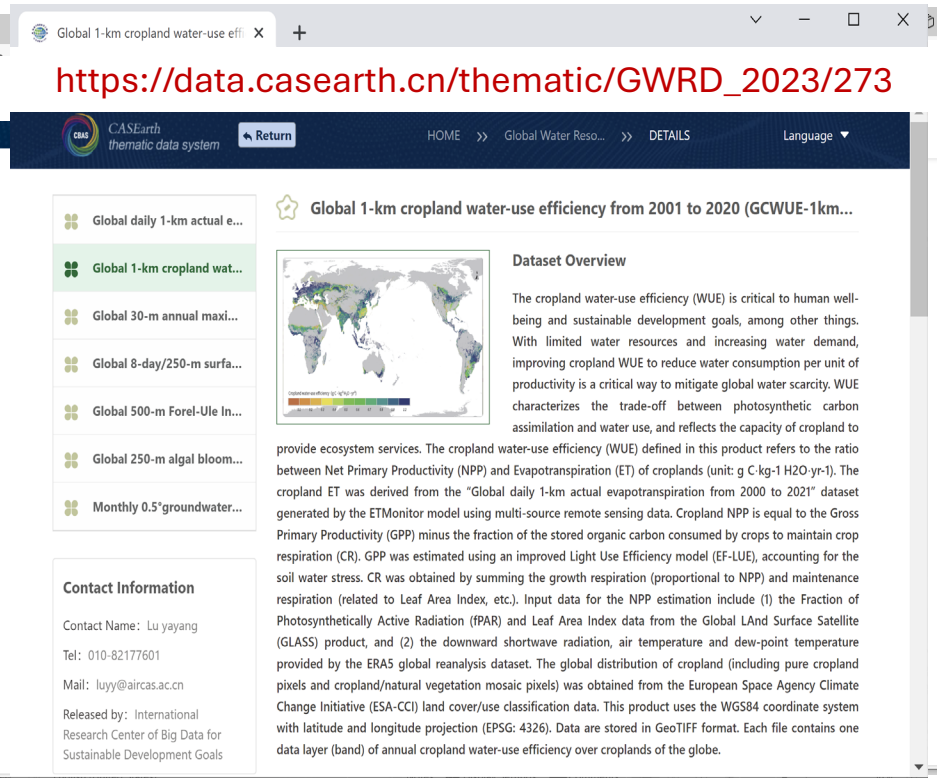
Welcome to download and provide feedback

- Global 1km Cropland **Gross Primary Productivity** from 2001 to 2020
- Global daily 1-km **actual evapotranspiration** from 2000 to 2021
- Global 1-km **cropland water-use efficiency** from 2001 to 2020

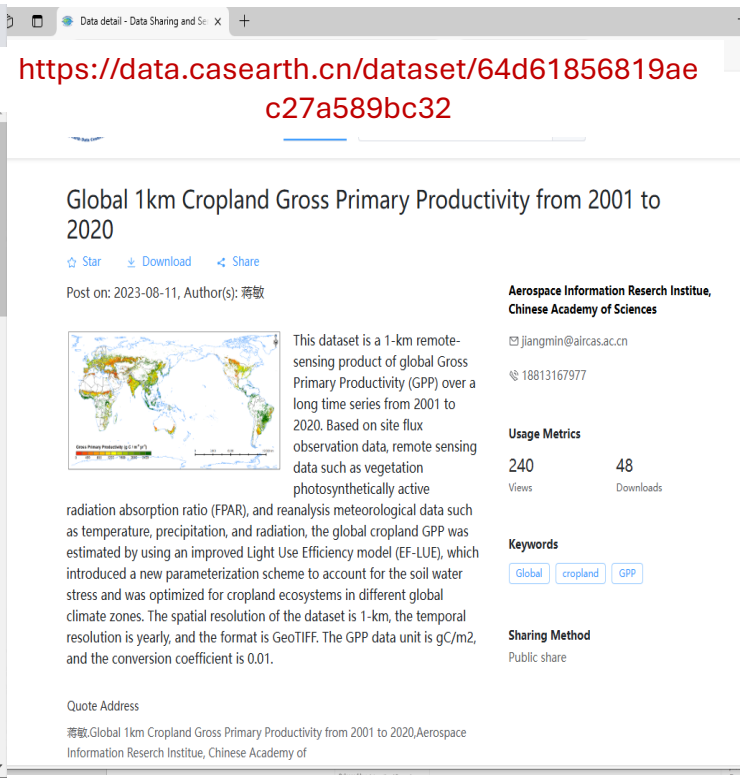
https://data.casearth.cn/thematic/GWRD_2023/272



https://data.casearth.cn/thematic/GWRD_2023/273



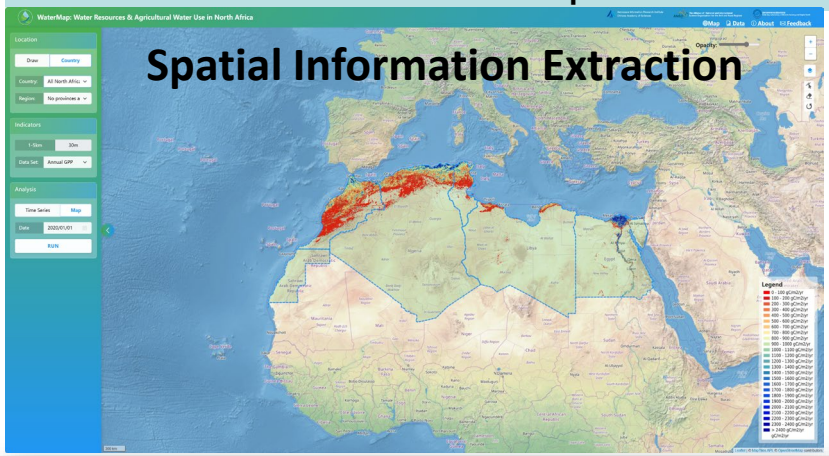
https://data.casearth.cn/dataset/64d61856819aec27a589bc32

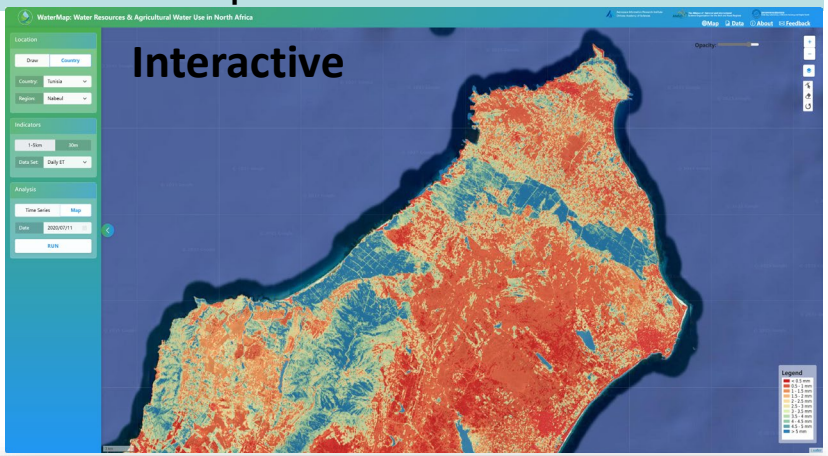


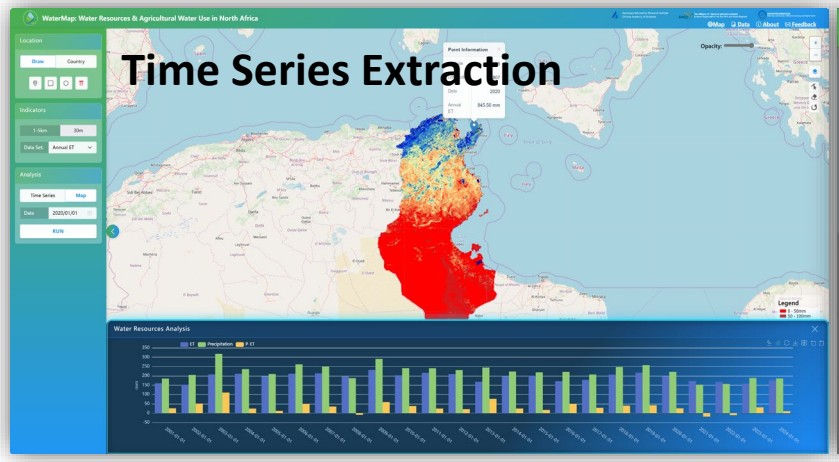
WaterMap: Cloud-based Platform for Monitoring and Assess Water Resources & Agricultural Water Use

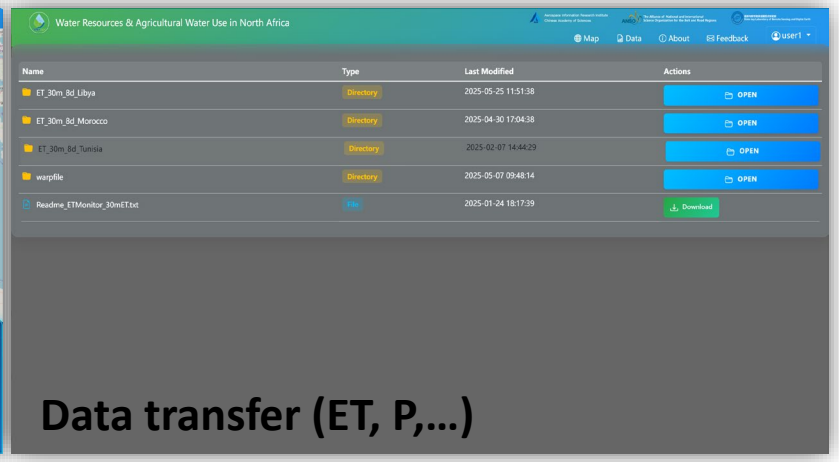
Monitoring and Assessment of Water Resources and Agricultural Water Use

watermap-nafrica.com/watermap



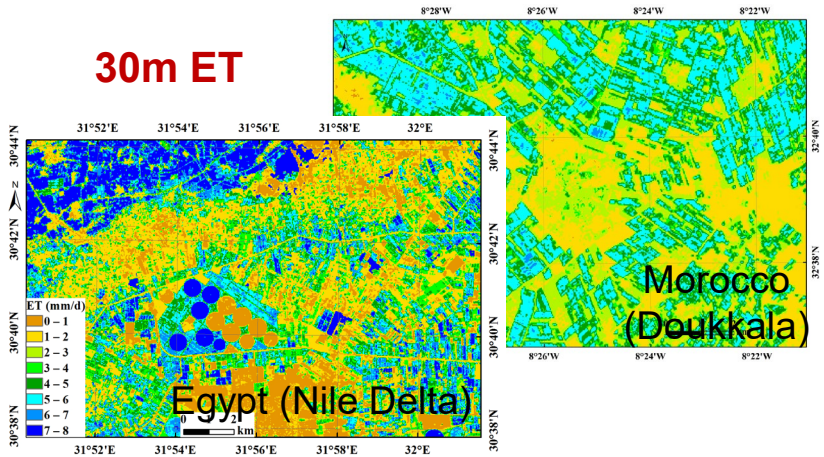






System Characteristics:

- Web-based information system
- Big data management and Analysis
- Open source architecture
- User-friendly WebGIS Graphical User Interface (GUI)



Developed at AIR-CAS, Supported by ANSO

POLIMI: The FEST-EWB energy-water balance model

FEST-EWB & SAFY model

SM → **Soil water balance**

LST → **Energy balance**

Crop growth

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

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

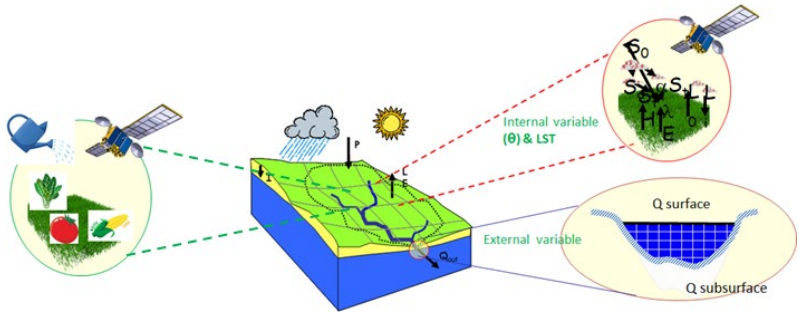
$$ETeff=\frac{LE}{\rho Cp}$$

$$\Delta DAM = APAR \cdot Pgro_Lue \cdot F_T(Ta)K_s$$

SM, LAI

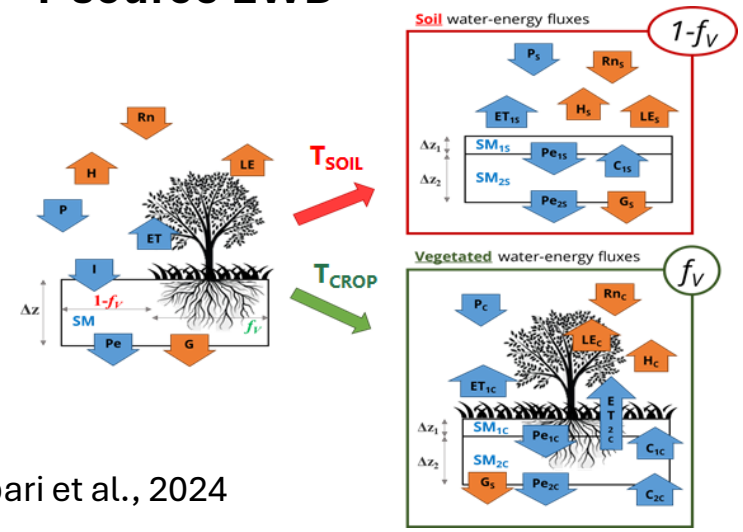
FEST-EWB: Flash – flood Event – based Spatially – distributed rainfall – runoff Transformation – including Energy - Water Balance

SAFY : (Simple Algorithm For Yield Estimate)



Corbari & Mancini, 2014 (JHM)
Corbari et al., 2014, (HSJ)

1-source EWB **2-sources 2x2-EWB**



Paciolla et al., 2023; Corbari et al., 2024

internal calibration of a distributed hydrological water balance model using **satellite** images

LST (SM,ET) for soil surface parameters Calibration pixel by pixel

LAI for crop parameters Calibration

Inputs

(1) meteorological forcings; (2) maps of soil hydraulic parameters; (3) vegetation parameters; (4) groundwater level; (5) irrigation volume.

Applications

- Irrigation prescription maps
- Irrigation mapping
- Water resources management
- Drought monitoring

FEST-2X2-EWB
Models calibration against temperature

In the Reggianini (REG) farm, three temperature data were available:

- Inverted longwave radiation from a **Radiometer** (880 m^2)
- Infrared temperature sensor (**IRTS**), focused on the plant (10 m^2)
- **Landsat 8-9** overpasses (30 m resolution constrained by the available vegetation data (from Sentinel-2, 100 m^2)

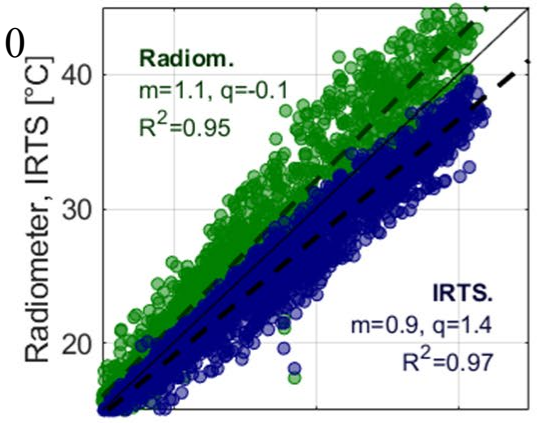
Both models were run at the 900 m² resolution

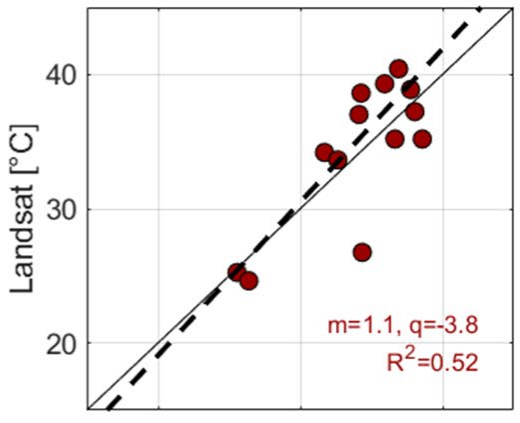
The FEST-EWB model struggled with interpreting the higher-resolution variability portrayed by radiometer and IRTS.

