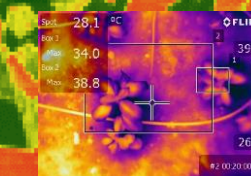
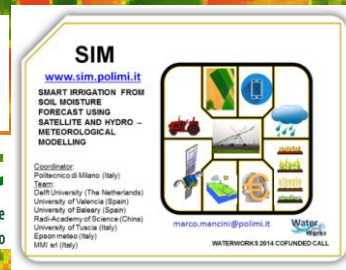
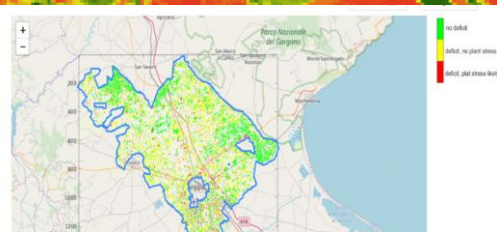


Irrigation management through a coupled energy-water balance and crop growth model driven by remote sensing data

Marco Mancini, C. Corbari, I. Ben Charfi, A. Al Bitar, Y. Kerr, D. Skokovic, J. Sobrino, and Giacomo Branca

Real Time Hydrologic Lab DICA
Politecnico di Milano
marco.mancini@polimi.it

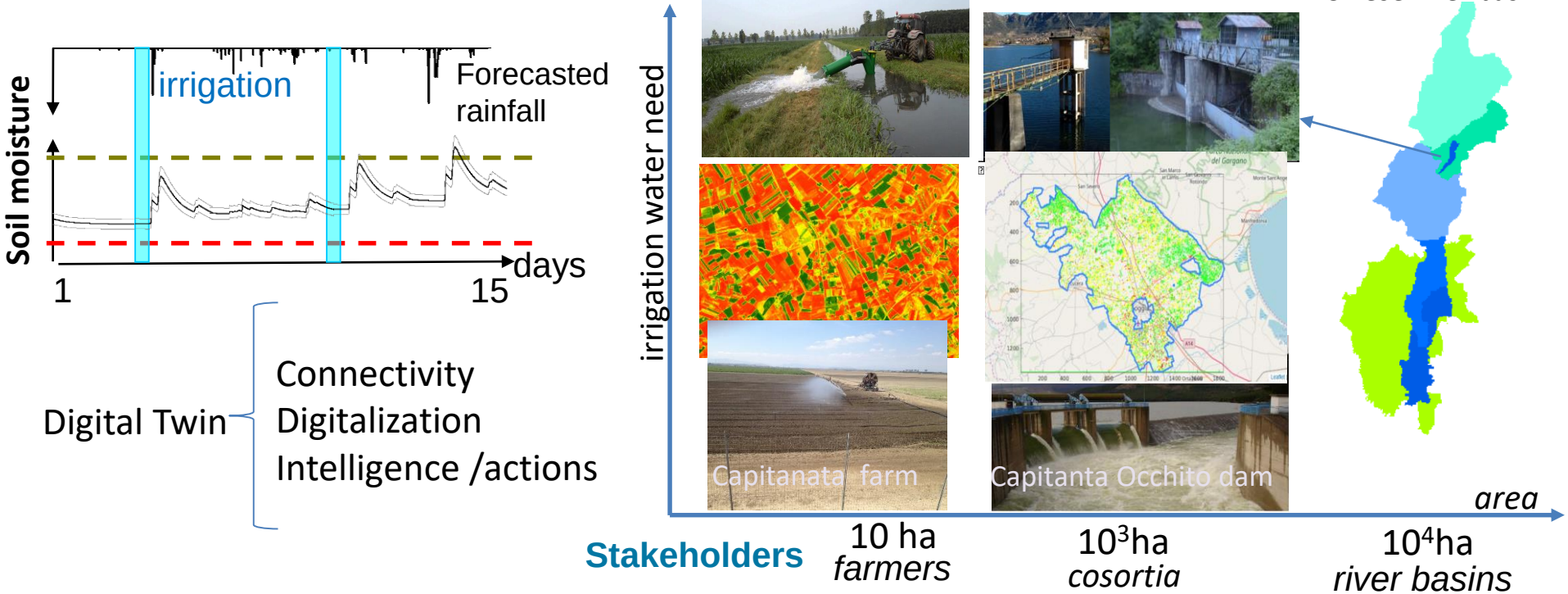




System Objectives and Stakeholders : the SIM project

1 MONITOR AND FORECAST CROP WATER NEED for parsimonious precise irrigation

2 SETTING A IRRIGATION STRATEGY: Increasing irrigation efficiency (ton/mc) and water productivity (€/mc)



Stellite data contribute to continuous in time model update :

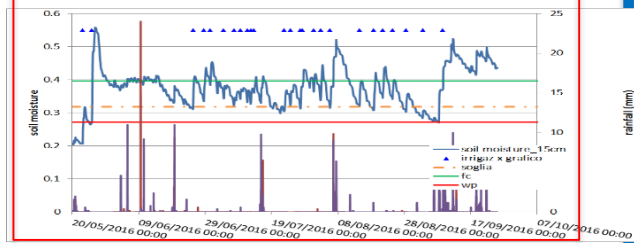
- **satellite multi platform (S2 L7, L8)** for Albedo, Fraction Cover, Leaf Area Index for cultivated area identification and parametrization.
- **satellite multi platform (L7, L8, S3)** land surface temperature data for soil moisture hydro model and



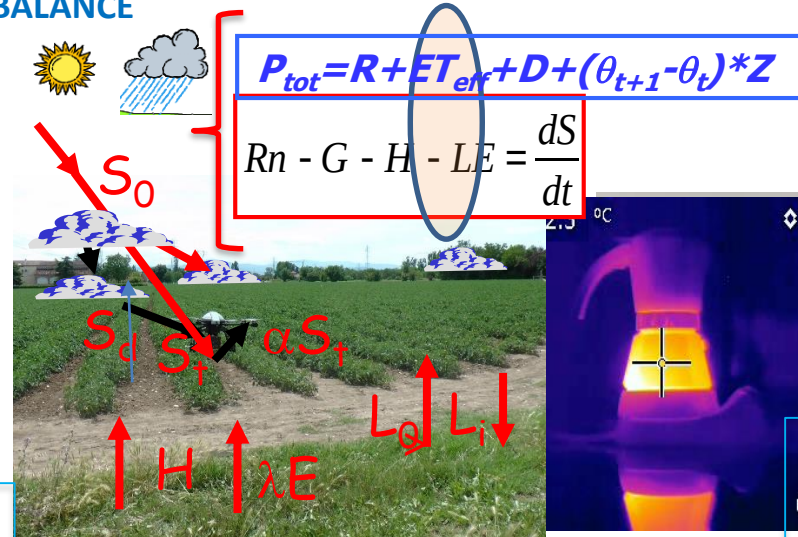
The SIM project methodology: from field to consortium area

www.SIM.polimi.it

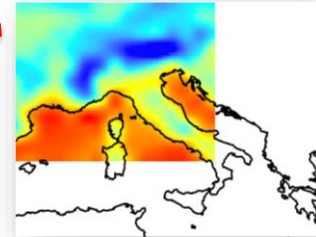
GROUND MONITORING



HYDROLOGICAL MODELING: MASS & ENERGY BALANCE

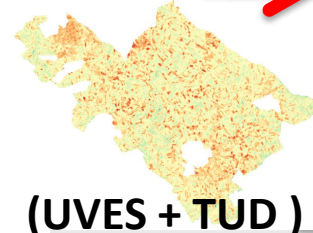
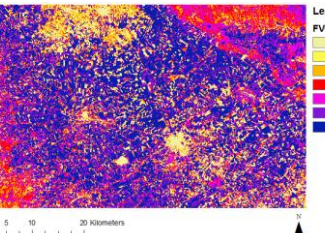


