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2023 DRAGON 5 SYMPOSIUM

3rd YEAR RESULTS REPORTING

11-15 SEPTEMBER 2023

[PROJECT ID. 59061]

Satellite Observations for Improving Irrigation Water Management (SAT4IRRIWATER)

Sept. 13, 2023

ID. 59061

Project Title: Satellite Observations for Improving Irrigation Water Management (SAT4IRRIWATER)

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Co-authors:

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Presented by: Prof. Li JIA

Objective

- to **develop data products or information using satellite observations with high accuracy and continuously spatial and temporal coverage →** essential to support monitoring and modelling of agricultural water use and efficiency at farm and basin scales.
- to **assess irrigation water needs and crop water productivity based on the integrated use of satellite data with high resolution, ground hydro-meteorological data and numerical modelling →** particularly significant for large ungauged agricultural areas.

For the 3rd year, we focus on:

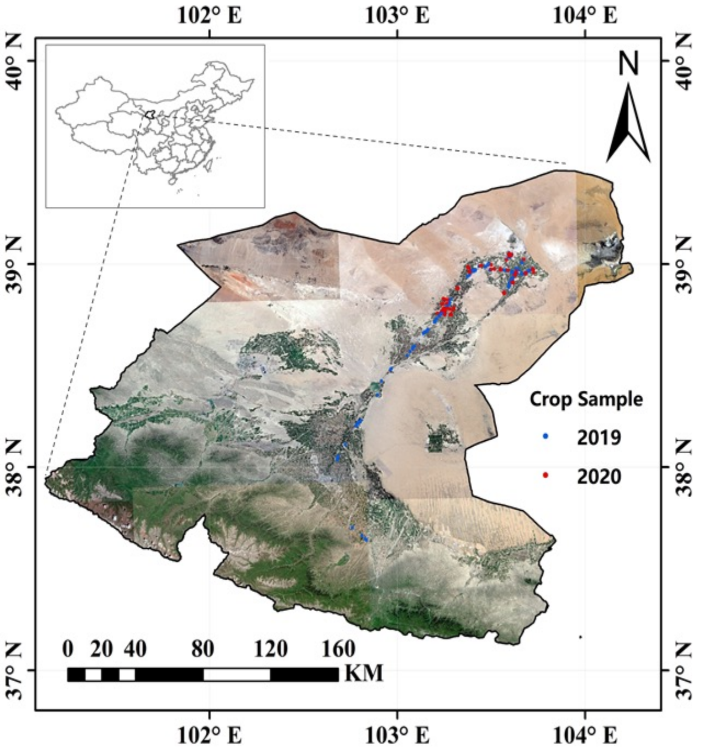
1. **Early-season crop identification using Sentinel-2 MSI data**
2. **Estimation of crop biomass accumulation and yield at high resolution in Shiyang river basin using multiple satellite data**
3. **Global high-resolution (1-km) surface soil moisture dataset**
4. **Topographic effect on soil moisture retrieval by SMOS data** (poster 145)
5. **Evaluation of Evapotranspiration Partitioning Methods for Water Accounting** (poster 142)
6. **Climate variability and land use/land cover change on the water balance in the Sahel** (poster 218)
7. **FEST-EWB model improvement in evapotranspiration estimates over crop trees areas**
8. **Optimized irrigation volumes from FEST-EWB and from FEST-2X2-EWB**
9. **Modelling of soil-plant-atmosphere interactions for tree crops** (poster 122)

1. Early-season crop identification using Sentinel-2 MSI data and deep learning algorithms

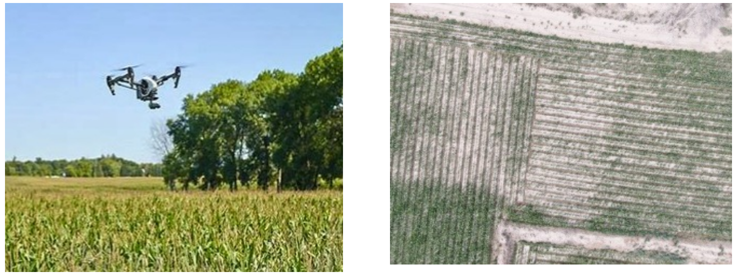
To fully exploit the potential of **deep-learning algorithms** and time-series **Sentinel-2** data for **early-season crop identification** and **early-season crop mapping**.

Shiyang river basin, northwestern China

- arid and semi arid
- spring wheat, maize, sunflower, fennel, alfalfa, melon.



Samples of plots' polygons from 2020 in UAV images



Drone-based ground samples

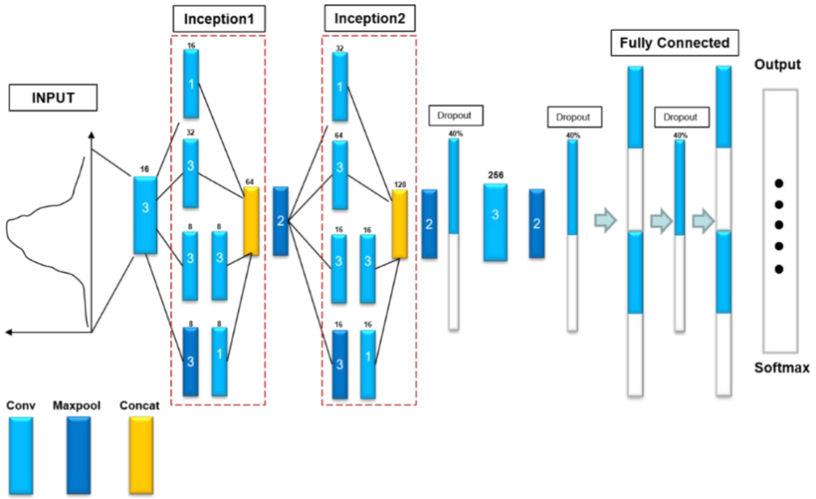
Field campaign:
Collection of Ground Samples

Class	Sample number
Wheat	2636
Corn	3702
Sunflower	2522
Melon	3562
Alfalfa	2909
Fennel	1549

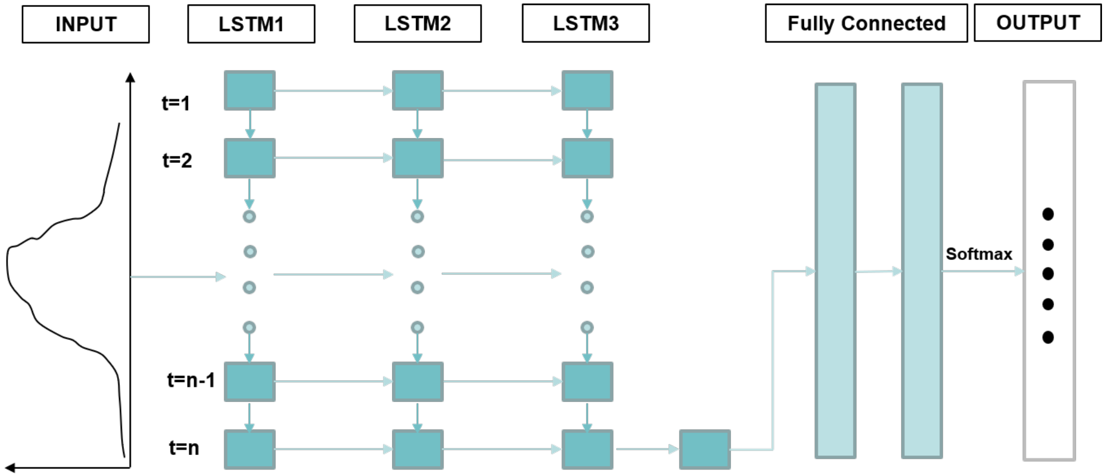
1. Early-season crop identification using Sentinel-2 MSI data and deep learning algorithms

❑ Deep learning models

- one-dimensional convolutional neural network (Conv1D)



- long short-term memory (LSTM)



❑ Shallow machine learning models

- Random Forest (RF)
- Support vector machine (SVM)

