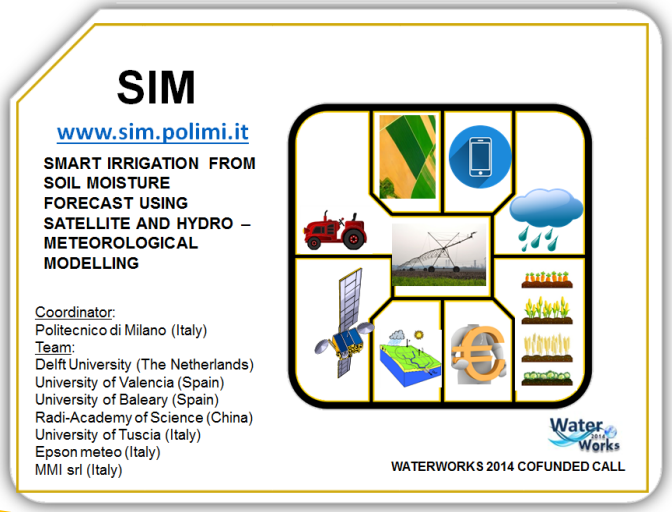
Smart Irrigation monitoring and forecasting using satellite and hydro–meteorological modelling



SIM water balance models and interaction with satellite data

C. Corbari, A. Ceppi, G. Lombardi, I. Ben Charfi, L. Cerri, M. Feki, N. Paciolla, G. Ravazzani, M. Mancini

Hydrological model calibration: IN SERIES technique using distributed satellite LST & local discharges

FEST-EWB model

J. Dooge(1986) observing internal state variables of hydrologic model (θ) & LST

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

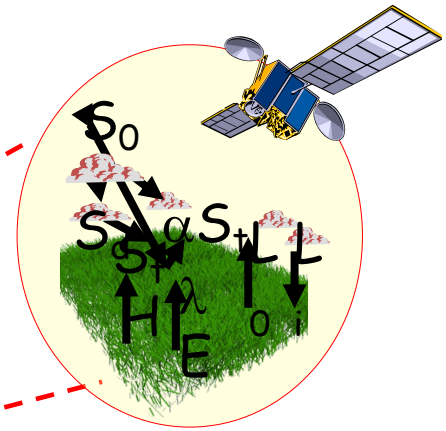
Soil water balance

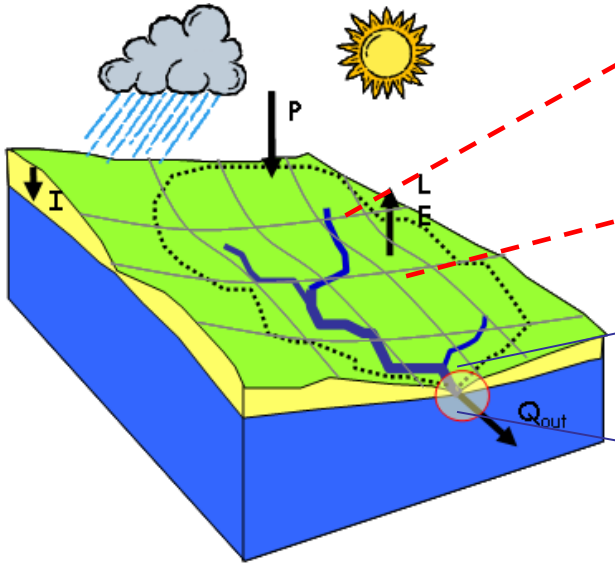
$$P_{tot}=R+ET_{eff}+D+(\theta_{t+1}-\theta_t)*Z$$

Energy balance

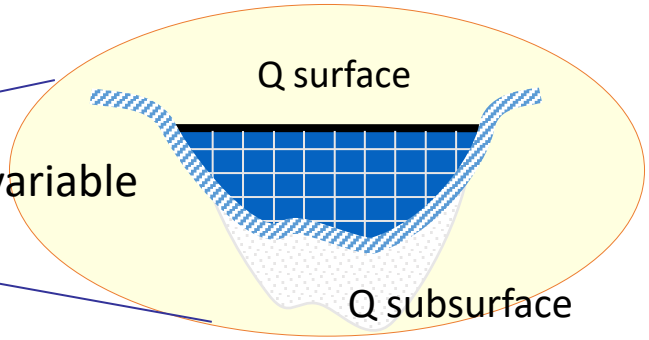
$$Rn-G-H-LE=\frac{dS}{dt} \qquad ETeff=\frac{LE}{\rho Cp}$$

Internal variable **(θ) & LST**





External variable



LST for soil surface parameters Calibration

Q for Calibration surface and subsurface routing parameters

It is reasonable to use evaporation flux "measures" similarly to discharge measurements

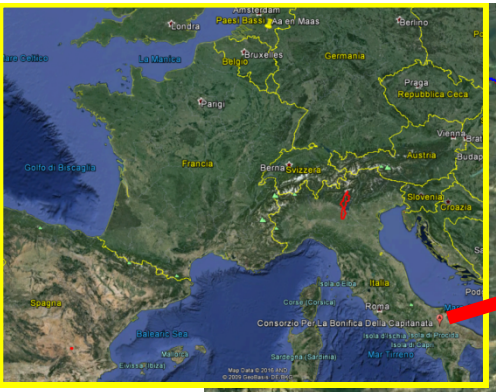
Dooge, J.C.I. (1986). Looking for hydrologic laws, Water Resour. Res., 22 (9) 46S-58S.

Consorzio della capitanata (Southern Italy): experimental sites and water distribution network

70% of crops are irrigated by drip irrigation

Sud Fortore 55.000 ha):
5900 km pressurized irrigation network aqueduct (Occhito and Celone dam)
96 million m3 water for irrigation a year

Eddy covariance from 2015 (tomatoes)

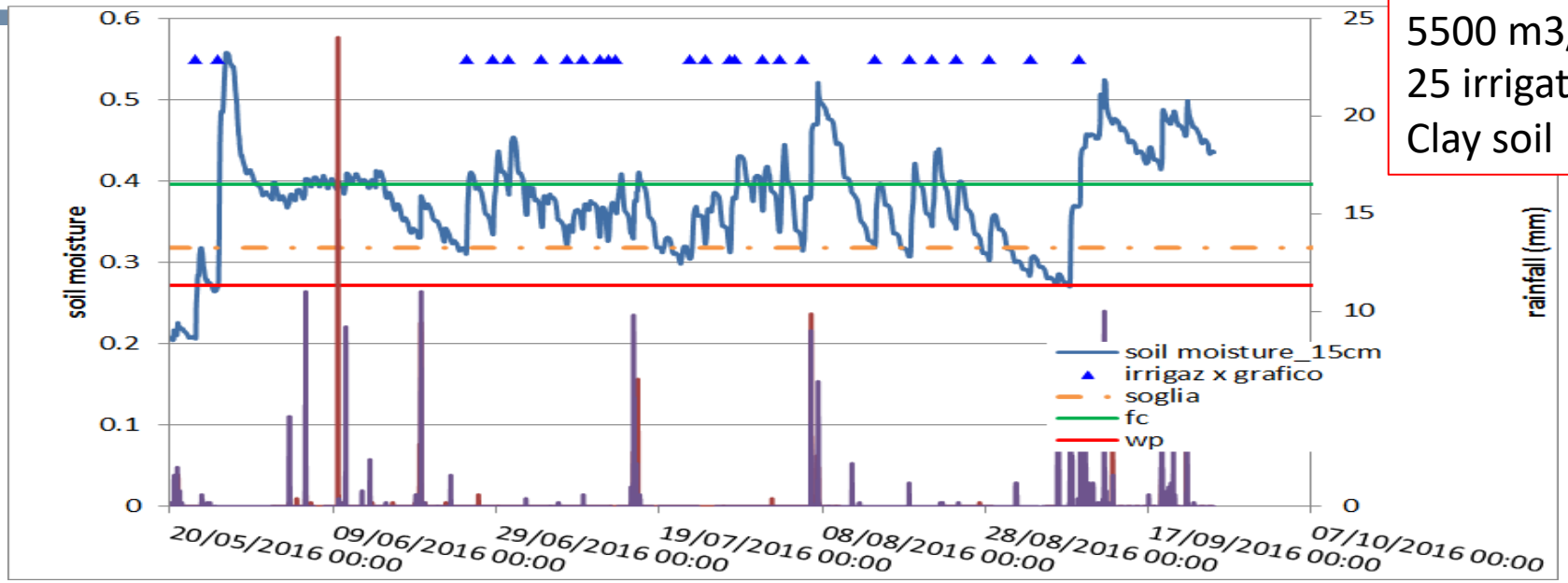


Eddy covariance from 2013 (asparagus, tomatoes)

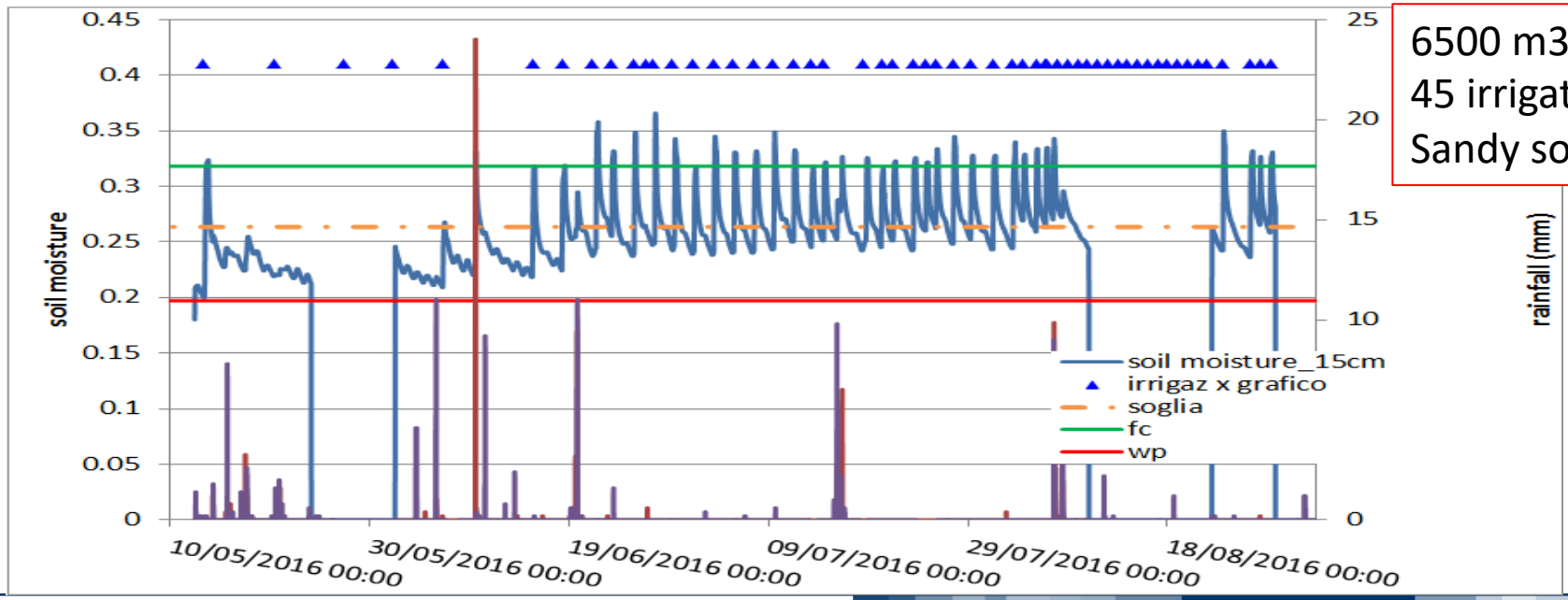
GROW OBSERVATORY

CONSORZIO PER LA BONIFICA DELLA CAPITANATA

Tomatoes fields irrigation comparison (2016)



5500 m3/ha
25 irrigations
Clay soil

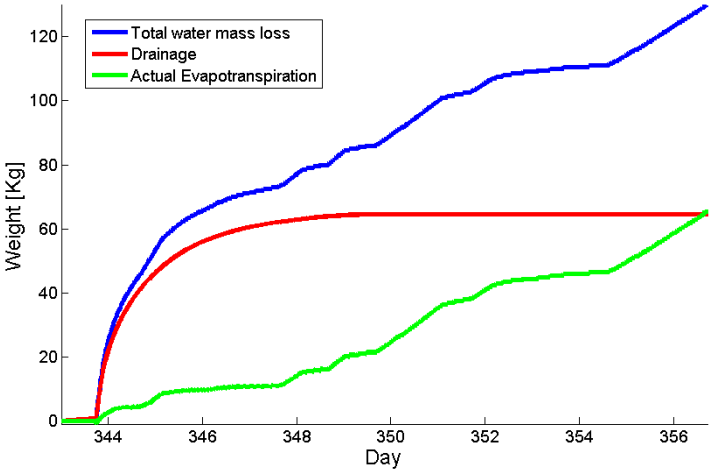


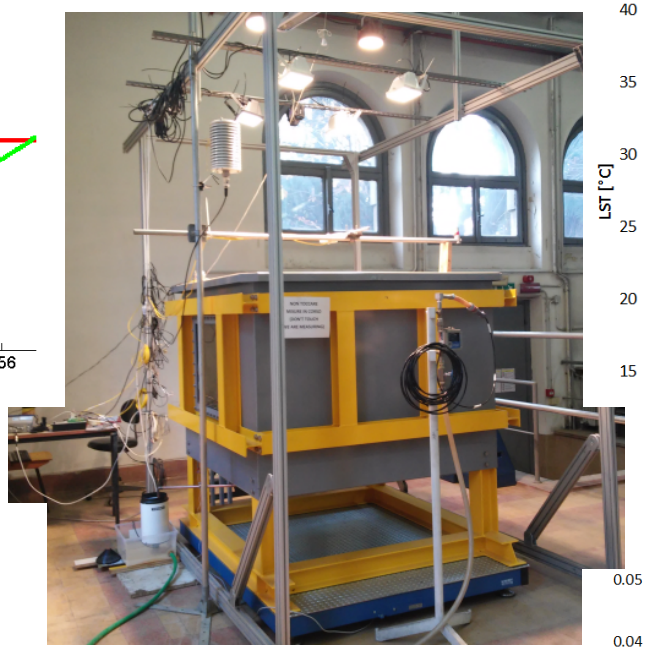
6500 m3/ha
45 irrigations
Sandy soil

The Lisimeter Laboratory experience: verifying FEST-EWB model parameterization

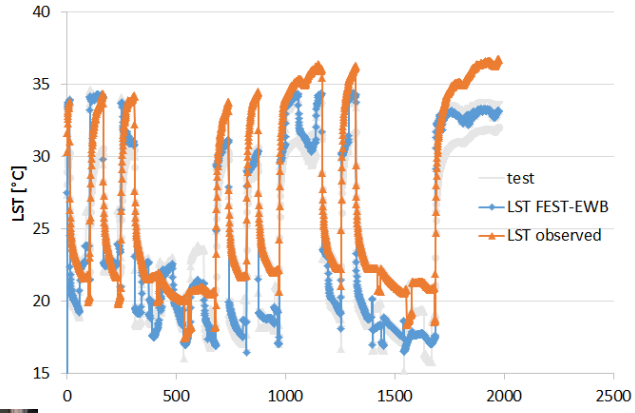
Fully equipped to measure all the process of the hydrological cycle

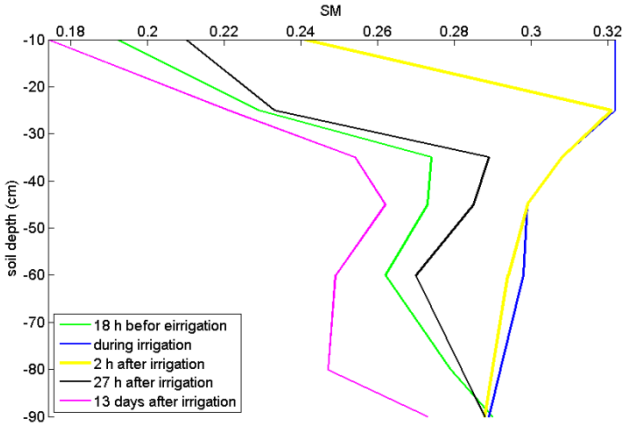
measured



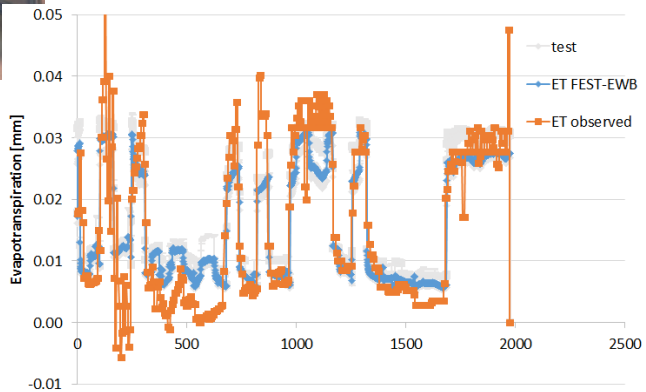


FEST-EWB model





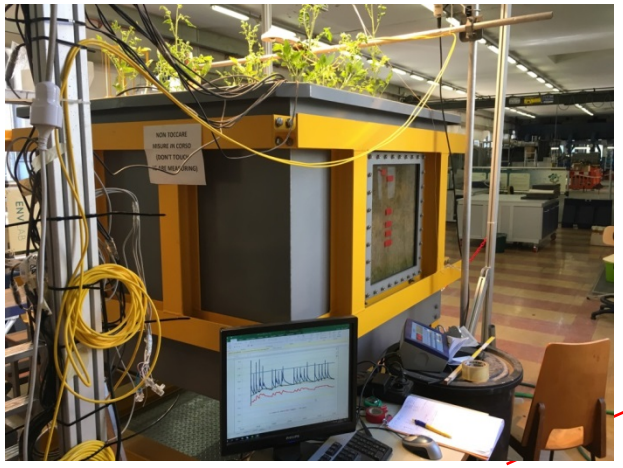
DIMENSIONS
Length, width =1.5 m
height =1.0 m
Weight = 956 kg without soil
Weight about 4700 kg with soil

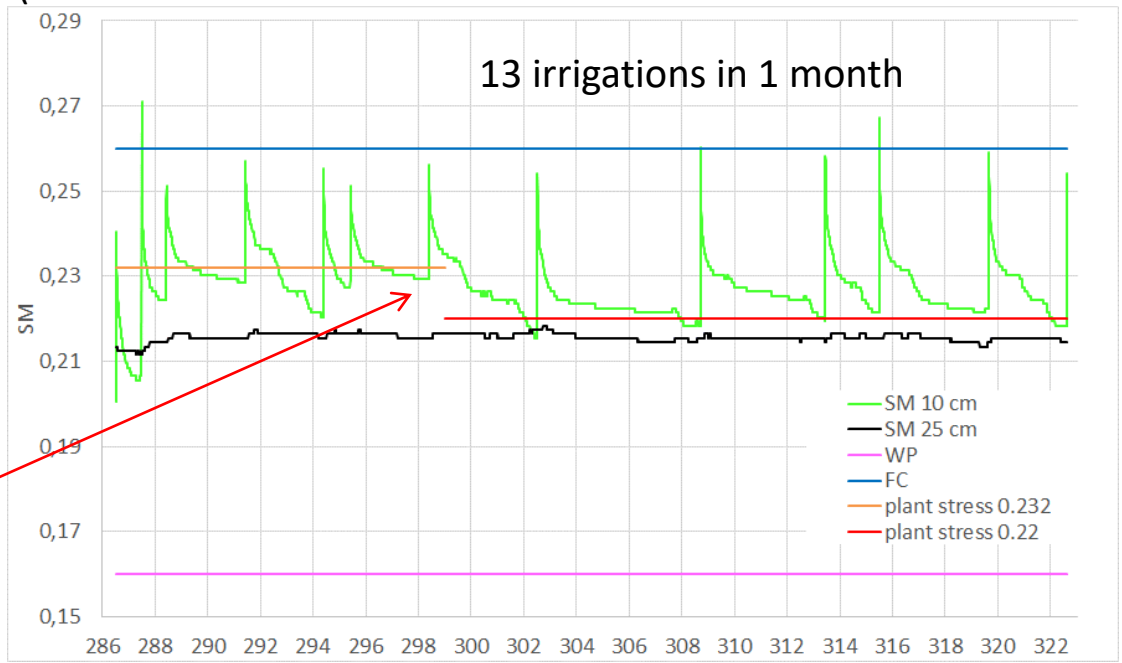


What happens with vegetation? When to irrigate?