Meteorological forecast UNIBAL + EPSON



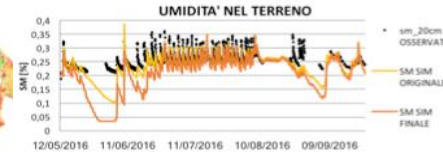
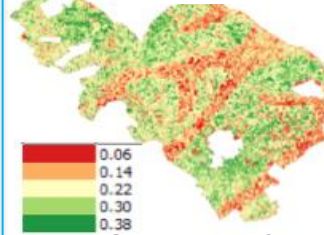
SATELLITE MONITORING

(LANDSAT – SENTINEL) Vegetation and LST



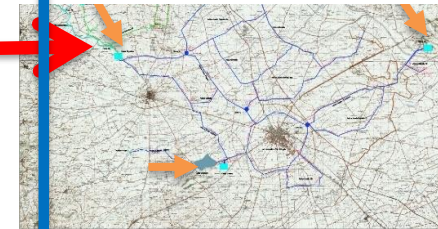
(UVES + TUD)

soil moisture and irrigation water need : mapping and pixel wise

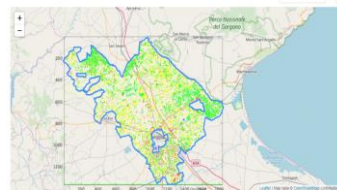
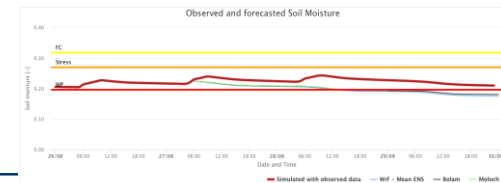


POLIMI FEST EWB, ETP RADI CAS

Irrigation aqueduct model MMI



POLIMI Irrigation water needs forecast and operative tool



Economic profitability (UNITUS)

Scenario		
1 = Water savings	3%	(% of 2015 Effective AWU)
2 = CY increased	2%	(% of 2015 CY at Average 2015 CP)
3 = Depreciation savings	2%	(% of technical duration of irrigation system)
4 = Energy cost savings	4%	(% of lifting and pressure costs)
5 = Labor cost savings	5%	(% of labor for maintenance irrigation system)
CAP	0,15	(average consortium price for m³/ha)



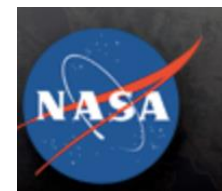
Operative satellite Data and hydrological parameters and variables

Sobrinho and all 2017

copernicus
observing the earth



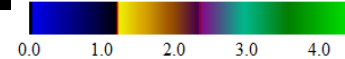
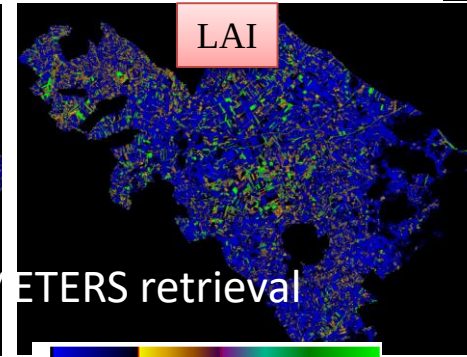
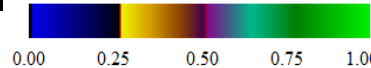
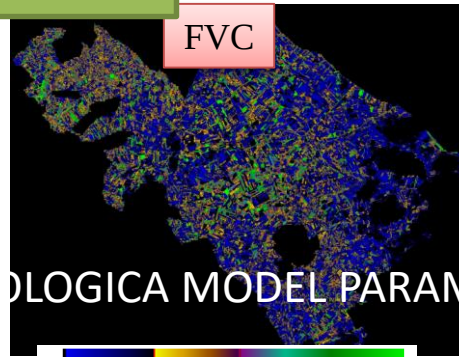
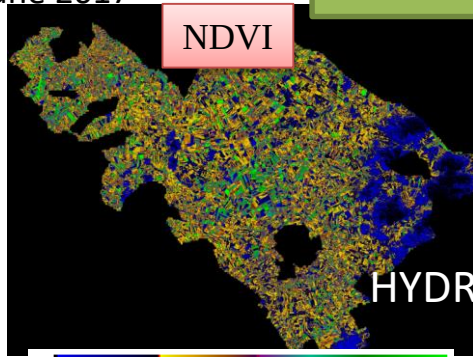
Near real time images



DATA integration IMPROVES revisit time

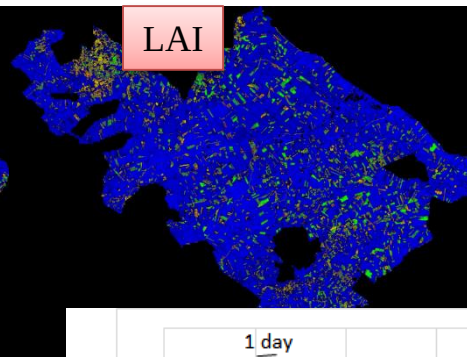
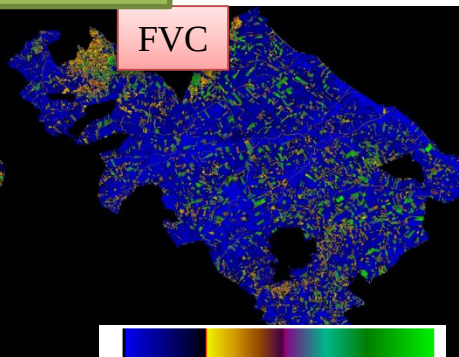
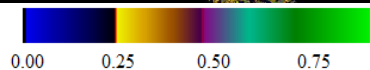
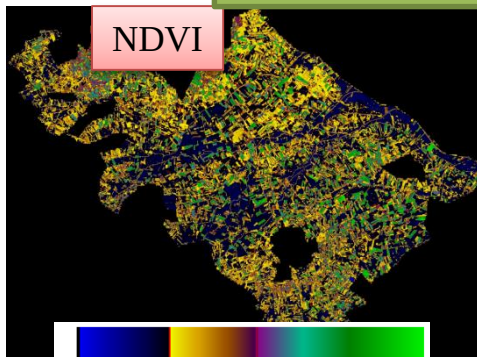
5 june 2017

SENTINEL-2 MSI

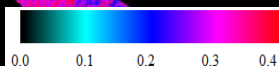
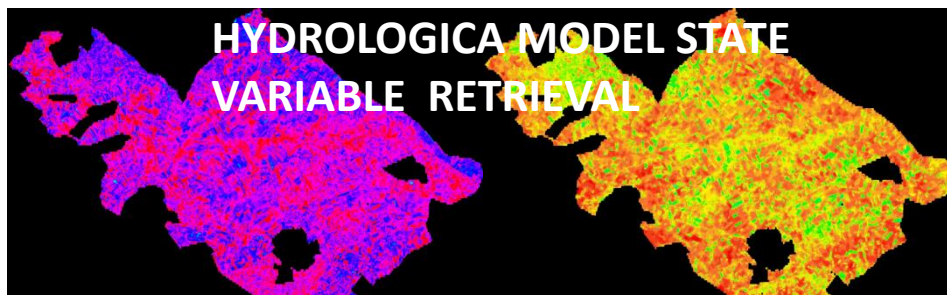