Yi et al., 2022

1. Early-season crop identification using Sentinel-2 MSI data and deep learning algorithms

❑ Feature construction

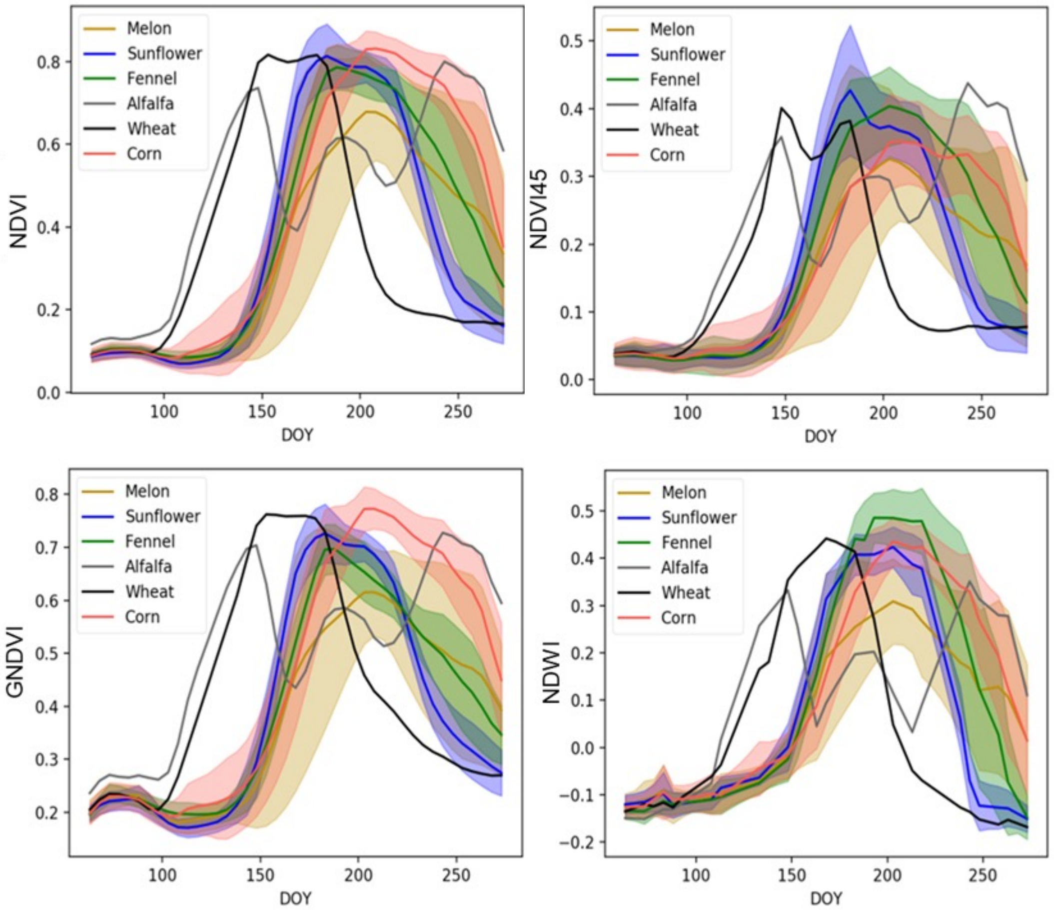
Sentinel-2 spectral index

$$NDVI = \frac{NIR - R}{NIR + R}$$

$$NDVI45 = \frac{RE1 - R}{RE1 + R}$$

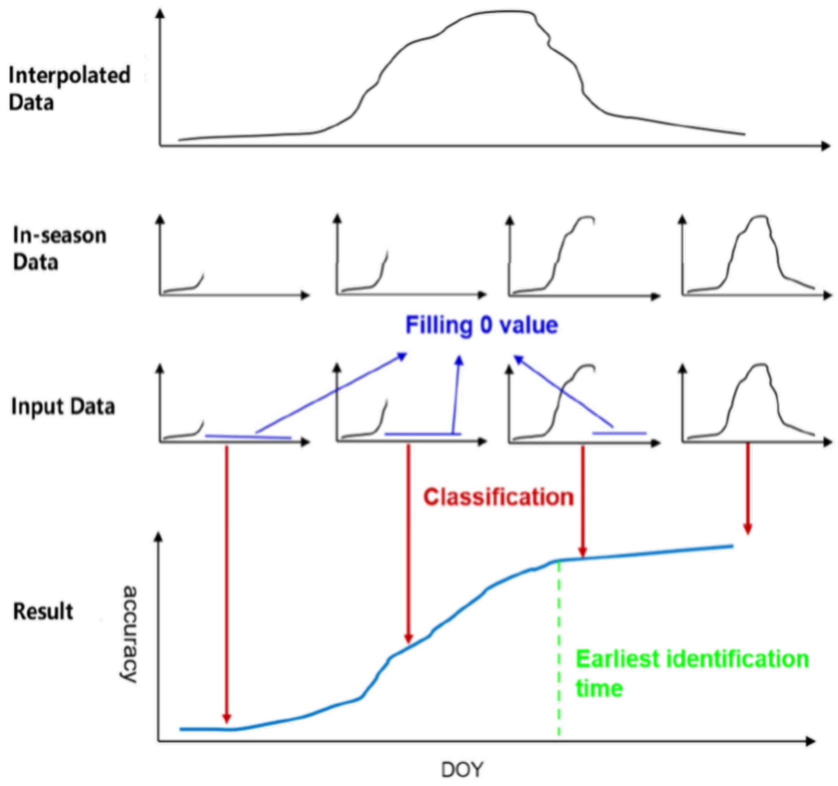
$$GNDVI = \frac{NIR - G}{NIR + G}$$

$$NDWI = \frac{NIR - SWIR1}{NIR + SWIR1}$$



Yi et al., 2022

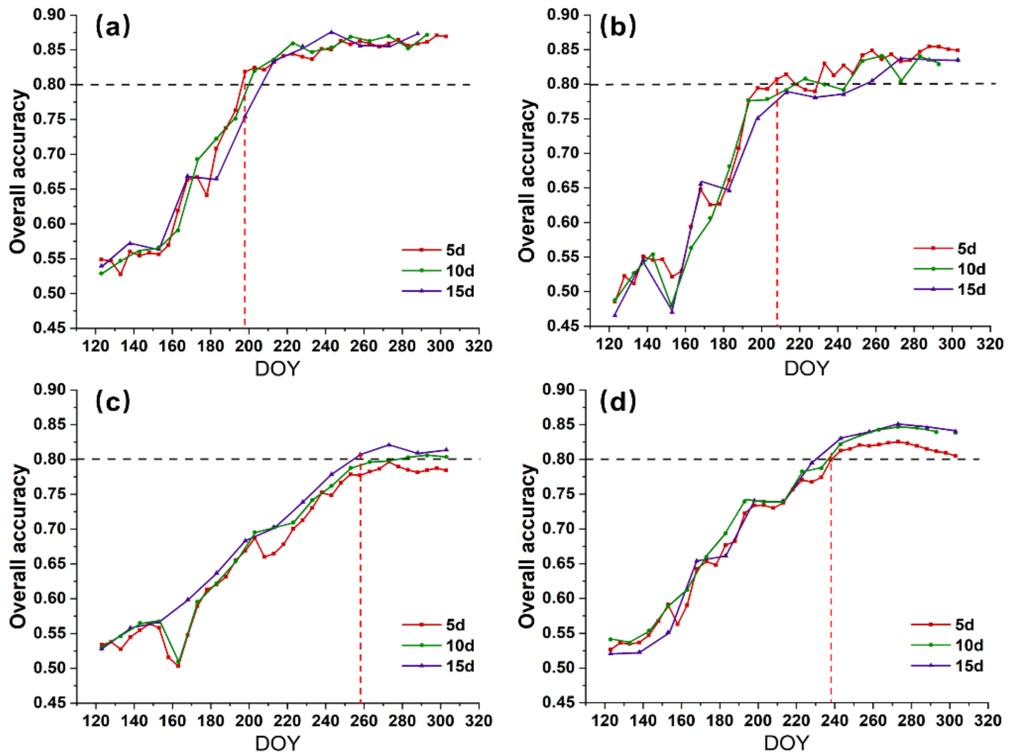
- **Crop earliest identification time based on the Sentinel-2 time series data**

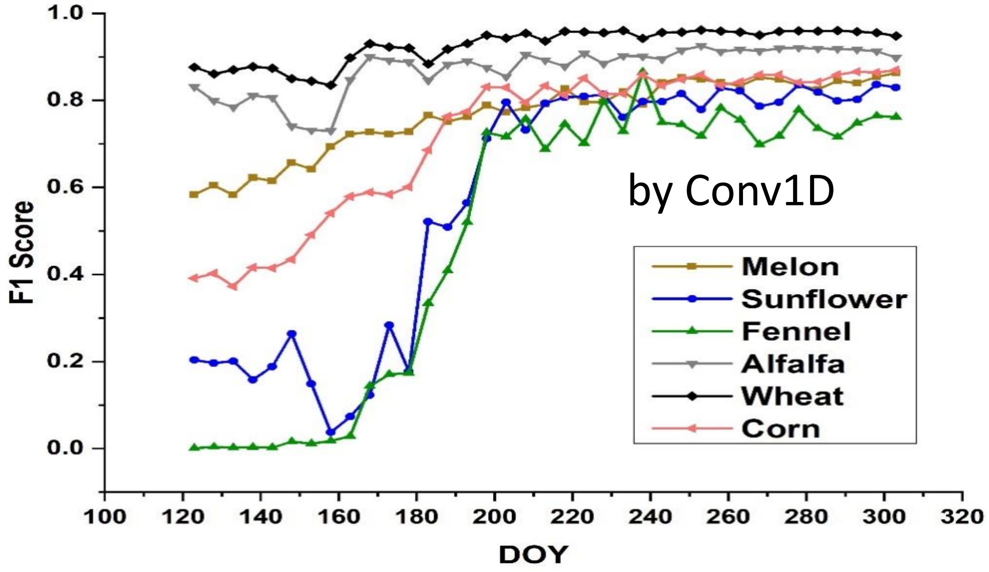


1. Early-season crop identification using Sentinel-2 MSI data and deep learning algorithms

❑ Results

Overall accuracy





Month	Mar.	Apr.			May			June			July			Aug.			Sept.			Oct.		
Croptype		E	M	L	E	M	L	E	M	L	E	M	L	E	M	L	E	M	L	E	M	L
Sunflower				1		2			3		4		5		6		7					
Fenel			1			2				3		4						5				
Alfalfa	1								2						3					4		
Wheat	1	2				3			4				5									
Corn				1		2				3			4		5		6	7				

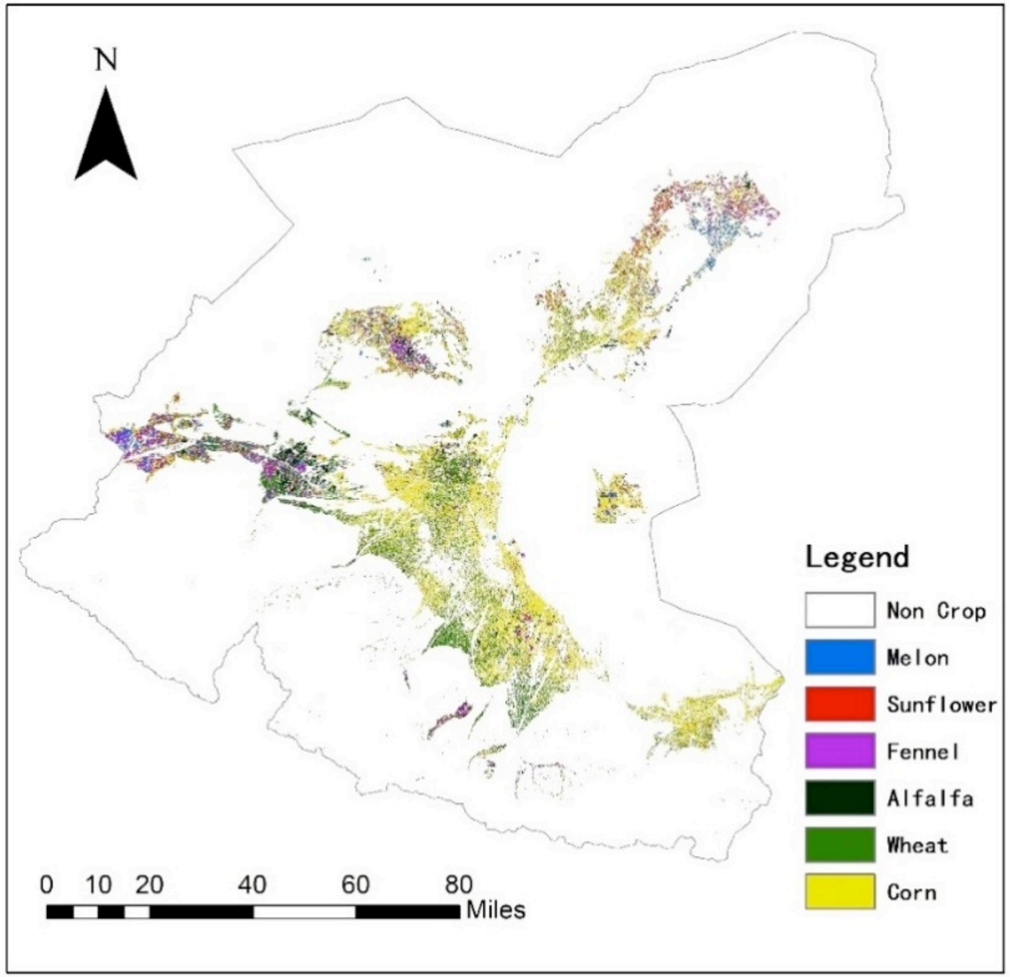
Conv1D network and 5-day interval time-series Sentinel-2 data outperformed the other schemes in obtaining the early-season crop identification time and achieving early mapping

Yi et al., 2022

Mid-term Results 2: Crop mapping by Sentinel-2 MSI data

1. Early-season crop identification using Sentinel-2 MSI data and deep learning algorithms

❑ Results



Early-season crop map of 2020
Shiyang River Basin

- Early-season crop map of 2020 by Conv1D and images acquired from DOY63 (early March) to DOY198 (mid of July) in 2020,
- Conv1D network was trained using the images acquired before DOY198 in 2019 and samples from 2019

overall accuracy : 0.81
kappa coefficient: 0.79.

Yi et al., 2022

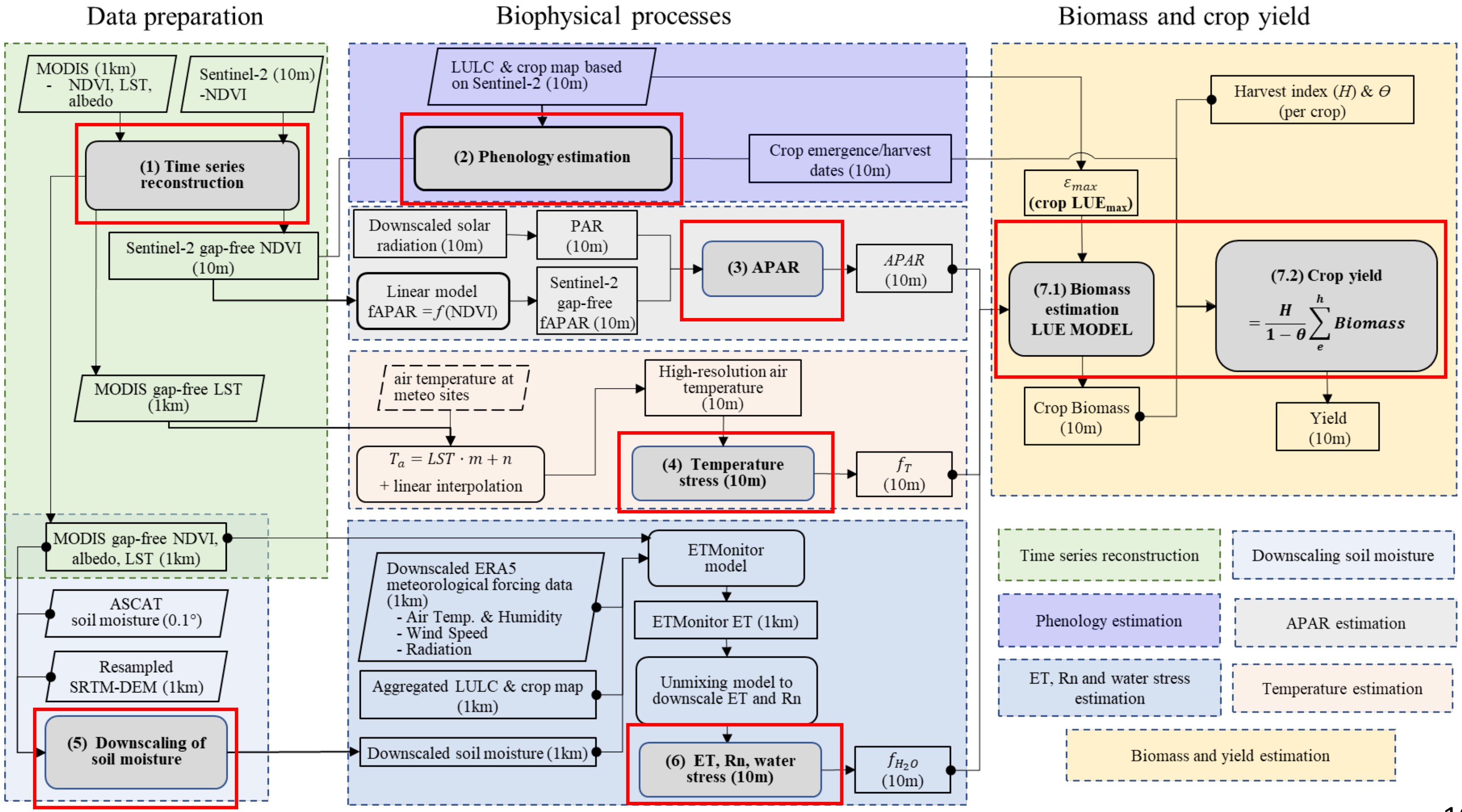
2. Biomass accumulation and crop yield estimation in Shiyang river basin

A new model was developed to estimate crop biomass accumulation and yield, with fully distributed and high spatial resolution, and applied to a Shiyang basin with highly heterogeneous desert-oasis agroecosystem.

Challenge: Lack of continues time series data at high resolution due to low frequency of revisit, clouds impact, etc.