POLITECNICO DI MILANO

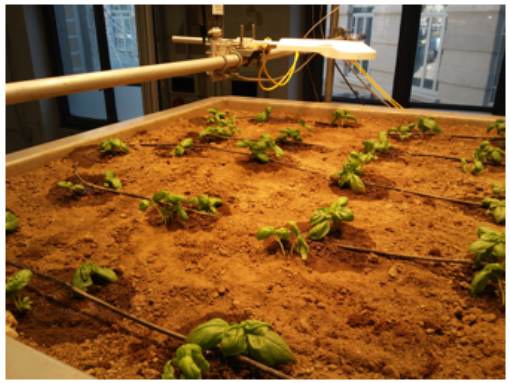
Triggering irrigation according to measured (or forecasted) **soil moisture** value and **plant stress threshold**





After 14 days the plant threshold (from FAO) is lowered

Basil planted on 12 october (day 286)

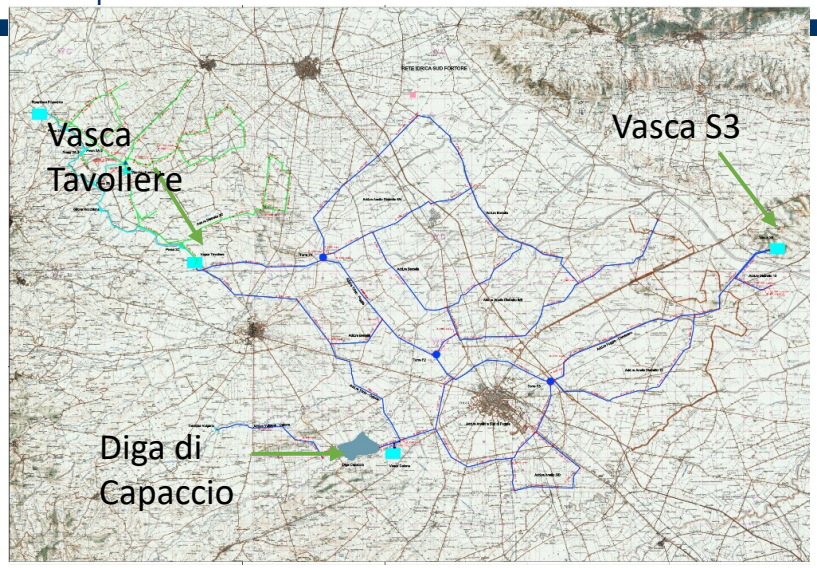


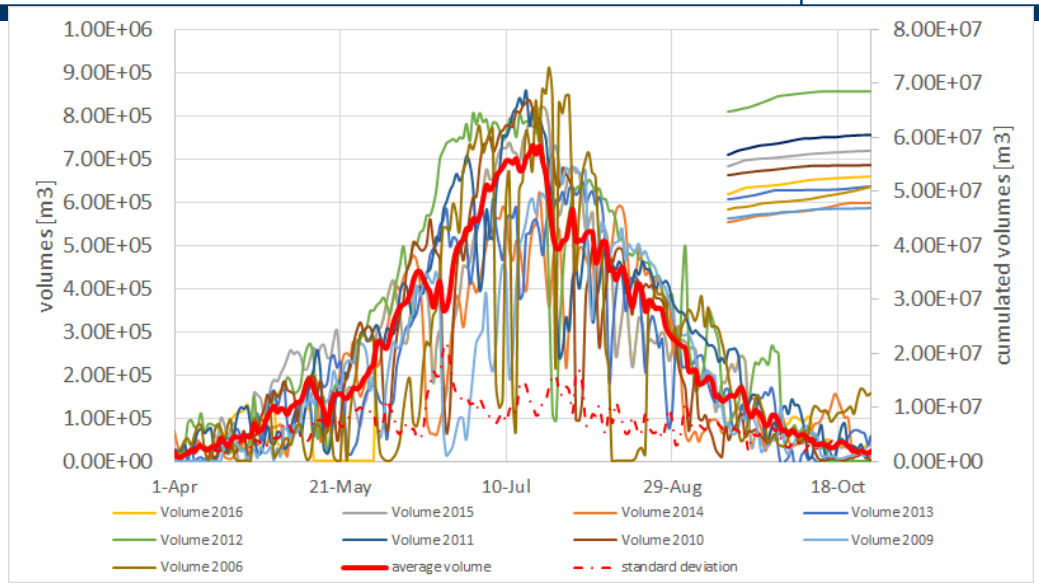
17 november (day322)

Stress threshold is a fucntion of:
-soil type
-vegetation type
-vegetation growth strage
-climatology

(http://www.fao.org/)

Irrigation water distribution aqueduct: on demand irrigation





CONSORZIO PER LA BONIFICA DELLA CAPITANATA

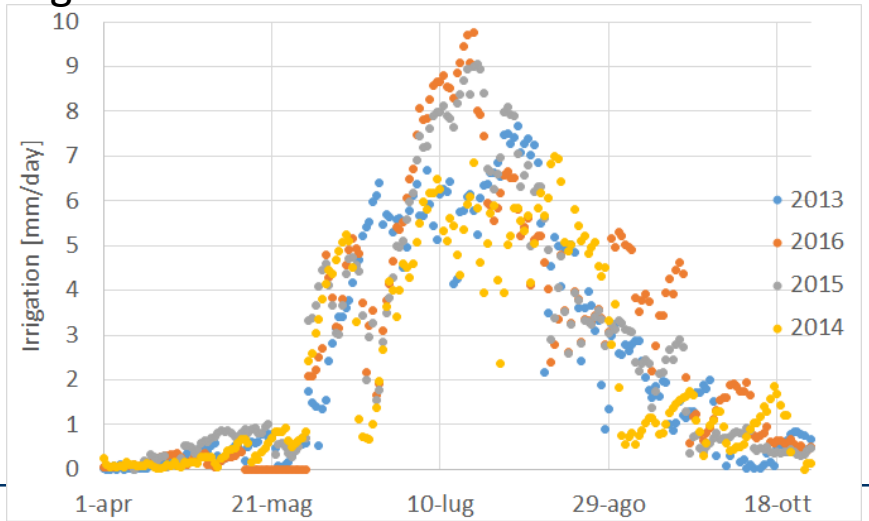
Irrigated crops during the summer season:

-mainly tomatoes
-asparagus
-vineyard
-olives trees

$$hi = \frac{Qg}{S\ pomodoro}$$

ANNO	Apertura Stagione	Chiusura Stagione
2014	01/04/2014	31/12/2014
2015	23/03/2015	01/12/2015
2016	01/04/2016	01/12/2016

Irrigation distribution into FEST-EWB hydrological model: which are the cultivated & irrigated areas?

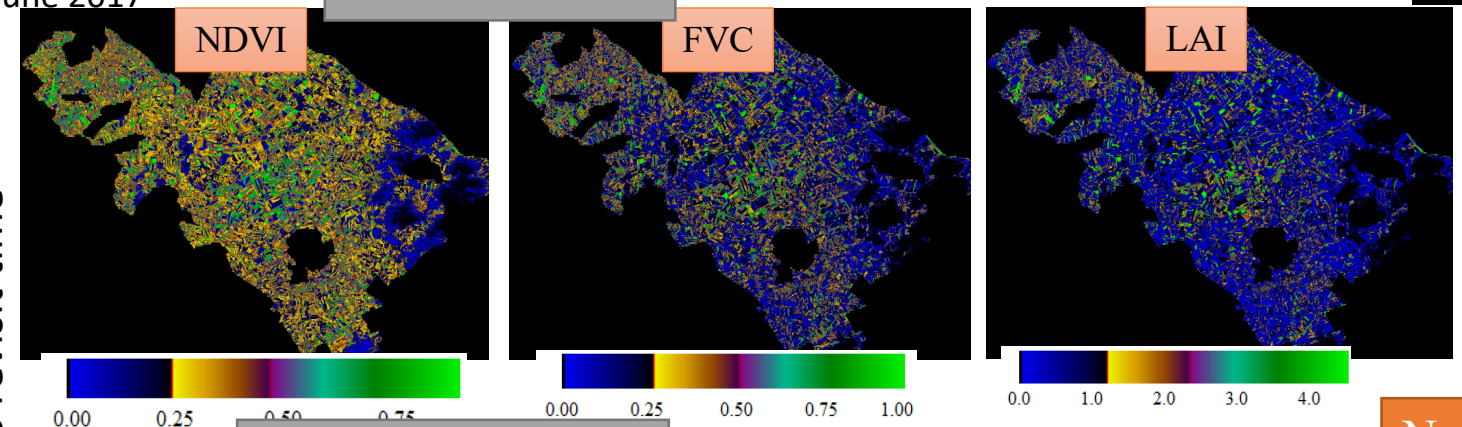


Satellite data supporting Hydrological model

5 june 2017

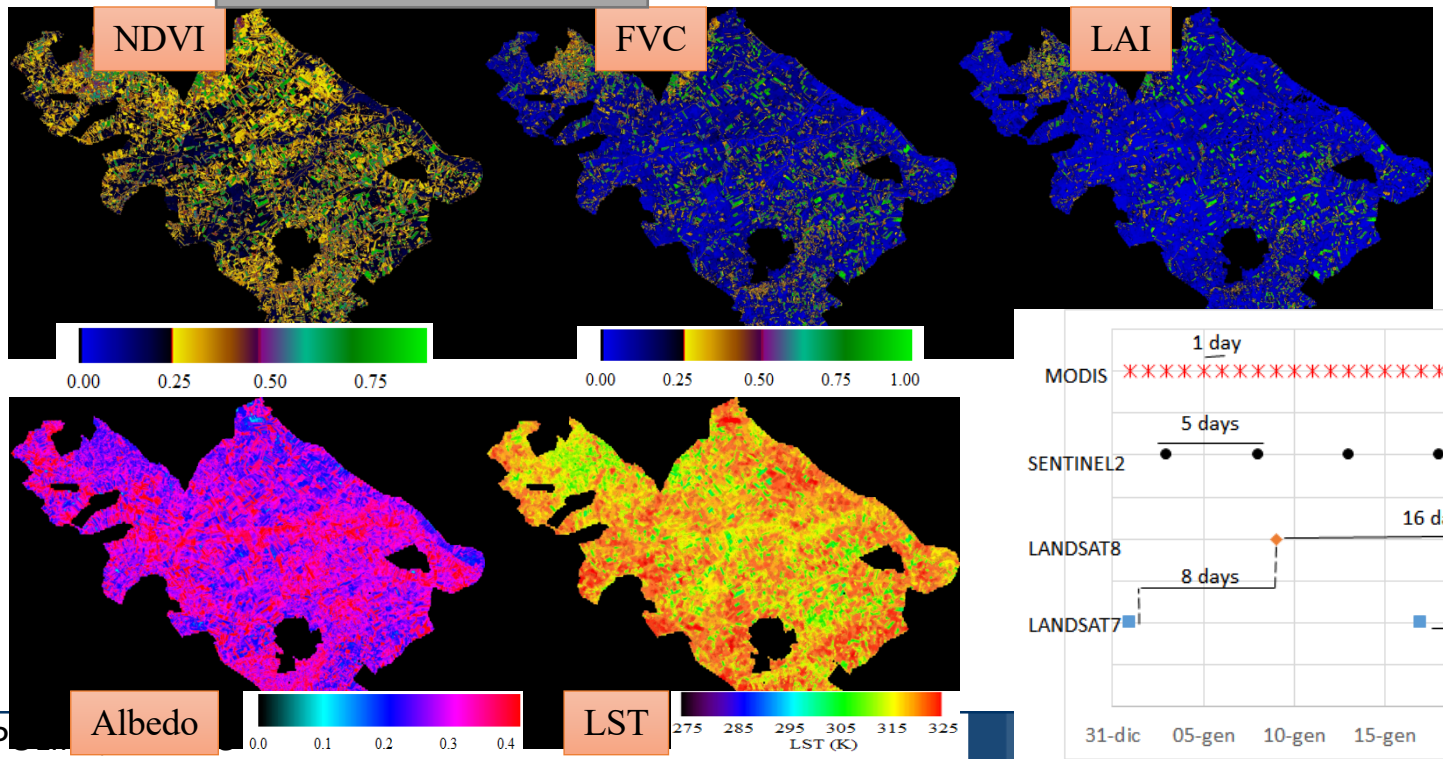
DATA integration IMPROVES revisit time

SENTINEL-2 MSI



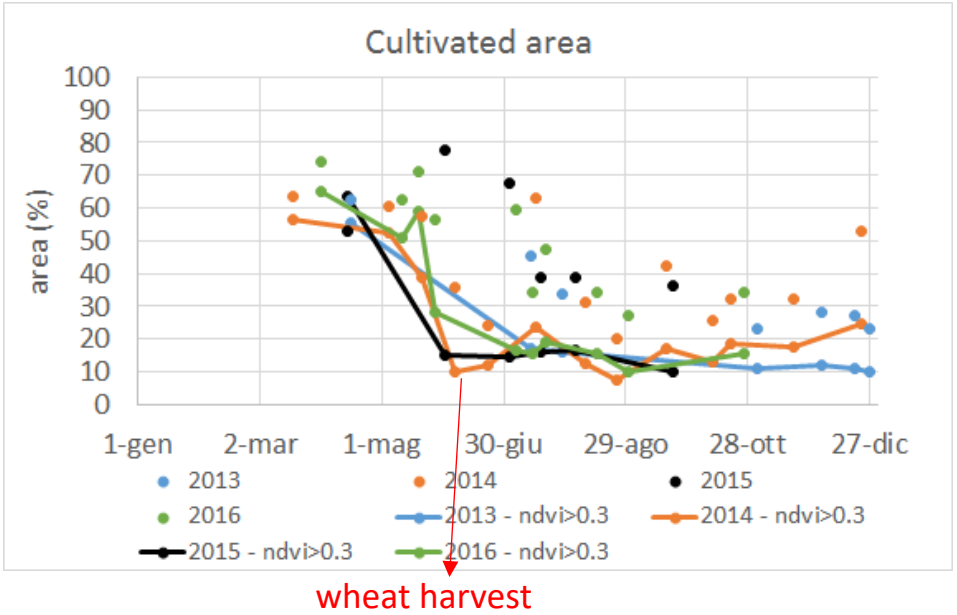
Sobrino and all 2017

LANDSAT-8 OLI/TIRS



Near real time images

Crops areas and dynamic identification from satellite data for irrigation distribution



To identify irrigated areas:

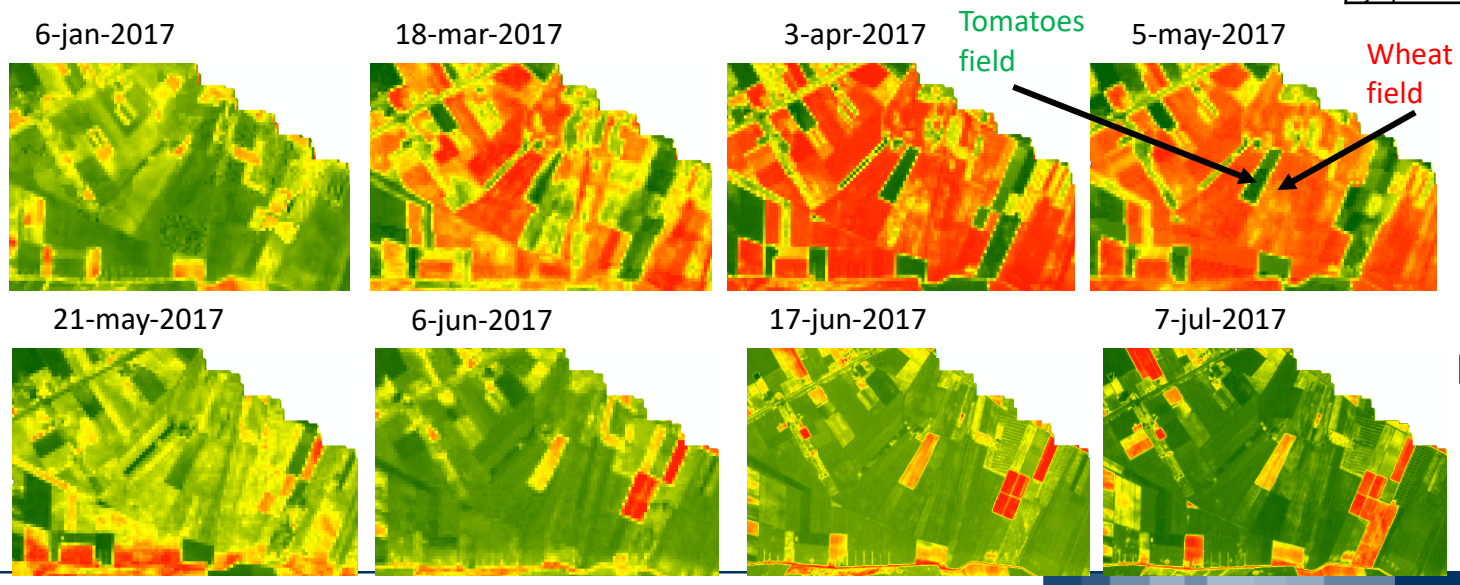
Vegetation fraction>0.05

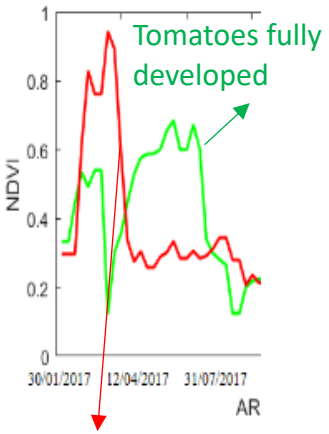
Ndvi>0.3 (end april)

		Vegetable +tomatoes	wheat
6 jan 2017	LANDSAT 8	0.889	0.242
18-mar-17	LANDSAT 8	0.667	0.411
03-apr-17	LANDSAT 8	0.443	0.792
5 may 2017	LANDSAT 8	0.554	0.877
21 may 2017	LANDSAT 8	0.1332	0.919
29 may 2017	LANDSAT 7	0.207	0.708
6 june 2017	LANDSAT 8	0.34	0.461
17 june 2017	SENTINEL 2	0.706	0.175
7 july 2017	SENTINEL 2	0.908	0.06

Tomatoes planting

wheat harvest

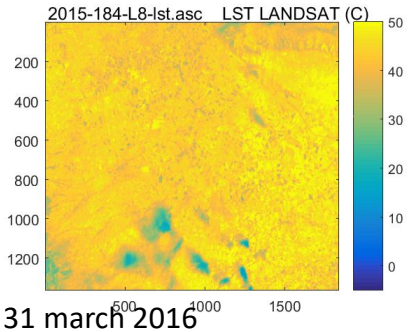




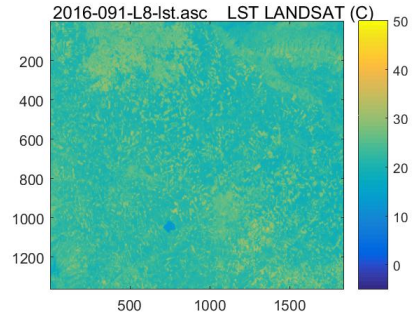
Calibration of FEST-EWB model: soil surface parameters calibration pixel by pixel through minimising LST differences