HYDROLOGICA MODEL PARAMETERS retrieval

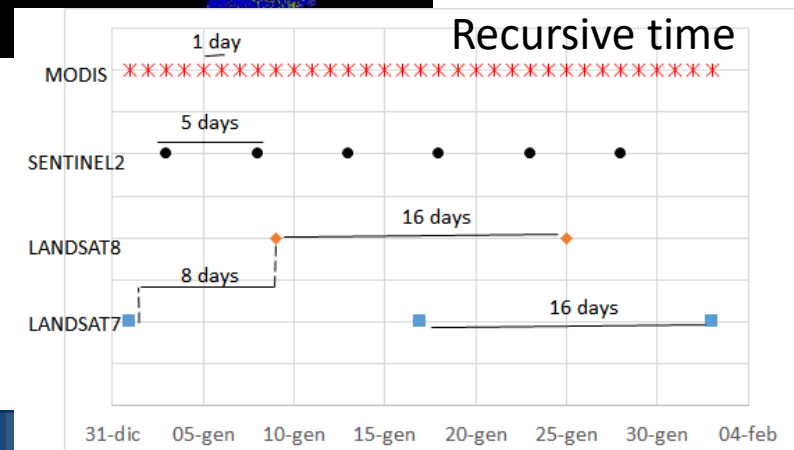
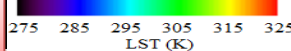
LANDSAT-8 OLI/TIRS



HYDROLOGICA MODEL STATE
VARIABLE RETRIEVAL



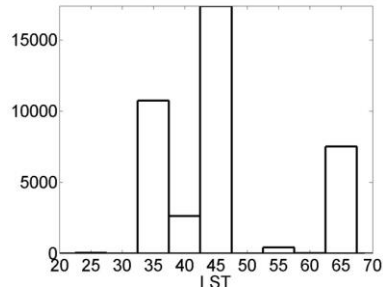
LST



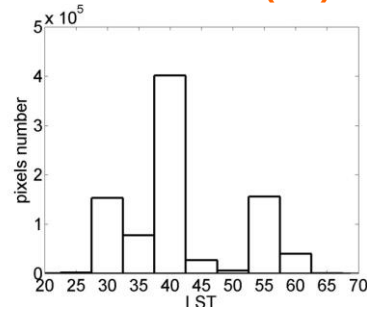


Is it reasonable to use evaporation flux measures similarly to discharge measurements?

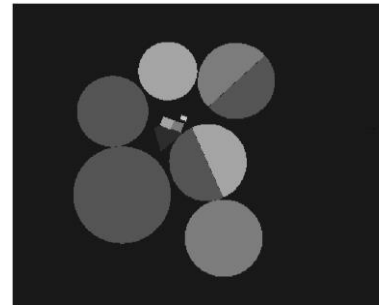
FEST_EWB (10m)



AHS (2m)



FEST_EWB (10m)



AHS (2m)



Barrax (Spagna)

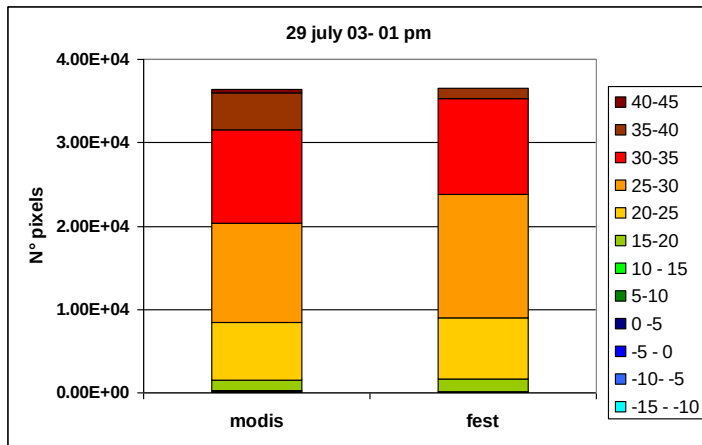
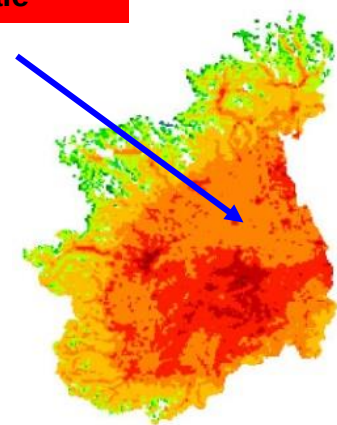
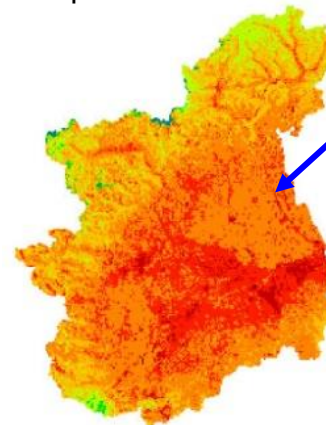
Piemonte (Italia)

FEST-EWB (1 km)

MODIS (1 km)

29 July 03 - 1pm

risaie



Satellite data & Pixel wise hydrological model: Field & district scale soil moisture monitoring

SATELLITE

HYDROLOGICAL MASS ENERGY MODEL FEST-EWB

LANDSAT_8 Surface Temperature

LST

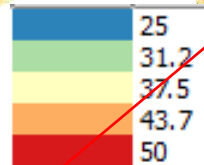
Soil moisture

1 June 2015

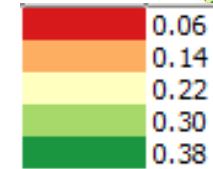
$\Delta x = 30$ m LST

Mean = 37 °C

°C

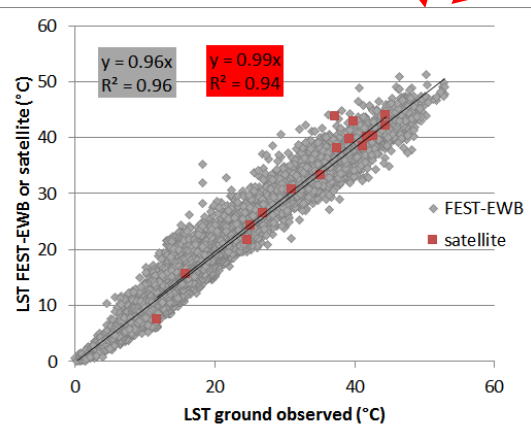
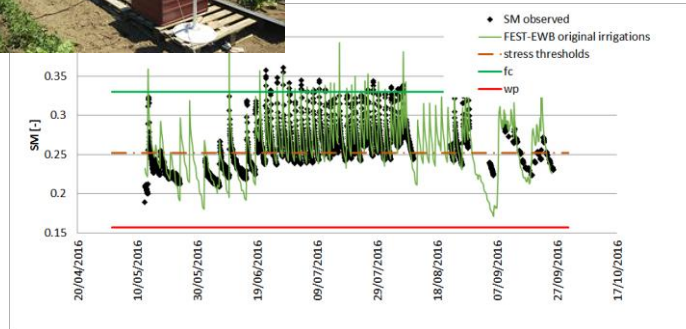
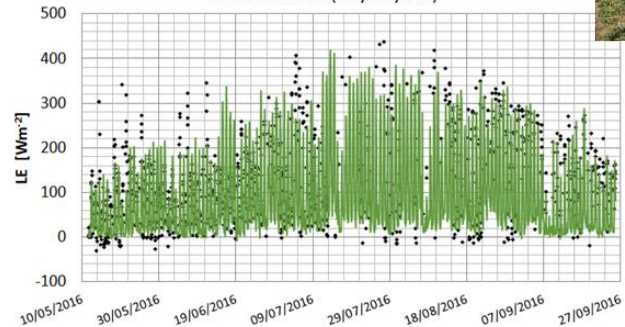


Mean = 36.5 °C



evapotranspiration

Tomatoes 2016 (silty clay soil)