Parameterizations:
- ✓ crop phenology
- ✓ absorbed PAR (APAR)
- ✓ LUE
- ✓ biomass accumulation
- ✓ crop yield

Forcing:
- ✓ Sentinal-2 / MSI reflectance
- ✓ ASCAT soil moisture
- ✓ ETMonitor ET
- ✓ MODIS data

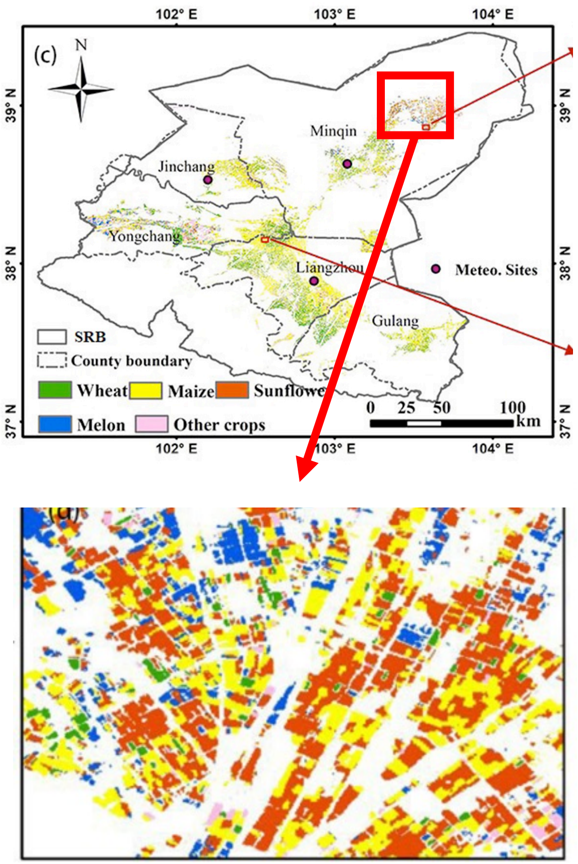


Chen et al., 2022

2. Biomass accumulation and crop yield estimation in Shiyang river basin

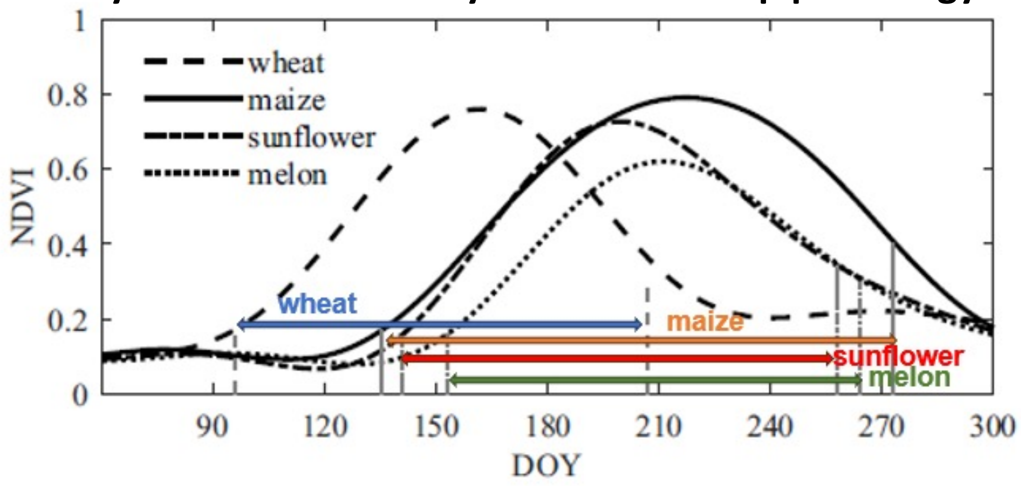
The change of crop conditions at field scale during the growing season are captured. The gaps in crop classification, soil moisture, ET, and environmental conditions, are mitigated by applying data fusion and downscaling.

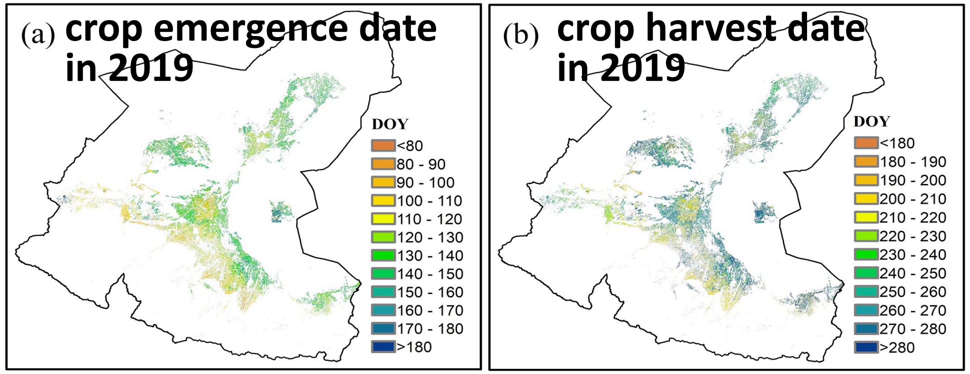
crop classification, 2019



Yi et al., 2022

daily NDVI time series by HANTS and crop phenology





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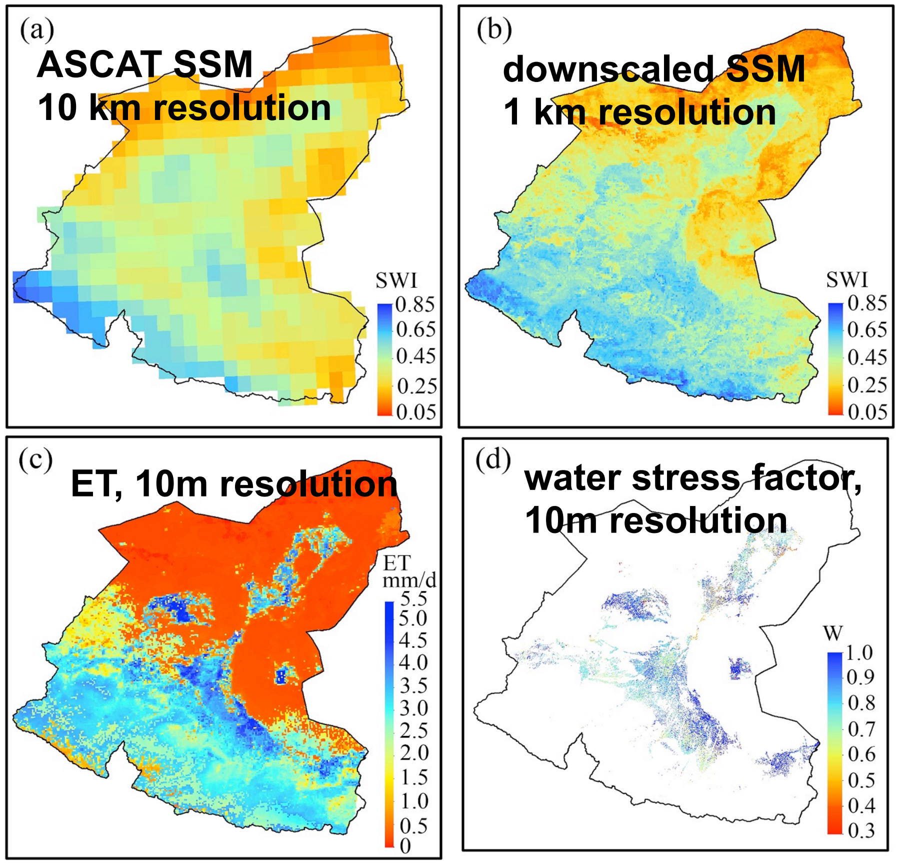
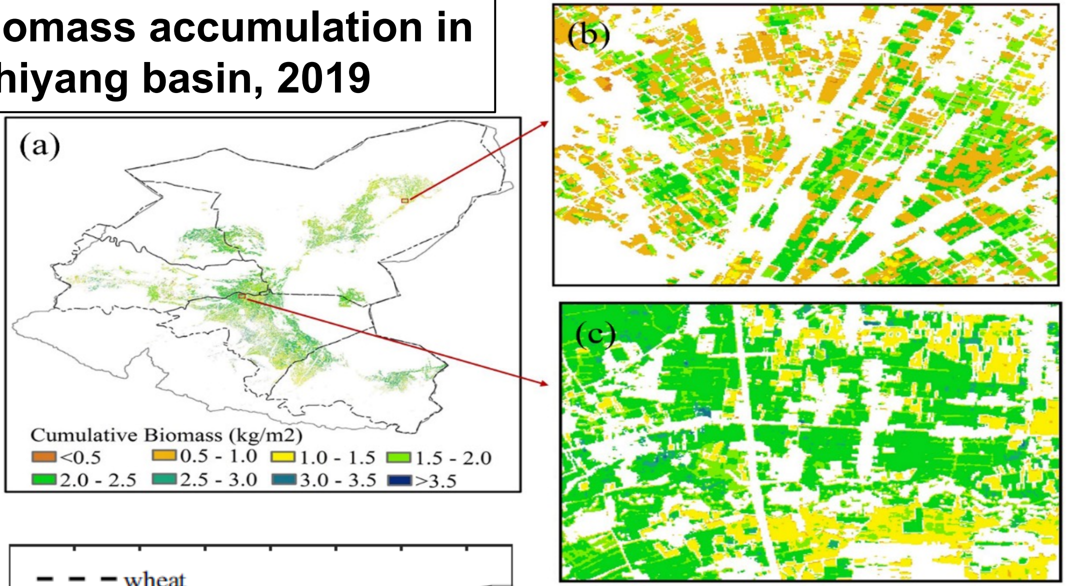
water stress factor, Aug. 16th, 2019

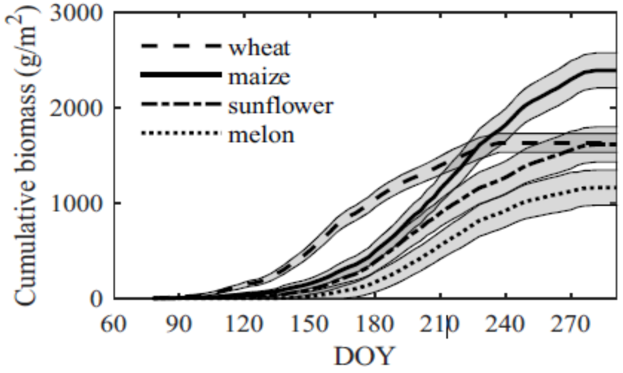


2. Biomass accumulation and crop yield estimation in Shiyang river basin

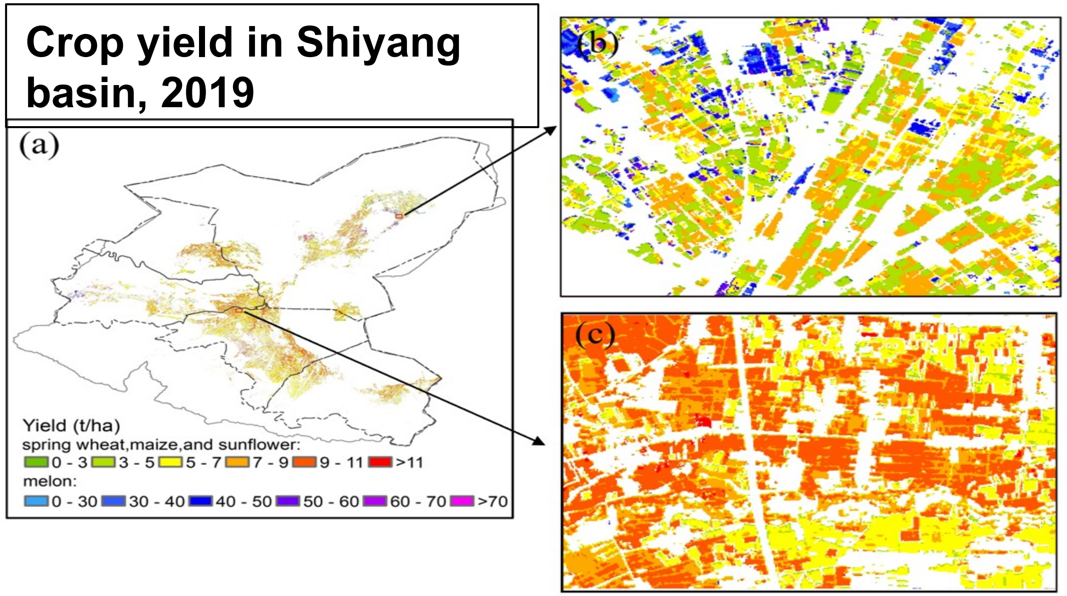
The estimation is reliable by comparing against official census data and field interviews. The estimated yield with high-resolution (10-m) can reflect the fragmented surface cover characteristics and response to drought.

biomass accumulation in Shiyang basin, 2019





Crop yield in Shiyang basin, 2019



	maize	wheat	sunflower	melon
Yield	8.53±1.93	5.87±1.3	6.38 t/ha	52.24 t/ha
error (%)	2.6%	3.9%	5%	16%

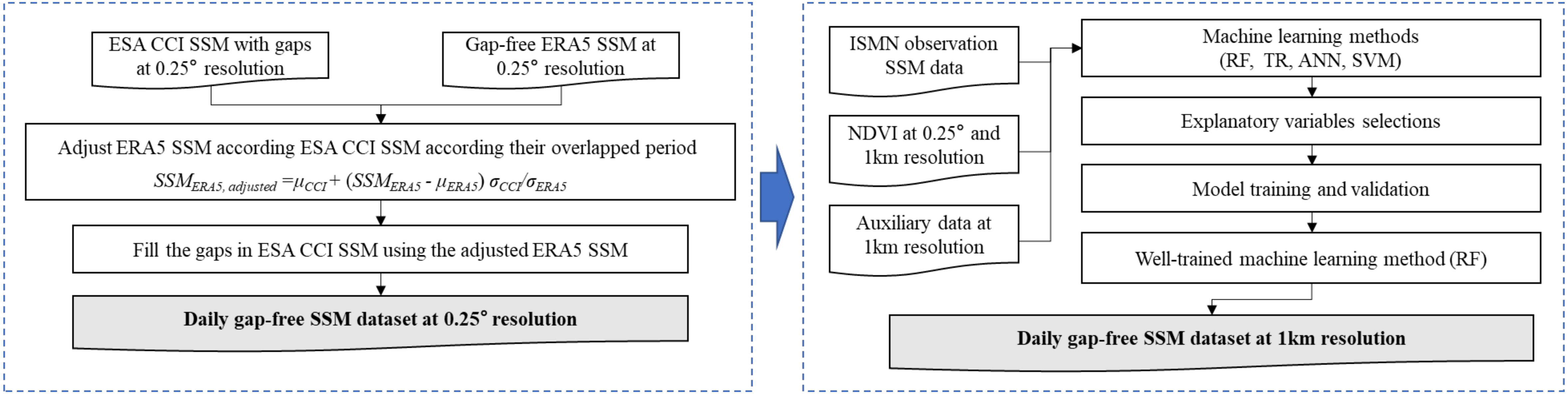
Chen et al., 2022

3. Global high-resolution (1-km) surface soil moisture

Challenge: Global satellite SM products are suffering from problems of **spatiotemporal discontinuity** and **coarse spatial resolution** (usually ≥ 0.25°)

Objectives: generating **global daily gap-free SSM dataset at 1-km resolution.**

1) **gap-filling ESA-CCI SSM** product using ERA5 reanalysis product for daily gap-free SSM data at 0.25° resolution;
2) 2) **machine learning models were used to downscale** the daily gap-free SSM data at 0.25° resolution to 1-km resolution with the help of fine-resolution auxiliary data.