LANDSAT 8

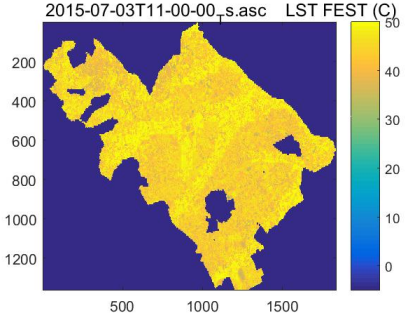
3 July 2015

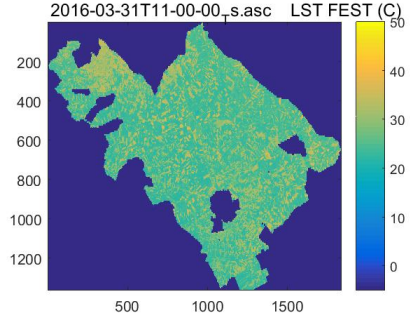


31 march 2016

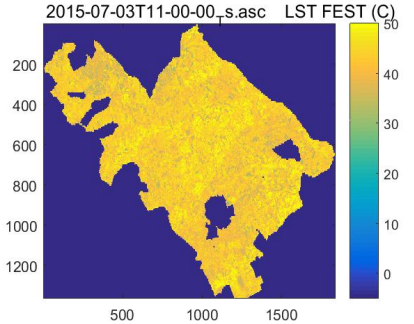


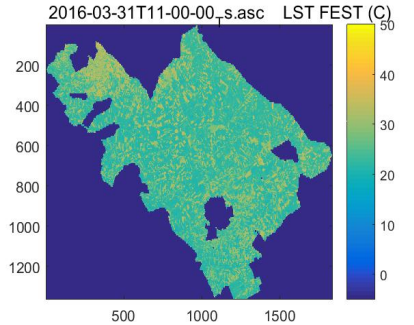
FEST-EWB not calibrated





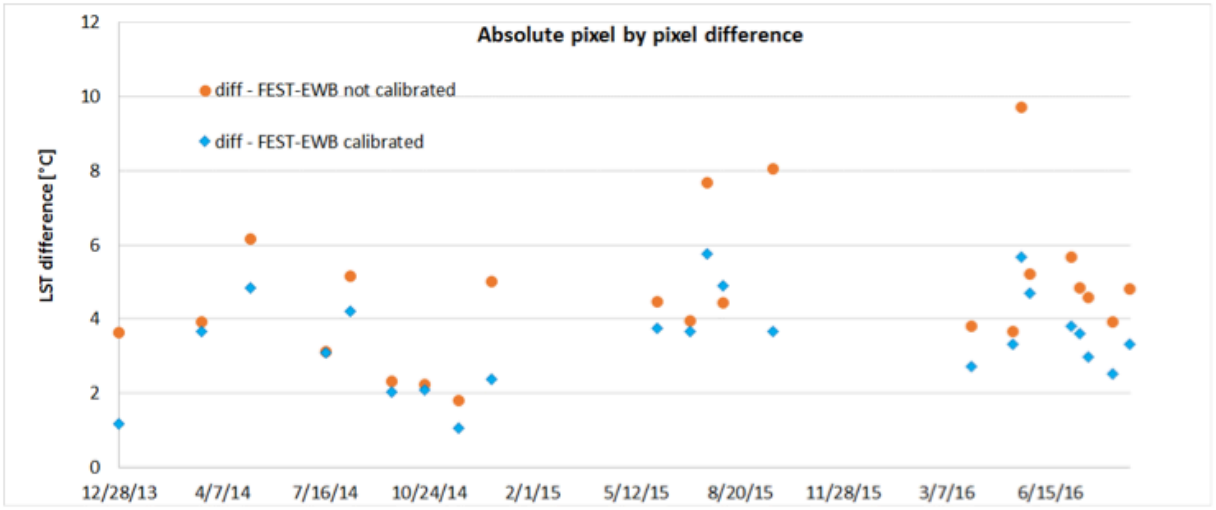
FEST-EWB calibrated





Statistics are computed for the same number of pixels (e.g. if MODIS is covered with clouds also FEST-EWB is clouded)

FEST-EWB model can help in creating complete long time series of LST data



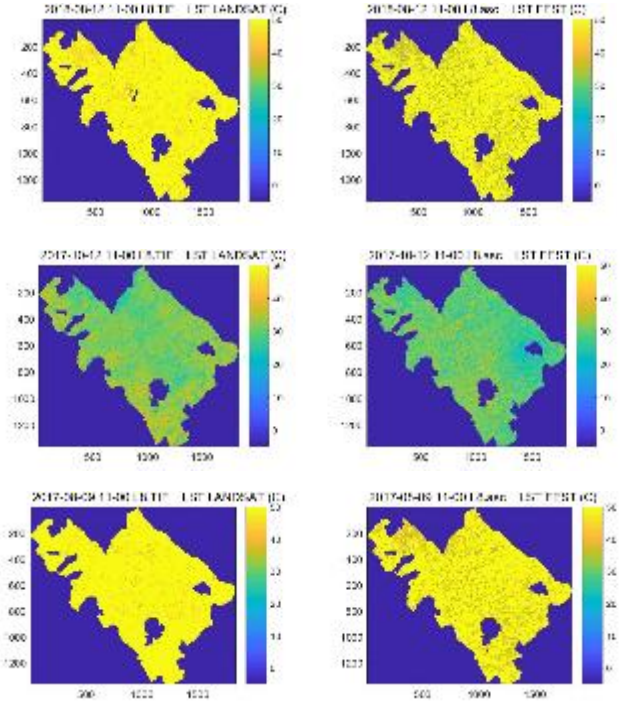
Mean error 5 °C

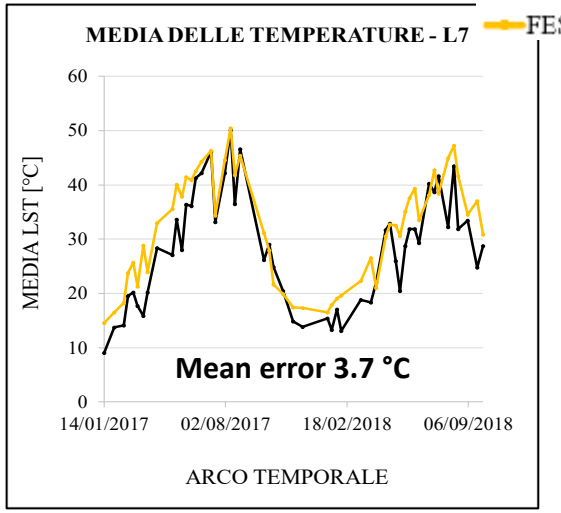
Mean error 2.5 °C

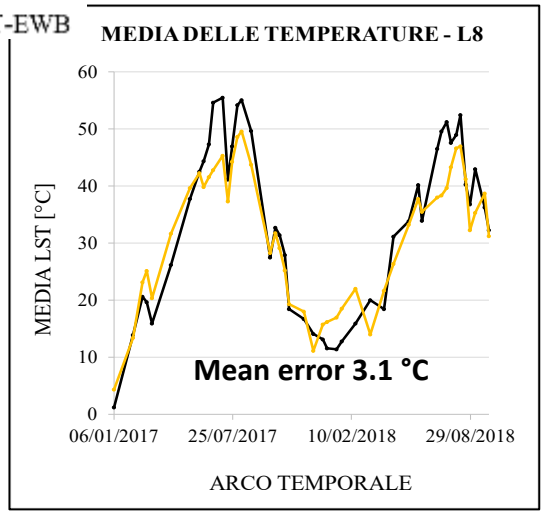
Validation soil moisture and LST of FEST-EWB model

LANDSAT 8

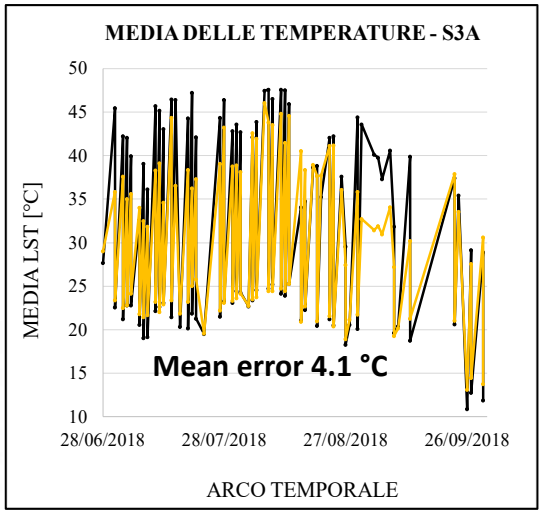
FEST-EWB calibrated





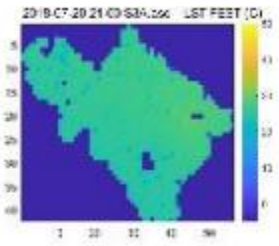


Mean error 3.5 °C

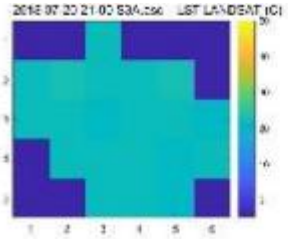


Scale issue

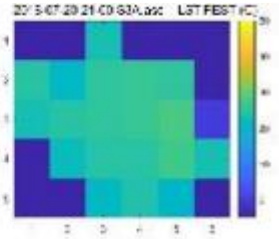
FEST-EWB



SATELLITE S3A

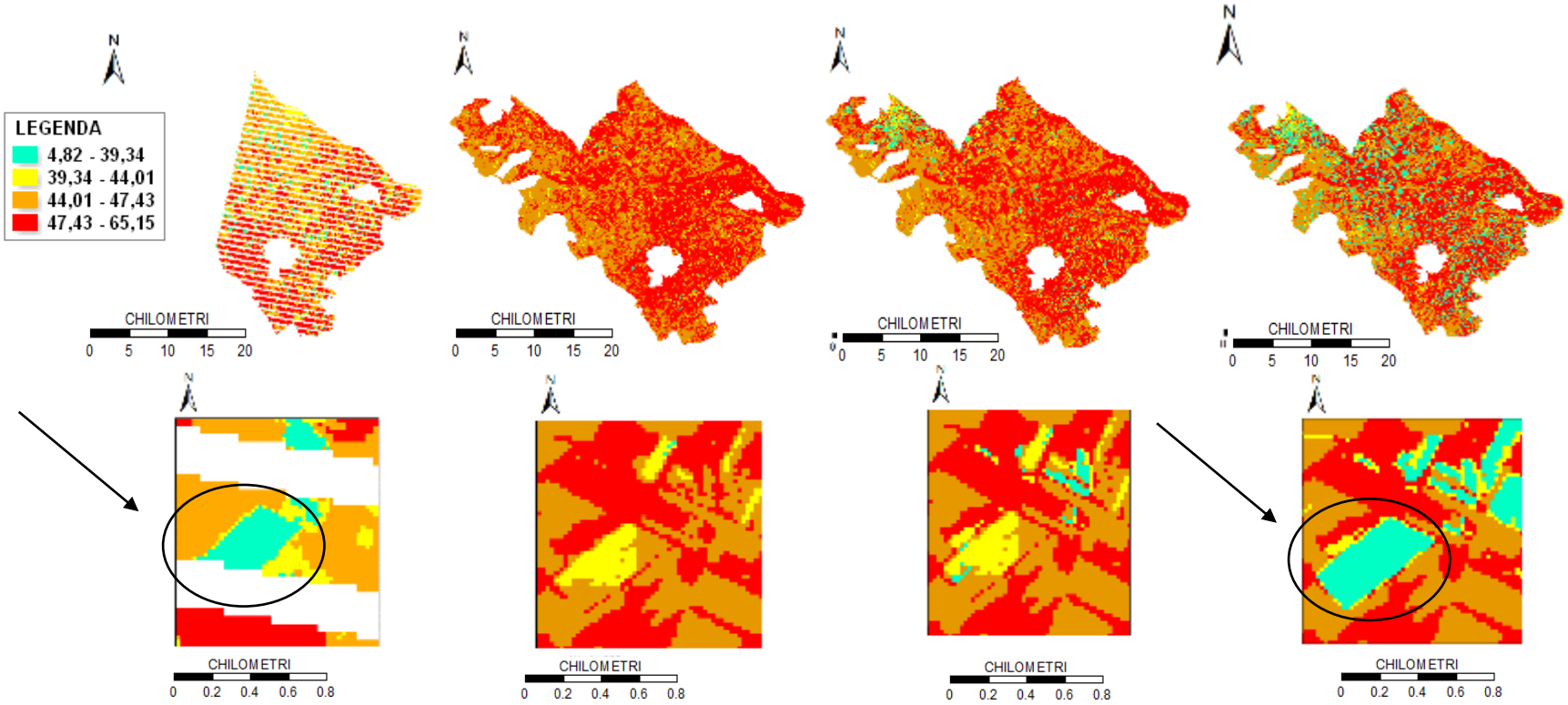


FEST-EWB



FEST-EWB hydrological model estimate and irrigation distribution

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



SATELLITE

(a) Uniform distribution of irrigation

(b) irrigation in all vegetated area

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

for 53 images 2017-2018

Mean error 4.7 °C

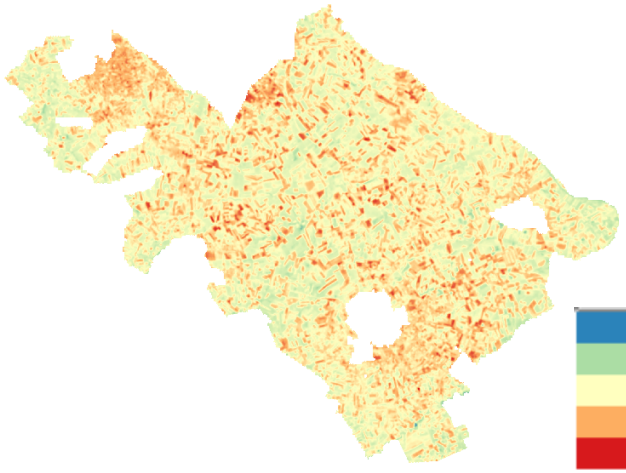
Mean error 4 °C

Mean error 3.5 °C

Hydrological FEST-EWB model & satellite temperature data for soil moisture

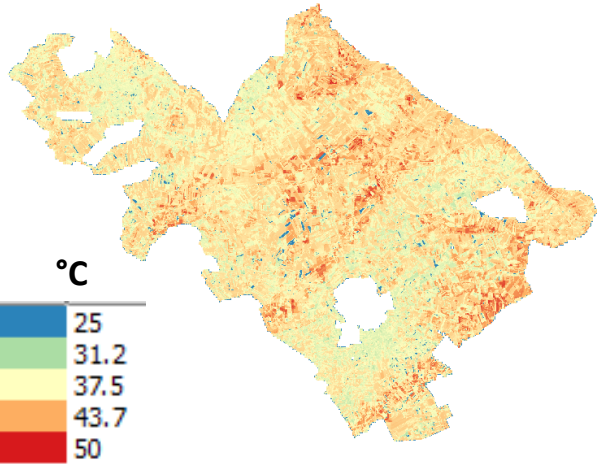
Example
1 June 2015

LANDSAT 8
Δx=30 mLST

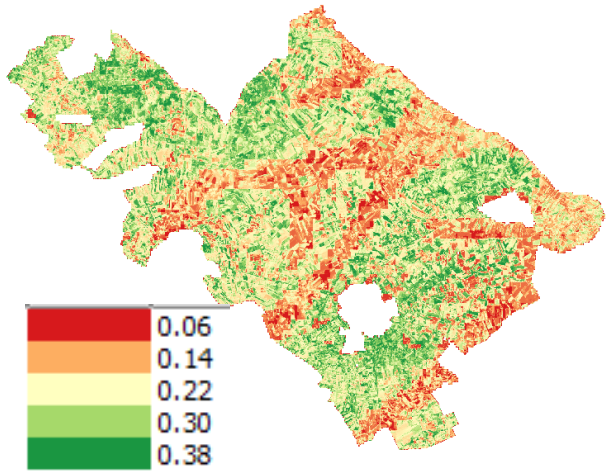


FEST-EWB calibrated

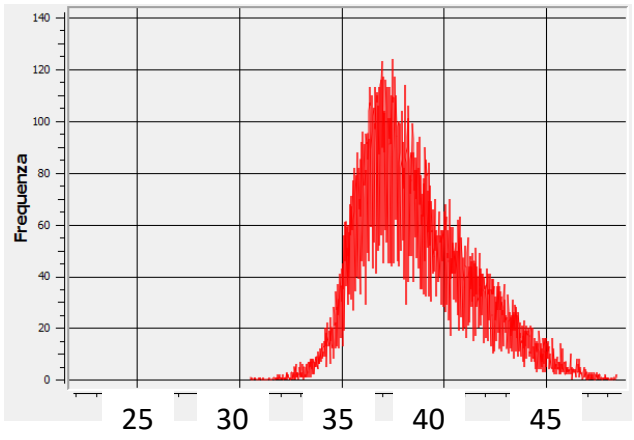
LST



Soil moisture

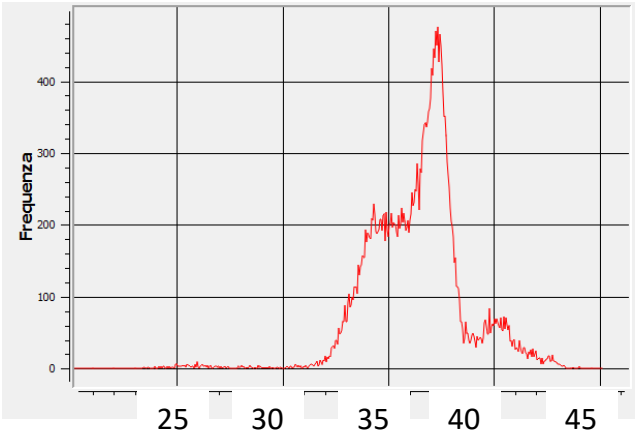


Mean = 37 °C

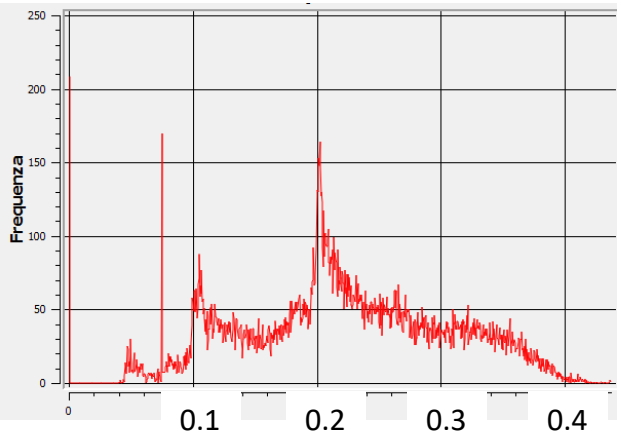


Land surface temperature [°C]

Mean= 36.5 °C



Land surface temperature [°C]



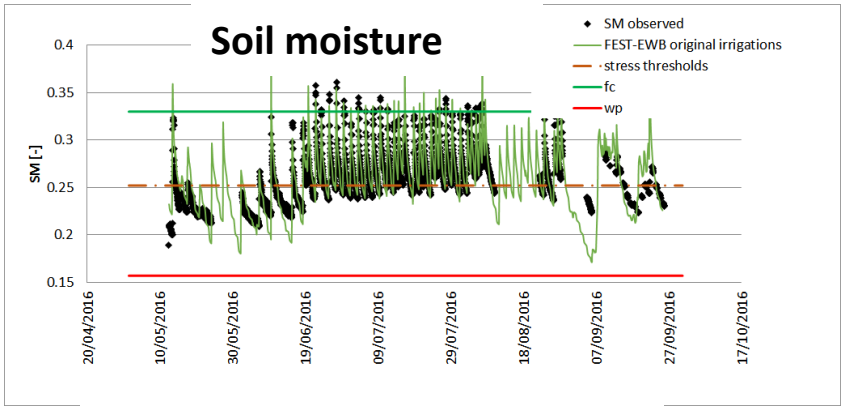
Soil moisture [-]