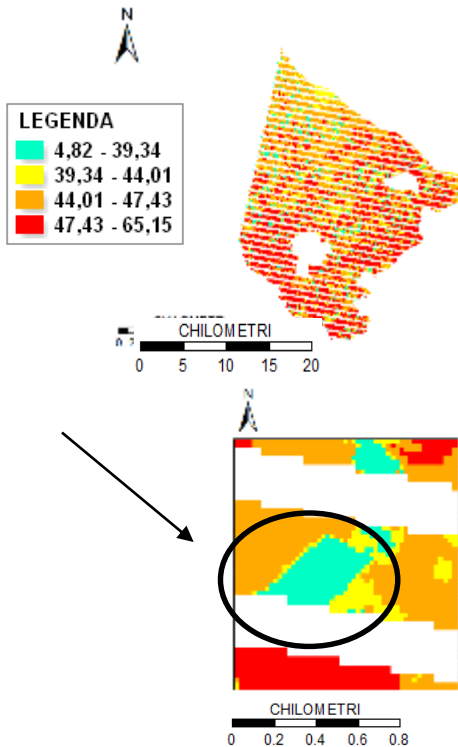


The effect of irrigation distribution on modeled fluxes

When irrigation is applied only in SATELLITE vegetated area with $ndvi > 0.3$, LST from FEST-EWB correctly reproduce the satellite observed LST

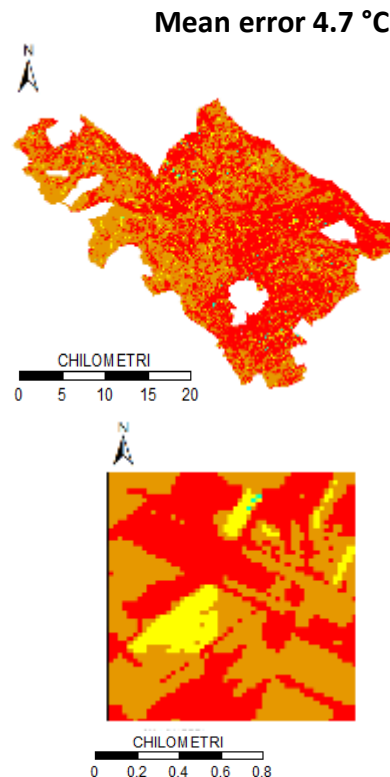
SATELLITE LST

for 53 images 2017-2018

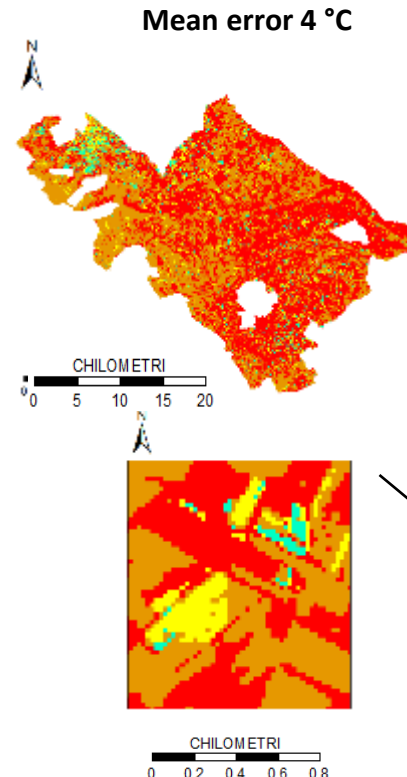


FEST-EWB LST

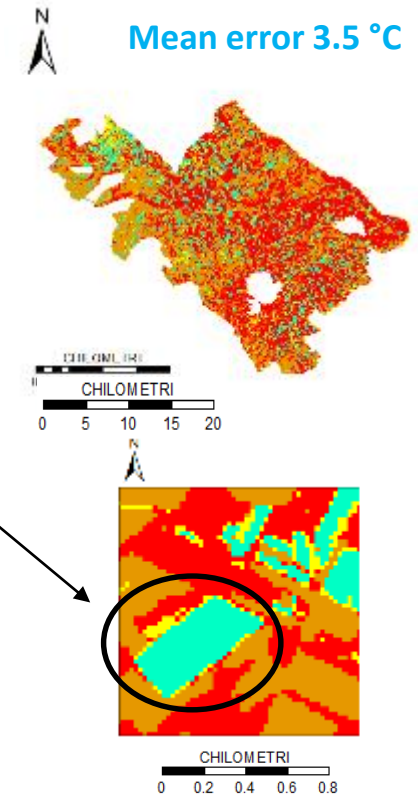
(a) Uniform distribution of irrigation



(b) irrigation in all vegetated area



(c) Irrigation in all vegetated areas with $NDVI > 0.3$



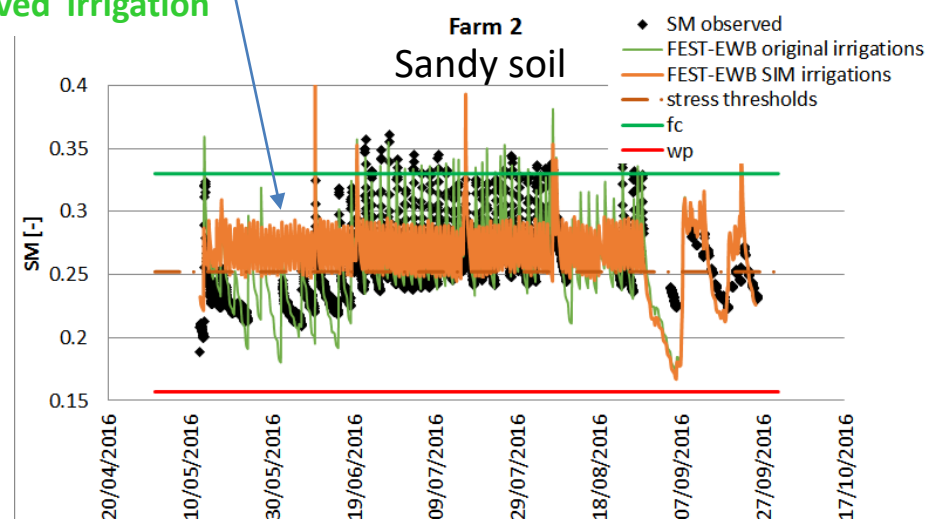
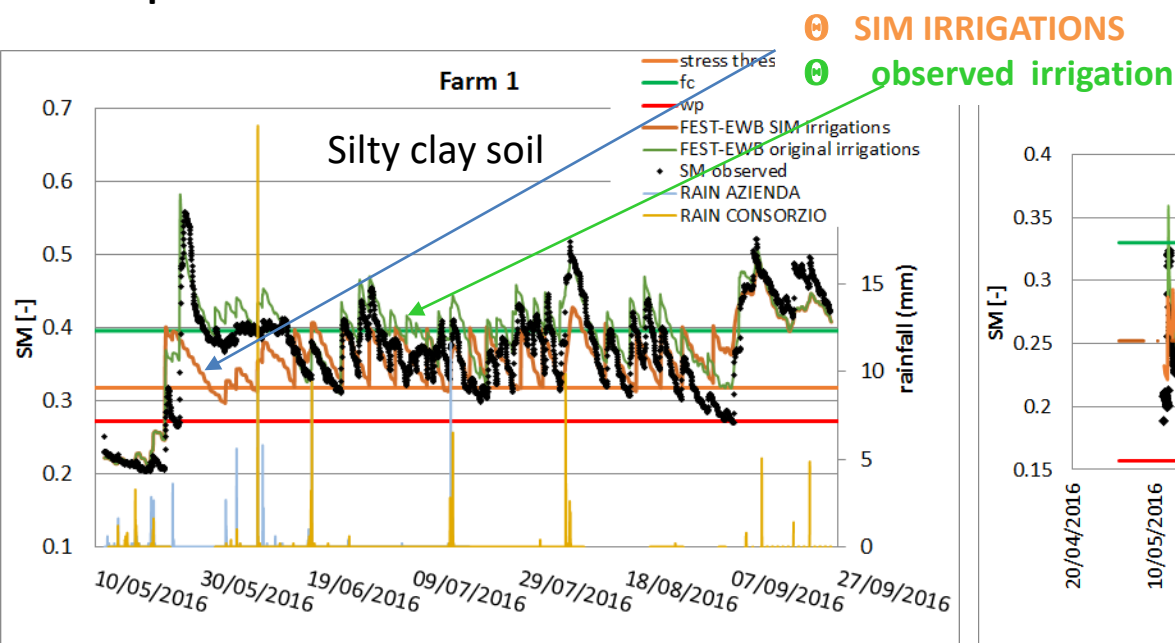