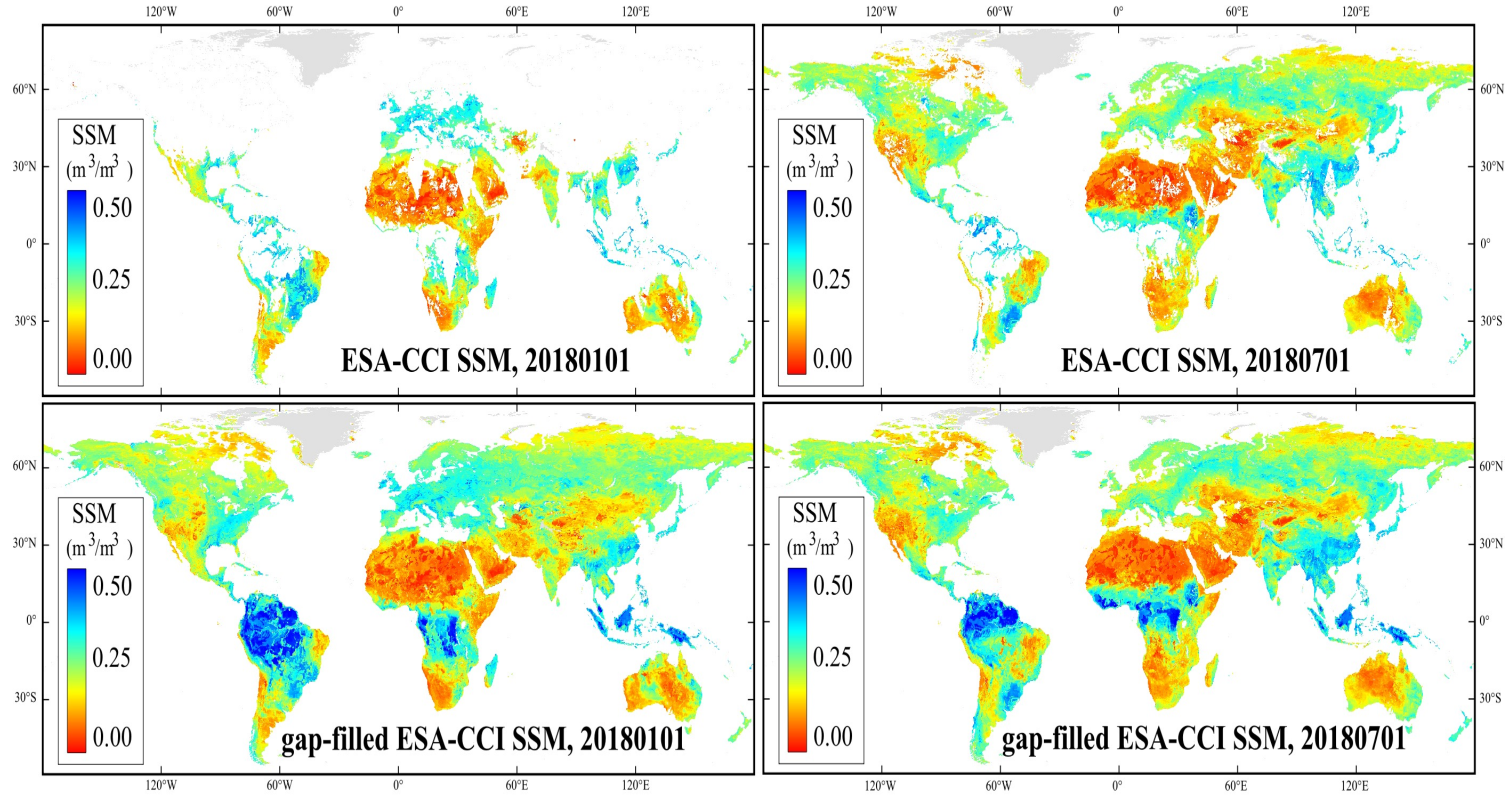


Zheng et al. 2023

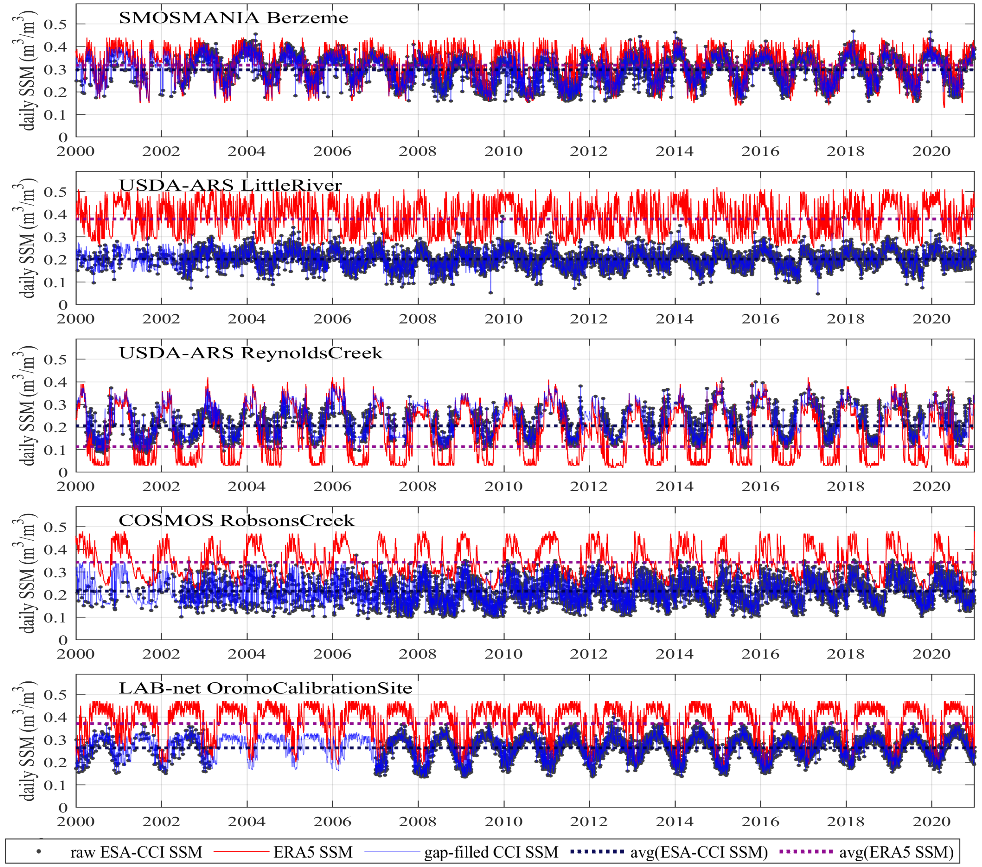
3. Global high-resolution (1-km) surface soil moisture

Gap-free SSM at 0.25° resolution. Generally, the gap-filled SSM data could capture the global SSM spatial variation with the raw ESA-CCI SSM information reserved.

Global maps of the raw ESA-CCI SSM product and gap-filled ESA CCI SSM on January 1st and July 1st, 2018.



Time series of gap-filled CCI SSM and the original CCI SSM product, ERA5 SSM products



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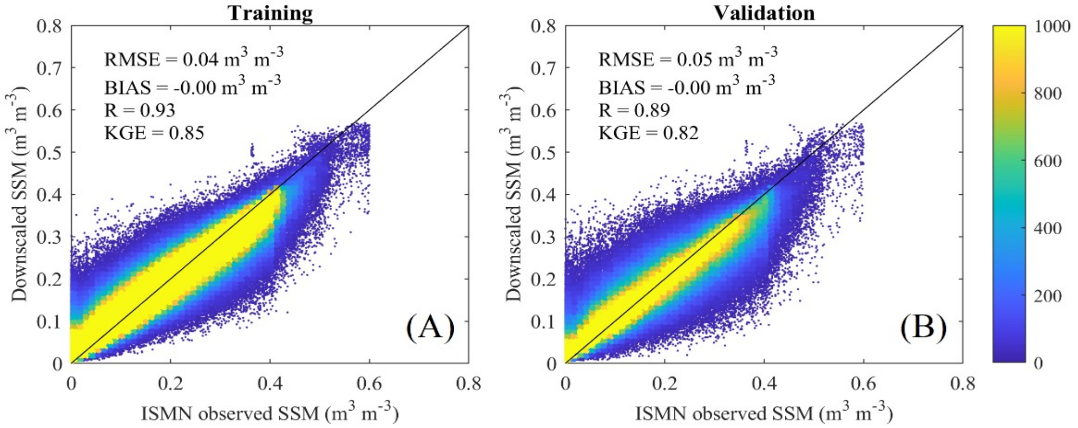
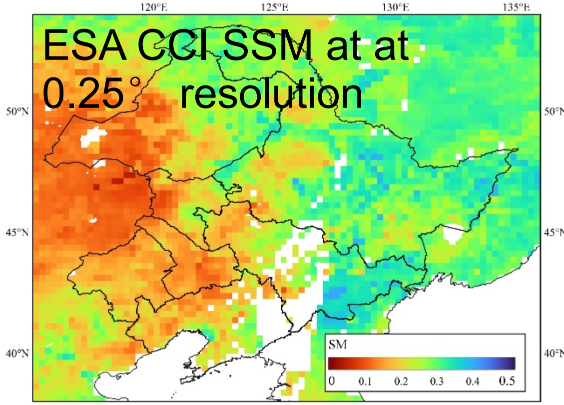
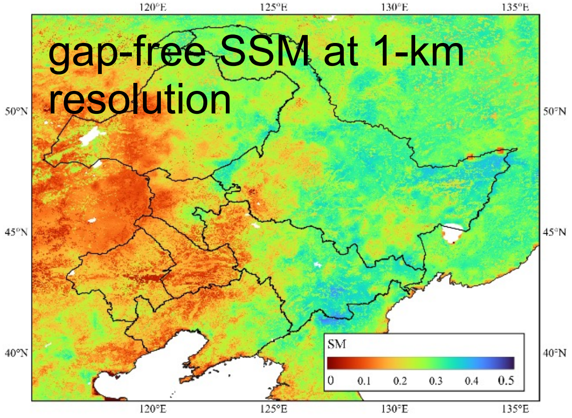
3. Global high-resolution (1-km) surface soil moisture

Gap-free SSM at 1-km resolution. The global 1-km SSM can capture well the overall spatial variations of global SSM, spatial features of SSM are well illustrated by the high resolution as shown in the sub-region maps.