The FEST-2x2-EWB model managed to represent the different temperatures

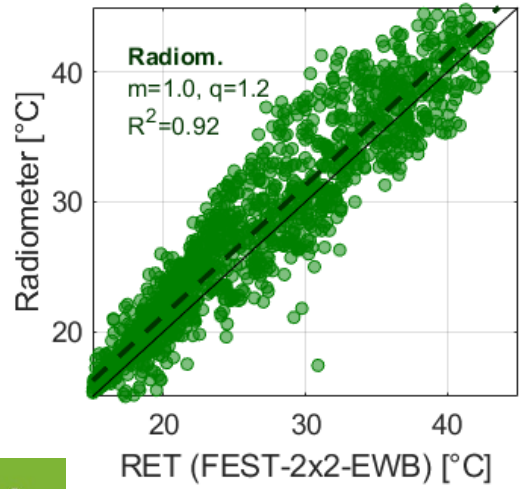


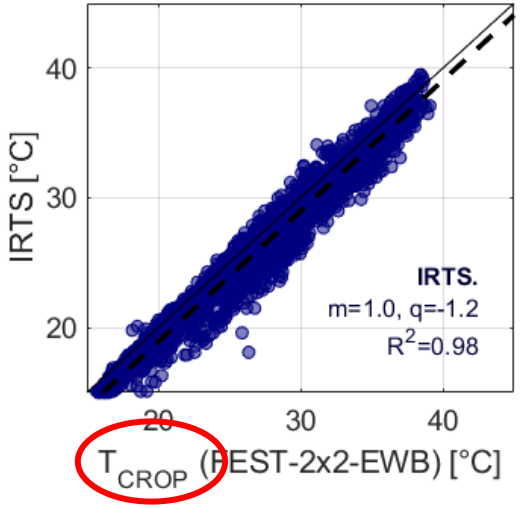
https://www.sciencedirect.com/science/article/pii/S0378377423003876
Corbari et al., 2023

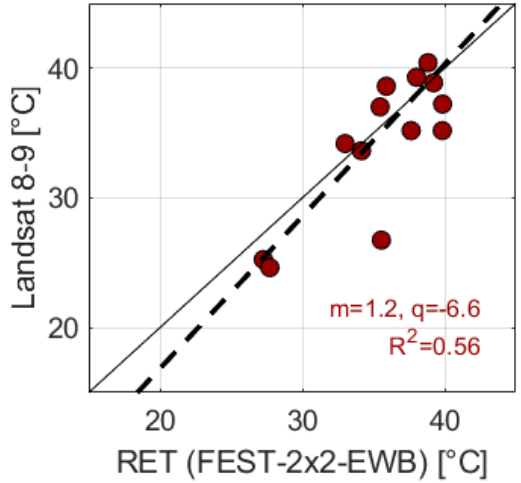




FEST-EWB







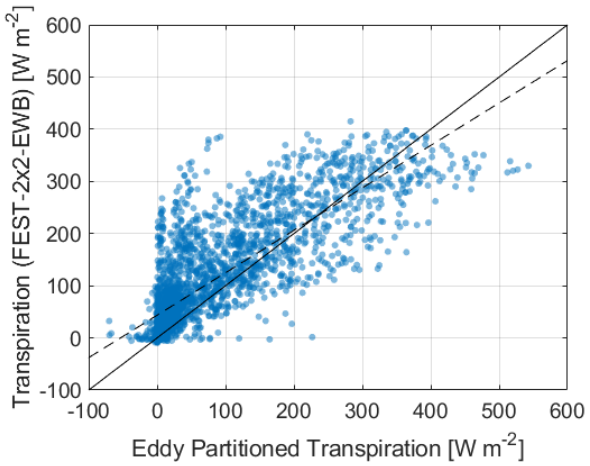
FEST-2x2-EWB

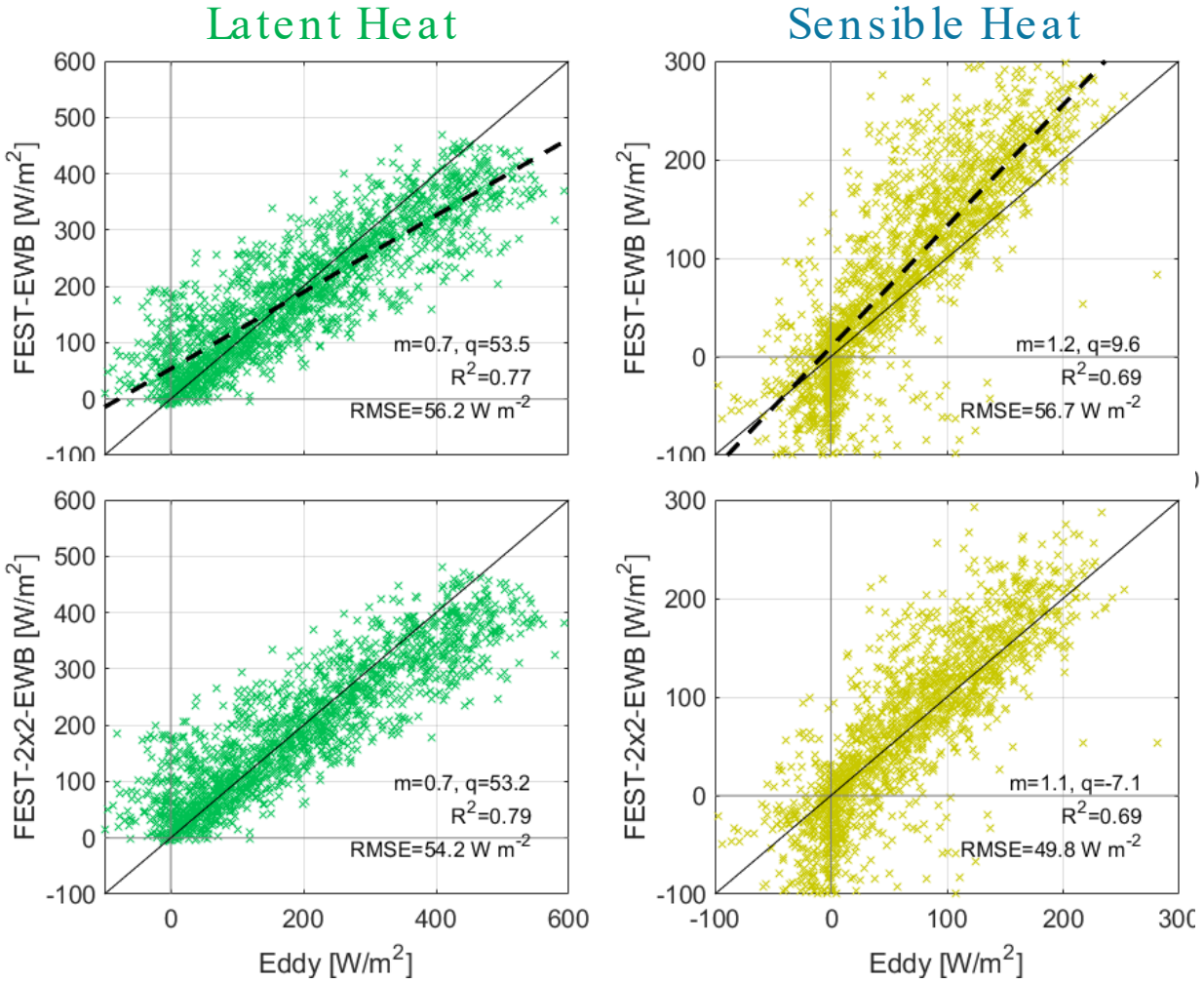
Models validation against eddy data (REG)

In the Reggianini (REG) farm, eddy covariance data were available, allowing to validate the model runs against latent heat and sensible heat data.

Furthermore, FEST-2x2-EWB produces Transpiration computed directly on the crop reference temperature. The observed flux was extracted from EC data via the uWUE method (Zhou et al., 2016).

The comparison between the two is slightly weak in the nocturnal low transpiration values, but good over the daytime peaks.





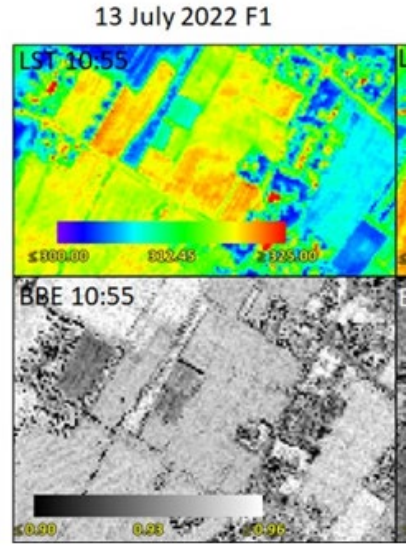
Improving evaporation estimates and crop water stress

Burana Irrigation Consortium – survey campaign areas



acquired airborne TIR data

64 bands of TIR aquisition



Eddy covariance station





Reggianini farm

PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

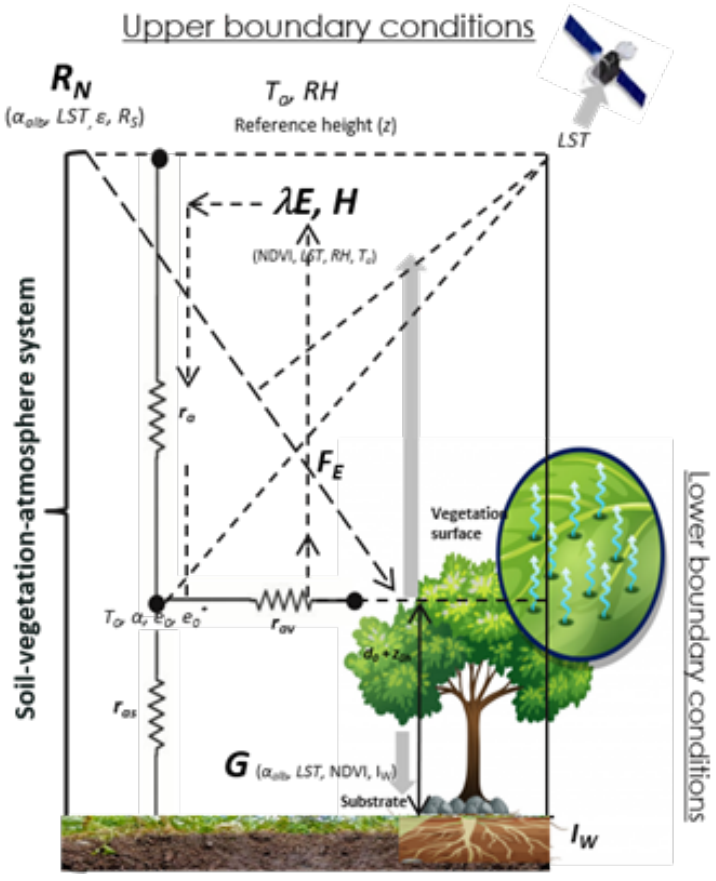
POLITECNICO MILANO 1863

LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY LIST

VNIVERSITAT DE VALÈNCIA

Evapotranspiration models

STIC analytical model



In contrast to the other SEB models that parameterize conductances to retrieve the energy fluxes, the **STIC model resolves evaporative fraction, aerodynamic temperature, and aerodynamic and surface conductances simultaneouly**

Models input data

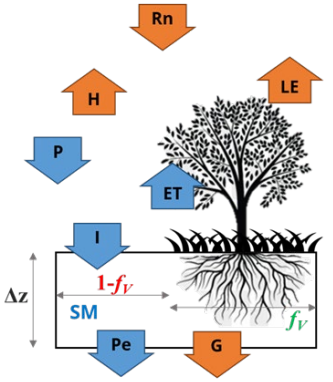
data	model	source	Spatial resolution
LST	FESTresidual, STIC, S-SEBI	airborne	1 and 4 m
Emissivity	FESTresidual, STIC, S-SEBI	airborne	1 and 4 m
FVC	FESTresidual, STIC	Planetscope	3.7 m
NDVI	S-SEBI	Planetscope	3.7 m
Albedo	FESTresidual, STIC, S-SEBI	Landsat	30 m
Incoming shortwave radiation	FESTresidual, STIC, S-SEBI	Ground stations / ERA5	Local / 0.25°
Wind speed	FESTresidual	Ground stations / ERA5	Local / 0.25°
Air temperature	FESTresidual, STIC	Ground stations / ERA5	Local / 0.25°
Air humidity	FESTresidual, STIC, S-SEBI	Ground stations / ERA5	Local / 0.25°

FESTresidual model

LE=Rn-H-G

Corbari et al., 2015 (Jh)
Corbari & Mancini, 2014 (JHM)
Corbari et al., 2014 (HSJ)

A SEB model that parameterize conductances to retrieve the energy fluxes



S-SEBI model

$$\Lambda = \frac{\lambda E}{\lambda E + H} = \frac{\lambda E}{R_n - G_0}$$

Roerink et al. (2000)

instantaneous evaporative fraction

$$\Lambda = \frac{T_H - T_0}{T_H - T_{\lambda E}}$$

temperatures corresponding to dry and wet conditions

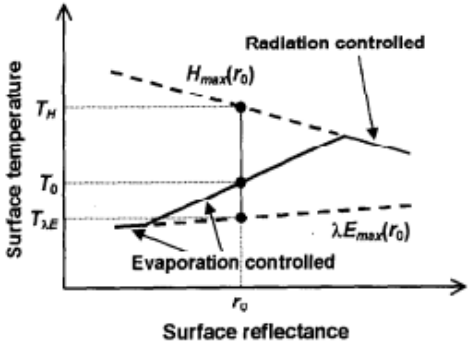


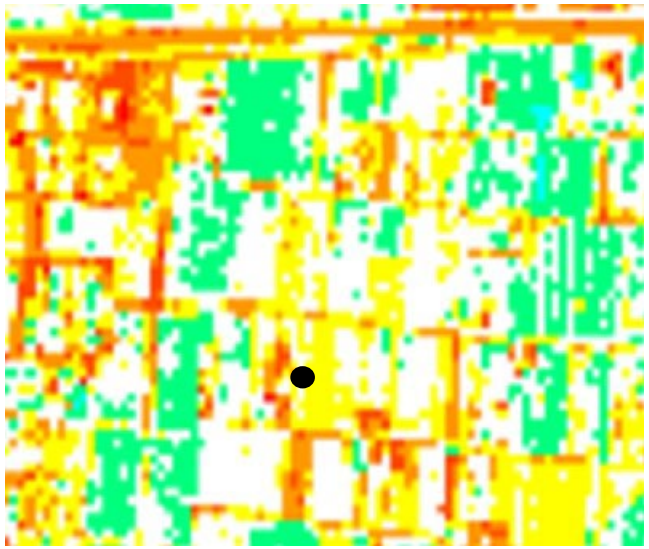
Fig. 2. Schematic representation of the relationship between surface reflectance and temperature together with the basic principles of S-SEBI.