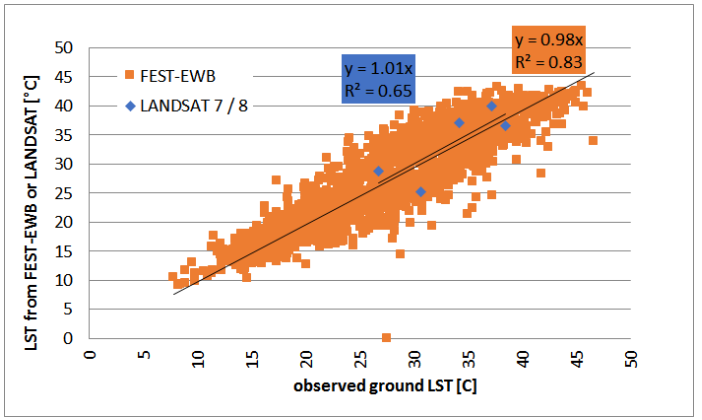
FEST-EWB model validation at FIELD scale: tomatoes field with sandy soil (2016)

POLITECNICO DI MILANO

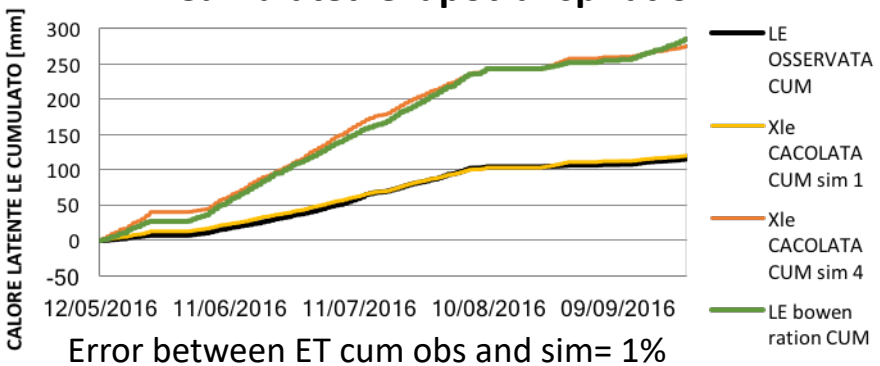
After calibration

RMSE		(Rn-G) = m (H+LE)		R^2	
SM	0.07				
LST	2.2	LST	1.00	LST	0.80
LE	139.90	LE	0.84	LE	0.81
G	46.88	G	0.94	G	0.61
Rn	54.42	Rn	0.95	Rn	0.94
H	50.12	H	1.10	H	0.62



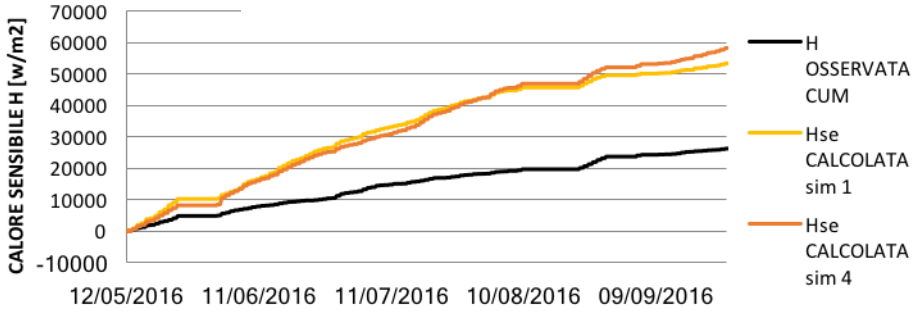


Cumulated evapotranspiration



Error between ET cum obs and sim= 1%

Cumulated sensible heat flux

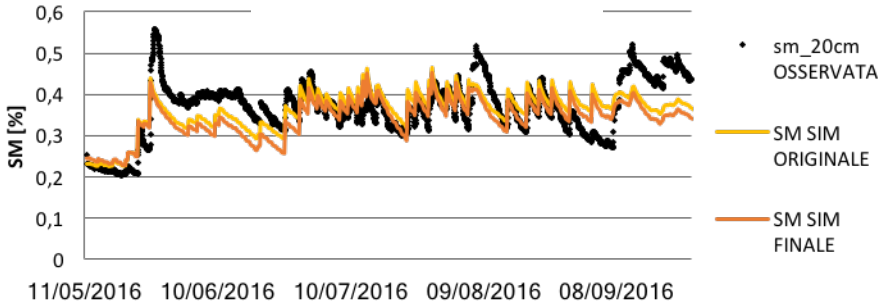


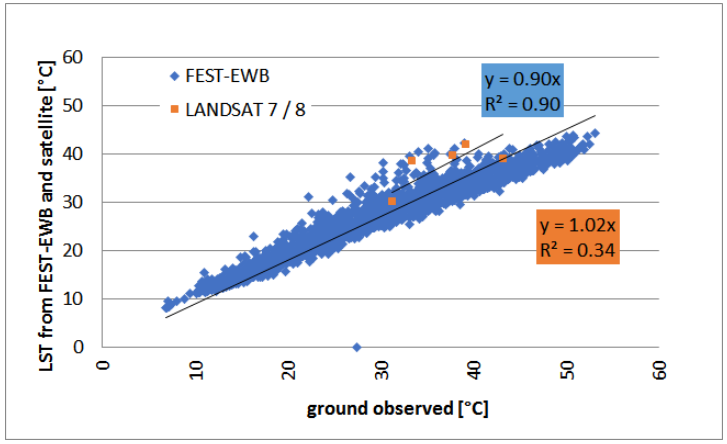
FEST-EWB model validation at field scale: tomatoes field with clay soil (2016)

After calibration

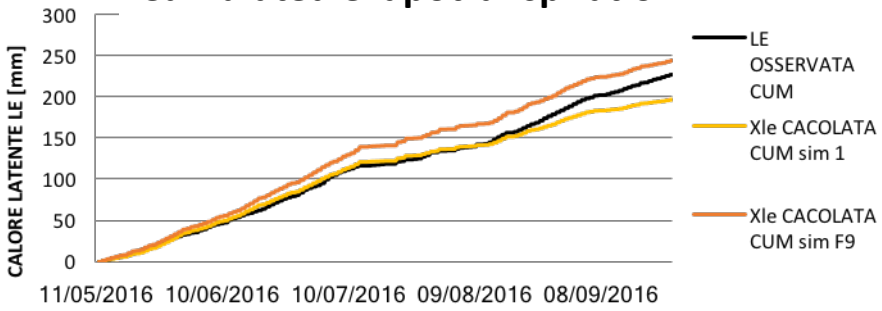
RMSE		(Rn-G) = m (H+LE)		R^2	
SM	0.06				
LST	2.1	LST	0.9	LST	0.90
LE	50.1	LE	0.89	LE	0.78
G	39.4	G	1.1	G	0.61
Rn	39	Rn	0.91	Rn	0.97
H	71.1	H	0.9	H	0.62

Soil moisture

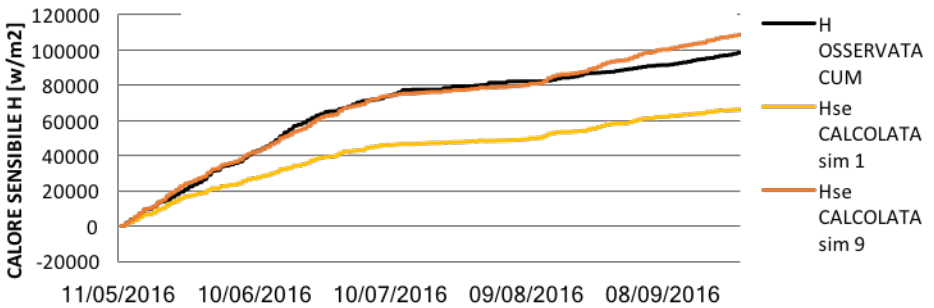




Cumulated evapotranspiration



Cumulated sensible heat flux



Error between ET cum obs and sim= 7%

FEST-EWB model validation at farm scale: asparagus (2013-2015)

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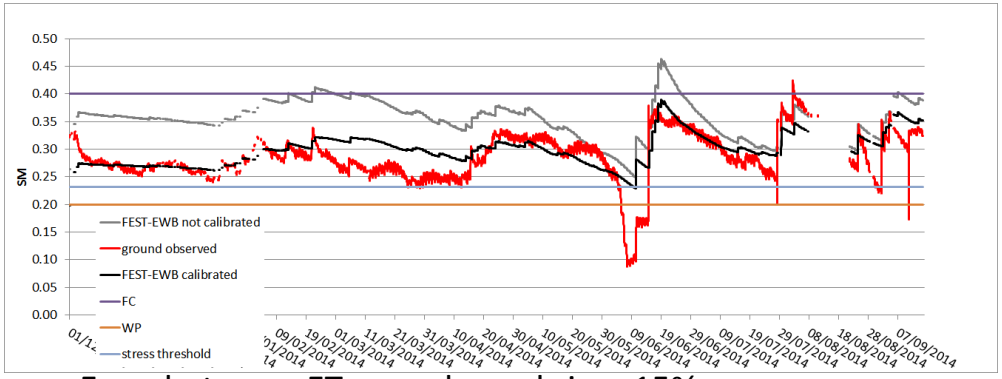
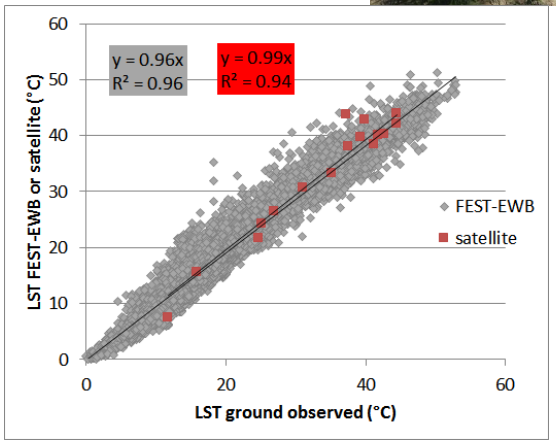
After calibration

RMSE		(Rn-G) = m (H+LE)		R^2	
SM	0.09				
LST	2.3	LST	0.94	LST	0.95
LE	60	LE	1.02	LE	0.7
G	51.1	G	0.68	G	0.61
Rn	39.4	Rn	0.96	Rn	0.94
H	53.4	H	0.89	H	0.62

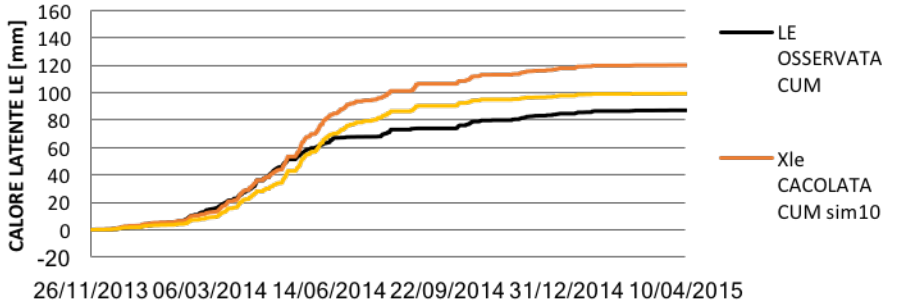
Soil moisture



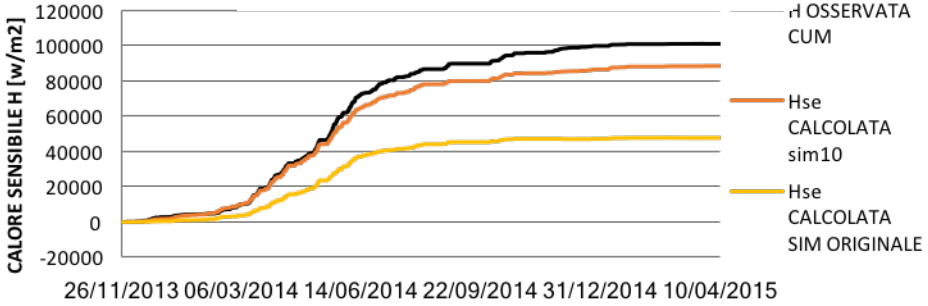


Error between ET cum obs and sim= 15%

Cumulated latent heat flux



Cumulated sensible heat flux



SIM IRRIGATION STRATEGY: for water saving

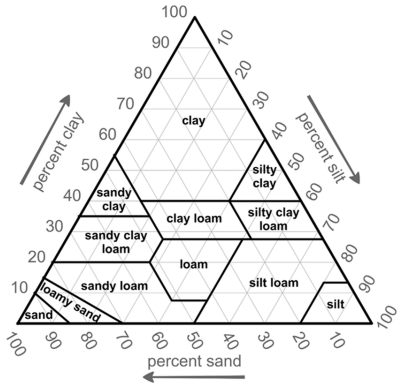
the SIM strategy allows to reduce the passage over the FC threshold reducing the percolation flux with a saving of irrigation volume

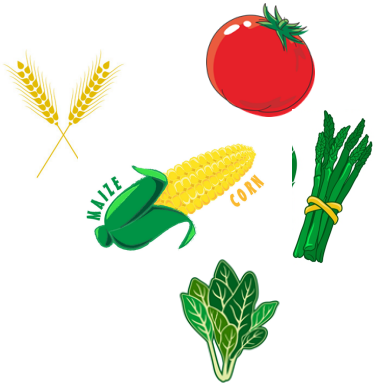
Irrigation intensity for irrigation system:
Drip
Sprinkler
furrow

The SIM strategy is based on irrigating only when the soil moisture reaches FAO

$$\text{Stress threshold} = FC - p * (FC - WP)$$

where p is the average fraction of Total Available Soil Water (TAW) that can be depleted from the root zone before moisture stress (Soil water depletion fraction), FC=field capacity, WP= wilting point.



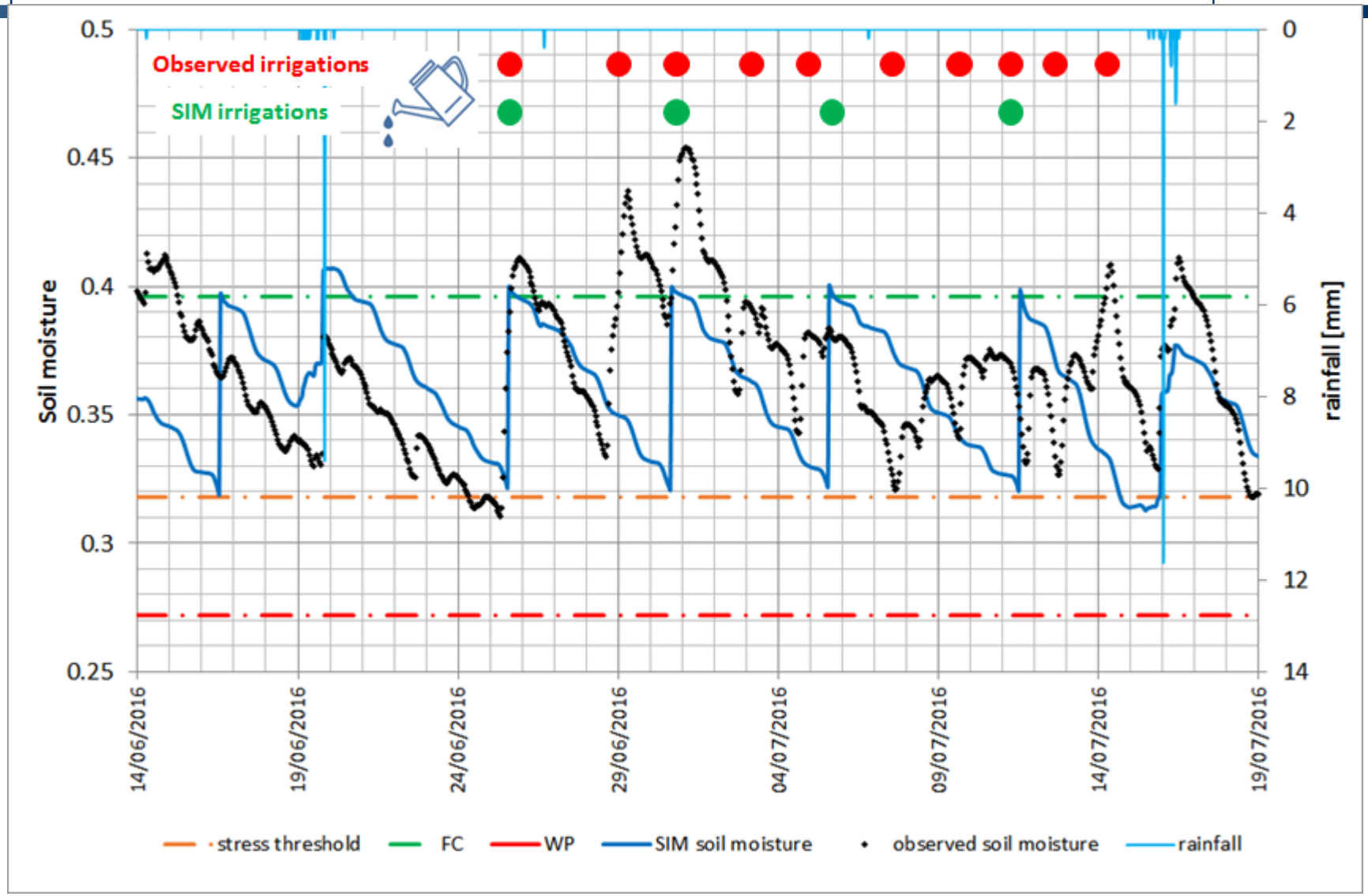


P is function of crop type

Crop	Threshold
Wheat	0,182
Corn	0,19
Sunflower	0,198
Barley	0,182
Poppy	0,166

FAO (Allen et al., 1996)

SIM IRRIGATION STRATEGY: water saving



SIM IRRIGATION STRATEGY : REANALYSIS RESULTS on soil moisture

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Tomatoes comparison

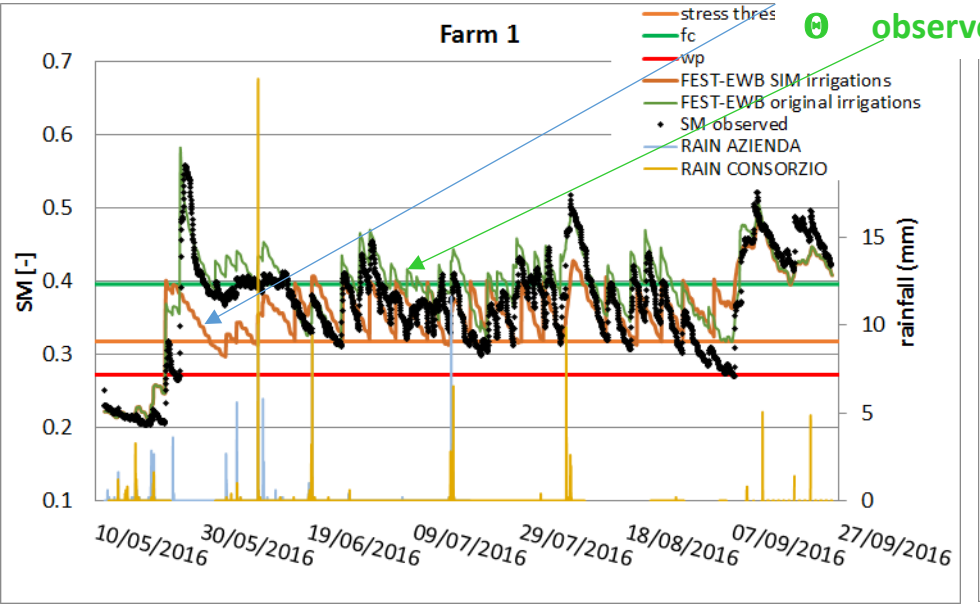
Irrigation rate and timing reduction of percolation losses