Performance of the downscaling model to downscale SSM data to 1-km resolution evaluated by observation from ISMN





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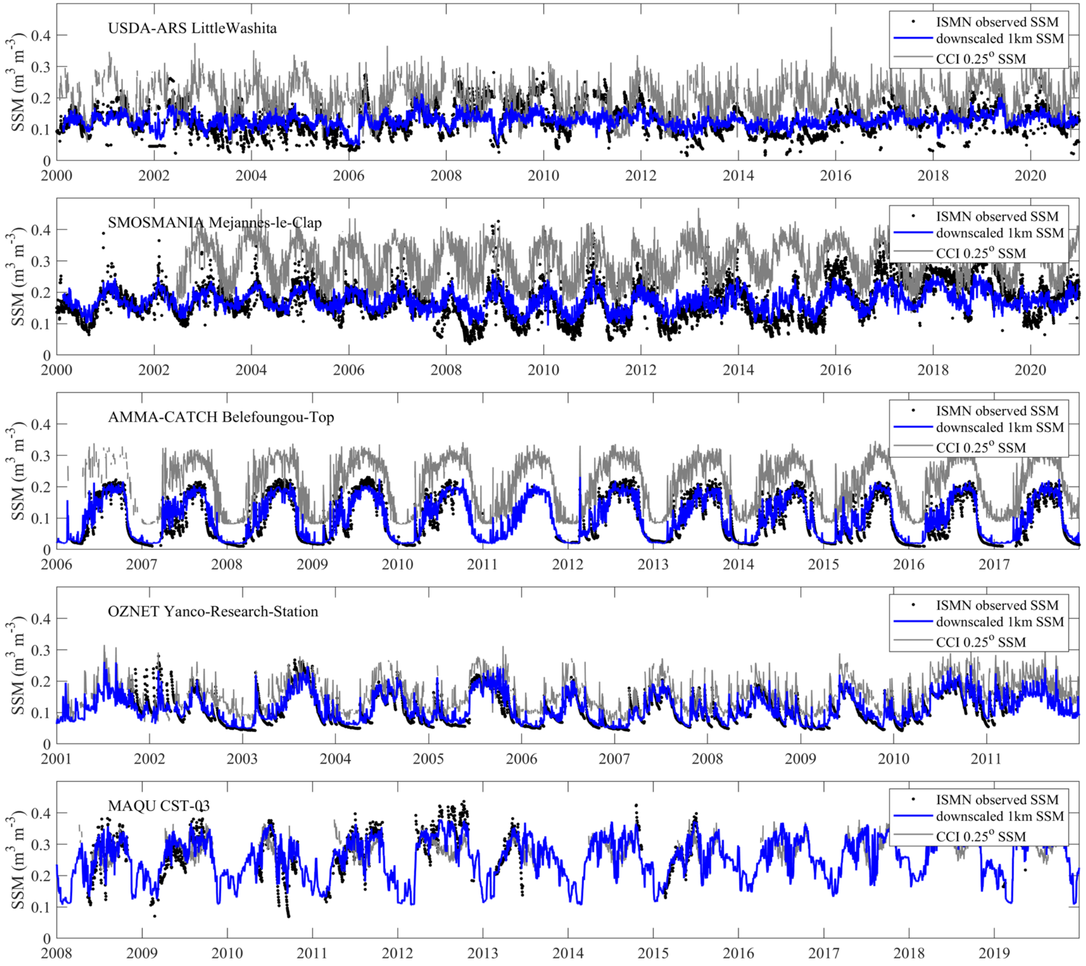
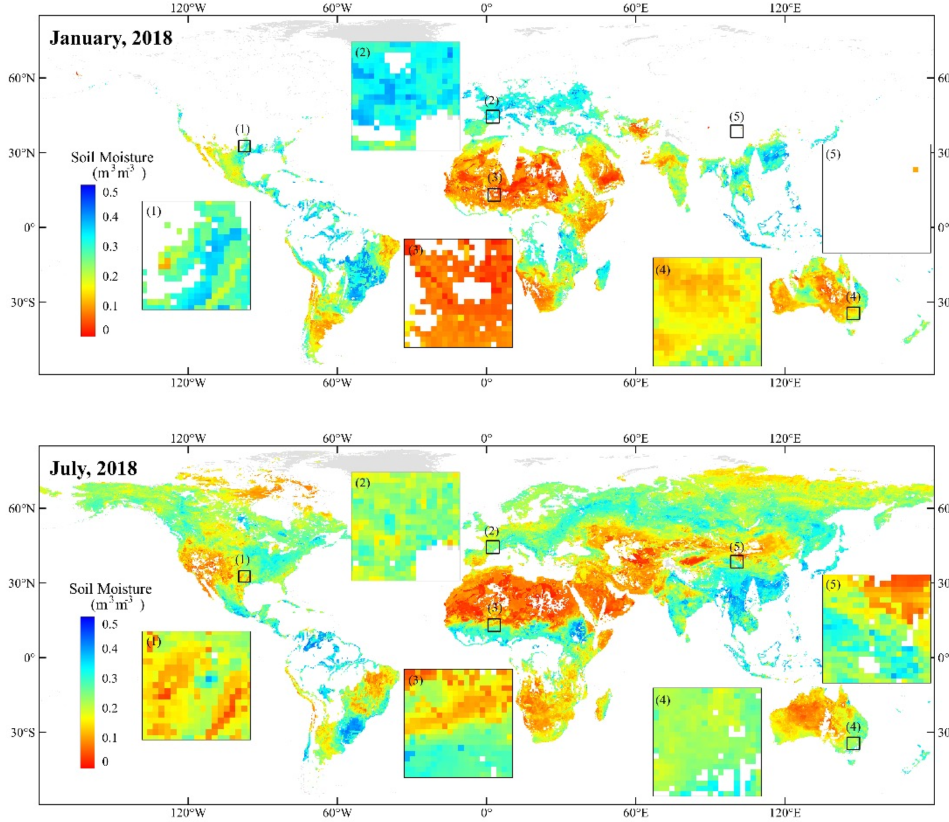


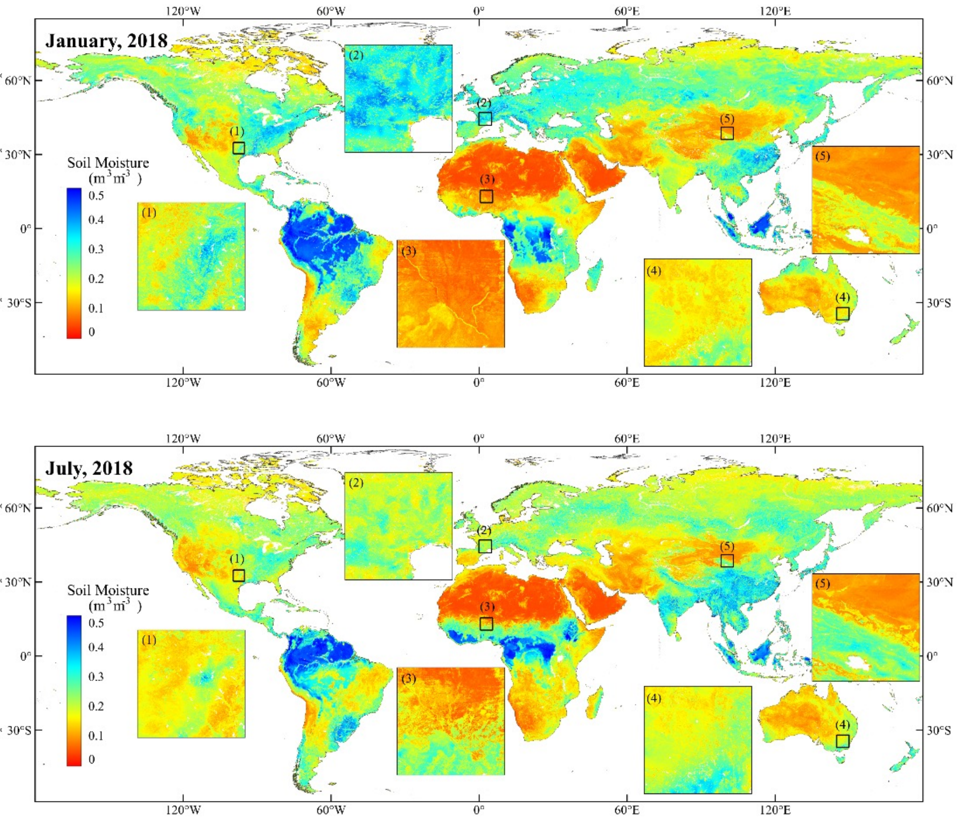
Time series of downscaled 1-km SSM from grids at the selected ISMN sites

3. Global high-resolution (1-km) surface soil moisture

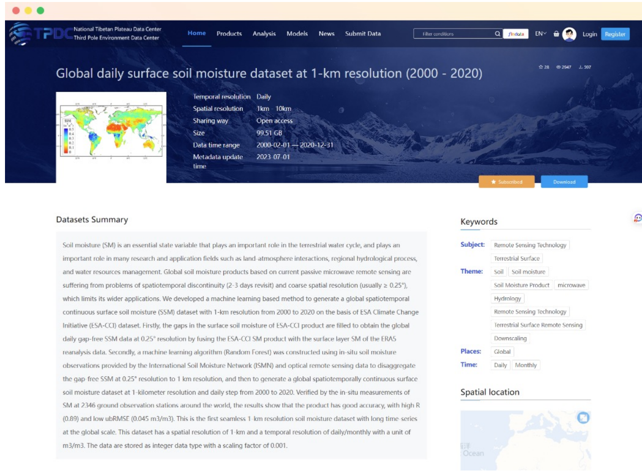
ESA CCI SSM at at 0.25° resolution



gap-free SSM at 1-km resolution



Dataset fully open at the TPDC data portal: https://doi.org/10.11888/RemoteSen.tpdc.272760.



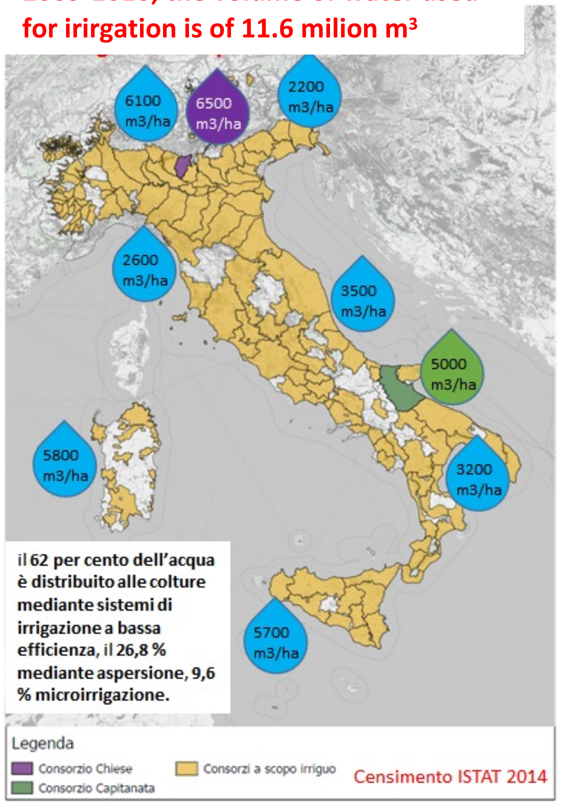
Zheng Chaolei, Jia Li, Zhao Tianjie. 2023. A 21-year dataset (2000-2020) of gap-free global daily surface soil moisture at 1 km grid resolution. Scientific Data. DOI:10.1038/s41597-023-01991-w

Zheng et al. 2023

4. FEST-EWB model improvement in evapotranspiration estimate over crop trees

Agriculture is the largest water user with about 70% of total freshwater consumption (FAO 2008)

2009-2010, the volume of water used for irrigation is of 11.6 milion m³



<u>FEST-EWB model improvement in evapotranspiration estimates over crop trees areas (</u>where arboreal canopy is interspersed with bare soil or low-cut grass land cover)<u> for optimizing crop irrigation efficiency</u>

The model can work both in the single-source version and in its double-source one. The former uses a single balance equation for the pixel, while the latter, although requiring the same amount of input data, distinguishes between the vegetated and non-vegetated areas in the pixel

The model has been applied, both in its single- and two-source structure, over field sites featuring walnut (Italy, 2019-21) and pear trees (Italy, 2022).

UN Sustainable Development Goals - 2030

62 % of water is distributed with low efficiency (27.2 and 34.8 respectively for surface sliding and lateral infiltration and submersion),

4. FEST-EWB model improvement in evapotranspiration estimate over crop trees

The **FEST-EWB** model is a distributed hydrological model that closes, for every step, both the energy and soil water balances of a pixel, computing internally the Representative Equilibrium Temperature (RET).