Zoom to the eddy station area: ET estimates for Modena 4m LST

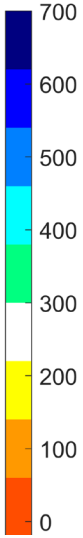
LST **LE eddy= 241.5 W/m2**



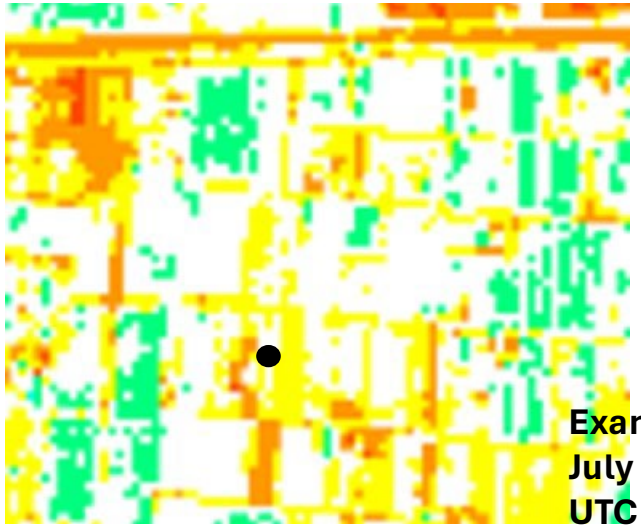
FESTresidual LE (footprint)= 230.3 W/m2



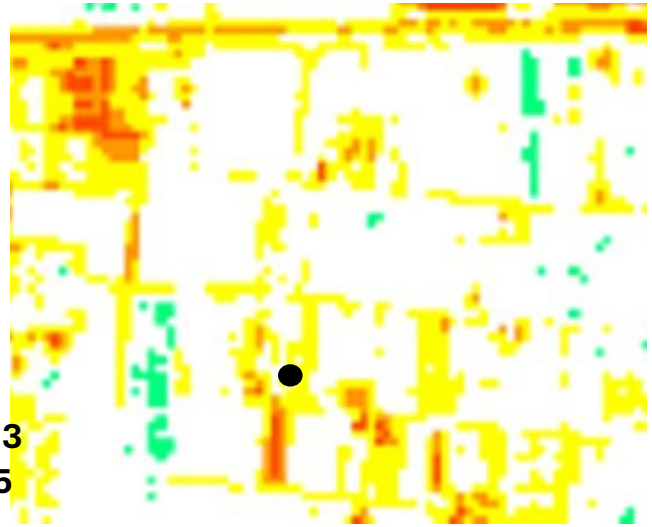
[W/m2]



S-SEBI LE (footprint)= 230.1 W/m2



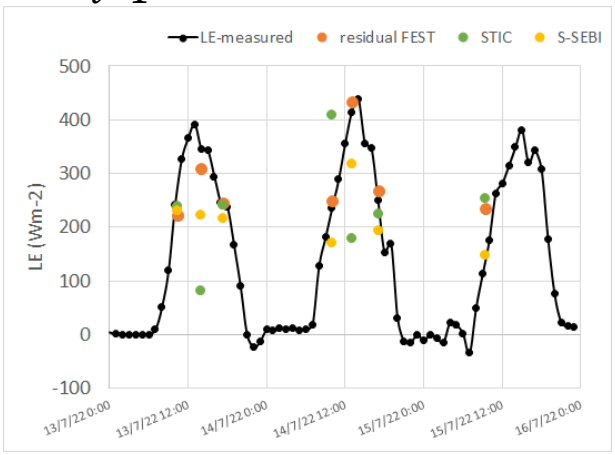
STIC LE (footprint)= 238.2 W/m2

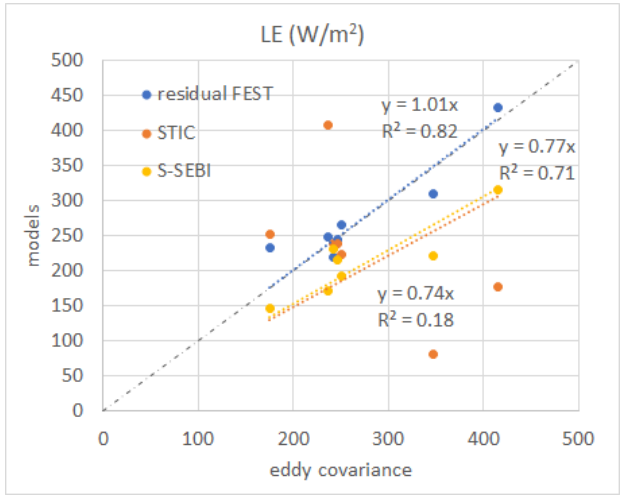


Example 13 July @ 8:35 UTC

Energy fluxes comparison at eddy covariance station

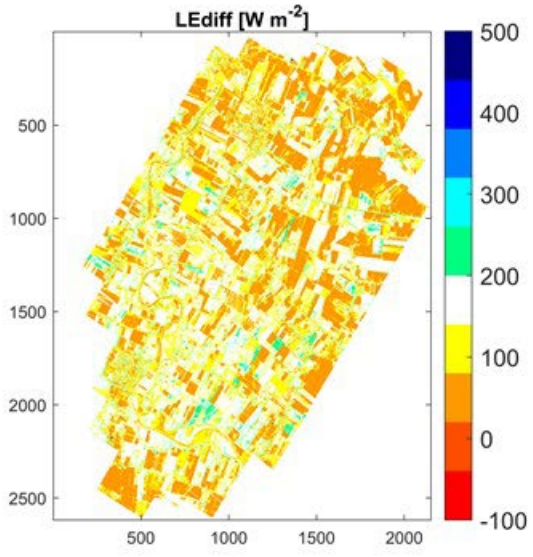
$$\bar{F} = \frac{\sum_{i=1}^{n} f(x_i, y_i, z_m) F(x_i, y_i)}{\sum_{i=1}^{n} f(x_i, y_i, z_m)}$$ Detto et al. 2006





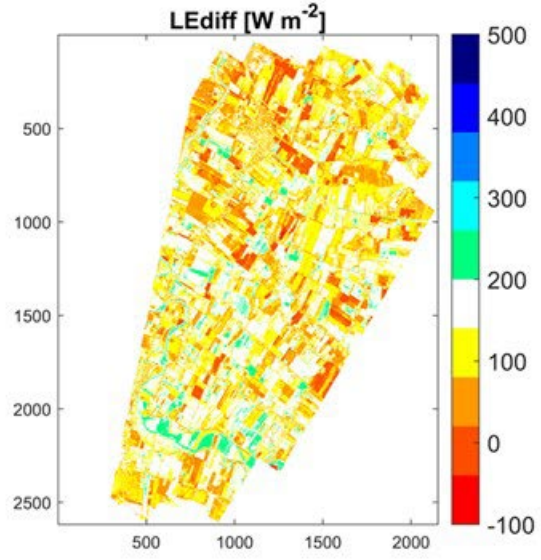
Difference of ET estimates for Concordia 4m

FESTresidual-STIC



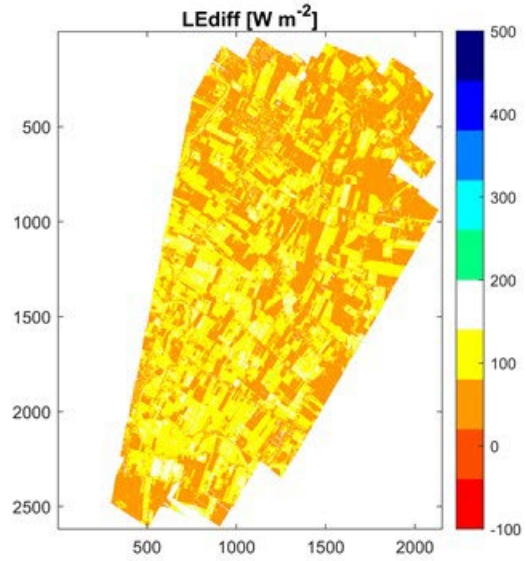
Mean abs (pixel diff) =135.8 W/m2
Mean (pixel diff) =96.3 W/m2

FESTresidual-S-SEBI



Mean abs (pixel diff) =108,1 W/m2
Mean (pixel diff) =88,5 W/m2

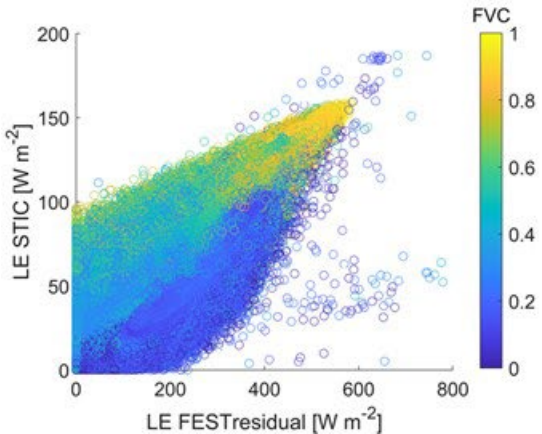
STIC-S-SEBI

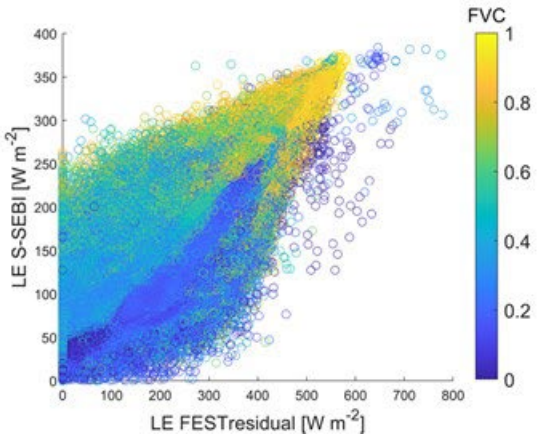


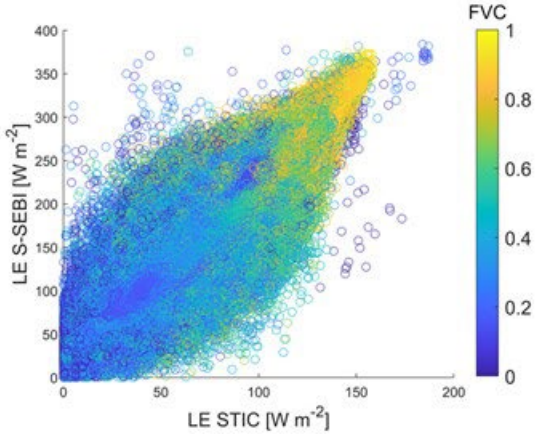
Mean abs (pixel diff) =92,7 W/m2
Mean (pixel diff) =19.3 W/m2

Average over the 7 flights

ET estimates and vegetation fraction







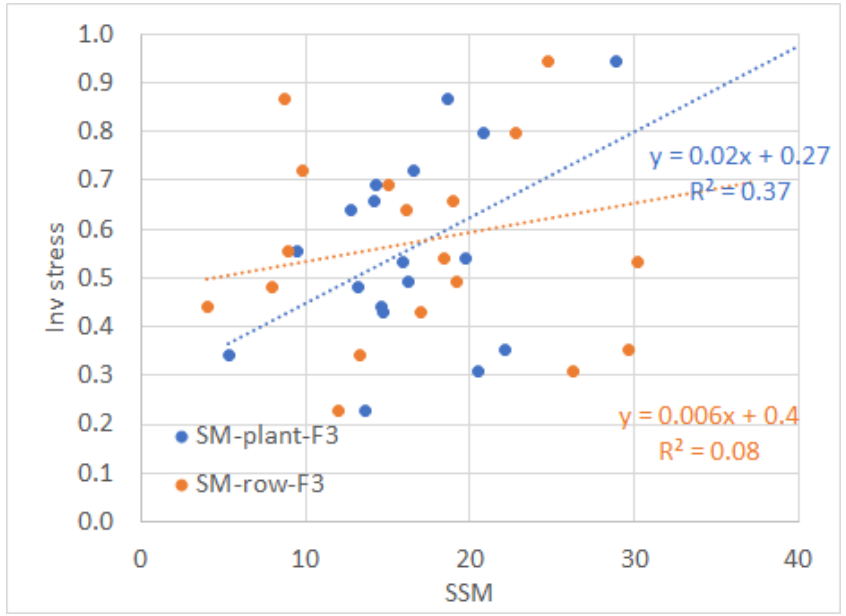
High spatial resolution thermal infrared data from airborne acquisition for crop water stress retrieval

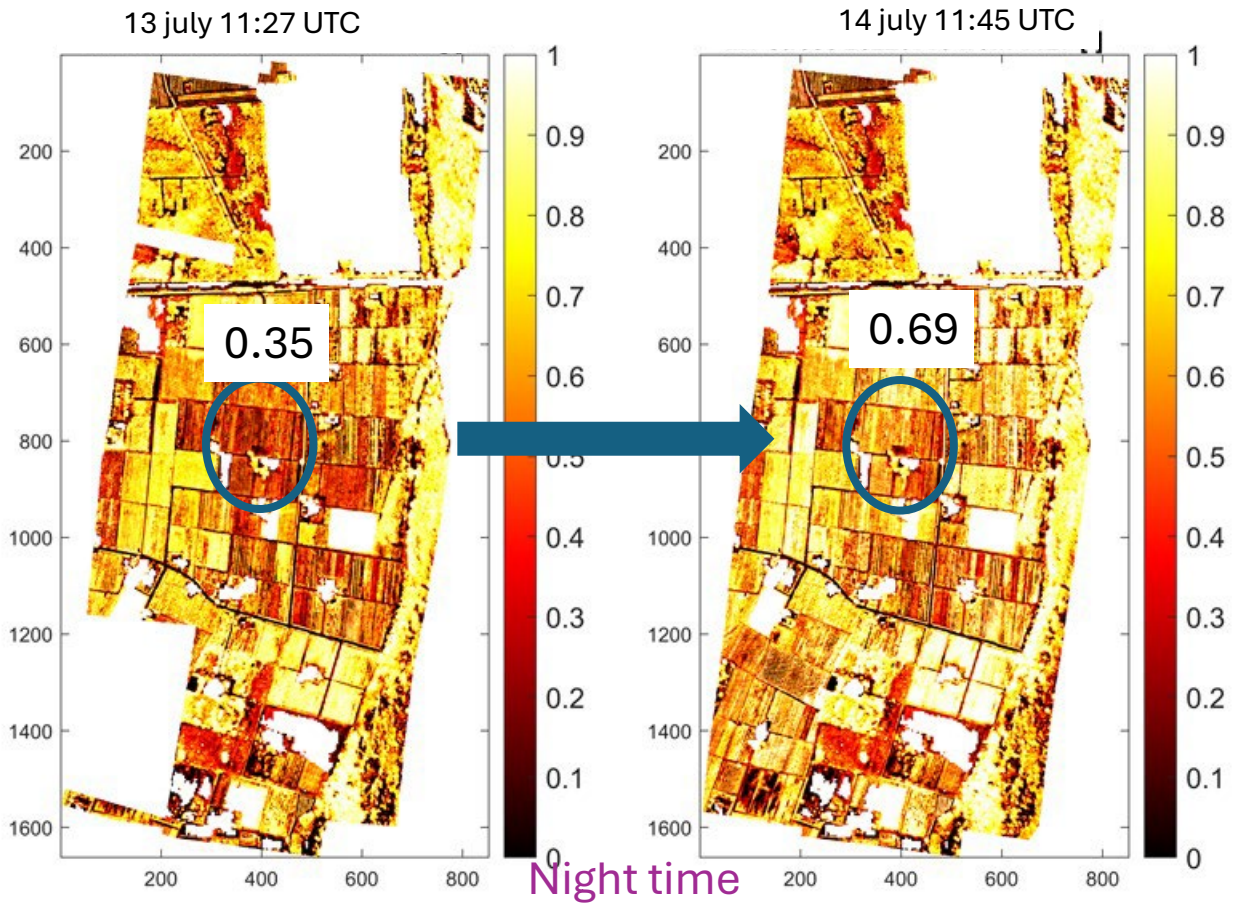
Water stress conditions (Diamante 1m)

Corbari et al., 2025
10.1016/j.rsase.2025.10156
3

Water stress metric = fraction of actual ET (from FEST-EWB model) to Allen et al. (1998) reference ET

0 maximum stress (full stomatal closure)
1 for non-stressed vegetation (fully transpiring).