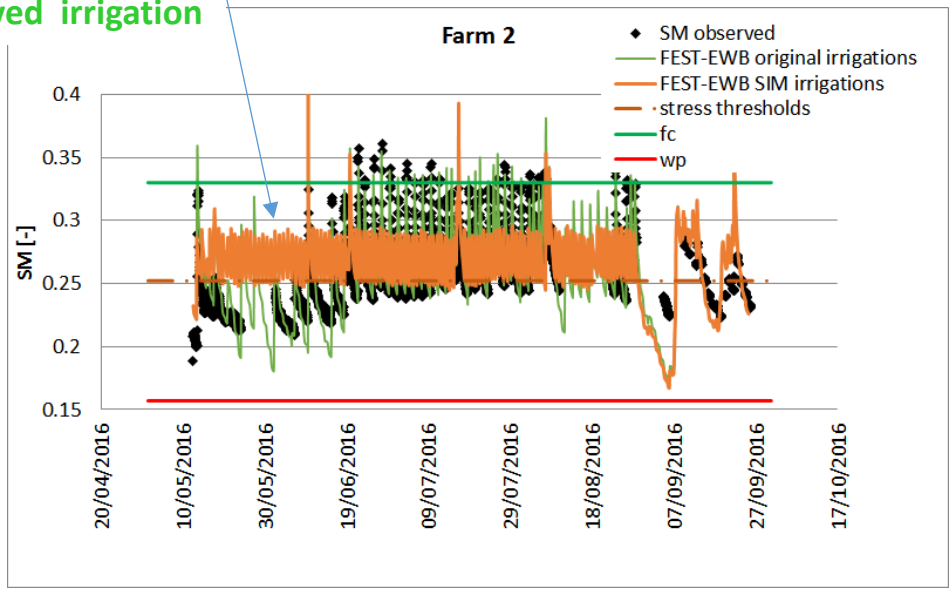
Silty clay soil

Θ SIM IRRIGATIONS

Θ observed irrigation

Sandy soil

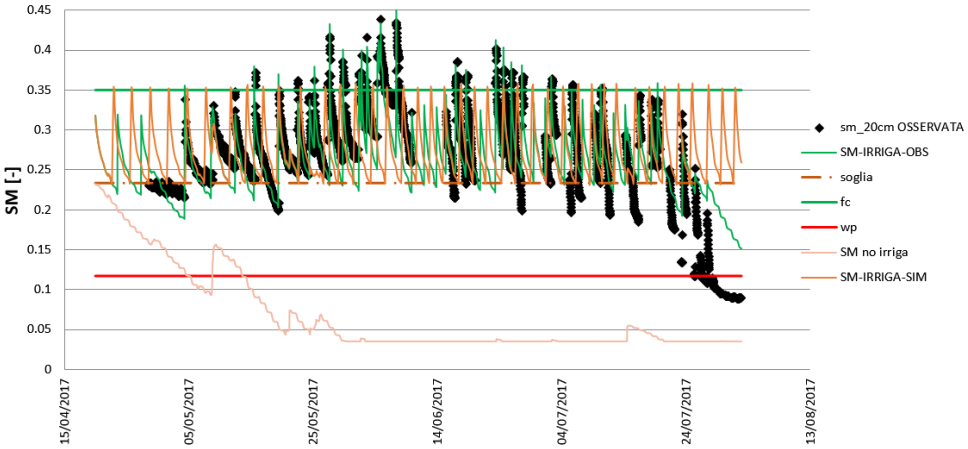




		Irrigation (mm)	Number of irrigations	Rainfall cum (mm)
Farm 1 (2016)	**Observed**	**547.9**	**27**	**145**
	SIM	322.3	15	
Farm 2 (2016)	**Observed**	**646.6**	**43**	**150**
	SIM	590	90	
Farm 3 (2017)	**Observed**	**1000**	43	28
	SIM	850	25	

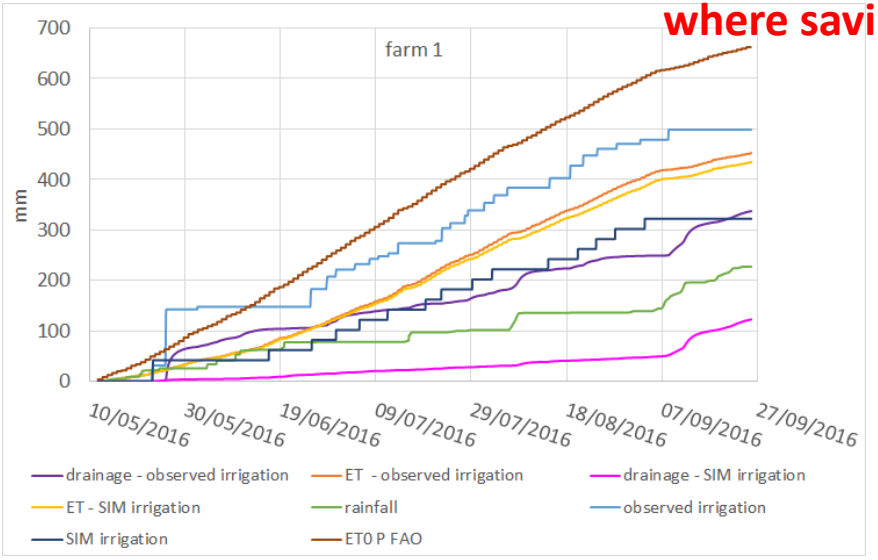
the SIM strategy allows to reduce the passage over the FC threshold reducing the percolation flux with a saving of irrigation volume

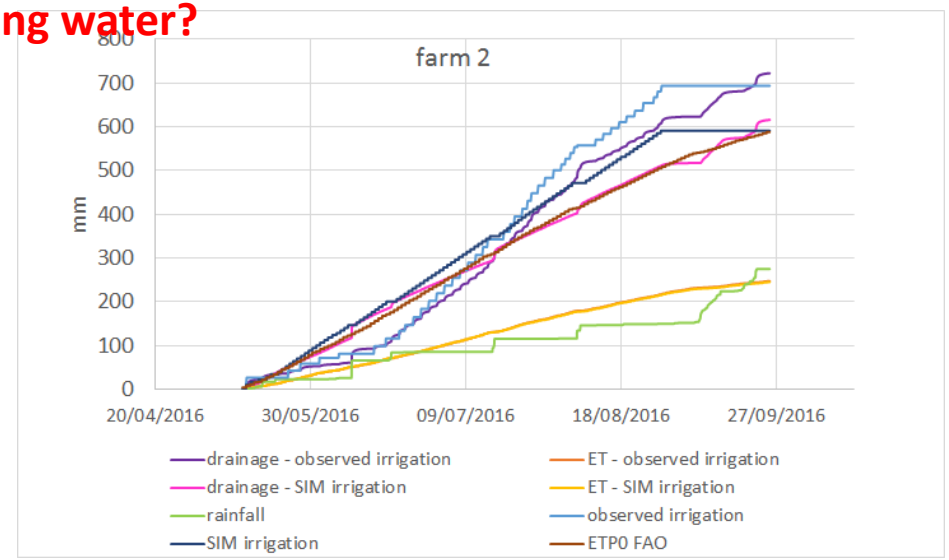
Sandy loam soil



SIM IRRIGATION STRATEGY: REANALYSIS RESULTS on irrigation, evapotranspiration, drainage

where saving water?





Rainfall + Irrigation = Evapotranspiration + Drainage + DW

145 + 547 = 450 + 320 – 70. (mm)

145+ 322 = 440 + 110 - 80 (mm) SIM

Rainfall + Irrigation = Evapotranspiration + Drainage + DW

150+ 696 = 260 + 730 - 140

150+ 590 = 260 + 620 - 140 SIM

SIM IRRIGATION STRATEGY: comparison crop yield

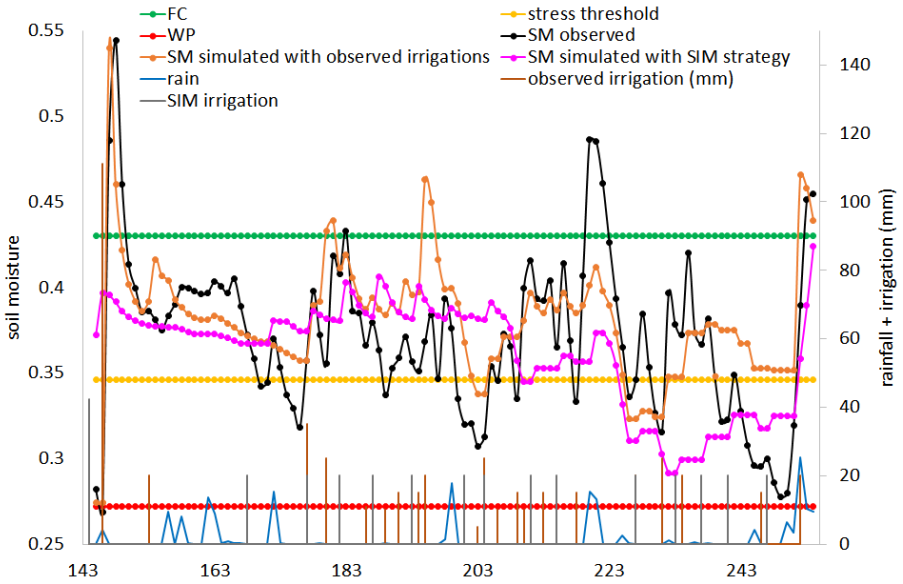
AQUACROP FAO MODEL as Crop Yeld control:

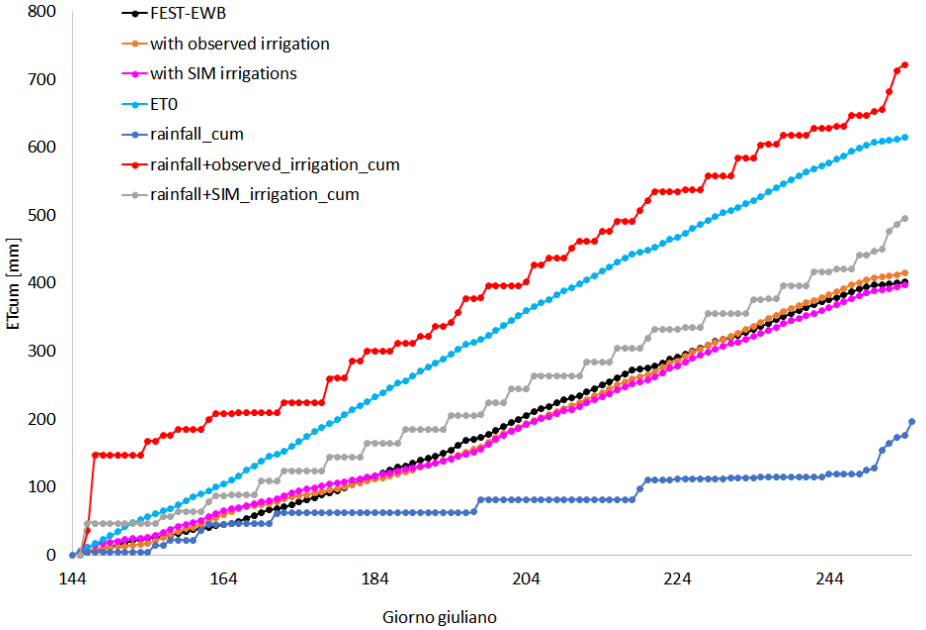
crop modelling based on **daily data** with ET computed with kc

Food and Agriculture Organization of the United Nations

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

FARM 1 - Silty clay soil

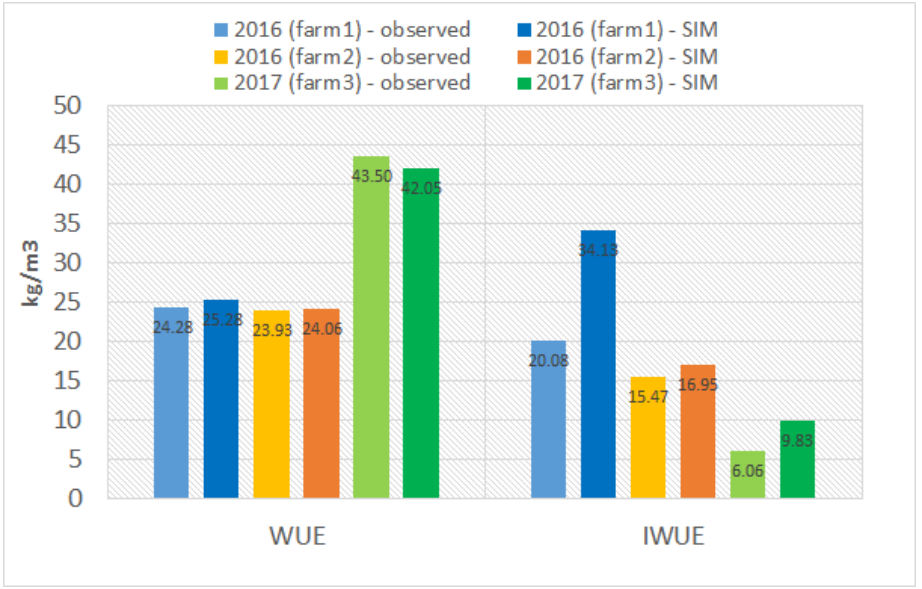


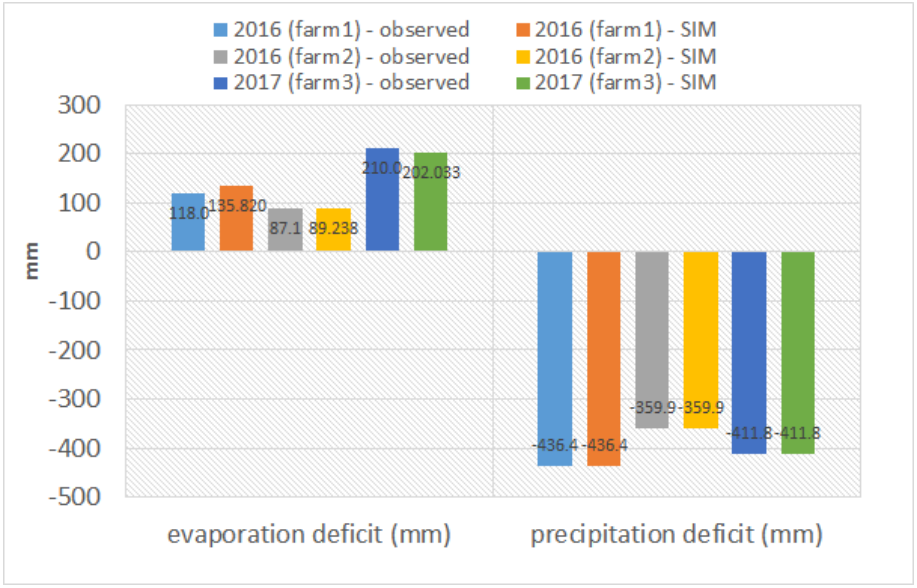


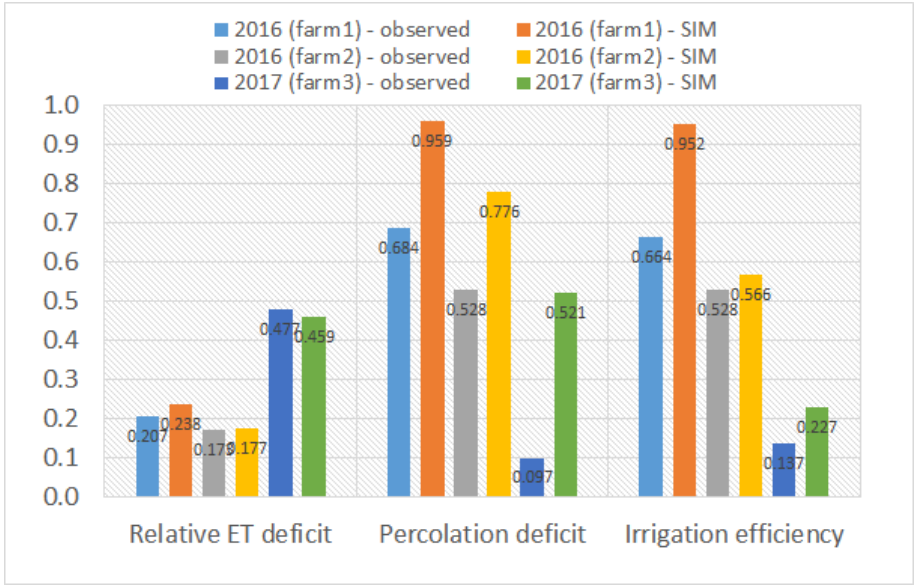
Steduto, P., Hsiao, T.C., Fereres, E., and Raes, D. 2012. Crop yield response to water. FAO Irrigation and Drainage Paper Nr. 66. Rome, Italy.

SIM IRRIGATION STRATEGY: water indicators at field scale

water use efficiency (WUE = yield/ET) [kg/m^3]
irrigation water use efficiency (IWUE = yield/irrigation [kg/m^3]
evaporation deficit =ETP – ET [mm]
precipitation deficit = P − ETP [mm]
Relative ET deficit = 1-ET/ETP [-]
Percolation deficit =((rainfall+irrigation) - percolation) / (rainfall+irrigation) [-]
Irrigation efficiency = ET /(rainfall+irrigation) [-]







SIM IRRIGATION STRATEGY: at consortium scale

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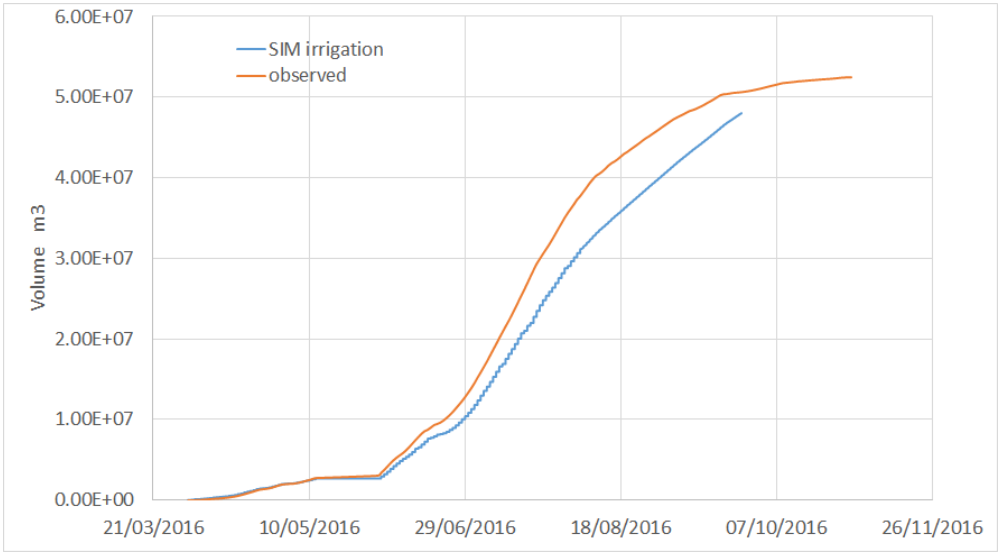
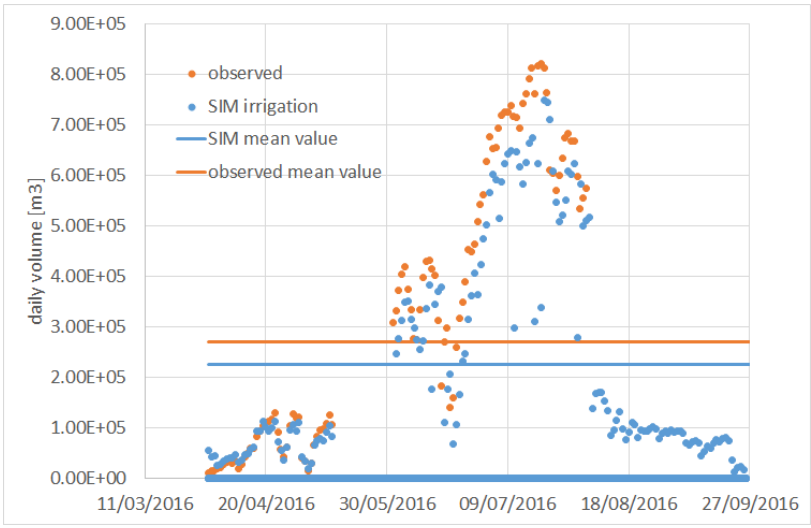
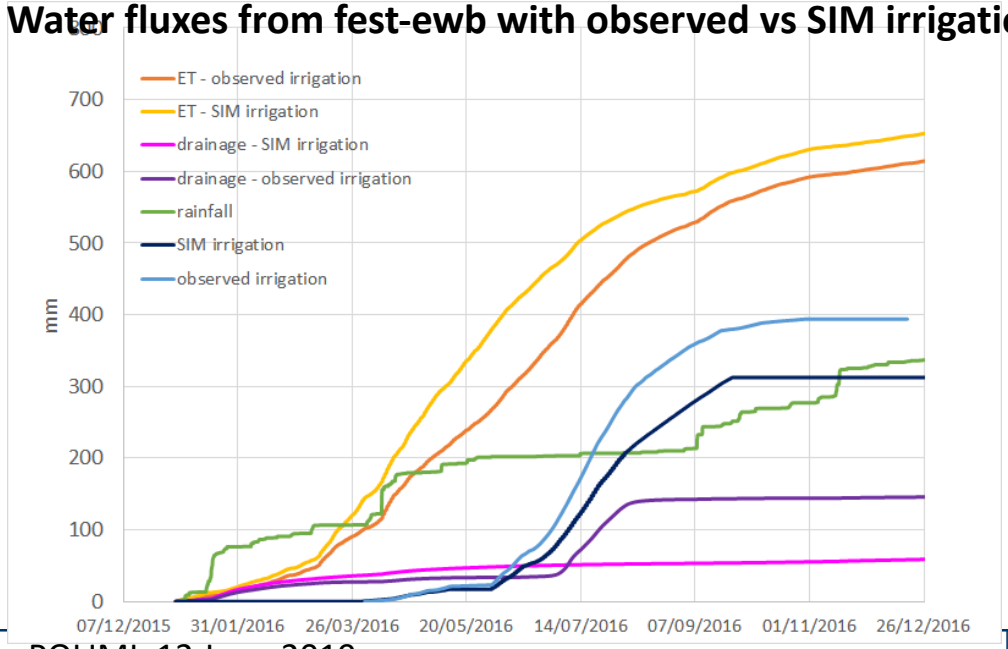
Cumulated irrigation observed vs SIM