FEST-EWB model

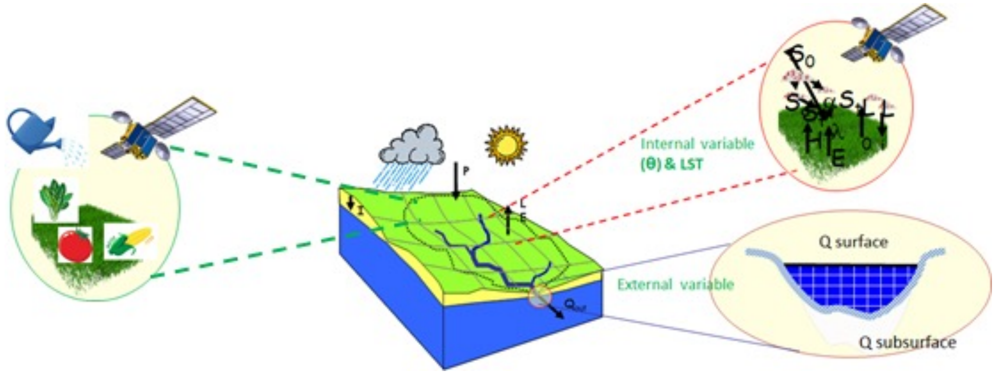
Soil water balance

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

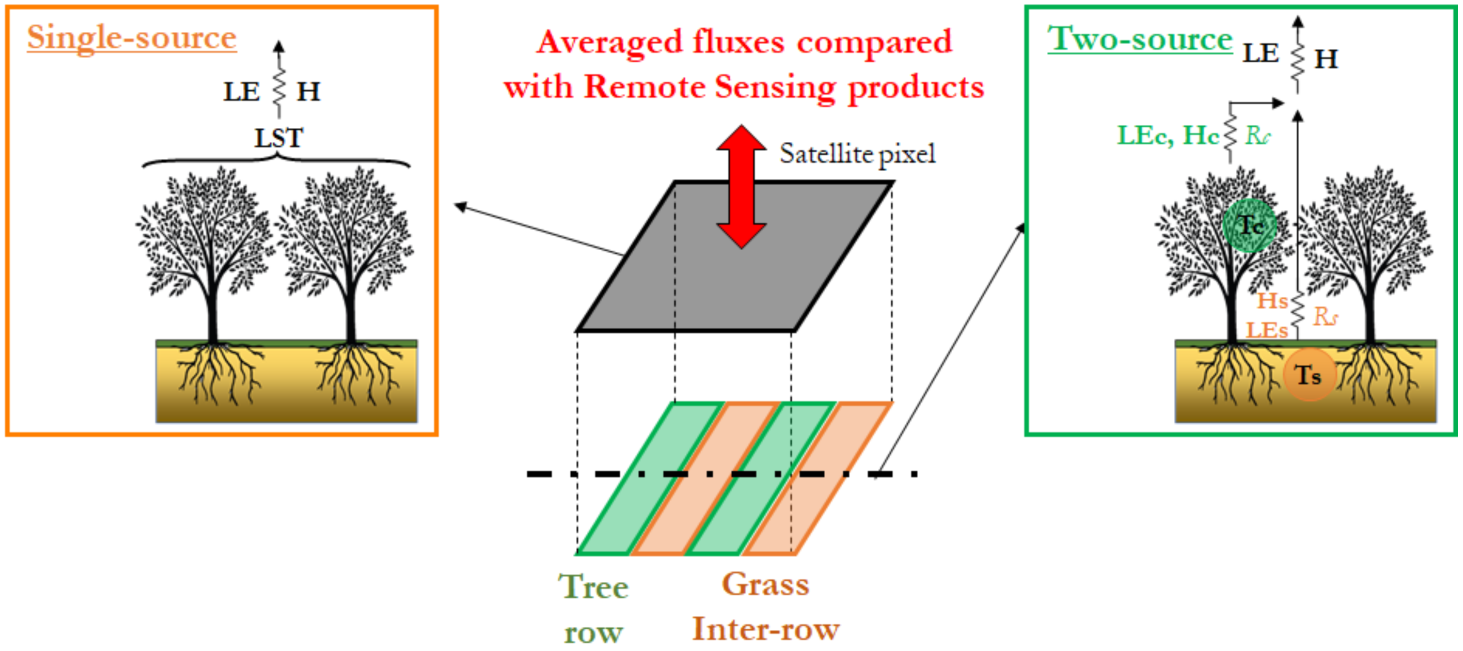
Energy balance

$$Rn-G-H-LE=\frac{dS}{dt} \qquad ETeff=\frac{LE}{\rho Cp}$$

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



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



While single-source models hold one single energy balance for the whole pixel, assuming intra-pixel homogeneity, **two-source** ones identify separate fluxes for the vegetated and non-vegetated portions of the pixel, closing two distinct energy balances, each with its own surface temperature.

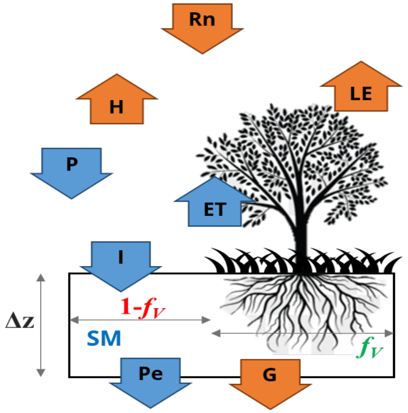
4. FEST-EWB model improvement in evapotranspiration estimate over crop trees

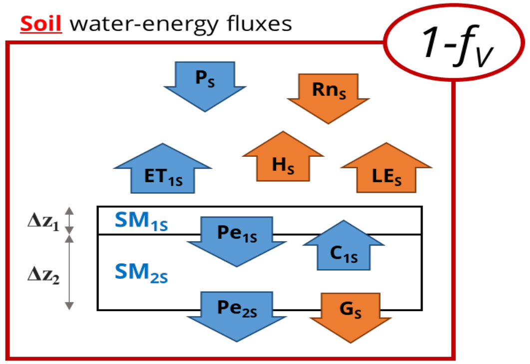
The **FEST-2x2-EWB** was developed to differentiate:

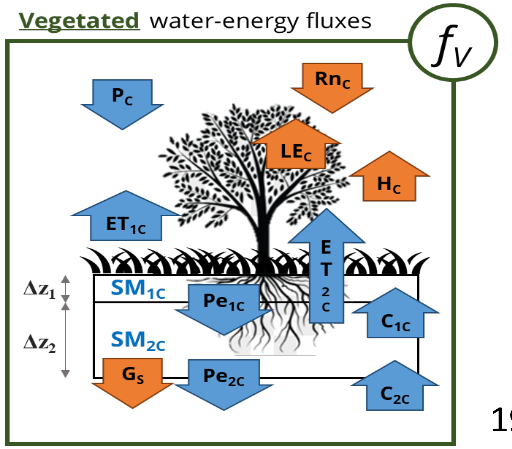
- the energy balance between vegetated and bare soil fractions of the pixel
- the soil water balance between shallow and deeper soil layer, referred to the main root zone depth

Same meteorological inputs → Two additional temperature outputs (T_{CROP} and T_{SOIL})

The models have been tested in the Burana Irrigation consortium (northern Italy) in pear tree fields and in Emilia Centrale consortium in walnut trees





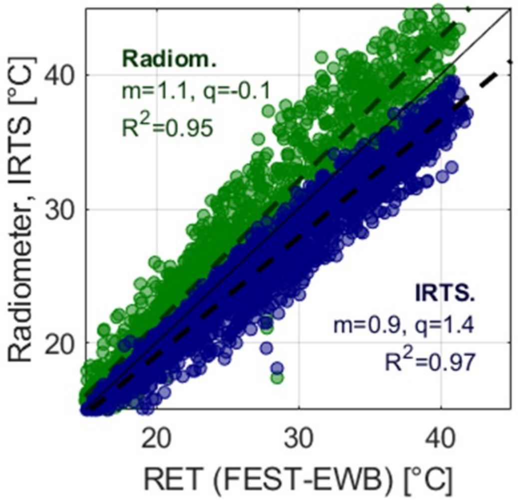


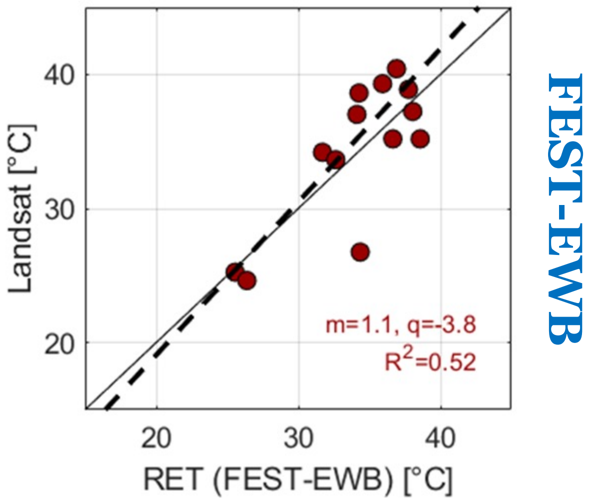
4. FEST-EWB model improvement in evapotranspiration estimate over crop trees

FEST-2X2-EWB model calibration against LST and SM

Burana Irrigation consortium (northern Italy) in pear tree fields

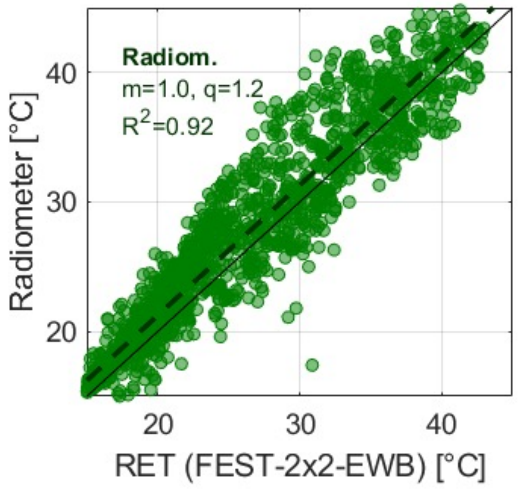
The **FEST-EWB** knows only one temperature for the entire pixel (RET) and cannot interpret the difference between the more soil-dominated radiometer ("Radiom.") temperature and the more vegetation-dominated "IRTS" temperature

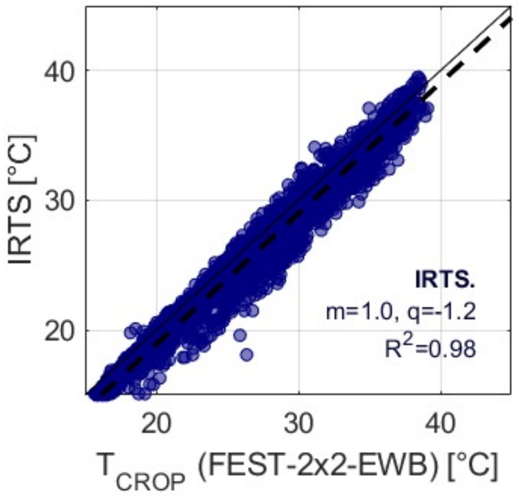


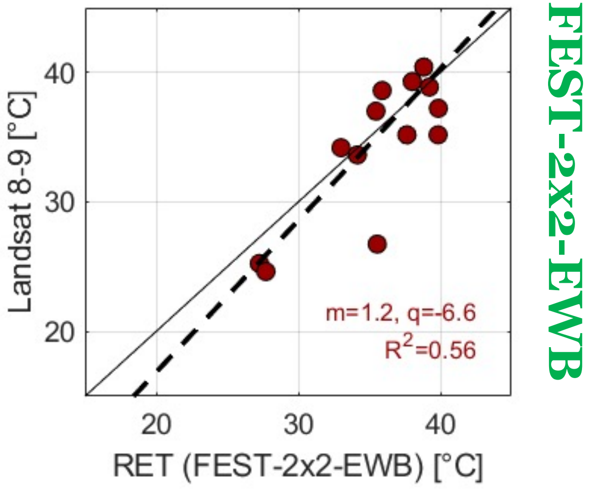


The **FEST-2x2-EWB** manages to represent both temperature accurately

Both temperatures well interpret the global pixel temperature seen from satellite







4. FEST-EWB model improvement in evapotranspiration estimate over crop trees

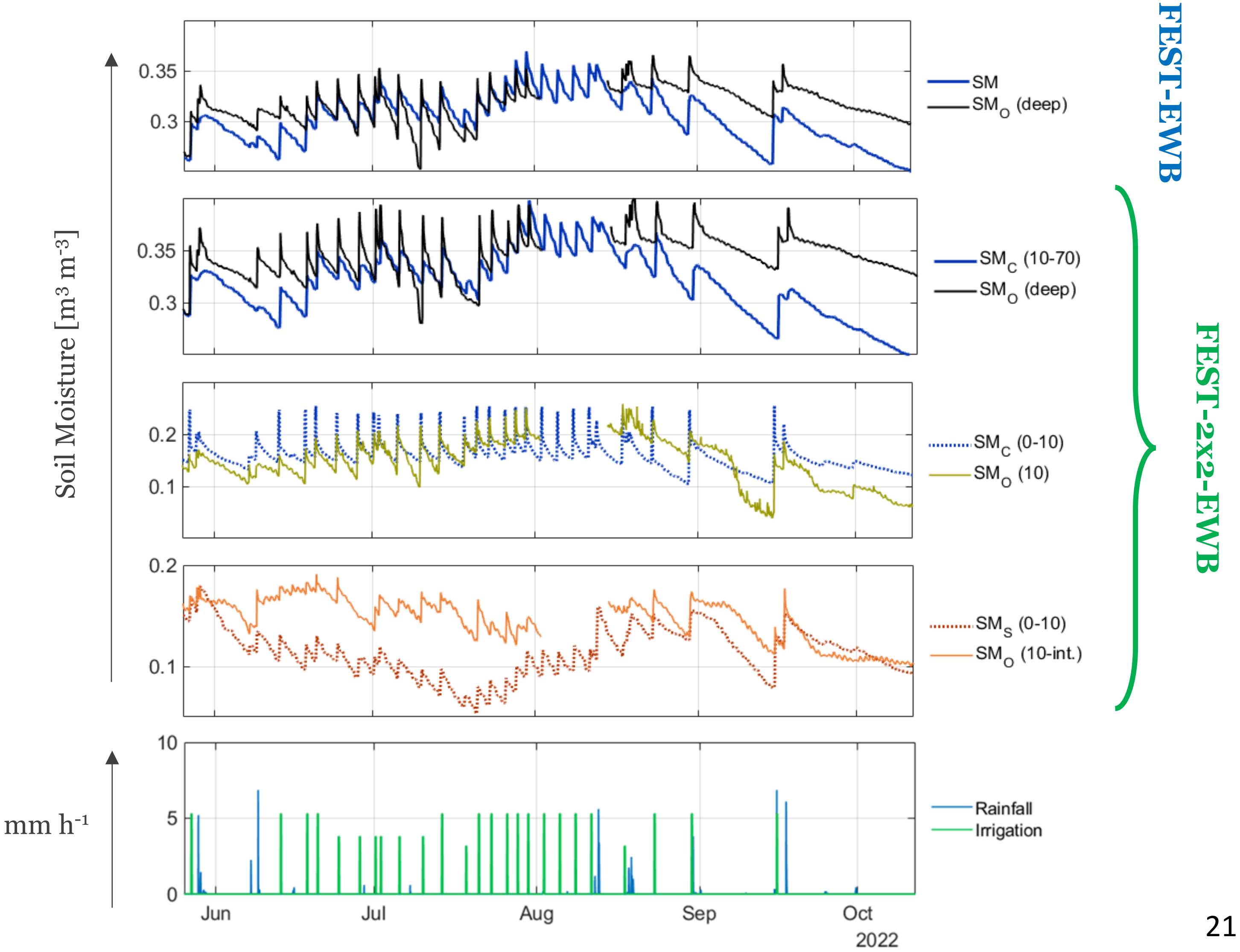
FEST-2X2-EWB model calibration against LST and SM

Burana Irrigation consortium (northern Italy) in pear tree fields

Looking at the temporal dynamics of soil moisture, the description in the 1-source model is limited to the deeper layers.