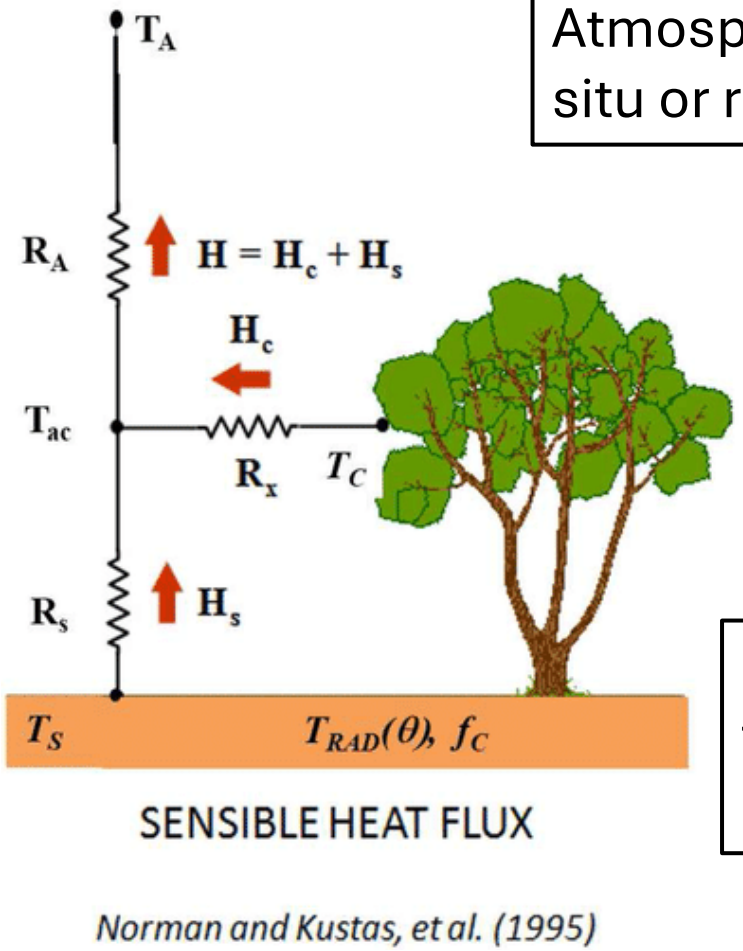
SM at 7cm = 0.12
SM at 50cm = 0.25

Night time Irrigation event

SM at 7cm = 0.16
SM at 50cm = 0.29

TWO SOURCE ENERGY BALANCE (TSEB) MODEL

Atmosphere is characterized with either in-situ or reanalysis data (T_A, wind speed, etc.).



Norman and Kustas, et al. (1995)

Surface information come from satellite data (LST, LAI, albedo, etc.)

a pixel is a blend of canopy (c) and soil

Two-source approximation

$$T_{RAD}(\theta)^4 \sim f_C(\theta)\, T_C^4 + [1-f_C(\theta)]\, T_S^4$$

System, soil, canopy budgets

$$R_n = H + \lambda E + G$$
$$R_{n,s} = H_S + \lambda E_S + G$$
$$R_{n,c} = H_C + \lambda E_C$$

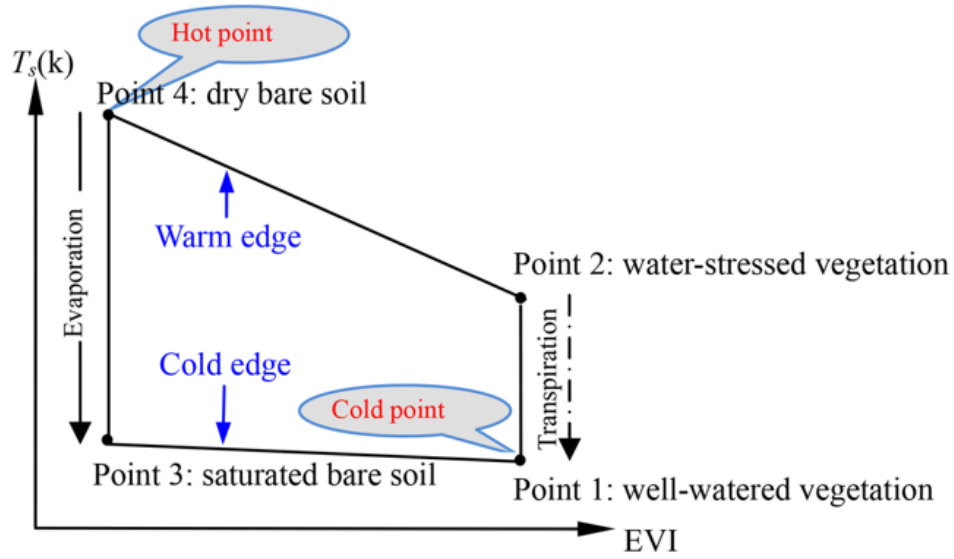
Cammalleri

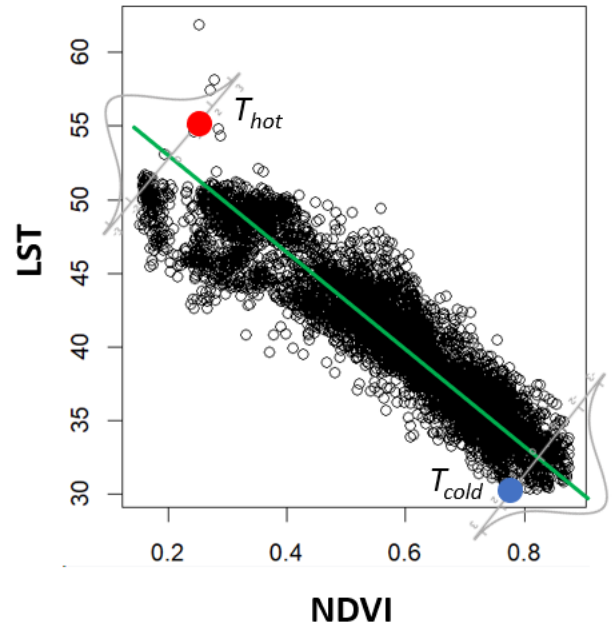
How to solve challenge 1? (inconsistency in T_A and LST)

SEBAL/METRIC/SEBS

Two boundary conditions are defined:
Cold pixel: H = 0
Hot Pixel: λET = 0

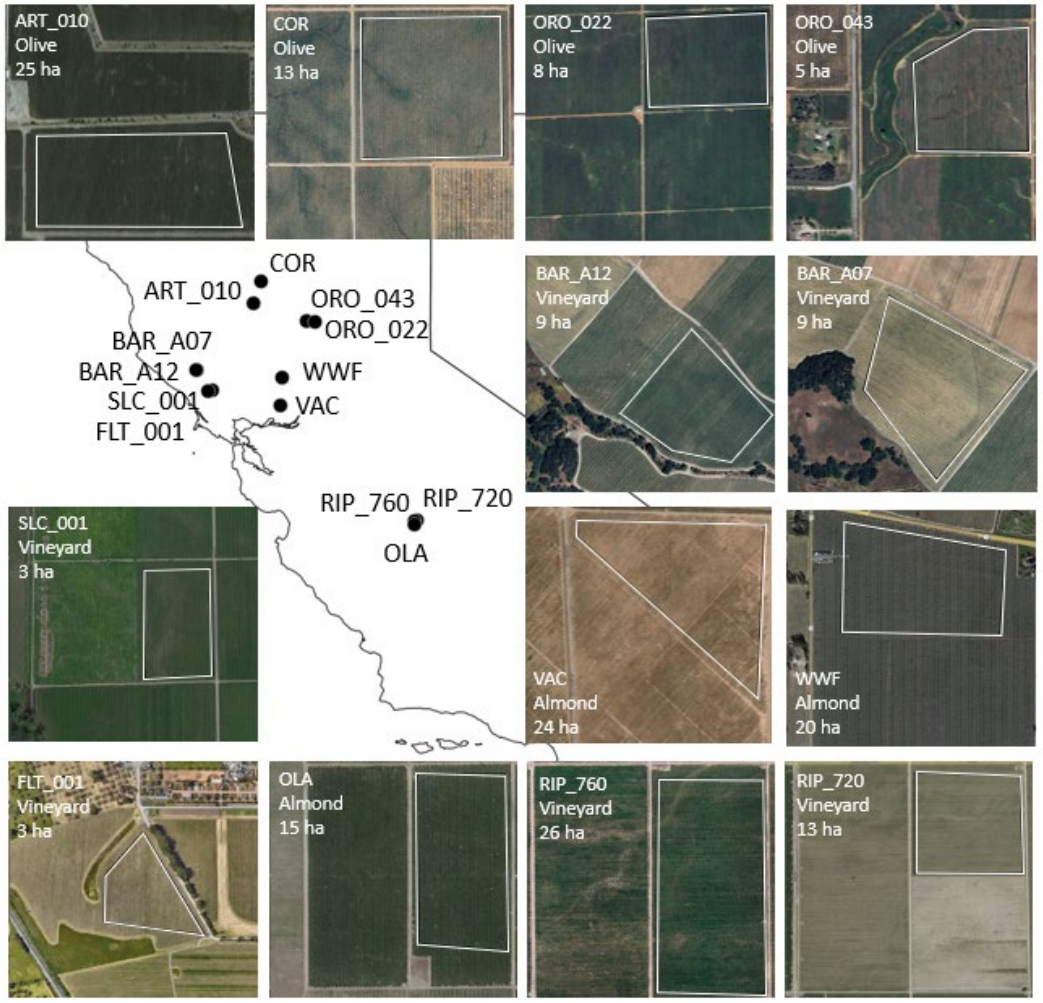
LST – T_A = empirical relationship

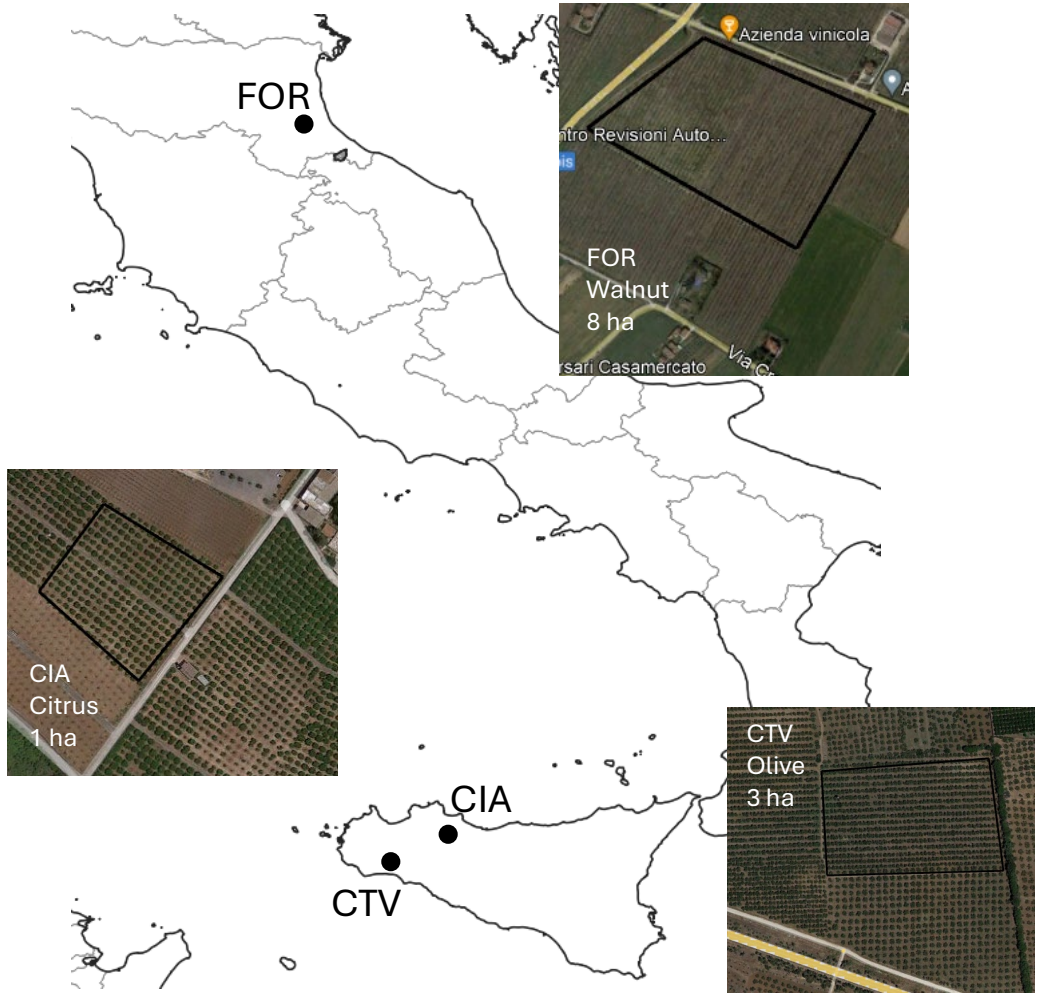




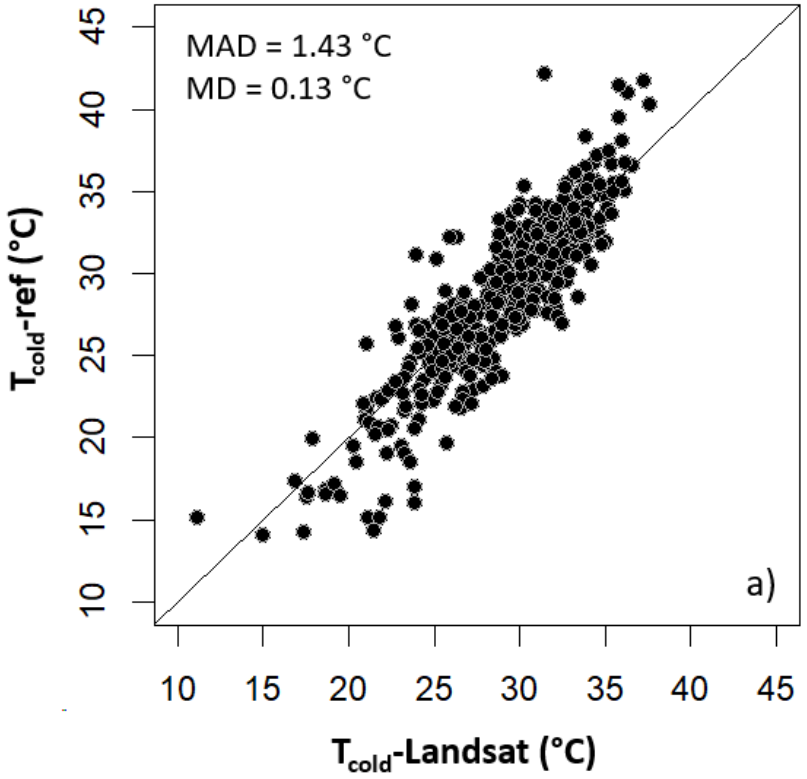
$$T_{cold} = b + (NDVI_{cold} m) - 1.25sd$$