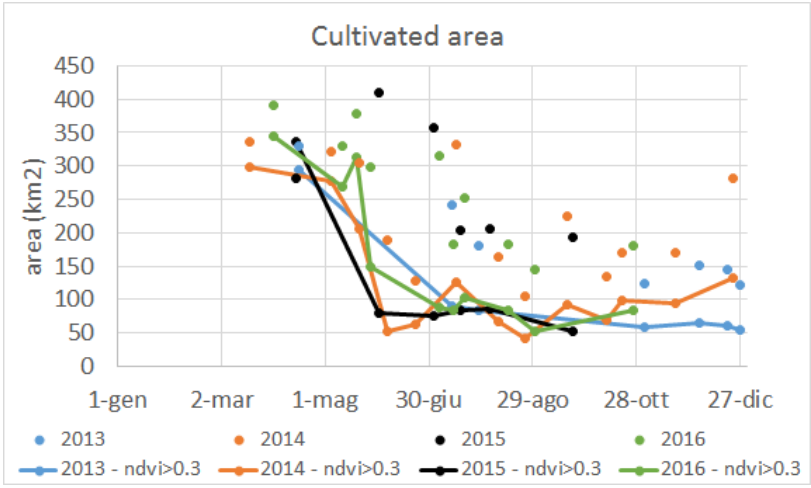




Water fluxes from fest-ewb with observed vs SIM irrigation



Cultivated area from satellite SENTINEL 2 – LANDSAT 7/8

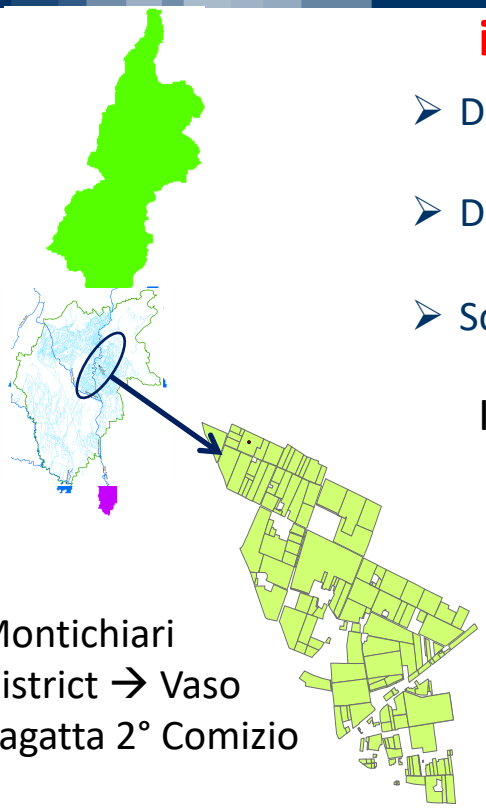


Case Study 2 : Chiese Irrigation consortium (Northern Italy)

irrigation scheme: fixed scheduled turn

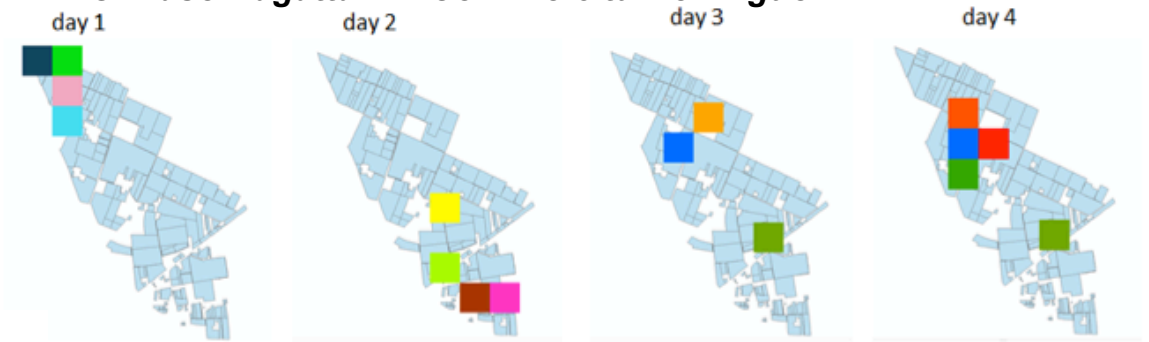
- Diverted dishcarge from the Chiese river for irrigation= 21 m3/s
- Dense irrigation channels network (1400 km)
- Scheduled irrigation: every 7 dyas and half

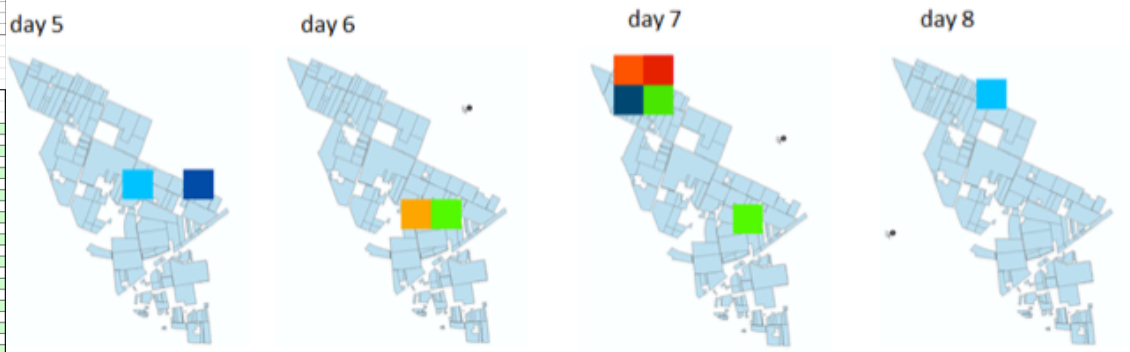
Irrigated area= 20'000 ha



Montichiari District → Vaso Bagatta 2° Comizio

ESEMPIO: Vaso Bagatta 2° Comizio e turno irriguo





User n°1

FOGLIO	MAPPALE	SUPERFICIE
15	55	1.8690
0	0	0.0000
0	0	0.0000
0	0	0.0000
0	0	0.0000

TOTALE SUPERFICIE (Ettari): 1.8690
COMPETENZA ORE (ore.min): 2:08
PERIODICITA' TURNO: 8 GIORNI 06:00 ORE

DALLE ORE	DEL GIORNO	ALLE ORE	DEL GIORNO
00:30	01-apr	02:38	01-apr
06:30	09-apr	08:38	09-apr
12:30	17-apr	14:38	17-apr
18:30	25-apr	20:38	25-apr
00:30	04-mag	02:38	04-mag
06:30	12-mag	08:38	12-mag
12:30	20-mag	14:38	20-mag
18:30	28-mag	20:38	28-mag
00:30	06-giu	02:38	06-giu
06:30	14-giu	08:38	14-giu
12:30	22-giu	14:38	22-giu
18:30	30-giu	20:38	30-giu
00:30	09-lug	02:38	09-lug
06:30	17-lug	08:38	17-lug
12:30	25-lug	14:38	25-lug
18:30	02-ago	20:38	02-ago
00:30	11-ago	02:38	11-ago
06:30	19-ago	08:38	19-ago
12:30	27-ago	14:38	27-ago
18:30	04-set	20:38	04-set
00:30	13-set	02:38	13-set
06:30	21-set	08:38	21-set

User n°2

FOGLIO	MAPPALE	SUPERFICIE
16	357	2.0000
0	0	0.0000
0	0	0.0000
0	0	0.0000
0	0	0.0000

TOTALE SUPERFICIE: 2.0000
COMPETENZA ORE: 2:19
PERIODICITA' TURNO: 8 GIORNI 06:00

DALLE ORE	DEL GIORNO	ALLE ORE	DEL GIORNO
02:38	01-apr	04:57	01-apr
08:38	09-apr	10:57	09-apr
14:38	17-apr	16:57	17-apr
20:38	25-apr	22:57	25-apr
02:38	04-mag	04:57	04-mag
08:38	12-mag	10:57	12-mag
14:38	20-mag	16:57	20-mag
20:38	28-mag	22:57	28-mag
02:38	06-giu	04:57	06-giu
08:38	14-giu	10:57	14-giu
14:38	22-giu	16:57	22-giu
20:38	30-giu	22:57	30-giu
02:38	09-lug	04:57	09-lug
08:38	17-lug	10:57	17-lug
14:38	25-lug	16:57	25-lug
20:38	02-ago	22:57	02-ago
02:38	11-ago	04:57	11-ago
08:38	19-ago	10:57	19-ago
14:38	27-ago	16:57	27-ago
20:38	04-set	22:57	04-set
02:38	13-set	04:57	13-set
08:38	21-set	10:57	21-set

Operative tool for real time irrigation water needs forecast

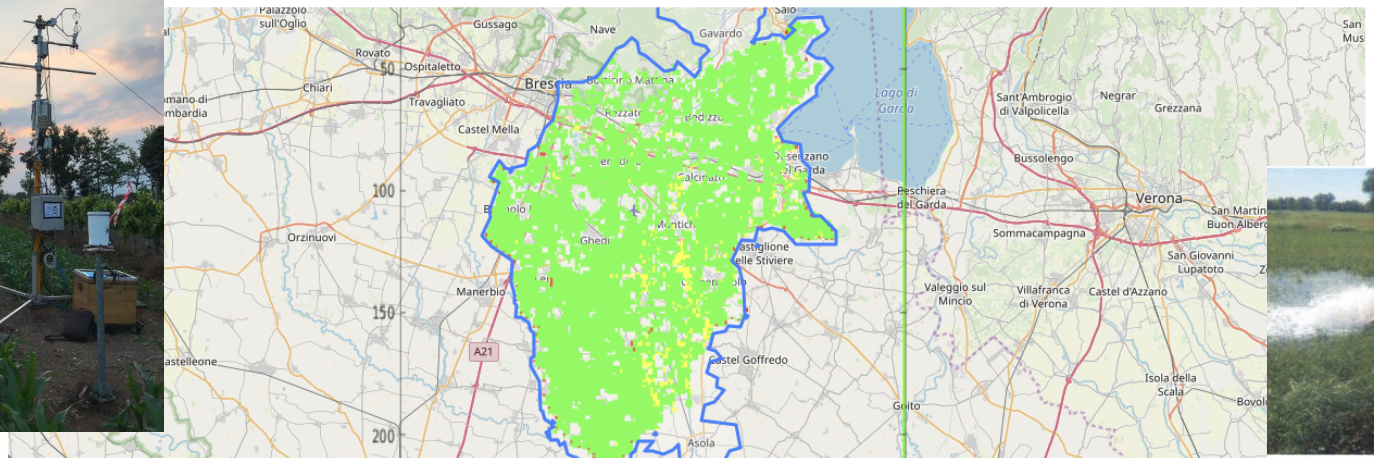
The SIM dashboard WATER INFORMATION SYSTEM

Basin: water deficit | Basin: water needs | Control Field | Farms | Meteorological Maps | Satellite Control | Economic Indicators | manager

Chiese river 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.

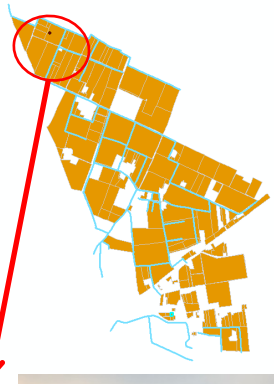
Idrological Model: FEST EWB | Emission Date: 2018-11-16 | Forecast time: Present | Apply | Reset Map | Histogram



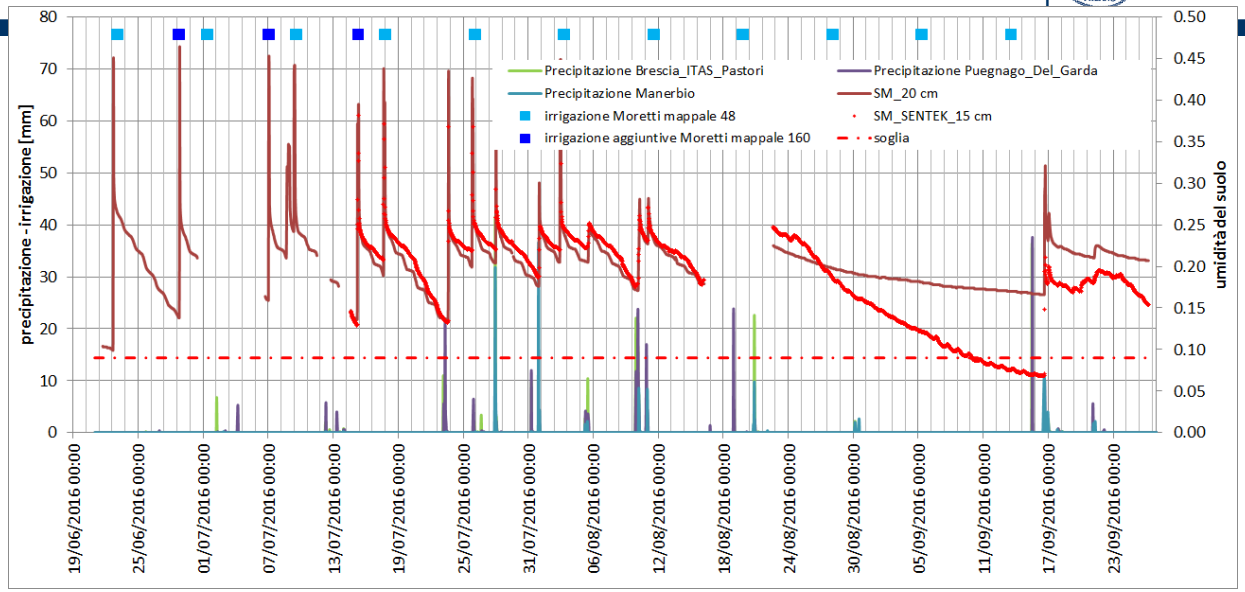
	Present	2018-11-17	2018-11-18	2018-11-19	
Water deficit surface (%)	0 20 40 60 80 100	0 20 40 60 80 100	0 20 40 60 80 100	0 20 40 60 80 100	Temporal Evolution
Cumulated Rainfall (mm)	0 1 2 3 4 5	0 1 2 3 4 5	0 1 2 3 4 5	0 1 2 3 4 5	Min. Avg. Max.
Air mean, maximum and minimum temperature (°C)	5 10	5 10	5 10	5 10	
Wind mean, maximum and minimum speed (km/h)	2 4 6	2 4 6	2 4 6	2 4 6	

Soil moisture ground monitoring: 3 years of maize field

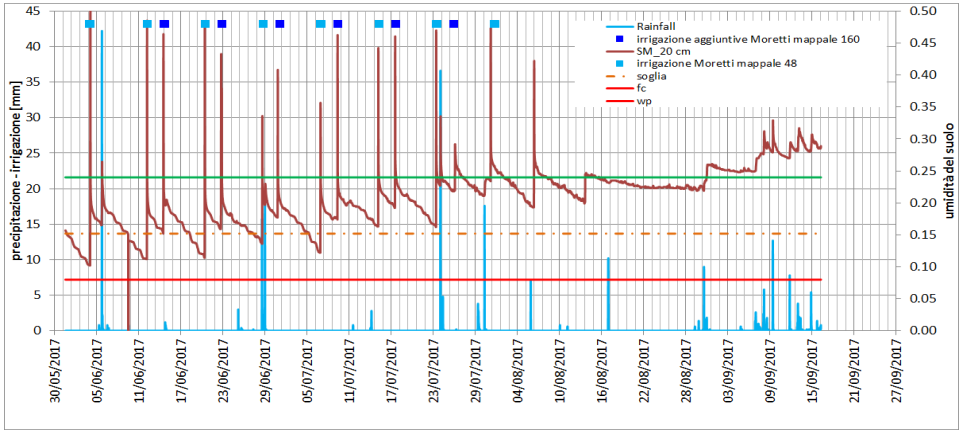
Vaso
Bagatta 2°
Comizio

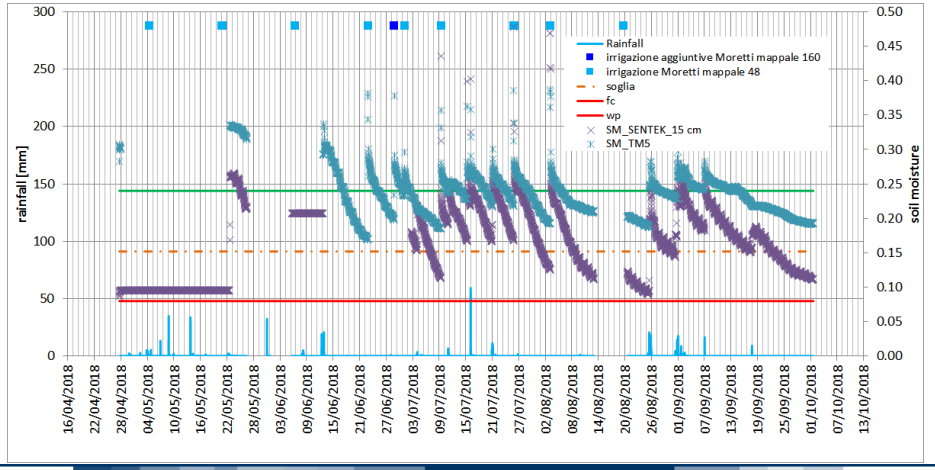


Eddy covariance station In a maize field (2016-2017, 2018)



	Irrigation (mm	Number of irrigation	Rainfall cum (mm)	Tair_average (°C)
2016	1294.1	11	223.8	23.7
2017	1523.4	14	236.4	24.6
2018	1274	10	515	23.2