The FEST-2x2-EWB model provides a more complete description of the soil moisture distribution in the generic pixel:

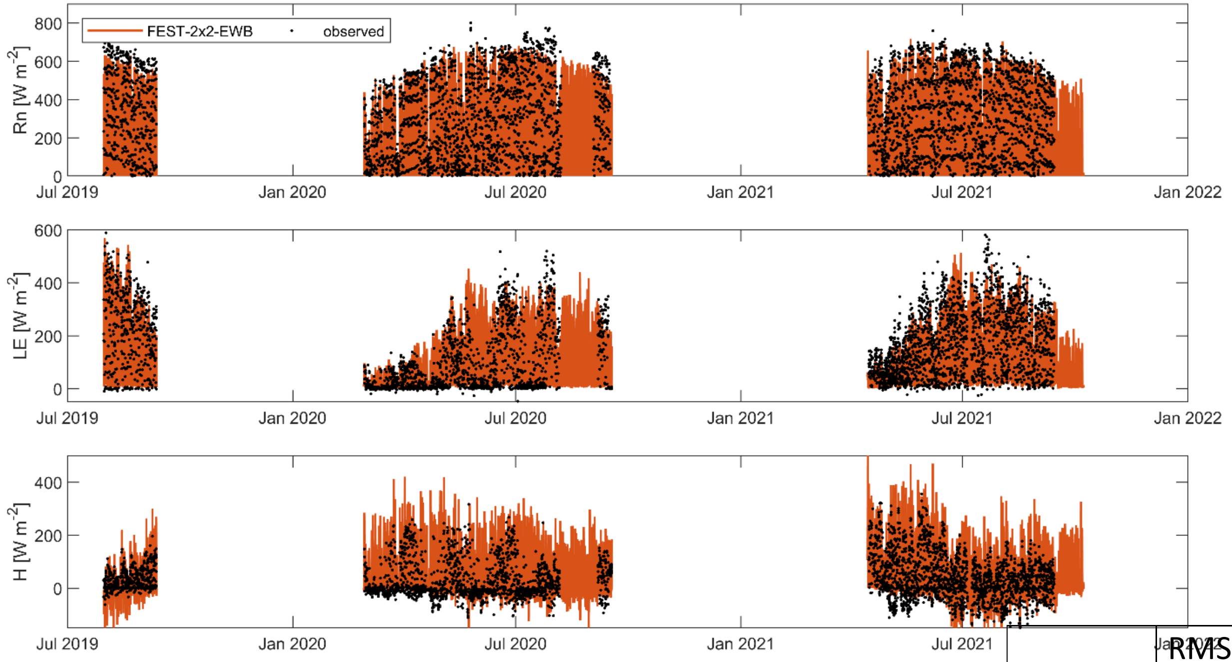
- Vegetated part of the pixel
  - Shallow layer (SM_C 0-10)
  - Root-zone layer (SM_C deep)
- Bare-soil part of the pixel
  - Shallow layer (SM_S 0-10)
  - Root-zone layer (SM_S deep)



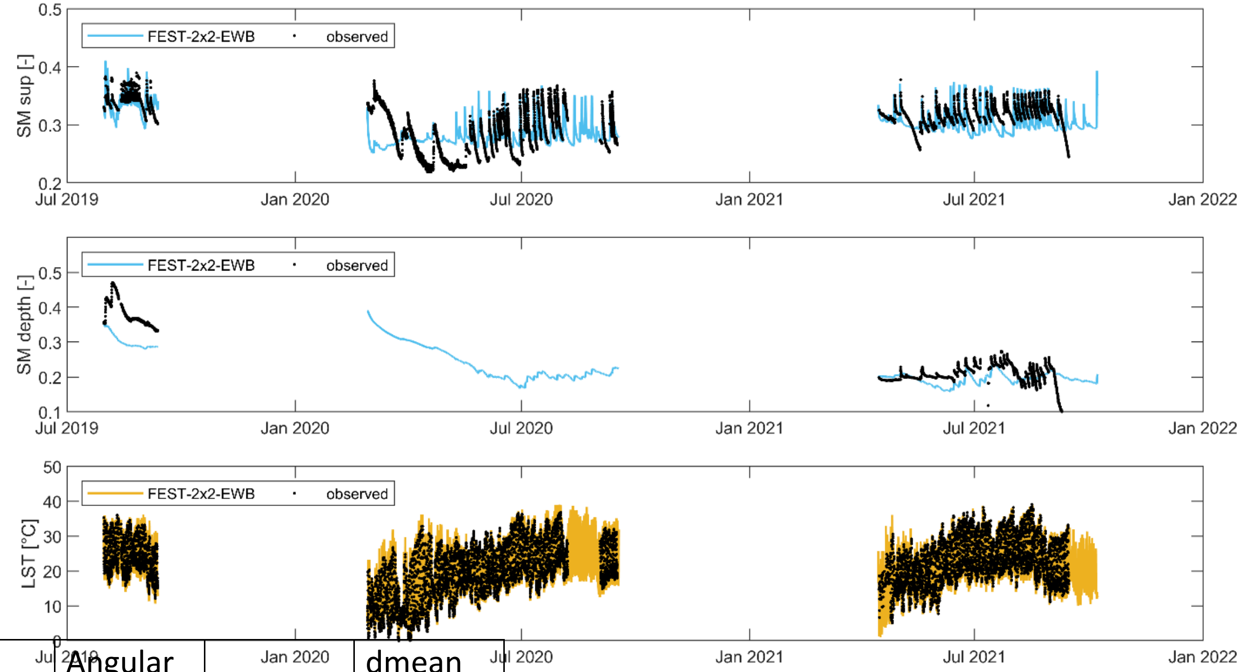
4. FEST-EWB model improvement in evapotranspiration estimate over crop trees

FEST-2X2-EWB model calibration against LST and SM

The energy fluxes



Soil moisture and LST

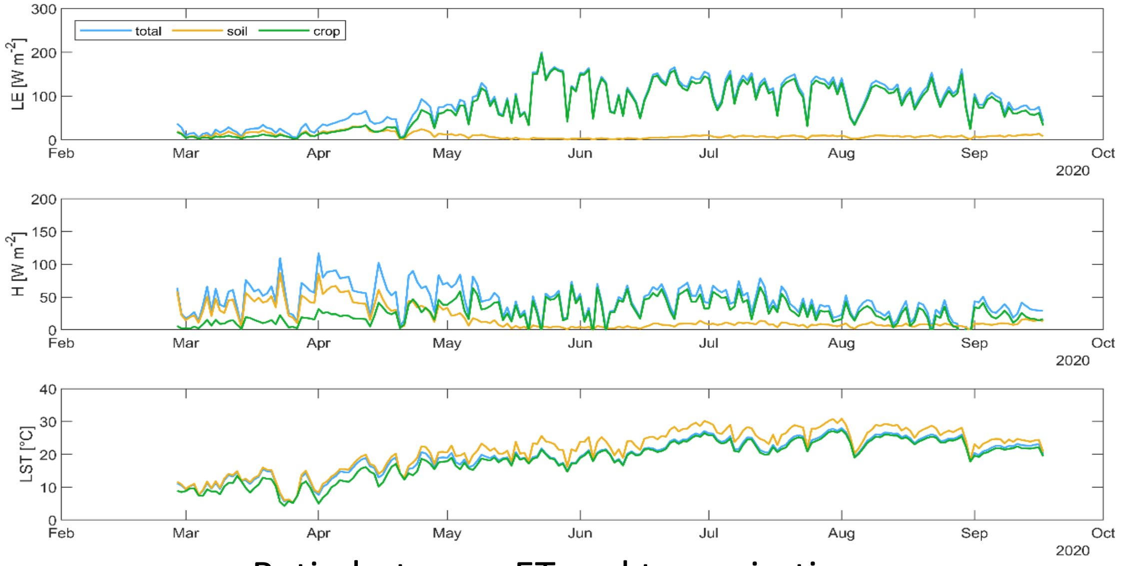


	RMSE (W/m2)	Angular coeff.	R2	dmean (W/m2)
Rn	61.0	0.88	0.94	45.7
LE	66.3	0.89	0.73	46.0
H	56.7	1.04	0.63	40.7
LST	2.02	1.05	0.95	1.70
SM sup	0.03	0.89	0.78	0.02
SM dep	0.08	0.90	0.85	0.08

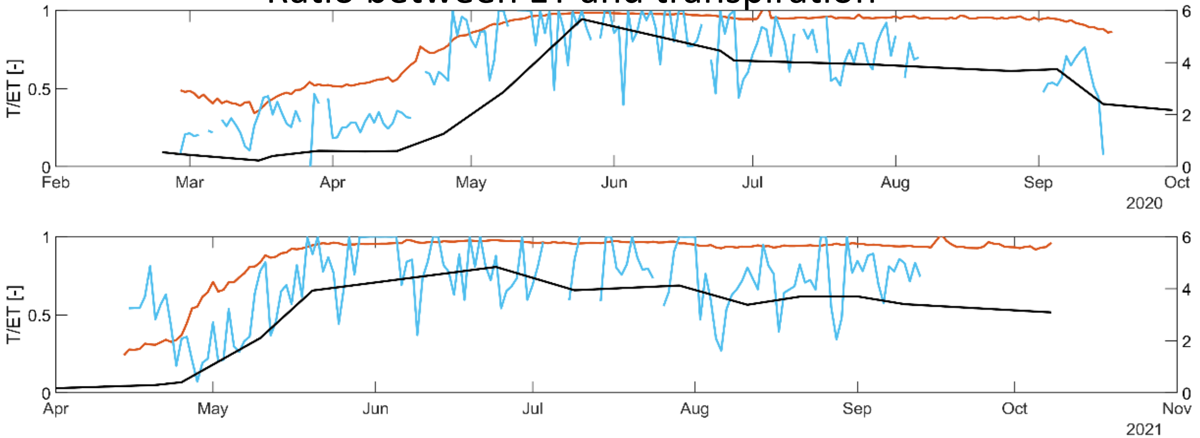
Emilia Centrale consortium in walnut trees

4. FEST-EWB model improvement in evapotranspiration estimate over crop trees

Emilia Centrale consortium in walnut trees



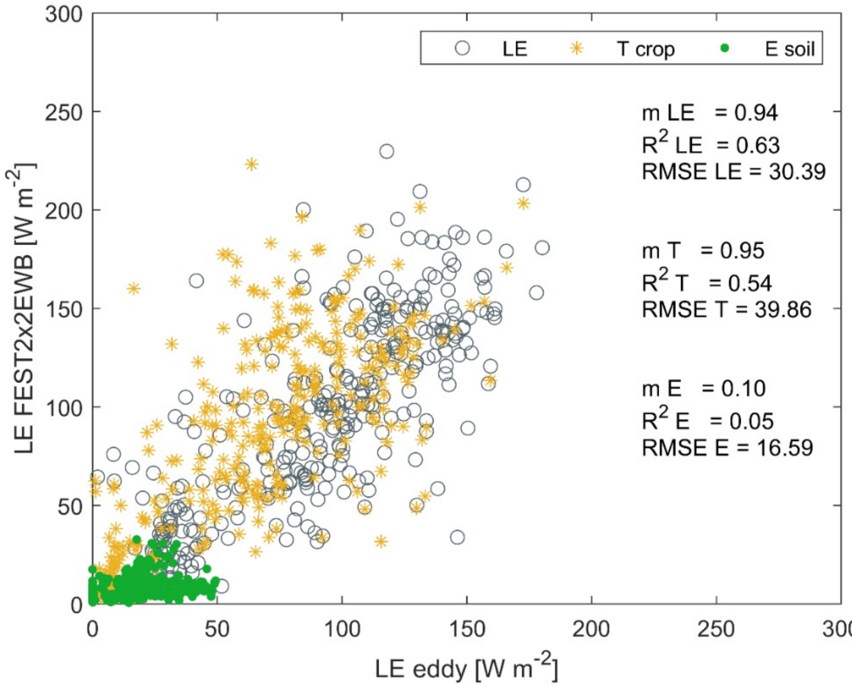
Ratio between ET and transpiration



eddy FEST-EWB LAI

Flux partitioning: comparison between FEST-2X2-EWB and Eddy covariance data

scatterplot between daily LE estimates from FEST-2X2-EWB and from EC with the uWUE method



EO Data Delivery

Data access (list all missions and issues if any). NB. in the tables please insert cumulative figures (since July 2020) 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. SMOS	10220
2. ASCAT	365
3. Sentinel-1	40
4. Sentinel-2	1766
5. ESA CCI soil moisture	7665
6.	
Total:	**20056**

Issues:
- Soil moisture retrieval (SMOS);
- Crop classification
- Biomass/yield estimate

ESA Third Party Missions	No. Scenes
1. Planet	4
2. Landsat 7/8/9	100
3.	
4.	
5.	
6.	
Total:	**104**