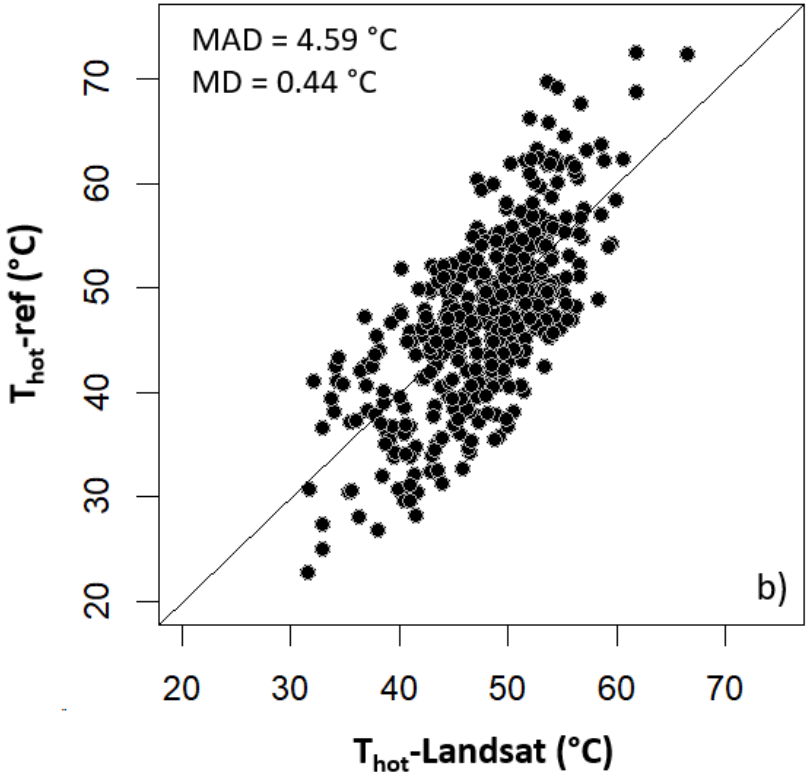
$$T_{hot} = b + (NDVI_{hot} m) + 1.25sd$$


ART_010
Olive
25 ha
COR
Olive
13 ha
ORO_022
Olive
8 ha
ORO_043
Olive
5 ha
COR
ART_010
ORO_043
ORO_022
BAR_A07
BAR_A12
WWF
SLC_001
VAC
FLT_001
BAR_A12
Vineyard
9 ha
BAR_A07
Vineyard
9 ha
RIP_760
RIP_720
OLA
SLC_001
Vineyard
3 ha
VAC
Almond
24 ha
WWF
Almond
20 ha
FLT_001
Vineyard
3 ha
OLA
Almond
15 ha
RIP_760
Vineyard
26 ha
RIP_720
Vineyard
13 ha


FOR
Azienda vinicola
FOR
Walnut
8 ha
CIA
Citrus
1 ha
CIA
CTV
CTV
Olive
3 ha

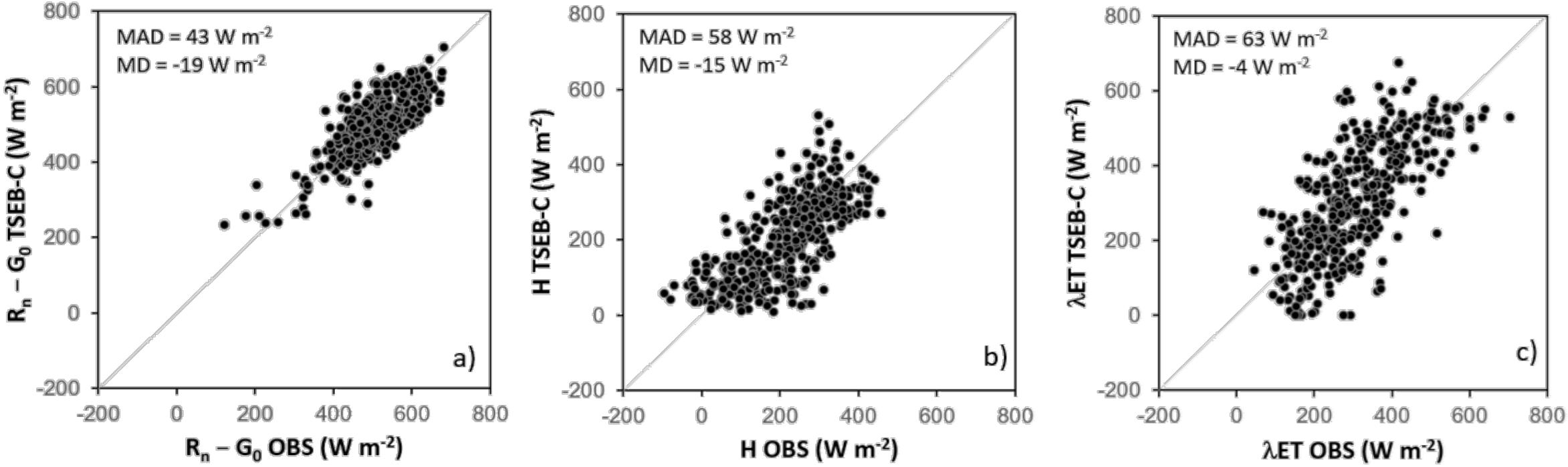
The approach was tested using Landsat data in April-September of different years.





- T_{cold} agree quite well with in-situ;
- Larger scatter for T_{hot} (wind speed);
- Both variables have low systematic bias.

The proposed model has a slight reduction in performance in H (10 W m^{-2}) and λET (20 W m^{-2}).



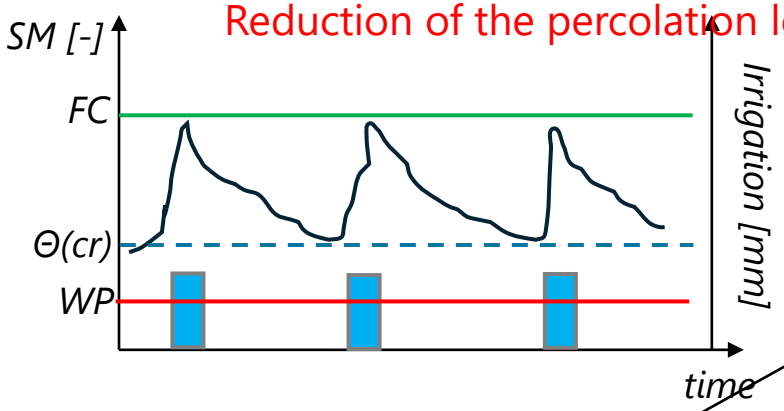
Irrigation following FAO prescription
Criterion for **soil moisture depletion**, maintain soil moisture above Θ_{crit}

3. Optimized irrigation volumes from FEST-EWB

the strategy prescribes to never overpass the FC threshold

▼

Reduction of the percolation losses



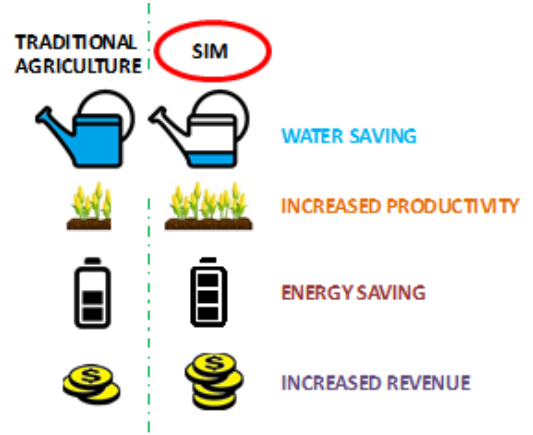
Crop	Maximum Root Depth [1] (m)	Depletion Fraction [2] (for ET ≈ 5 mm/day) p
a. Small Vegetables		
Broccoli	0.4-0.6	0.45
Brussel Sprouts	0.4-0.6	0.45
Cabbage	0.5-0.8	0.45
Carrots	0.5-1.0	0.35
Cauliflower	0.4-0.7	0.45
Celery	0.3-0.5	0.20
Garlic	0.3-0.5	0.30
Lettuce	0.3-0.5	0.30
Onions		
- dry	0.3-0.6	0.30
- green	0.3-0.6	0.30
- seed	0.3-0.6	0.35
Spinach	0.3-0.5	0.20
Radishes	0.3-0.5	0.30
b. Vegetables - Solarium Family *(Solanaceae)*		
Egg Plant	0.7-1.2	0.45

θ_{CRIT} = f(crop, cultivar, soil, climate)

θ_{CRIT} = FC-**p**(FC-WP)

The water-saving irrigation strategy concerns the management of the SM within two bounds:

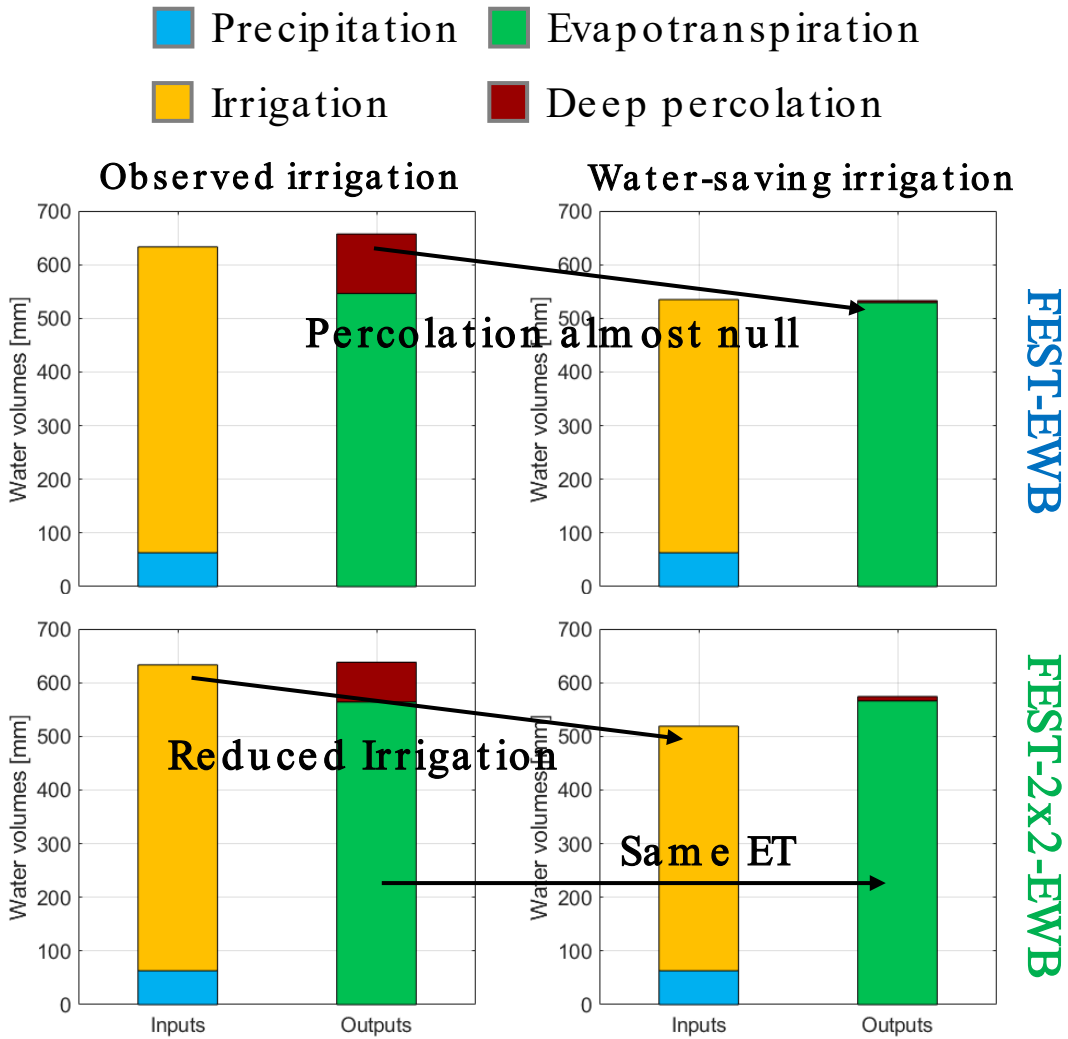
- The water stress threshold (θ_{CRIT}), below which the crop ET begins to decrease and final quality of the product worsens
- The field capacity (FC), above which deep percolation reaches values relatively comparable to the other components of the water balance



Main hypothesis: **crop yield is expected to remain constant, as SM never falls below the stress threshold.**

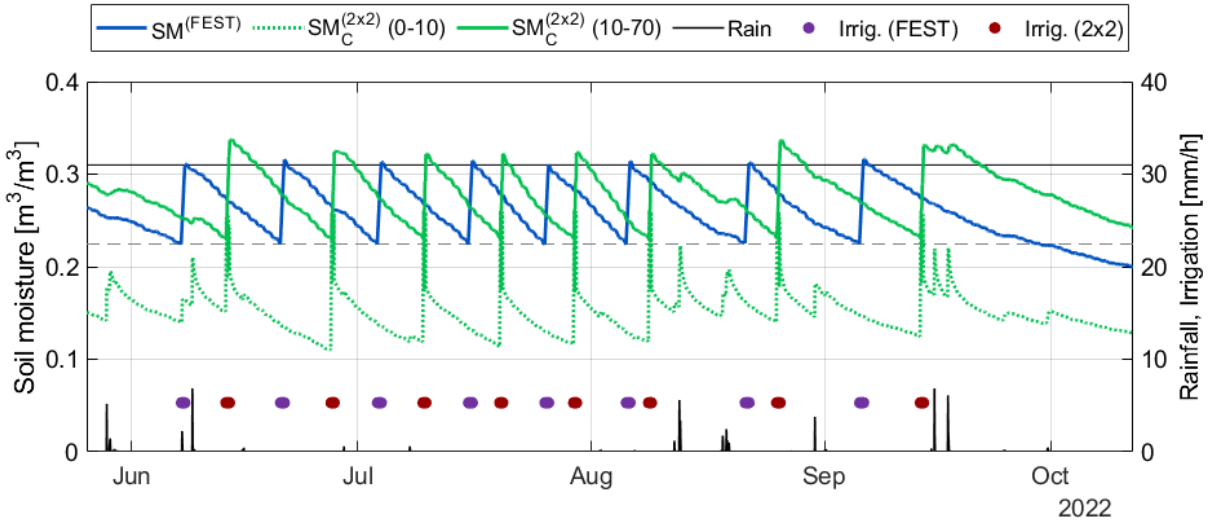
Water-saving irrigation strategy at field scale: one source vs two-sources energy-water balance scheme

The new water-saving irrigation strategy reduced the water losses due to deep percolation, preserving the Evapotranspiration (and, with it, plant activity).



For FEST-2x2-EWB, the regulation is performed on the deeper soil layer, wh stores the water available to the plant **root system**.