SIM IRRIGATION STRATEGY: effect on soil moisture

Capitanata irrigation consortium

Capitanata Consortium fields: tomatoes

on demand pressurized Irrigation



		Irrigation (mm)	Number of irrigations	Rainfall cum (mm)
Farm 1 (2016)	Observed	547.9	27	145
	SIM	322.3	15	
Farm 2 (2016)	Observed	646.6	43	150
	SIM	590	90	
Farm 3 (2017)	Observed	1000	43	28
	SIM	850	25	

the SIM strategy allows to reduce the passage over the FC threshold reducing the percolation flux with a saving of irrigation volume





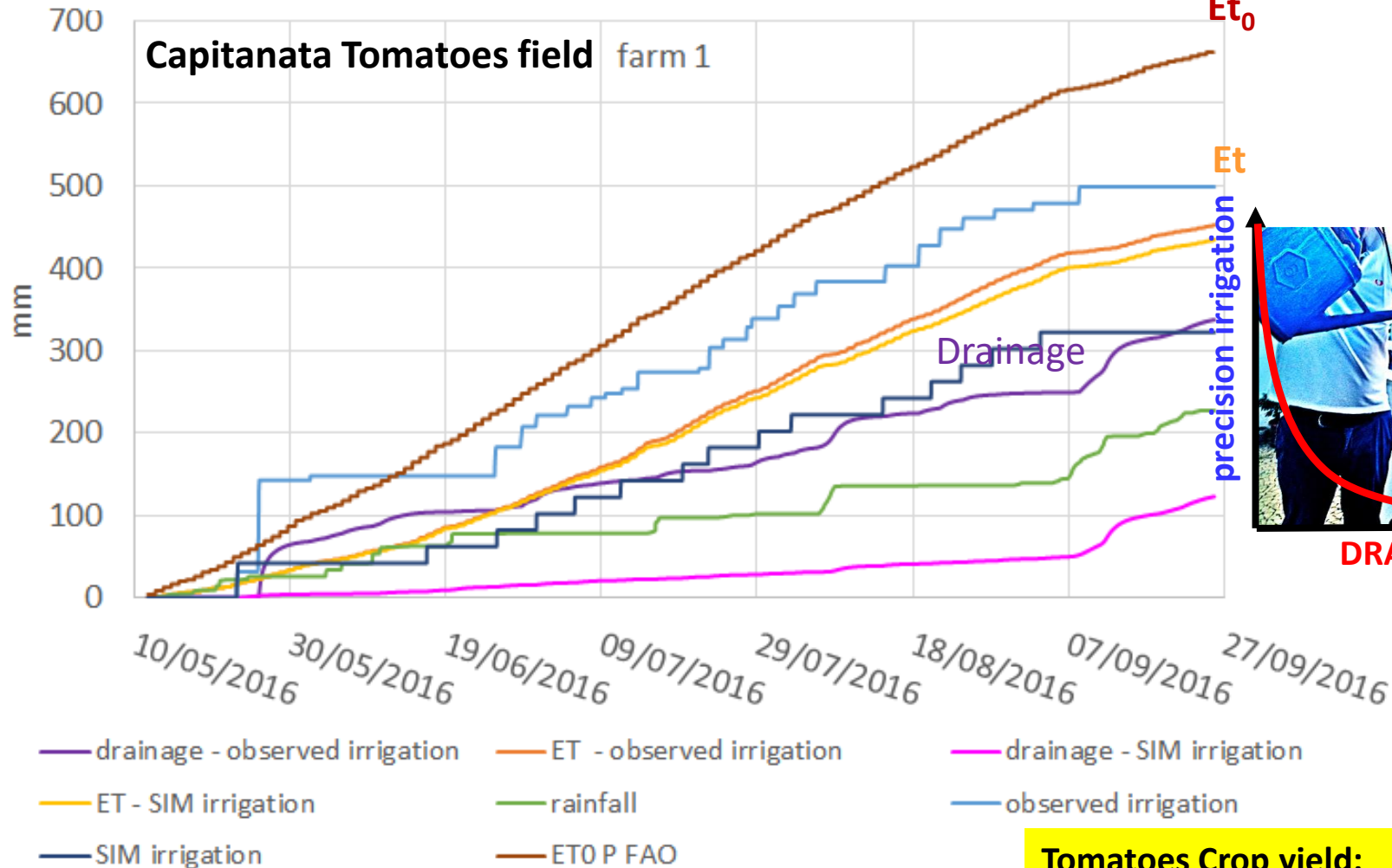
SIM IRRIGATION STRATEGY: where saving water AND IMPROVE WATER EFFICIENCY ?



POLITECNICO
DI MILANO

$$\begin{array}{rclclcl} \text{Rainfall} + \text{Irrigation} & = & \text{ETP} & + & \text{Drainage} & + & \text{DW} \\ 145 & + & 547 & = & 450 & + & 320 & - & 70. \text{ (mm)} \\ 145. & + & 322 & = & 440 & + & 110 & - & 80 \text{ (mm)} \end{array}$$

SIM IRRIGAZIONE
 Et_0



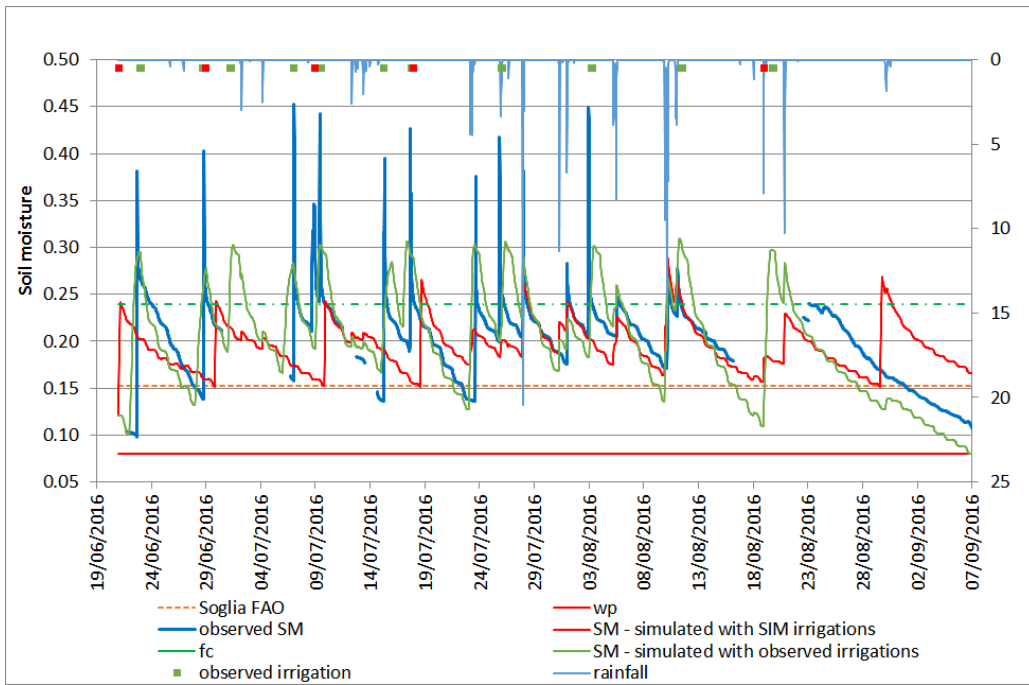
DRAINAGE

Tomatoes Crop yield:

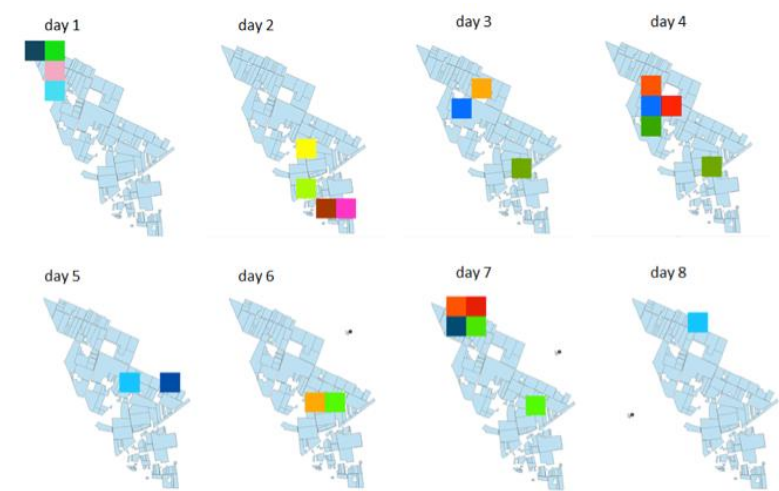
- with observed irrigation 120 ton/ha
- with SIM strategies 116,3 ton/ha



Chiese irrigation consortium Fields ,Maize fields



Scheduled flooding irrigation



TOTAL SUPERFICIE (Ectari)				TOTAL SUPERFICIE (Ectari)			
COMPETENZA ORE (ore/anni)				COMPETENZA ORE (ore/anni)			
1.880				2.080			
TERMINOLOGIA: 1 Ectaro = 10.000 mq				TERMINOLOGIA: 1 Ectaro = 10.000 mq			
DEL GIORNO				DEL GIORNO			
DALLE ORE	DEL GIORNO	ALLA ORE	DEL GIORNO	DALLE ORE	DEL GIORNO	ALLA ORE	DEL GIORNO
02:30	01 ago	02:30	01 ago	02:30	01 ago	04:57	01 ago
04:57	09 ago	08:30	09 ago	04:57	09 ago	10:57	09 ago
12:30	17 ago	14:30	17 ago	14:30	17 ago	16:57	17 ago
18:30	25 ago	20:30	25 ago	20:30	25 ago	22:57	25 ago
00:30	04 set	02:30	04 set	02:30	04 set	04:57	04 set
06:30	12 set	08:30	12 set	08:30	12 set	10:57	12 set
12:30	20 set	14:30	20 set	14:30	20 set	16:57	20 set
18:30	28 set	20:30	28 set	20:30	28 set	22:57	28 set
00:30	06 ago	02:30	06 ago	02:30	06 ago	04:57	06 ago
06:30	14 ago	08:30	14 ago	08:30	14 ago	10:57	14 ago
12:30	22 ago	14:30	22 ago	14:30	22 ago	16:57	22 ago
18:30	30 ago	20:30	30 ago	20:30	30 ago	22:57	30 ago
00:30	07 ago	02:30	07 ago	02:30	07 ago	04:57	07 ago
06:30	15 ago	08:30	15 ago	08:30	15 ago	10:57	15 ago
12:30	23 ago	14:30	23 ago	14:30	23 ago	16:57	23 ago
18:30	01 ago	20:30	01 ago	20:30	01 ago	22:57	01 ago
00:30	09 ago	02:30	09 ago	02:30	09 ago	04:57	09 ago
06:30	17 ago	08:30	17 ago	08:30	17 ago	10:57	17 ago
12:30	25 ago	14:30	25 ago	14:30	25 ago	16:57	25 ago
18:30	02 ago	20:30	02 ago	20:30	02 ago	22:57	02 ago
00:30	10 ago	02:30	10 ago	02:30	10 ago	04:57	10 ago
06:30	18 ago	08:30	18 ago	08:30	18 ago	10:57	18 ago
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06:30	19 ago	08:30	19 ago	08:30	19 ago	10:57	19 ago
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18:30	04 ago	20:30	04 ago	20:30	04 ago	22:57	04 ago
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06:30	20 ago	08:30	20 ago	08:30	20 ago	10:57	20 ago

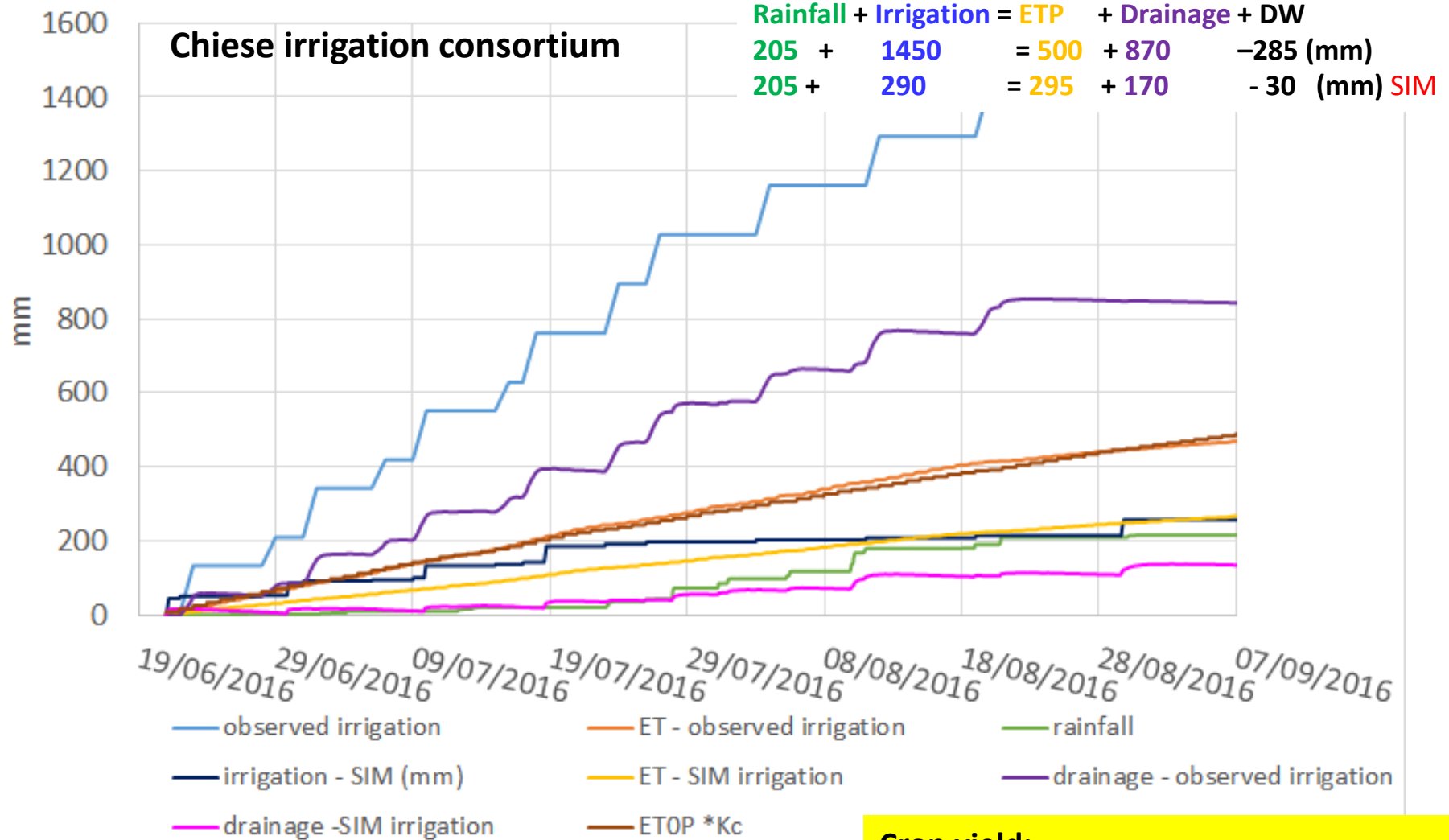
		Irrigation (mm)	Number of irrigations	Rainfall cum (mm)
2016	Observed	1426	11	269
	SIM	301	5	
2017	Observed	1480	17	223
	SIM	488	10	
2018	Observed	1750	13	515
	SIM	200	5	





SIM IRRIGATION STRATEGY : where saving water?