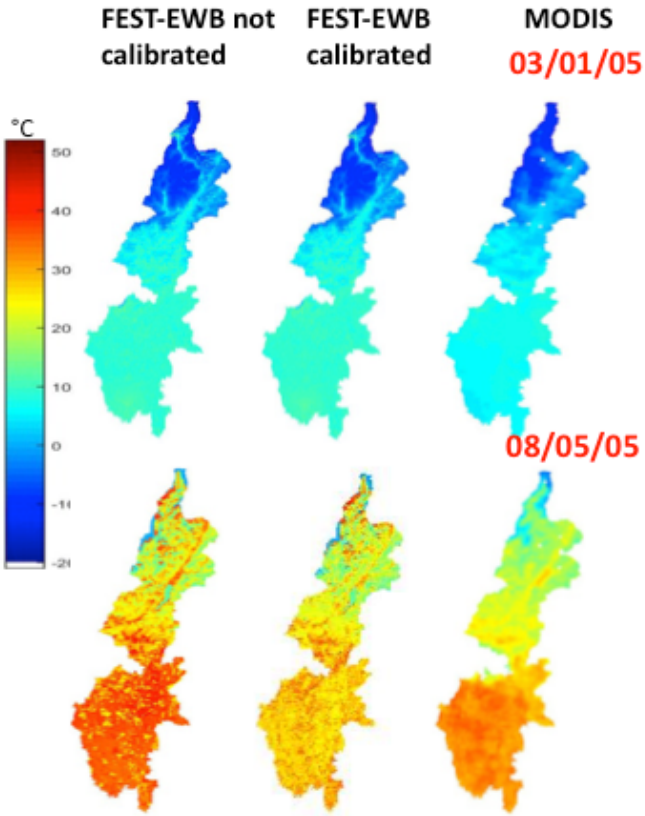




FEST-EWB model calibration/ validation

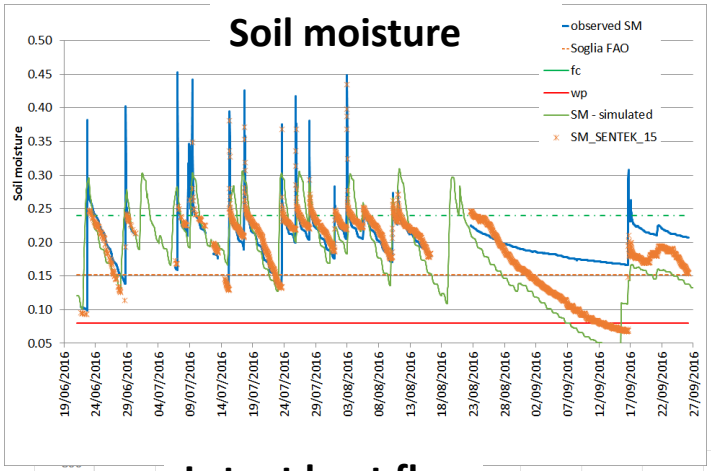
at FIELD scale: maize field (2016)

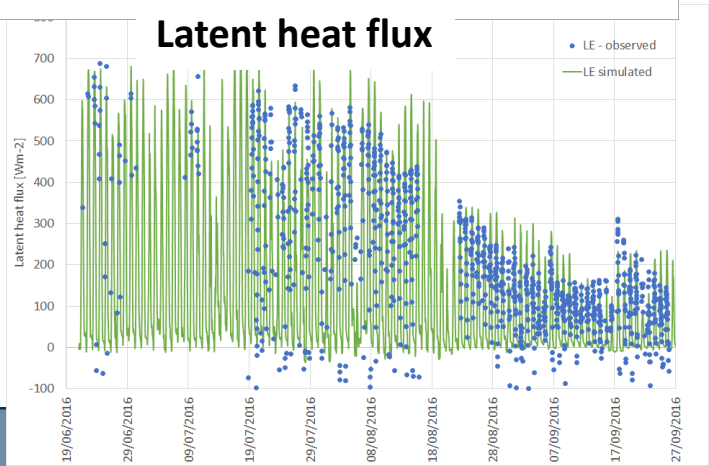
FEST-EWB calibration using **MODIS LST** data (2005-2016) at 250 m (downscaled)



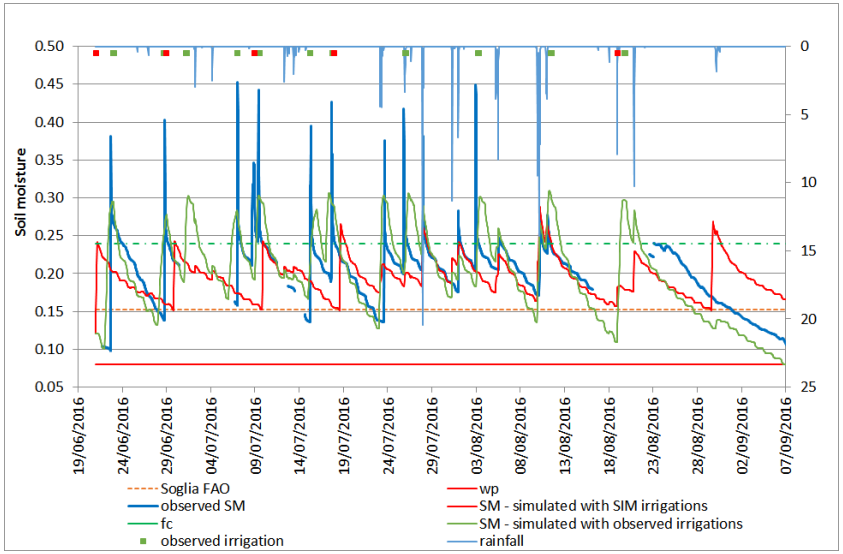
MODIS and **RET calibrated = mean error 3 °C**

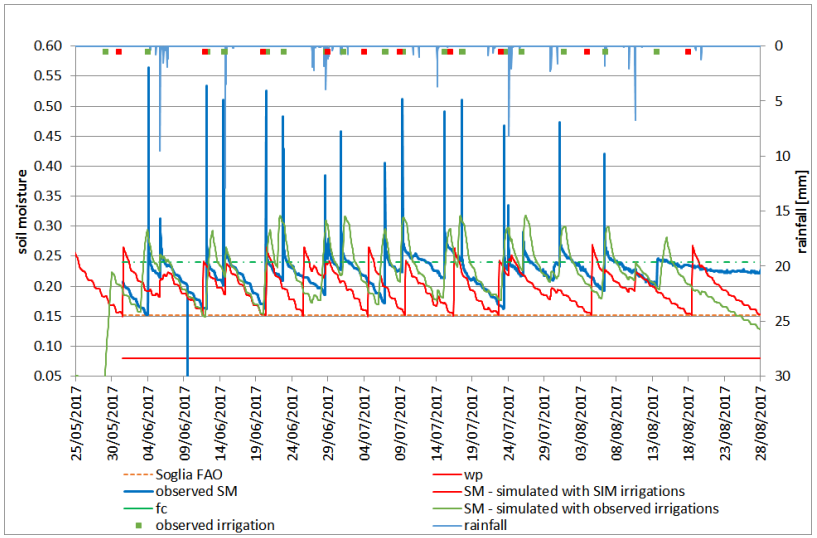
RMSE		(Rn-G) = m (H+LE)		R^2	
SM	0.07				
LST	2.2	LST	1.00	LST	0.80
LE	139.90	LE	0.84	LE	0.81
G	46.88	G	0.94	G	0.61
Rn	54.42	Rn	0.95	Rn	0.94
H	50.12	H	1.10	H	0.62



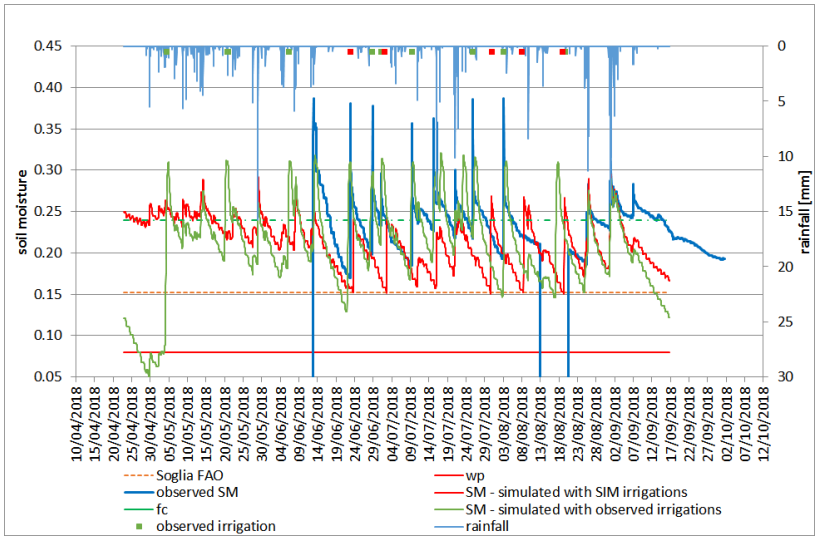


SIM IRRIGATION STRATEGY: reduction of percolation losses
a different irrigation schedule and volume



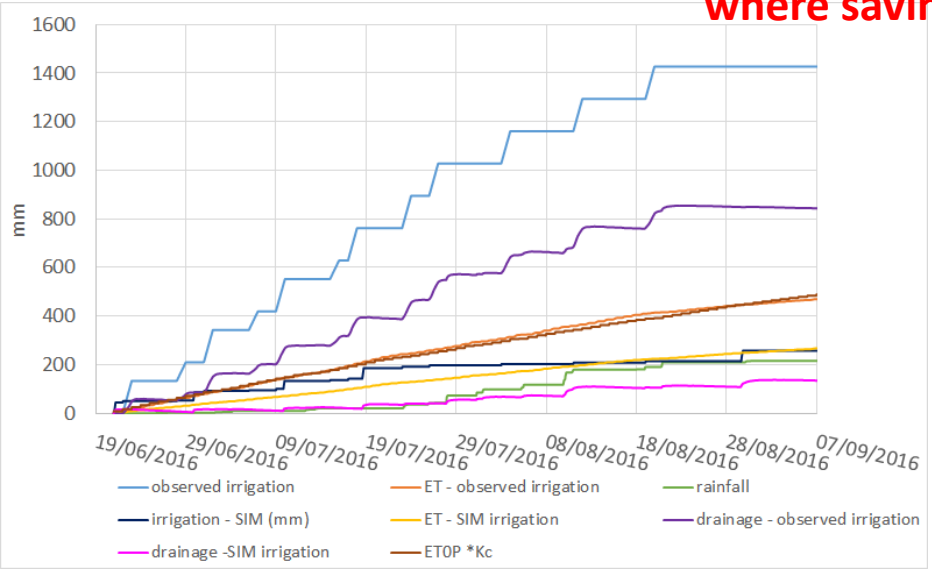


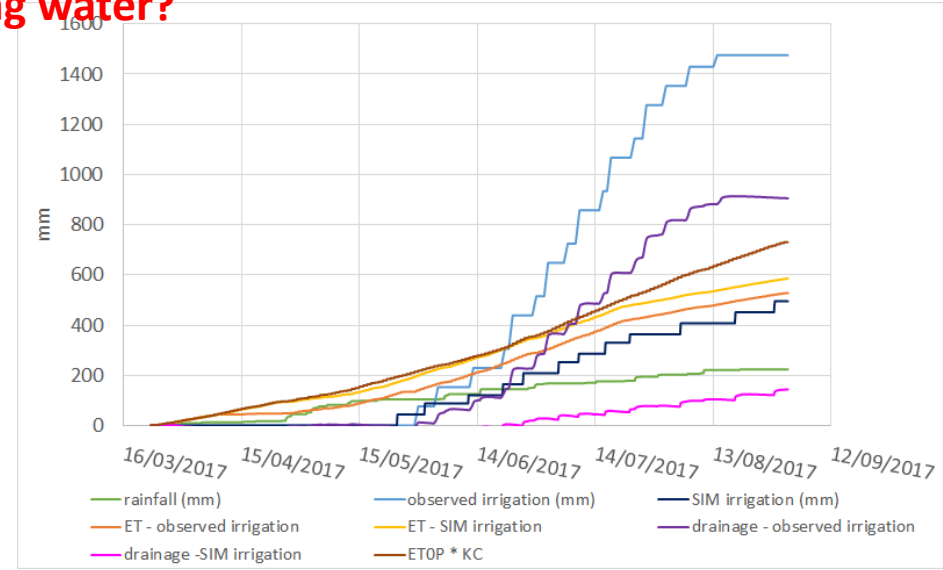
		Irrigation (mm)	Number of irrigations	Rainfall cum (mm)
2016	**Observed**	**1426**	**11**	**269**
	SIM	**301**	**5**	
2017	**Observed**	**1480**	**17**	**223**
	SIM	**488**	**10**	
2018	**Observed**	**1750**	**13**	**515**
	SIM	**200**	**5**	

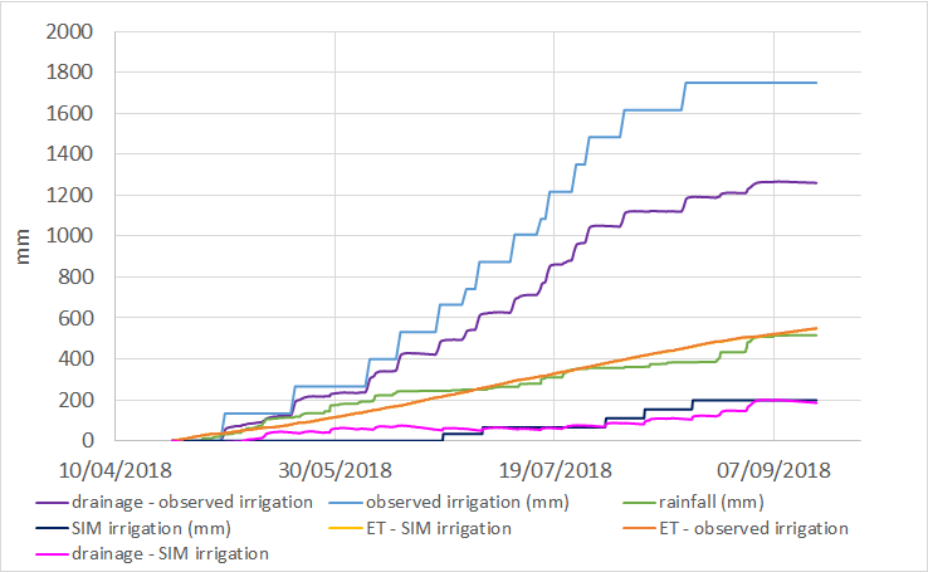


SIM IRRIGATION STRATEGY: REANALYSIS RESULTS on irrigation, evapotranspiration, drainage

where saving water?







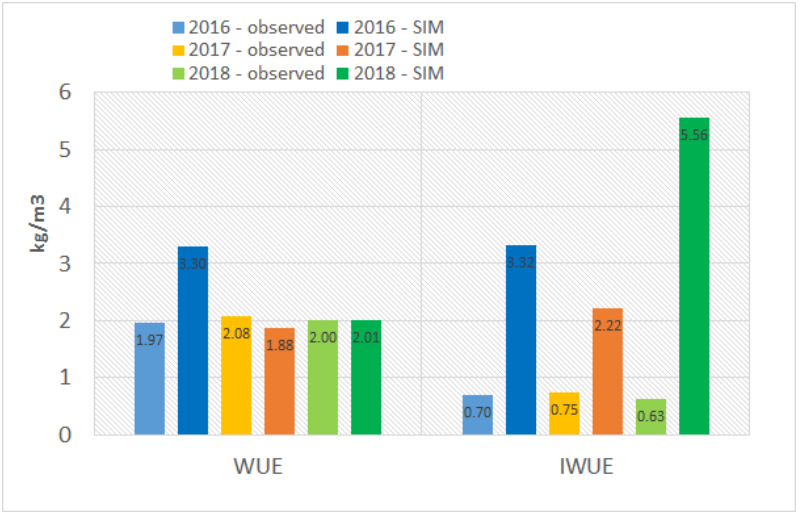
Rainfall + Irrigation = Evapotranspiration + Drainage + DW
205 + 1450 = 500 + 870 –285 (mm)
205+ 290 = 295 + 170 - 30 (mm) SIM

Rainfall + Irrigation = Evapotranspiration + Drainage + DW
225 + 1470 = 600 + 950 –145 (mm)
225+ 500 = 550 + 170 - 5 (mm) SIM

Rainfall + Irrigation = Evapotranspiration + Drainage + DW
515 + 1250 = 540 + 1270 –45 (mm)
515+ 200 = 540 + 200 - 25 (mm) SIM

SIM IRRIGATION STRATEGY: water indicators

water use efficiency (WUE = yield/ET) (kg/m3)
irrigation water use efficiency (IWUE = yield/irrigation) (kg/m3)
evaporation deficit=ETP – ET (mm)
precipitation deficit = P − ETP (mm)
Relative soil water deficit = 1-(Sm-Wp)/(Fc-Wp) (-)
Relative ET deficit = 1-ET / ETP (-)
Percolation deficit =((rainfall+irrigation) - percolation) / (rainfall+irrigation) (-)
Irrigation efficiency = ET /(rainfall+irrigation) (-)



Crop yield:

2016

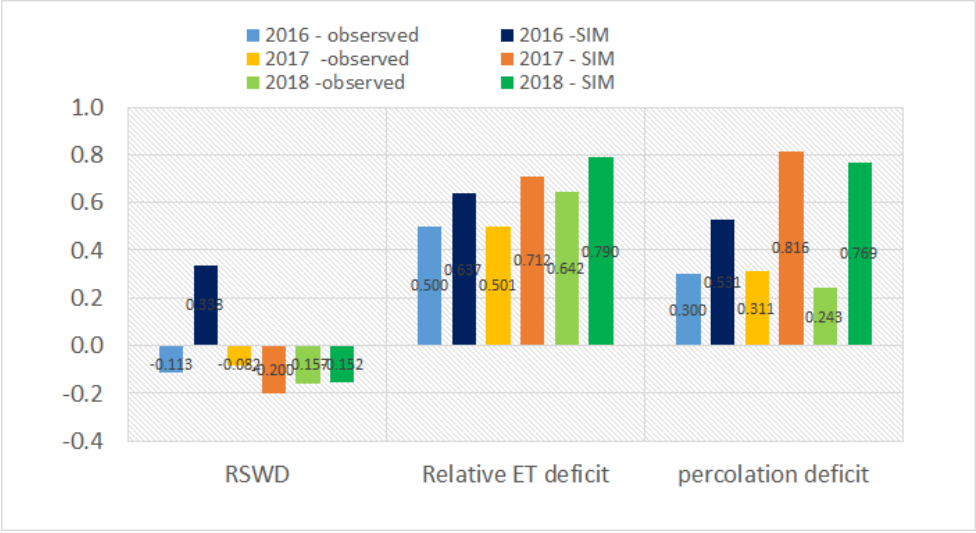
-with observed irrigation 8,93 ton/ha

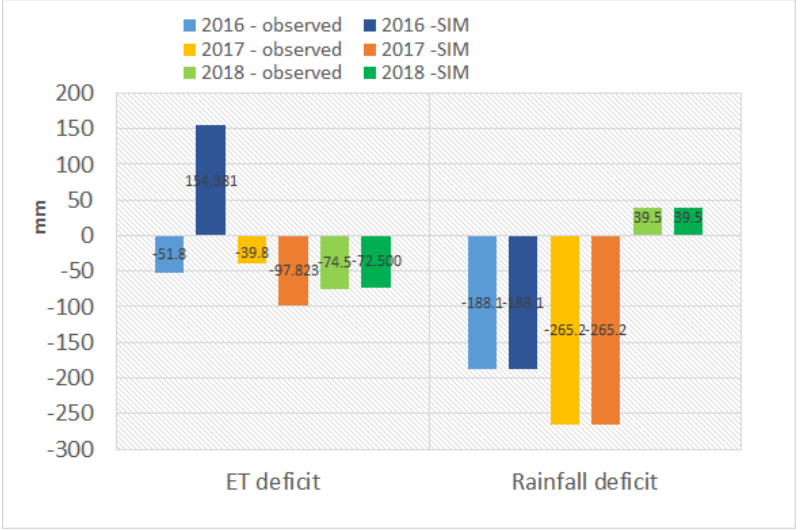
-with SIM strategies 8,9 ton/ha

2017

-with observed irrigation 8,87 ton/ha

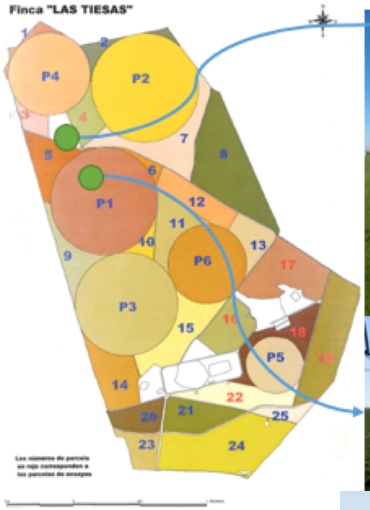
-with SIM strategies 8,67 ton/ha





Case Study 3 : **Barrax** (Sapin)