Both FEST-EWB and FEST-2x2-EWB agree on the minimum required irrigatio volume (472 and 456 mm, respectively), distributed over 8 irrigation events (against the **observed** 570 mm over 22 events)



Optimizing variable rate irrigation using model-based dynamic prescription maps

ESA No. 4000137200/22/I-DT-lr

Irrigated with a pivot system which allows a variable rate irrigat

HYPERCROP

European Space Agency

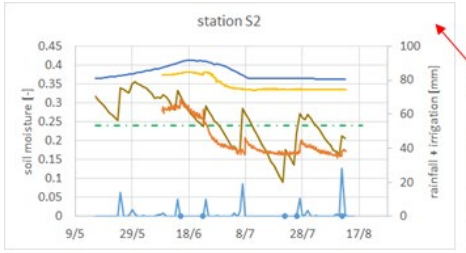
POLITECNICO MILANO 1863

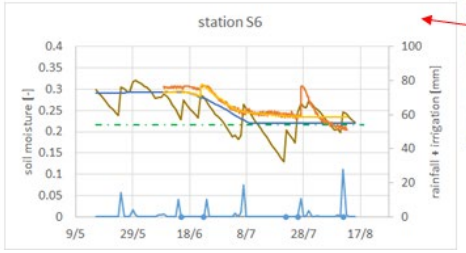
UNIVERSITÀ DEGLI STUDI DI PADOVA

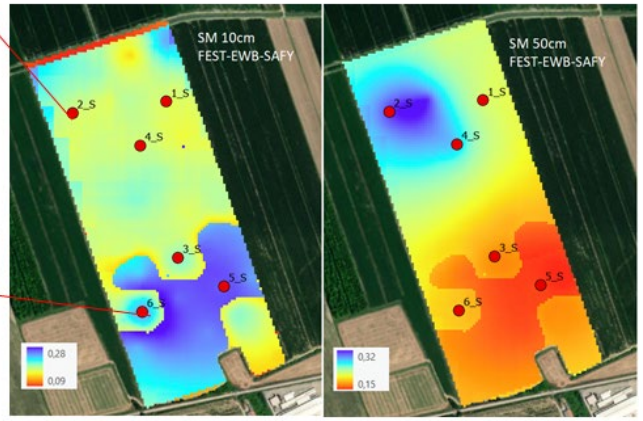




Modeled soil moisture maps







13 July 2022

https://www.sciencedirect.com/science/article/pii/S0378377424002312

Corbari et al., 2024

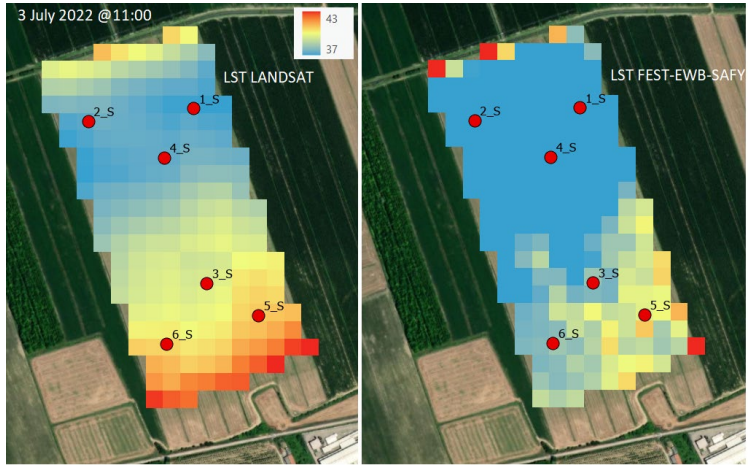
Real-time irrigation prescription maps

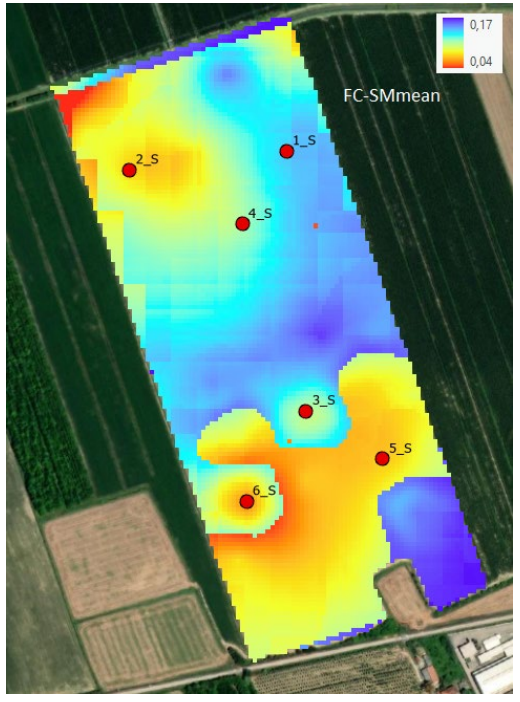
13 July 2022

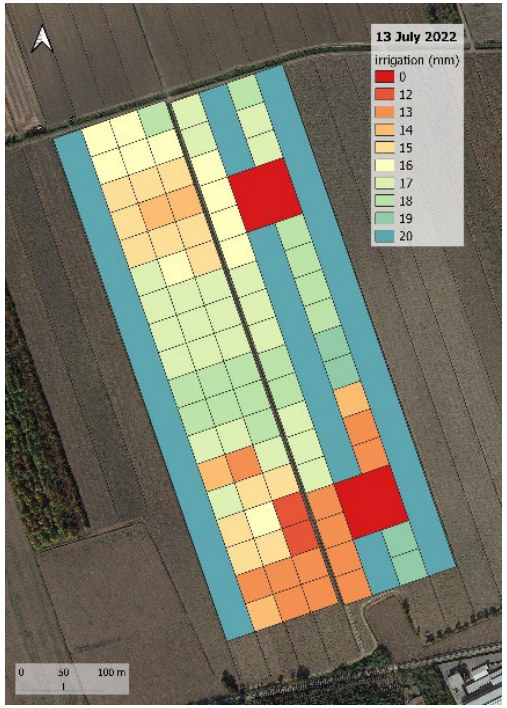
Land surface temperature maps

LANDSAT9 data

FEST-EWB-SAFY







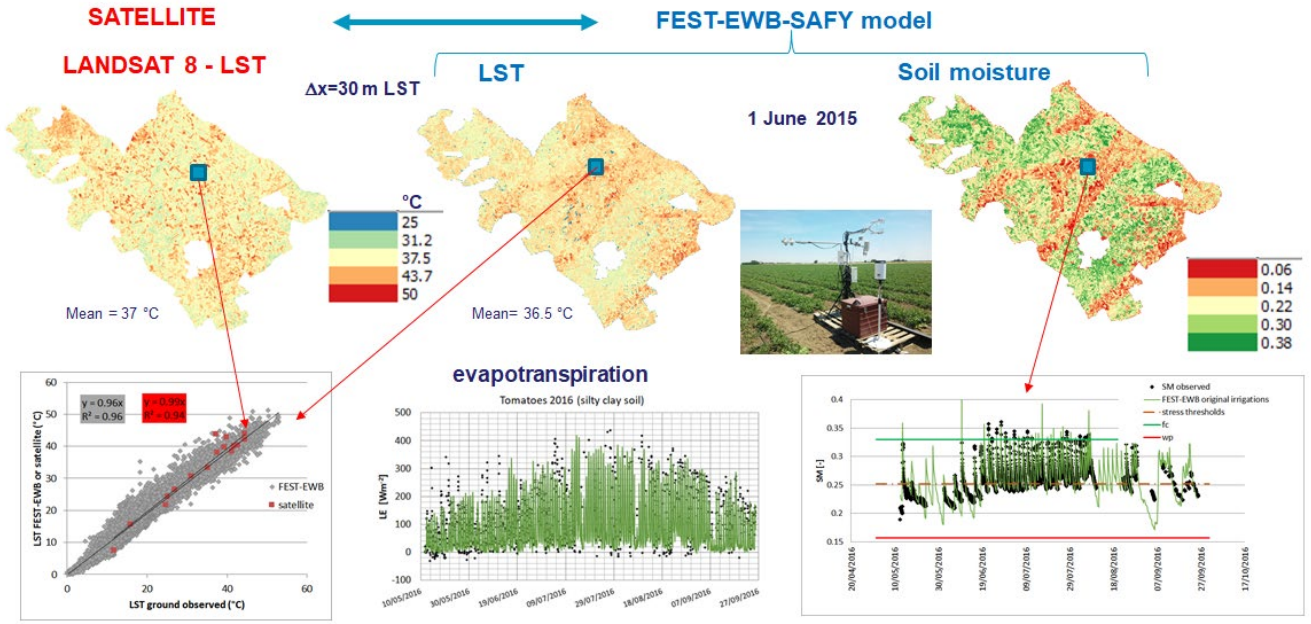
IRRIGATION OPTIMIZATION STRATEGY: Comparing water volumes at consortium scale

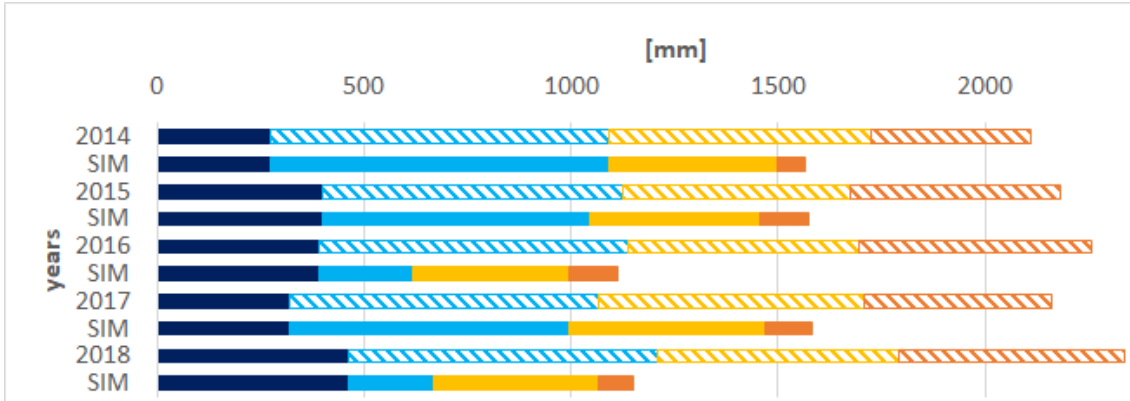
FEST-EWB model calibration at basin scale against LST and SM, validation with local EC stations





Irrigation optimization (FAO strategy on soil moisture thresholds)





https://link.springer.com/article/10.1007/s00271-022-00780-4
Corbari & Mancini 2023

Capitanata Irrigation Consortium

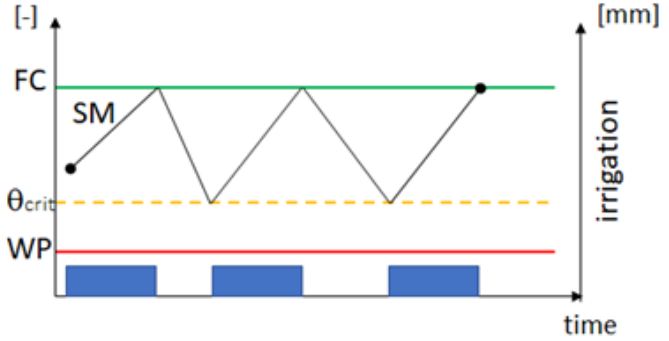


The FEST-EWB monitoring irrigation strategies

1 FAO approach

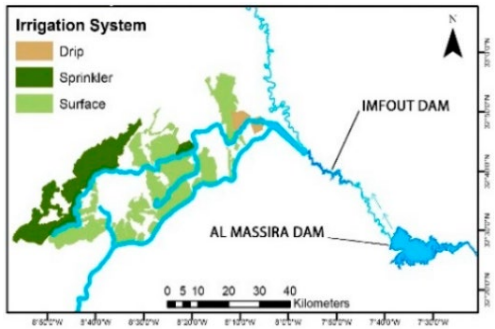
Optimal irrigation volume in between the two thresholds reducing the percolation flux

$$\boldsymbol{\Theta_{crit} = f(crop, cultivar, soil, climate)}$$



Efficiencies for different irrigation systems

Irrigation system	Overall efficiency
Surface	45%
Sprinkler	75%
Localized	90%



2 Assimilation of SMAP/Sentinel1 downscaled Soil moisture

1km spatial resolution

The irrigation volume: additional water input that, considering the water losses for drainage plus soil water storage, allows

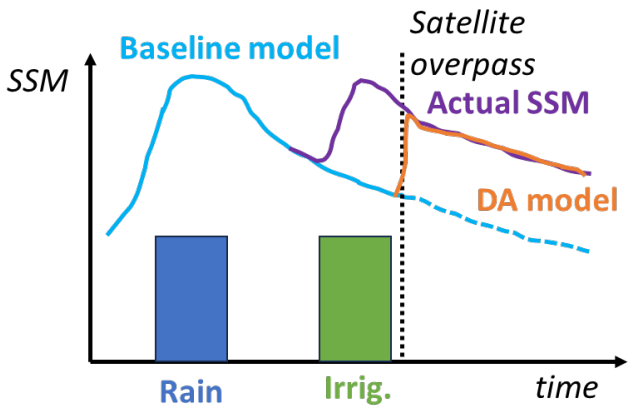
$$SM_{FEST\text{-}EWB} = SM_{satellite} + e$$

3 Assimilation of downscaled Sentinel3/2 Land surface temperature

30 m spatial resolution

The irrigation volume: additional water input that, considering the water losses for drainage plus soil water storage, allows

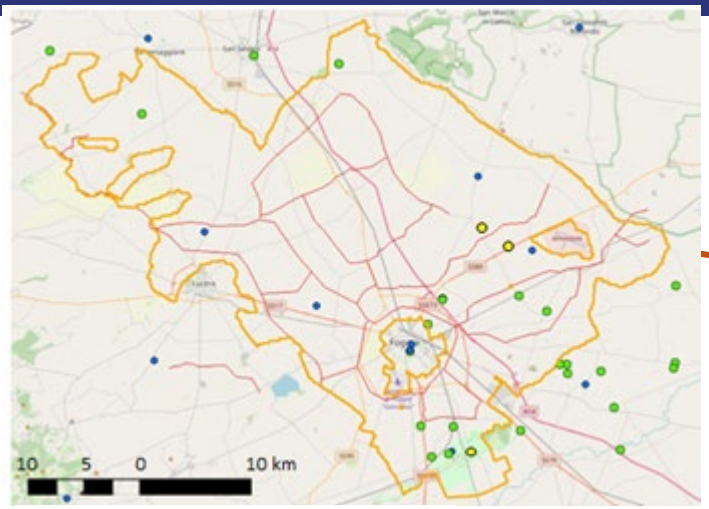
$$LE_{FEST\text{-}EWB} = LE\ (LST)_{FESTresidual} + e$$



WRR Corbari et 2025

http://dx.doi.org/10.1029/2024WR038926

An italian case study: the CAPITANATA irrigation consortium





Sud Fortore: 5900 km pressurized irrigation network aqueduct (Occhito and Celone dam)