Chiese irrigation consortium



Crop yield:

- with observed irrigation 9,1 ton/ha
- with SIM strategies 8,9 ton/ha



The coupled FEST-EWB – SAFY model – SIM irrigation strategy

Comparing consortium scale: economic indices

Irrigation water use efficiency

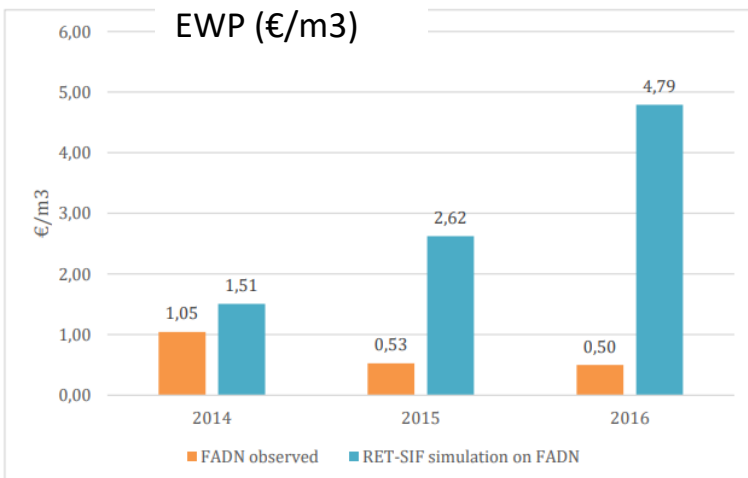
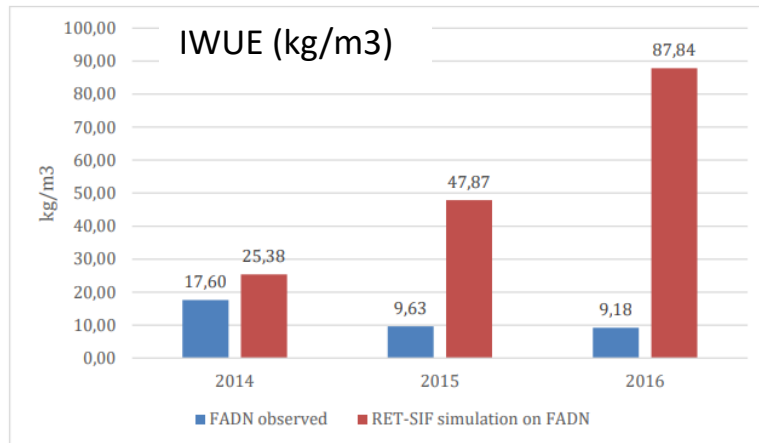
$$IWUE = \frac{Yield}{Irr\ vol} = \frac{kg/ha}{m^3/ha}$$

economic water productivity

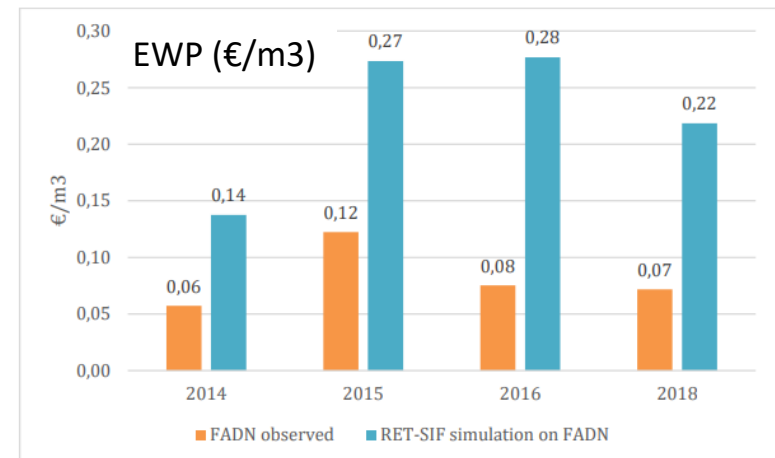
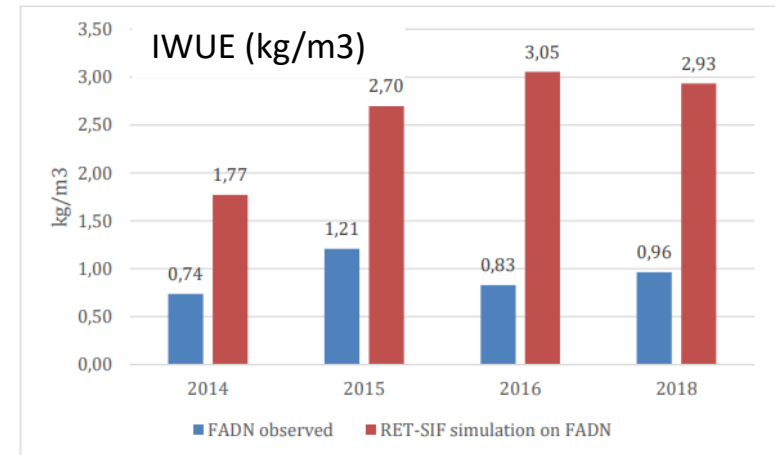
$$EWP = \frac{Gross\ margin}{Irr\ vol} = \frac{€/ha}{m^3/ha}$$

Observed: EU Farm Accountancy
Data Network (FADN)
SIM: simulated with FEST-
EWB_SAFY model