Issues:
- Crop mapping;
- Crop water use, irrigation efficiency

Chinese EO data	No. Scenes
1. GF 1 & 2	100
2.	
3.	
4.	
5.	
6.	
Total:	100

Issues:
High resolution ET estimate

European Young scientists contributions in Dragon 5

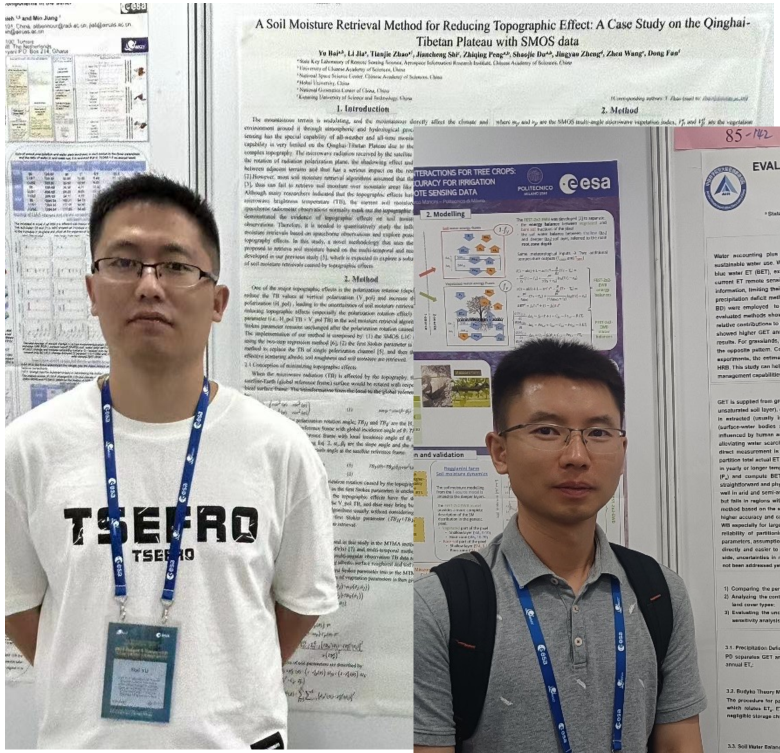
Name	Institution	Poster title	Contribution including period of research
Nicola Paciolla	Politecnico di Milano	ET estimates across scales using remotely sensed LST and an energy-water balance model (2022, **Paciolla**, Corbari, Mancini)	Study of relevance of scale in representing LST from satellite over heterogeneous tree crops. Analysis of the impacts in modelling ET using remotely-sensed data at different resolutions
Nicola Paciolla	Politecnico di Milano	Modelling of soil-plant-atmosphere interactions for tree crops: higher complexity to enhance accuracy for irrigation management employing remote sensing data (2023, **Paciolla**, Corbari, Ceppi, Mancini) (poster **ID 122**)	Improvement of a physically-based model for the application over heterogeneous tree crops. Development of a 2-source, 2-soil-layer scheme able to simulate all water and energy exchanges between soil, plant and atmosphere employing satellite observations of vegetation data as input and LST as calibration data.

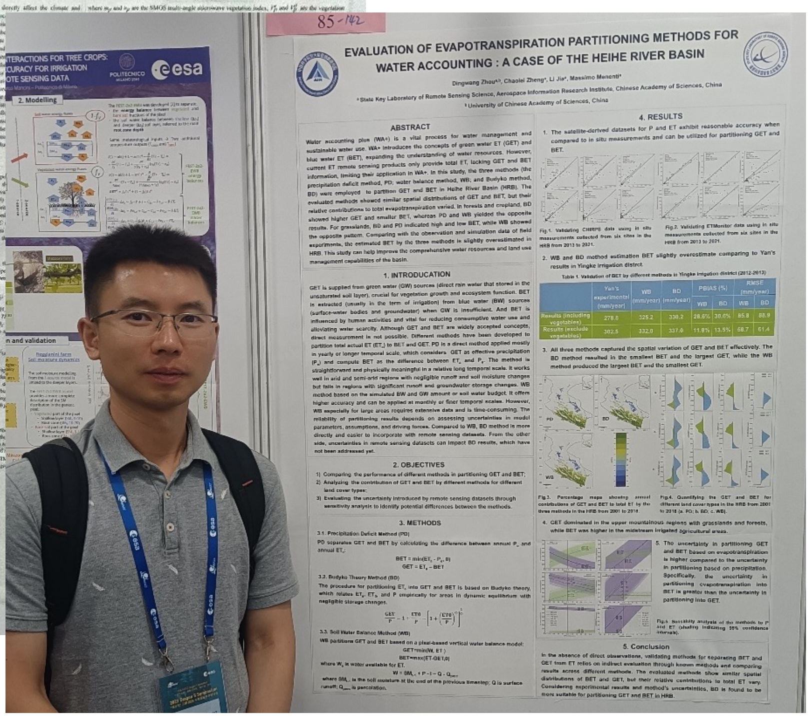
Chinese Young scientists contributions in Dragon 5

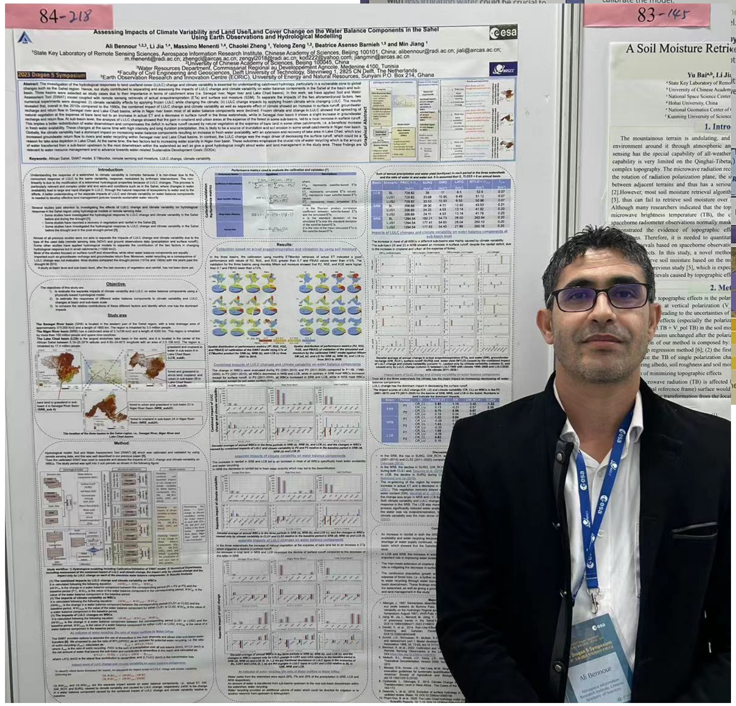
Name	Institution	Poster title	Contribution including period of research
Yu Bai	Aerospace Information Research Institute, Chinese Academy of Sciences	A Soil Moisture Retrieval Method for Reducing Topographic Effect: A Case Study on the Qinghai–Tibetan Plateau With SMOS Data (poster **ID 145**)	soil moisture retrieval 2020-2023
Dingwang Zhou	Aerospace Information Research Institute, Chinese Academy of Sciences	Evaluation of Evapotranspiration Partitioning Methods for Water Accounting: A Case of the Heihe River Basin in the Arid-semi-arid Region (poster **ID 142**)	Water accounting 2020-2023
Ali Bennour	Aerospace Information Research Institute, Chinese Academy of Sciences	Assessing Impacts Of Climate Variability And Land Use/Land Cover Change On The Water Balance Components In The Sahel Using Earth Observations And Hydrological Modelling (poster **ID 218**)	Hydrology cycle modelling 2020-2023

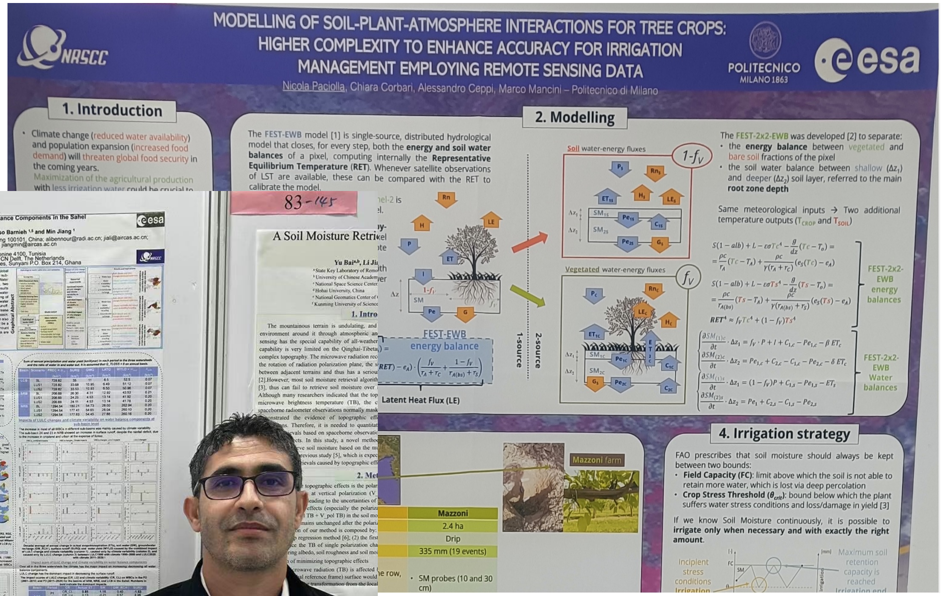
Posters:

1. **Reducing topographic effect on soil moisture retrieval by SMOS data** (poster 145)
2. **Evaluation of evapotranspiration partitioning methods for water accounting** (poster 142)
3. **Climate variability and land use/land cover change on the water balance in the Sahel** (poster 218)
4. **Modelling of soil-plant-atmosphere interactions for tree crops** (poster 122)









Publications

1. Zheng C., Jia L., Zhao T. 2023. A 21-year dataset (2000-2020) of gap-free global daily surface soil moisture at 1 km grid resolution. Scientific Data, 10:139. DOI:10.1038/s41597-023-01991-w.
2. Bennour A., Jia L*, Menenti M., Zheng C., Zeng Y., Barnieh B., Jiang M. 2023. Assessing impacts of climate variability and land use/land cover change on the water balance components in the Sahel using Earth observations and hydrological modelling. Journal of Hydrology: Regional Studies, 47, 101370. DOI:10.1016/j.ejrh.2023.101370.
3. Chen Q., Jia L., Menenti M., Hu G., Wang K., Yi Z., Zhou J., Peng F., Ma S., You Q., Chen X., Xue X. 2022. A data-driven high spatial resolution model of biomass accumulation and crop yield: Application to a fragmented desert-oasis agroecosystem. Ecological Modelling, 475, 110182.
4. Yi Z, Jia L, Chen Q, Jiang M, Zhou D, Zeng Y. 2022. Early-Season Crop Identification in the Shiyang River Basin Using a Deep Learning Algorithm and Time-Series Sentinel-2 Data. Remote Sensing. 14(21):5625.
5. Bai Y., Jia L., Zhao T., et al. 2023. A Soil Moisture Retrieval Method for Reducing Topographic Effect: A Case Study on the Qinghai–Tibetan Plateau With SMOS Data. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing,16, 4276-4286.
6. Zheng C., Jia L., Hu, G. 2022. Global Land Surface Evapotranspiration Monitoring by ETMonitor Model Driven by Multi-source Satellite Earth Observations. Journal of Hydrology, 613, 128444. https://doi.org/10.1016/j.jhydrol.2022.128444.
7. Mi P., Zheng C., Jia L., Bai Y. 2023. Reconstruction of global long-term gap-free daily surface soil moisture from 2002 to 2020 based on machine learning method. Remote Sensing, 15(8), 2116. DOI:10.3390/rs15082116.
8. Asenso Barnieh B, Jia L, Menenti M, Yu L, Nyantakyi EK, Kabo-Bah AT, Jiang M, Zhou J, Lv Y, Zeng Y, et al. Spatiotemporal Patterns in Land Use/Land Cover Observed by Fusion of Multi-Source Fine-Resolution Data in West Africa. Land. 2023; 12(5):1032
9. Zeng, Y., Jia, L., Menenti, M. et al. Changes in vegetation greenness related to climatic and non-climatic factors in the Sudano-Sahelian region. Reg Environ Change 23, 92 (2023). https://doi.org/10.1007/s10113-023-02084-5
10. Jiang M, Li X, Xin L, Tan M, Zhang W. Impacts of Rice Cropping System Changes on Paddy Methane Emissions in Southern China. Land. 2023; 12(2):270. https://doi.org/10.3390/land12020270

Submitted:

1. Zheng C., Jia L., Menenti M., Hu G., Lu J., Chen Q., Jinag M., Mancini M., Corbari C. 2023. Integrating hydrologic modeling and satellite remote sensing to assess the performance of sprinkler irrigation. Geo-spatial Information Science. (under review)

Plan for Next Year

- Assessing high resolution irrigation water demand maps with different techniques
- Assessing farmland crop water use efficiency using high resolution data using ETMonitor and EF-LUE models

- Generating global SMOS products using the new algorithm
- Assessing global crop water use efficiency

- Chinese young scientist visit to European institute/university

Thank you!

Prof. Li Jia
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AIR-CAS

- Inform on the project's objectives
- Detail the Copernicus Sentinels, ESA, Chinese and ESA Third Party Mission data utilised after 3 years (complete slide 4)
- Detail the in-situ data measurements and requirements
- Provide details on field data collection campaigns and periods in P.R. China or other study areas
- Inform on the results after 3 years of activity
- Inform on the project's schedule, planning & contribution of the partners for the following year
- Report on the level and training of young scientists on the project achievements, including plans for academic exchanges
- Report on the peer reviewed publications (nr. of papers, journal name and publication title) after 3 years of activity

Delete