CONSORZIO PER LA BONIFICA DELLA CAPITANATA

76 million m^3 water for irrigation a year









Capitanta Occhito dam







Main crops: tomatoes, wheat, fresh vegetables

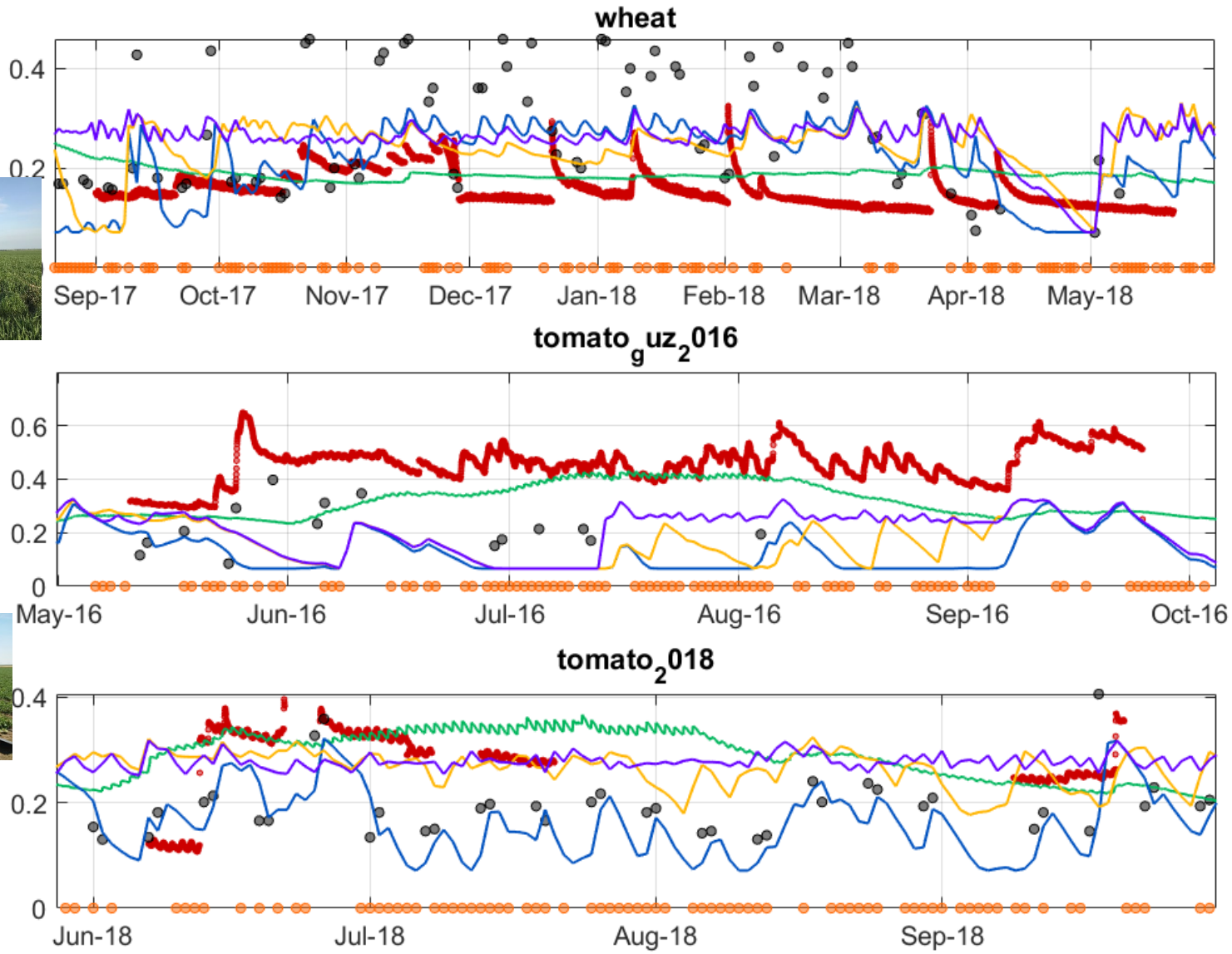
Two eddy covariance stations from 2013 - 2019 , soil moisture, irirgation volumes, crop yield

Irrigated surface	Irrigation technique	irrigation timing
50000 ha	drip (70%) & spring (30%)	on demand

Comparison between ground SM and the FEST-EWB approaches







FEST model (irriga_oss)

FEST-SM model (DA)

FEST-LST model (DA)

FEST-FAO model

SSM (ground)

SSM (Sentinel-1)

LST (MODIS)

Spatial scale inconsistencies either for summer or winter crops between the **ground** and Sentinel1 SSM as well as LST 1km

Crop	Satellite	FEST	FEST-SM
Cabbage	0.380	0.266	0.282
Wheat	0.173	0.048	0.100
Asparagus	0.129	0.077	0.117
Tomato (2016a)	0.236	0.156	0.258
Tomato (2016b)	0.121	0.233	0.155
Tomato (2018)	0.116	0.070	0.103

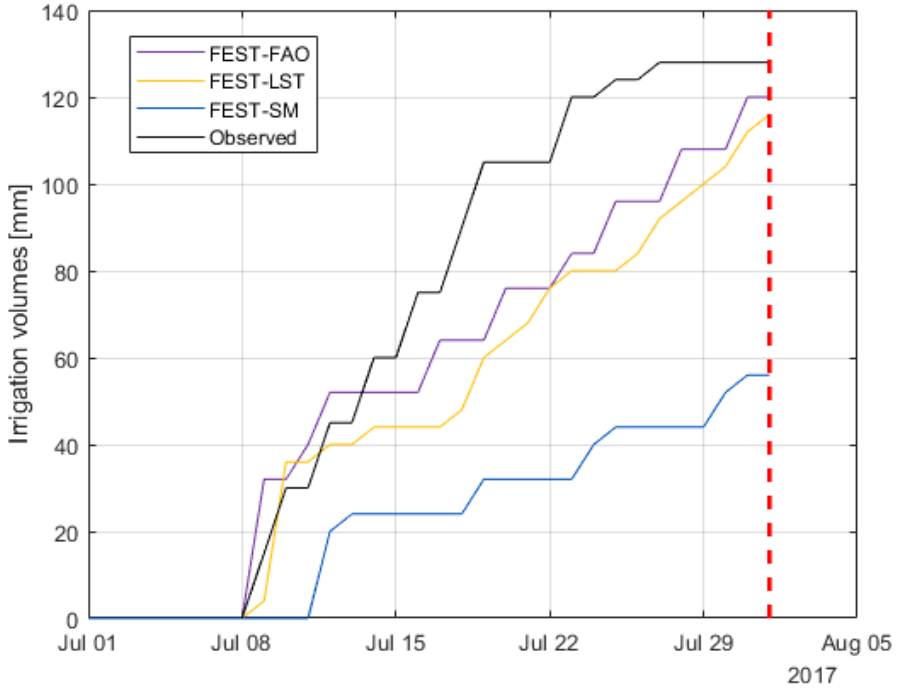
Comparison with ground measured irrigation at field scale

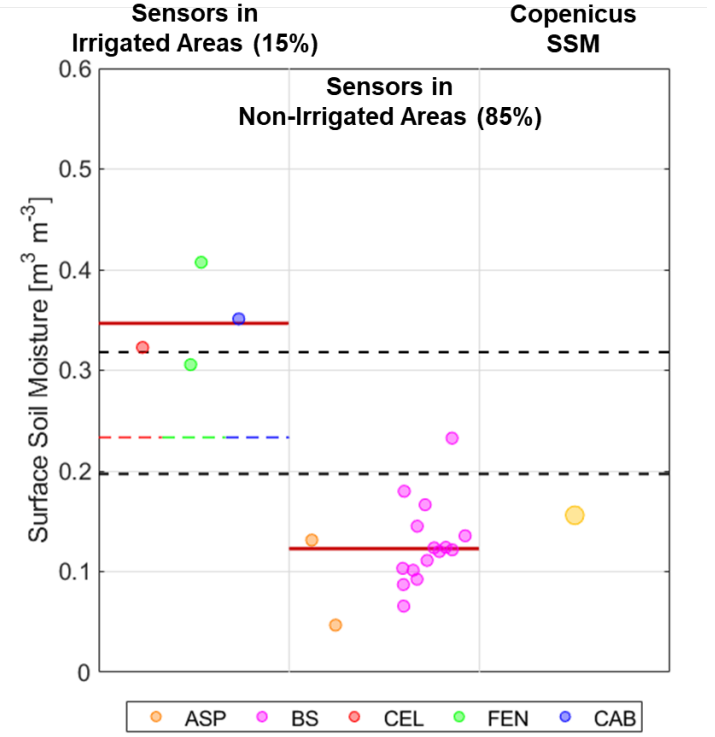
First results for one field

Inconsistencies in estimated irrigation volumes:

- Spatial variations in modelled SSM are associated with underlying vegetation information (higher resolution)
- Similar values from FEST-FAO and FEST-LST

Tomatoes field 2017



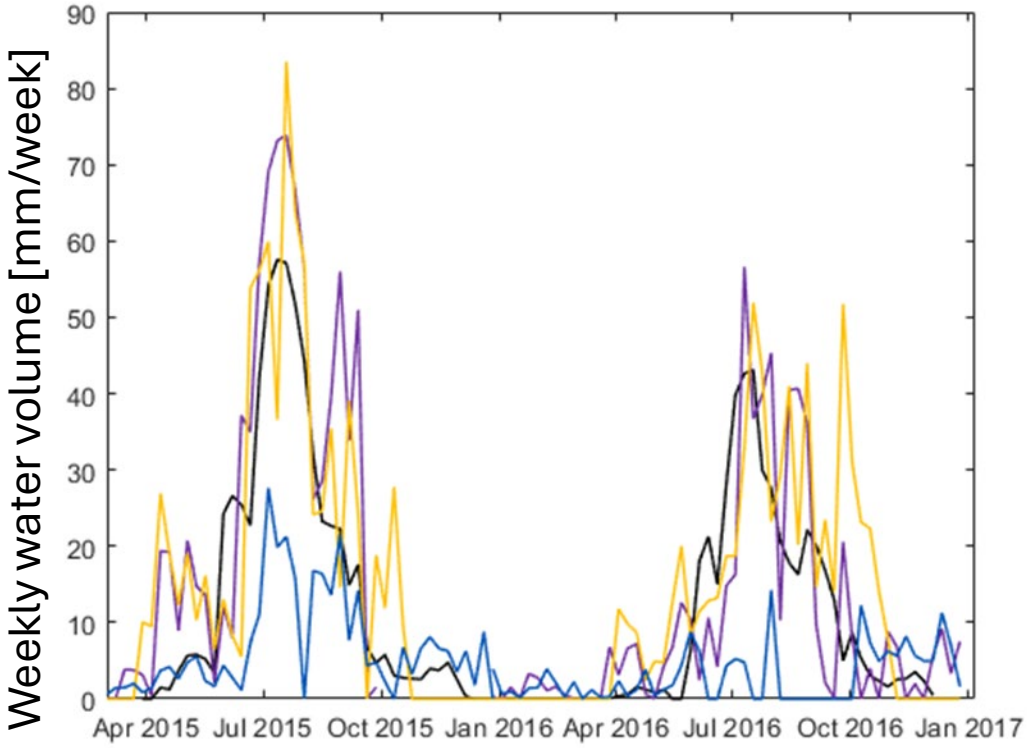


25 low cost Parrot sensors inside 1 Sentinel 1 pixel



Monitoring irrigation: simulated vs observed

Additional private water pumping wells not monitored!



$$Vol = Rate(mm) x\ AreaPixel\ x\ NonWheatFraction\ (Tomato + WinterVeg)$$

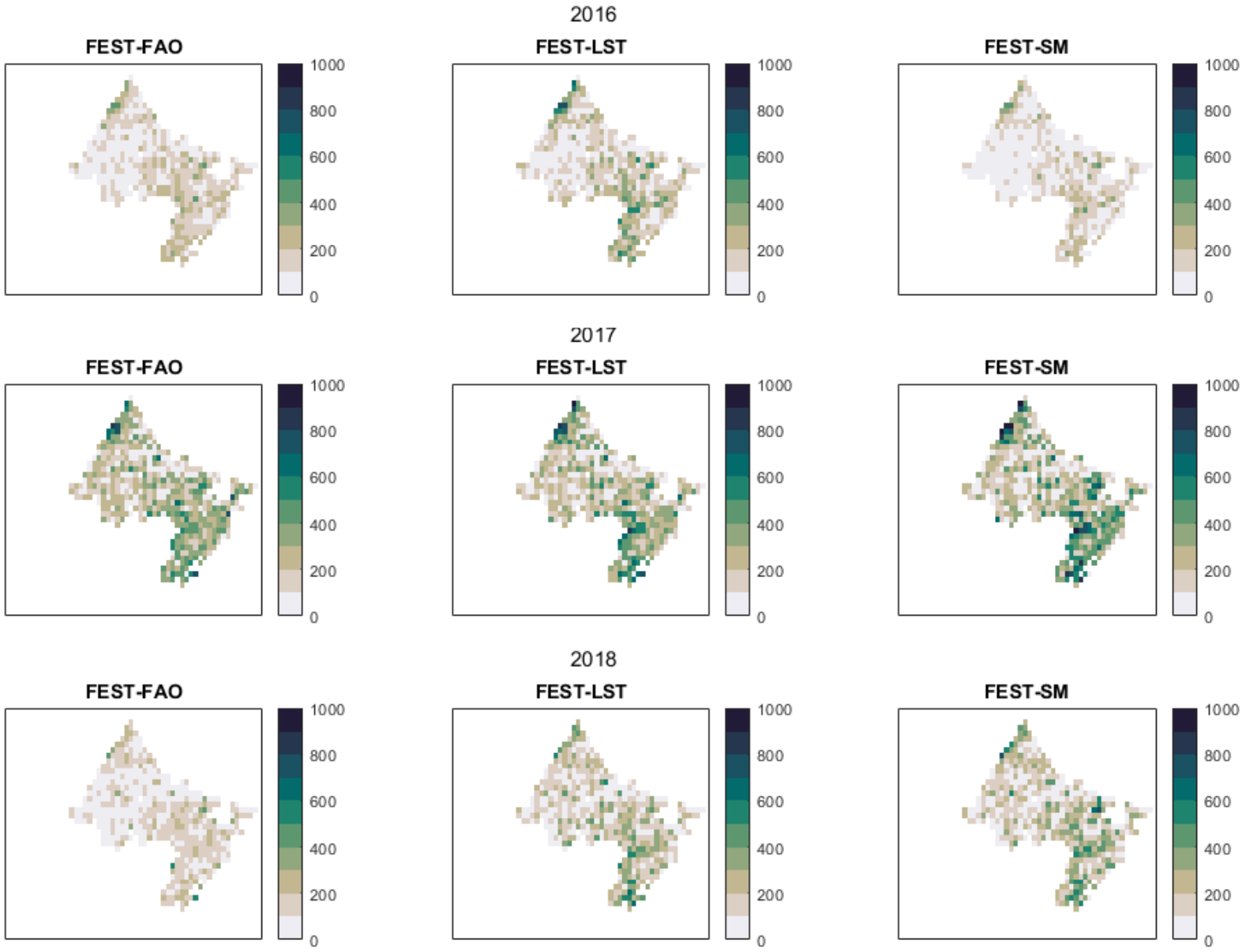
System efficiency 90%

Year	# images Sentinel-1 (SSM)	# images MODIS (LST)
2015	67	165
2016	62	167
2017	99	177
2018	90	160
2019	90	139

MODIS LST - With at least 70% of consortium coverage, we get **one image every two days**
Sentinel-3A from feb 2016 - Sentinel-3B from apr 2018