Tomatoes Capitanata consortium



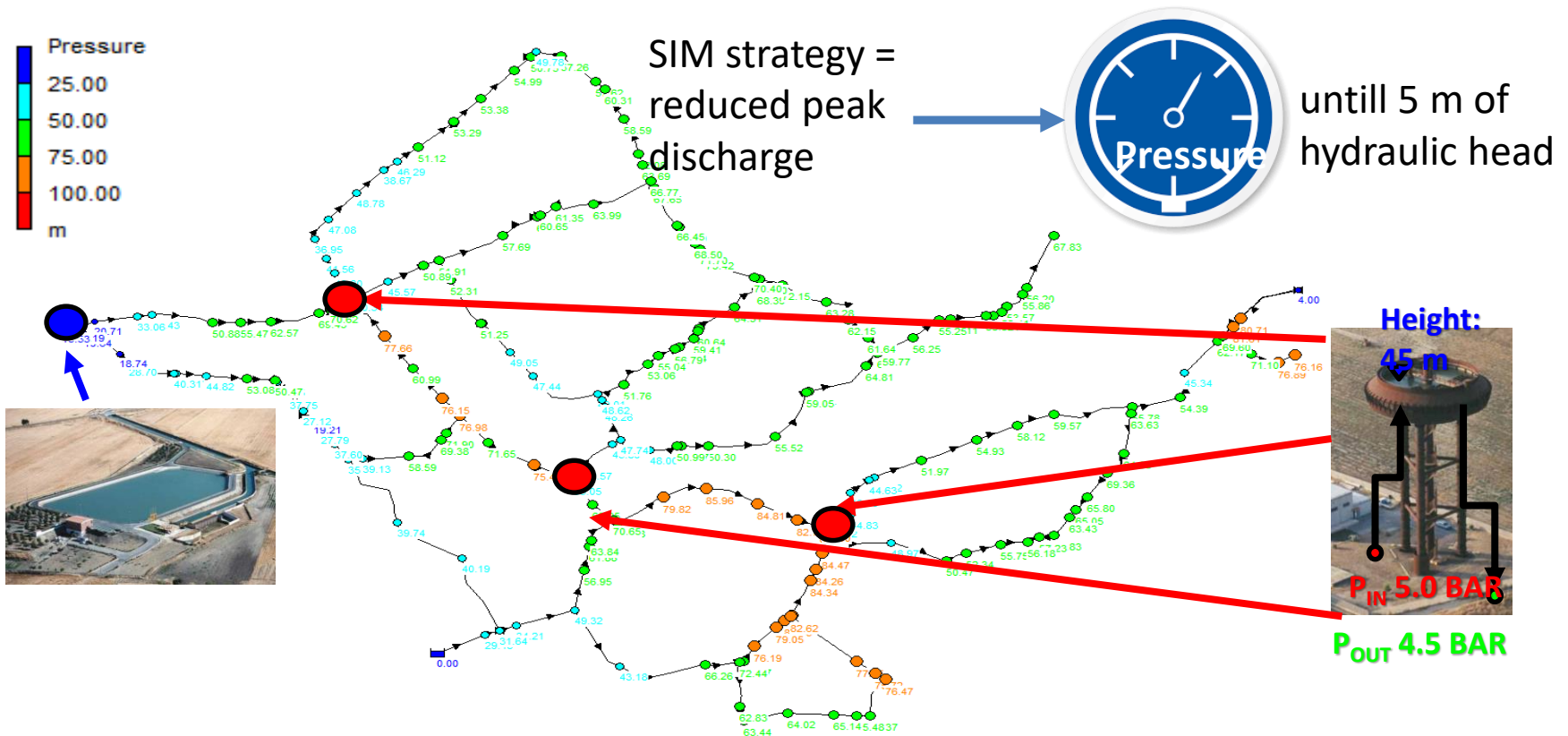
maize Chiese consortium



SIM IMPACT ON PRESENT IRRIGATION SYSTEM

PRESSURIZED DISTRIBUTION NETWORK: THE CAPITANATA SUD FORTORE EXAMPLE

- USERS DEMAND $10 \div 500$ L/S IN 124 NODES
- NODES ARE LINKED TO A SECOND MORE COMPLEX NETWORK MANAGED BY THE CONSORTIUM



PRESSURES FROM 8 to 4 BAR

**Real-time
monitoring:
www.sim.polimi.it**



Capitanata sud Fortore agricultural basin: Water deficit

The following map displays the daily mean water deficit obtained coupling a hydrological model (FEST-EWB or ETMonitor) with several meteorological models outputs (WRF, ECMWF, BOLAM, MOLOCH). In green the areas where soil moisture is higher than the field capacity, in yellow the areas where soil moisture is in between the field capacity and the crop stress threshold, in red the areas where soil moisture is below the crop stress threshold.

Idrological
Model

FEST EWB

Emission Date

2017-10-16

Forecast time

Present

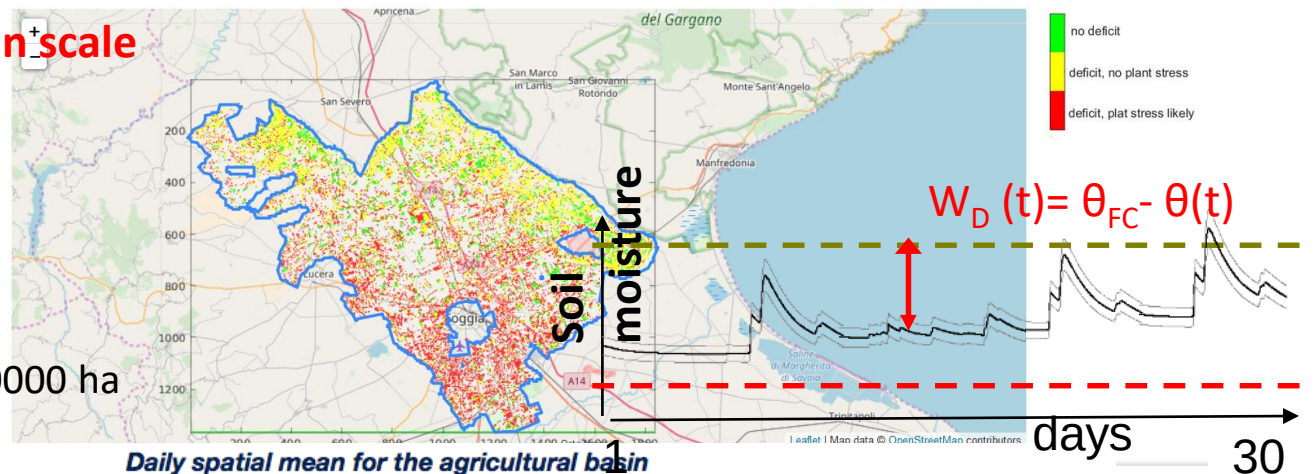
Apply

Reset Map

Histogram

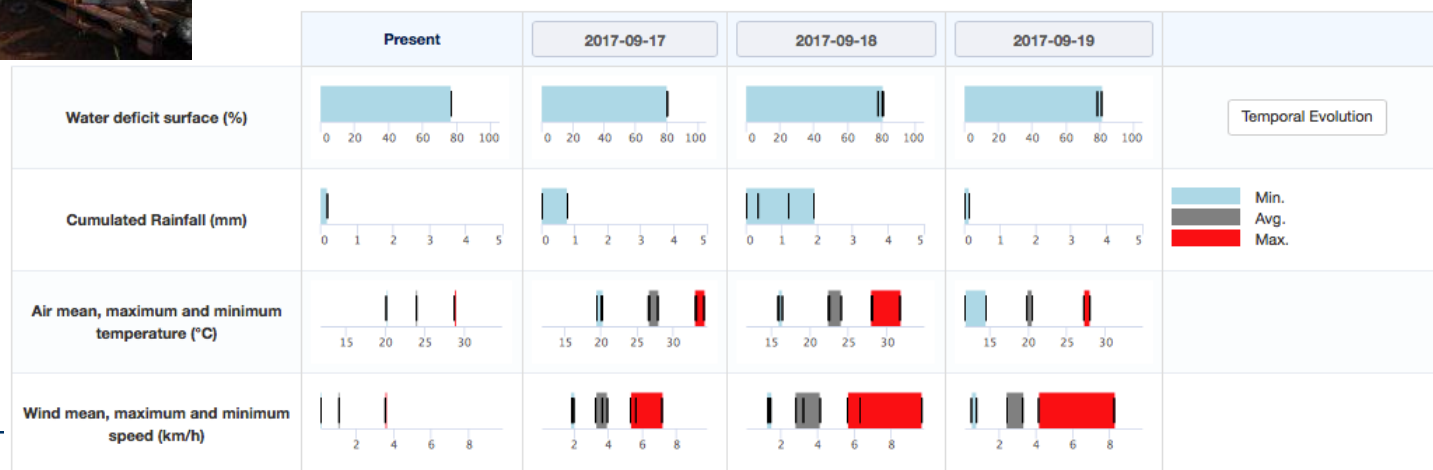
Basin scale

area 50000 ha



Daily spatial mean for the agricultural basin

spatial mean for present and forecasted hydro-meteorological outlooks. The "Present" column is computed with observed meteorological data. The highlighted sector refers to interval of hydro-meteorological model outlooks.





Concluding remarks



**SATELLITE DATA MAY PROVIDE A SIGNIFICANT SUPPORT IN PRECISE IRRIGATION
COMBINING:**

- Pixel wise hydrologic energy water balance models where modelled LST may be compared with the satellite data
- Ground hydro - meteorological data with pixel wise models

Do not forget near sensing OBSERVATION for water engineering satellite data applications