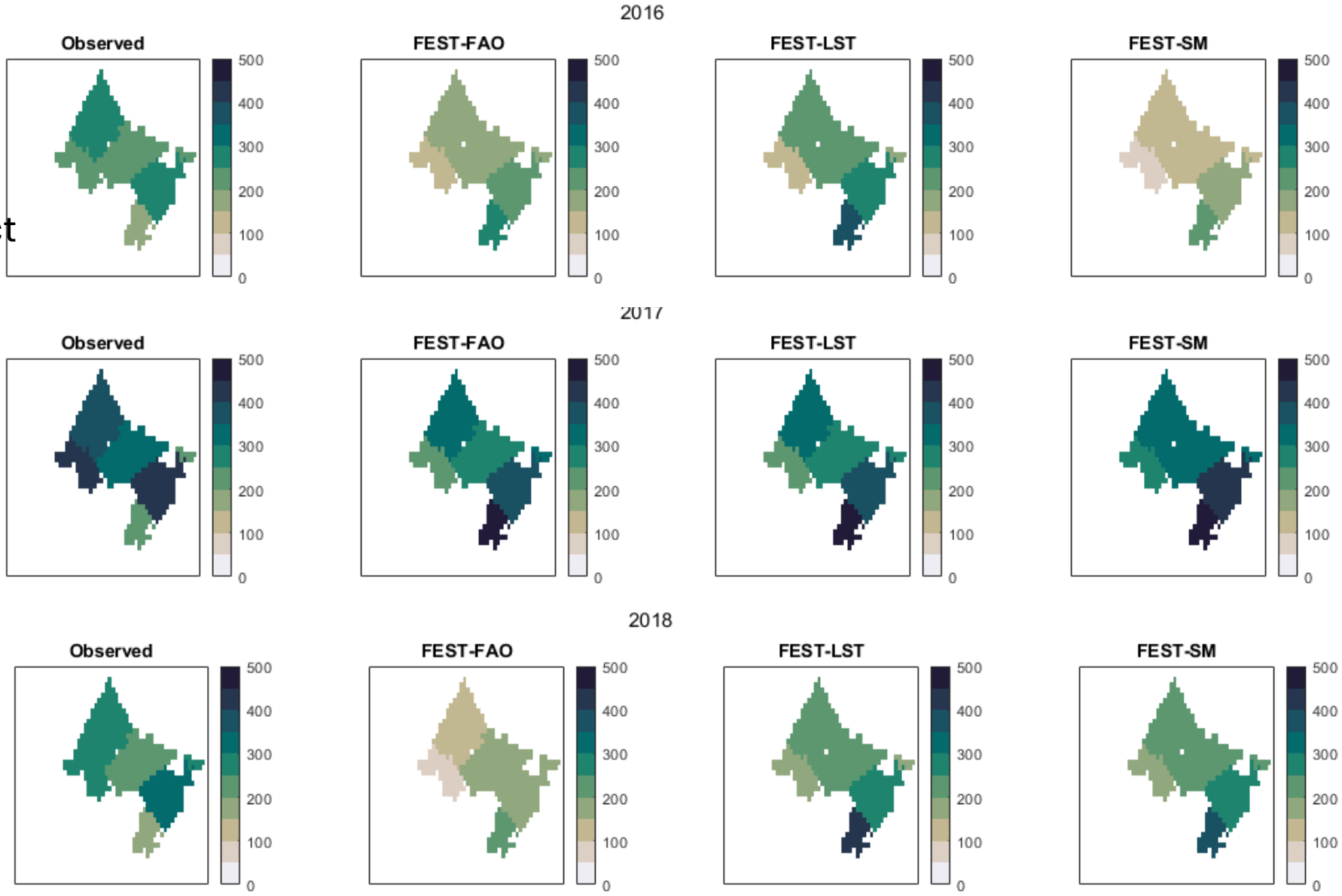
Monitoring irrigation: pixel based extimates

At pixel level



Monitoring irrigation: simulated vs observed aggregated information over the water distribution districts

For operative applications: district areas aggregation



Testing LAI-Based equation for vegetation roughness computation in 1D hydraulic models

Verónica Herrera Gómez, Giovanni Ravazzani, Marianna Mattiazzi, Marco Mancini

Objectives

- Investigate the impact of arboreal vegetation on hydraulic roughness and flood routing and extent.
- Test a LAI based equation to assess Manning hydraulic roughness coefficient .

LAI-BASED EQUATION

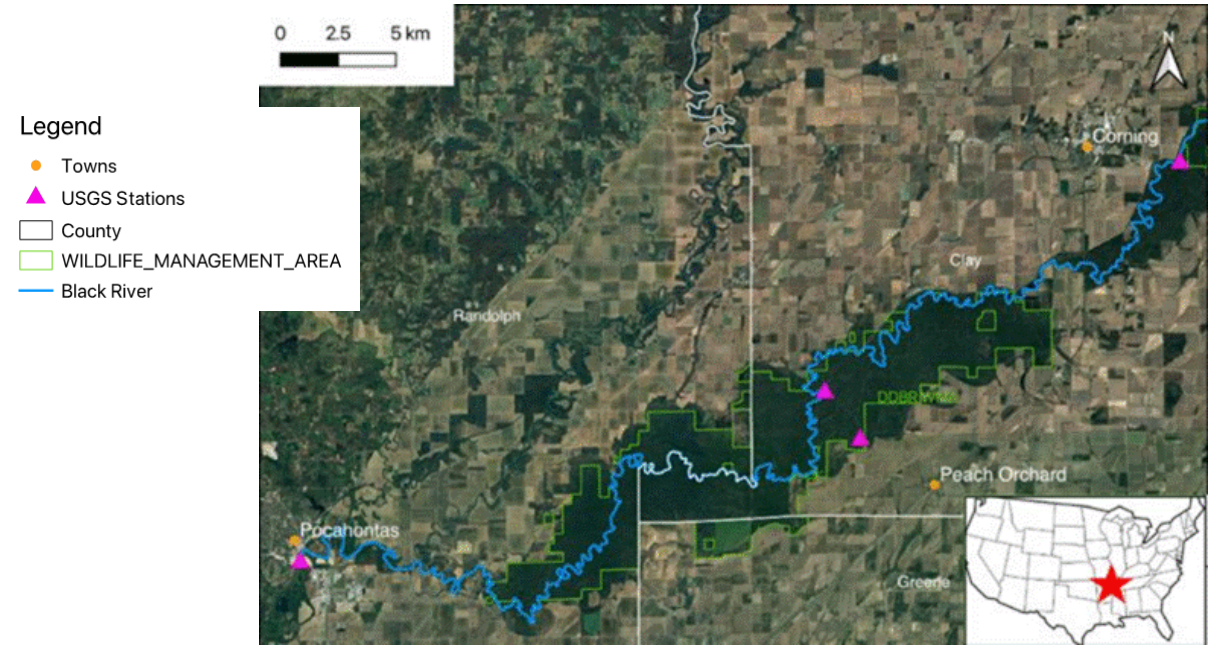
Järvelä (2004): $f = 4C_{D\chi}LAI\left(\frac{U}{U_\chi}\right)^{\chi}\frac{h}{h_v}$



Black River flood, Arkansas, USA

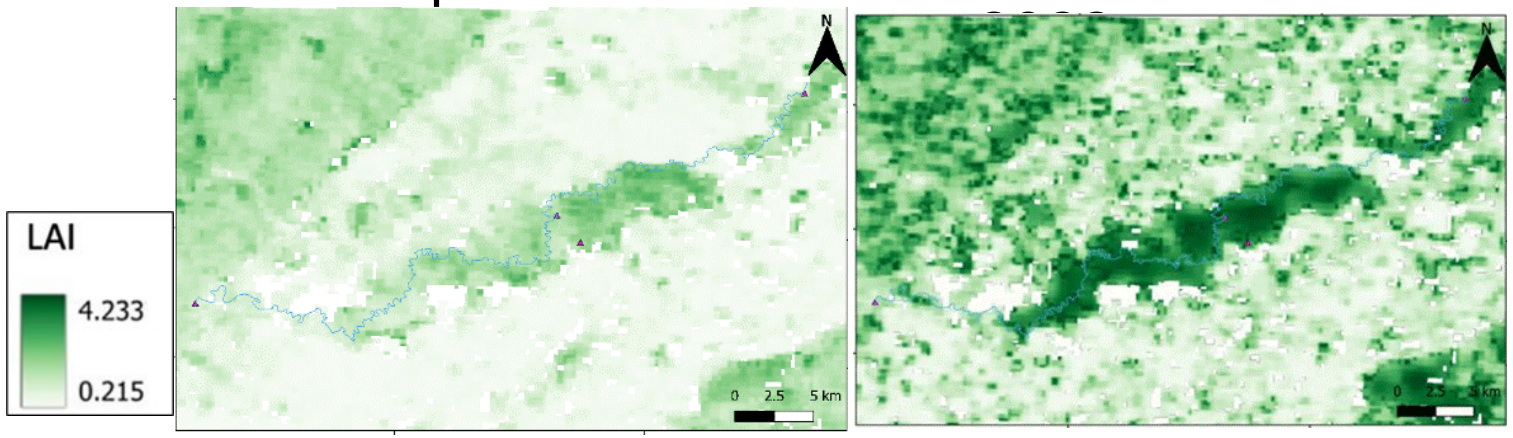
Study area: Black River, Arkansas, USA

- **River reach between Corning and Pocahontas:** 120 km
- **Basin area at Corning**: 4532 km^2
- **Mean annual discharge at Corning**: 55 m^3/s
- **River monitoring stations**:
  - Upstream: Corning
  - In the middle: Peach Orchard
  - Downstream: Pocahontas
- **Vegetation characteristics**:
  - 33% basin fraction vegetation coverage
  - Species: Taxodium distichum, Pinus taeda, Acer rubrum, Quercus sp., Populus sp.
  - Vegetation density: 2000 tree/ha
  - Tree height: 15 m
  - Tree diameter: 21 cm



April 2022

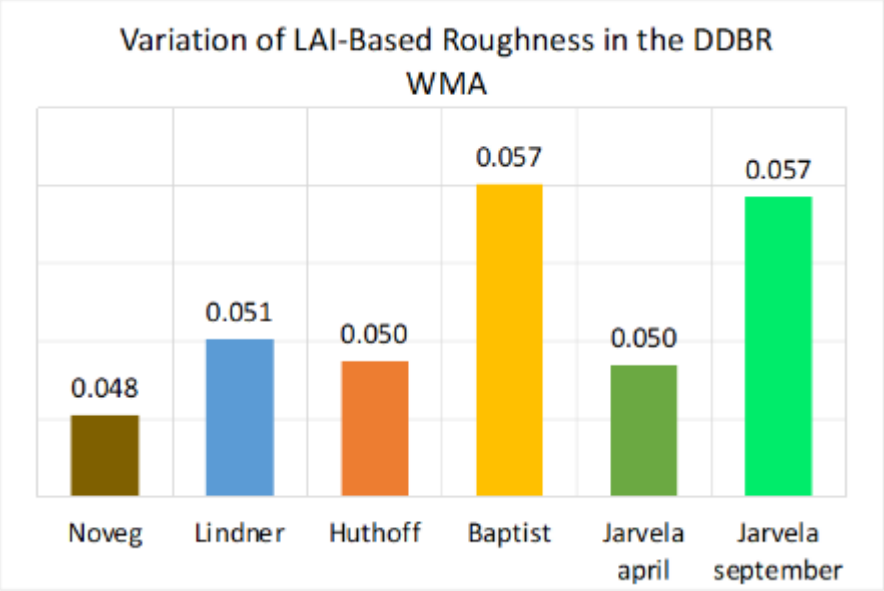
September

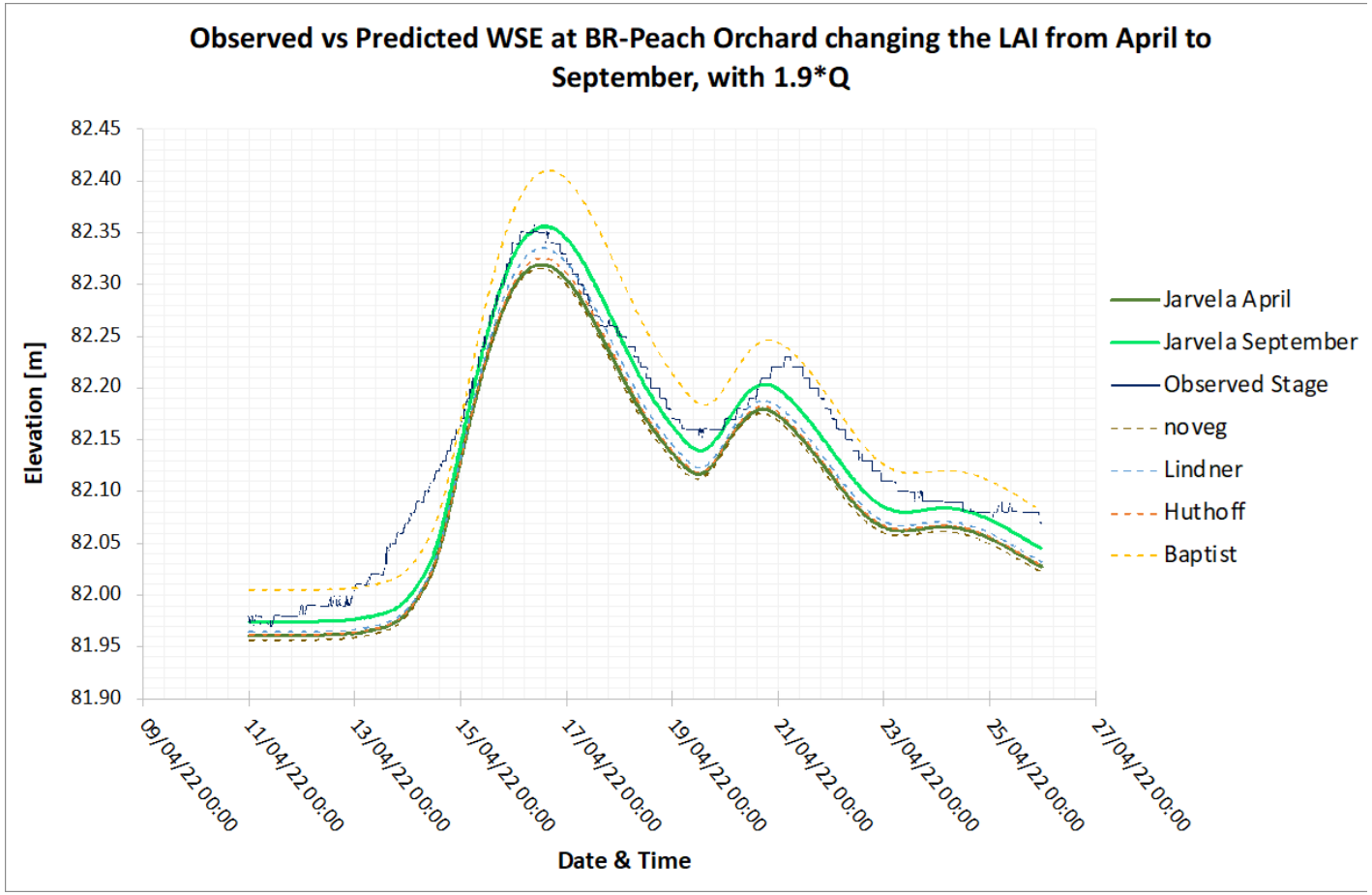


Copernicus Europe's eyes on Earth
Land Monitoring Service

Impact on flood hydrograph

- A change in LAI has impact on water surface elevation: denser vegetation implies greater roughness coefficient





Thank you!

2025 DRAGON 6 SYMPOSIUM

14-18 JULY 2025

[PROJECT ID. 95424]

SATELLITE DATA APPLICABILITY AND ACCURACY AT DIFFERENT SPATIOTEMPORAL SCALES FOR SUSTAINABLE AGRICULTURAL WATER MANAGEMENT (SAA4WATER)