Meteorological data and LST in **continuous from 2013 to 2017**

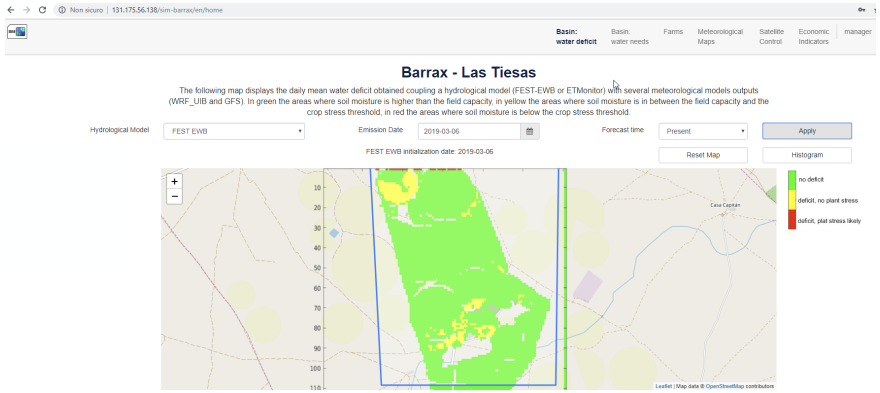


HETEROGENEUS AREA: During the campaign, a large part of the crops were already harvested with the exception of maize, vineyard, sunflower, orchards and forest nursery (1500 ha)

Airborne data: AHS (3m spatial resolution) VIS + NIR + TIR

Intensive field campaigns: 2005, 2009, 2011, 2012: (REFLEX) - EUFAR
(Timmermans et al. 2014)

The SIM operative dashboard



Irrigation scheme: on demand irrigation with central pivot sprinkler

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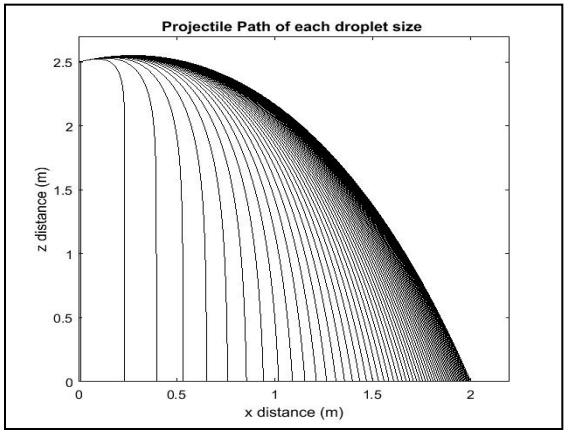
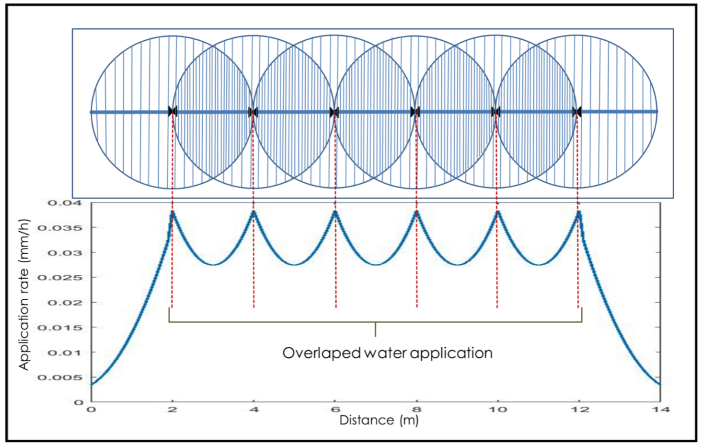
Balistic theory

Drop trajectory and application rate

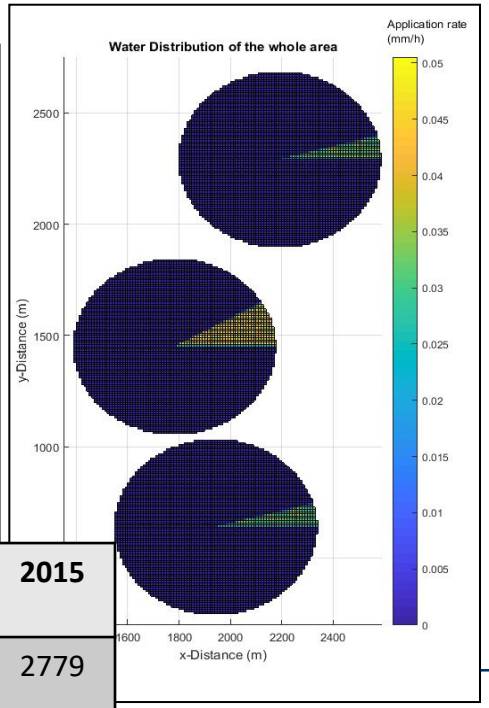




Number of sprinklers: 187
Distance between sprinklers: 2m

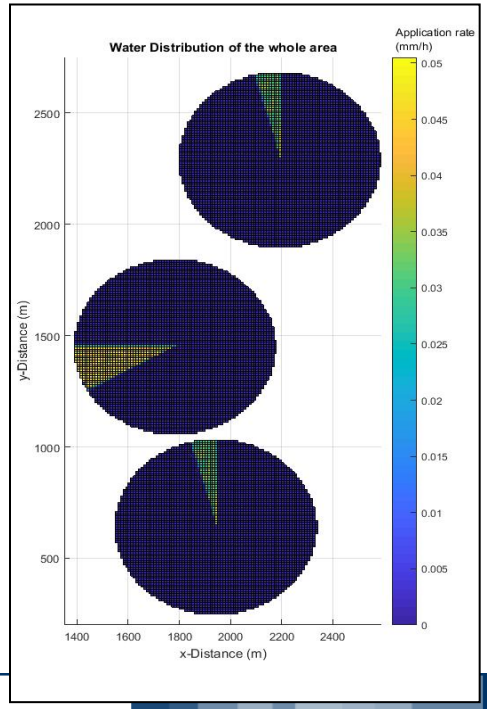
Simulated water distribution patterns of center pivots 1,2,3 [27th of May 2015]

Hour = 01:00

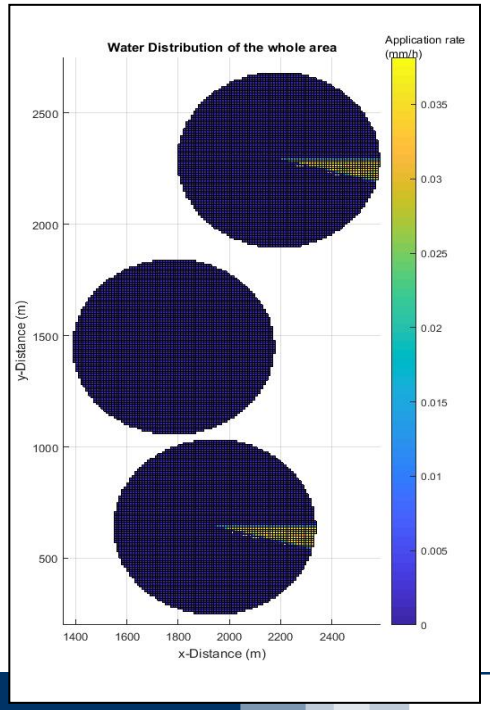


Year	2014	2015
Total of irrigation volume (mm)	1338	2779

Hour = 13:00



Hour = 23:00



FEST-EWB PIXEL TO PIXEL CALIBRATION (Summer 2012)

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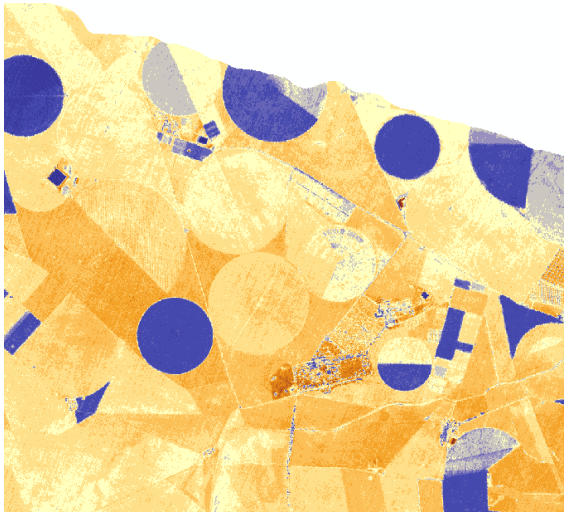
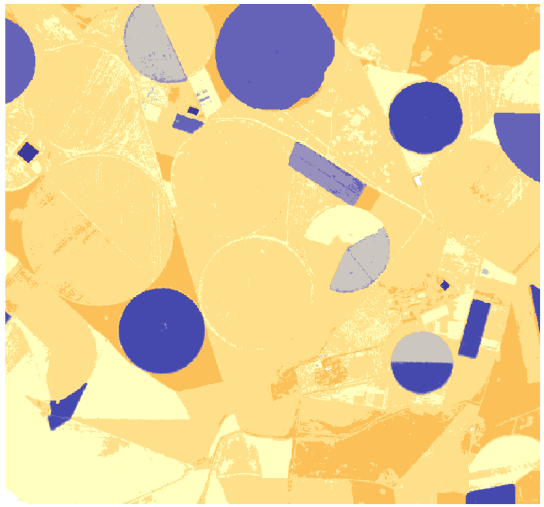
25 July 9:30 UTC

Δx= 5 m

LST AHS



RET
FEST-EWB calibrated



°C

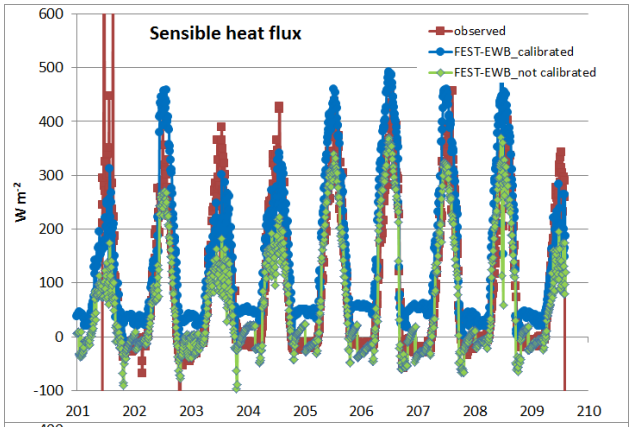
- 22.00720025 - 25
- 25.00000001 - 28
- 28.00000001 - 31
- 31.00000001 - 34
- 34.00000001 - 37
- 37.00000001 - 40
- 40.00000001 - 43
- 43.00000001 - 46
- 46.00000001 - 49
- 49.00000001 - 52
- 52.00000001 - 55
- 55.00000001 - 58
- 58.00000001 - 61

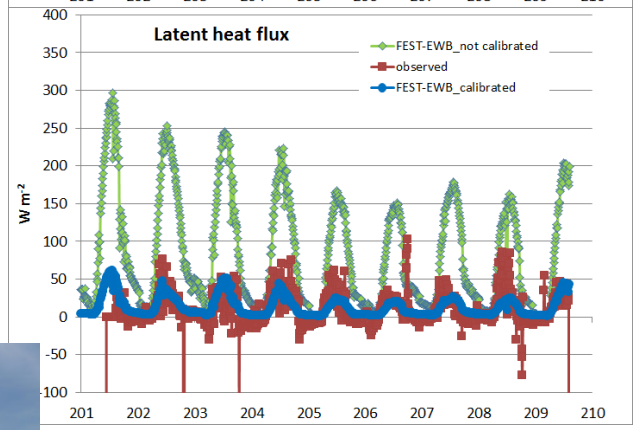
Considering all the available images

calibrated			
MAE (%)	MD(AHS - FEST-EWB) (° C)	MAD	RMSD
3.4	-0.9	1.5	2.1

Corbari et al., 2013 (IJRS)
Corbari et al., 2014 (AG)

validation with fluxes from the micrometeorological station





	calibrated	
	MAD (W m^{-2})	MAE (%)
Rn	10	3
G	98	46
H	33	23
LE	12	47

P3 – corn from May to September 2014: SIM Strategy

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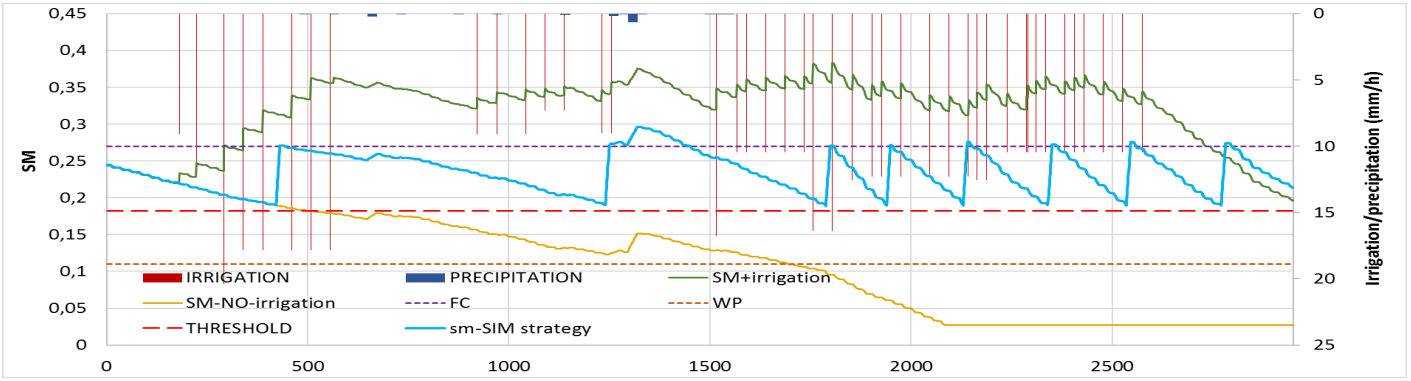
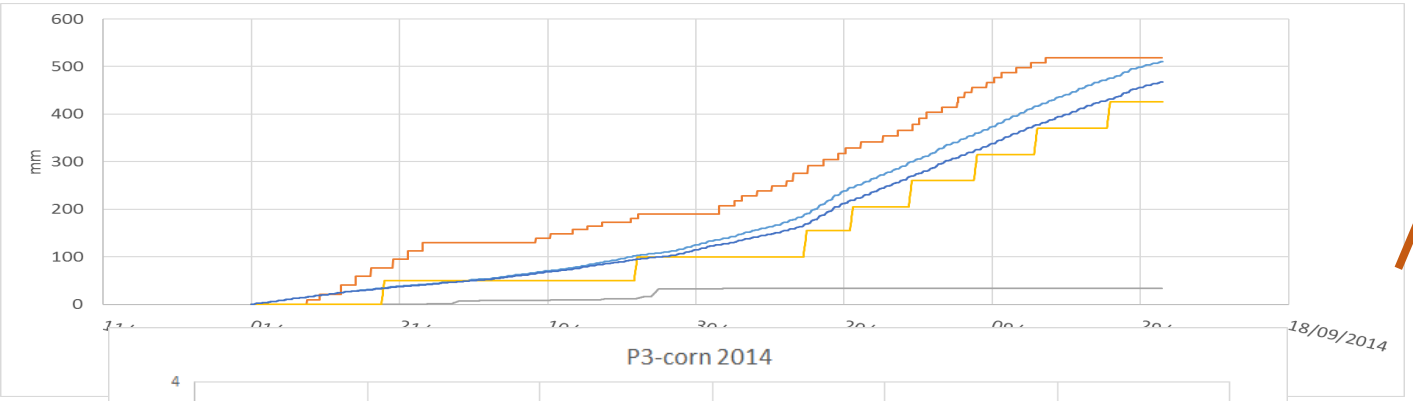
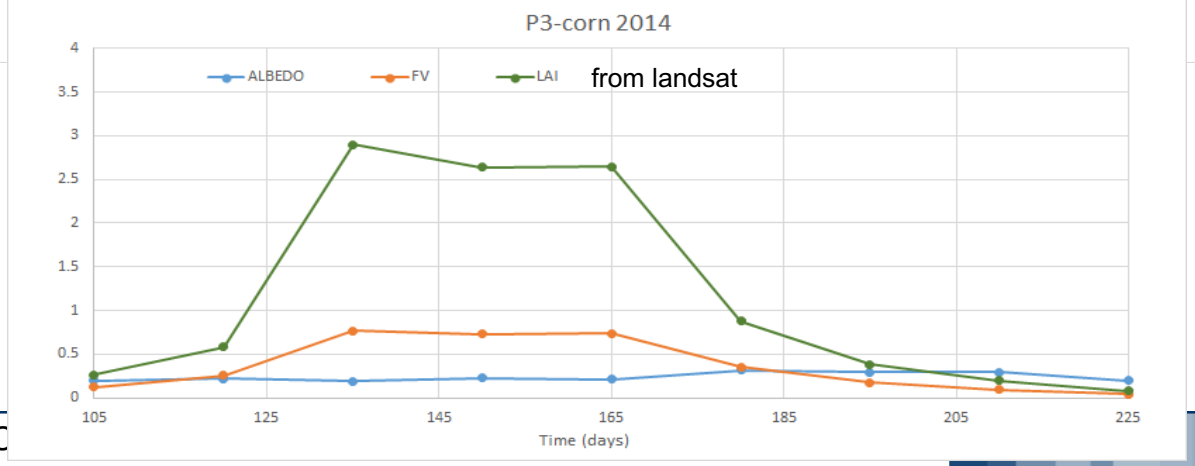
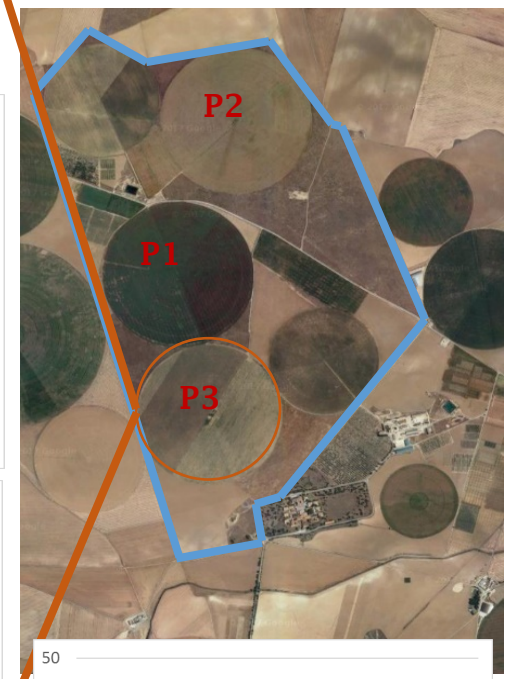
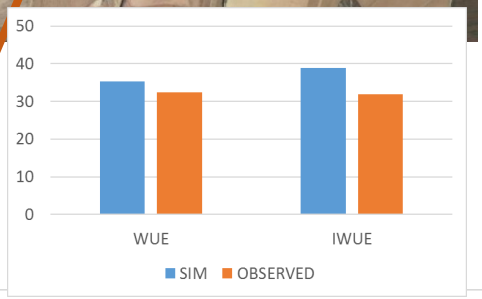
P3 – corn from may to september 2014

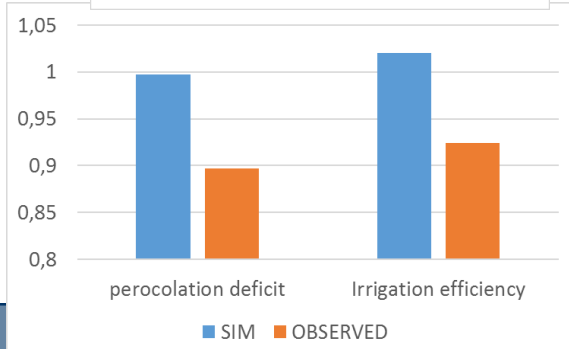












Case study: **Aa en Maas – Raam district** (The Netherlands)

Irrigation is made both from surface and groundwater (75 %)

Area = 420 km2
Agricultural area= 40 %
Irrigated area= 25 %

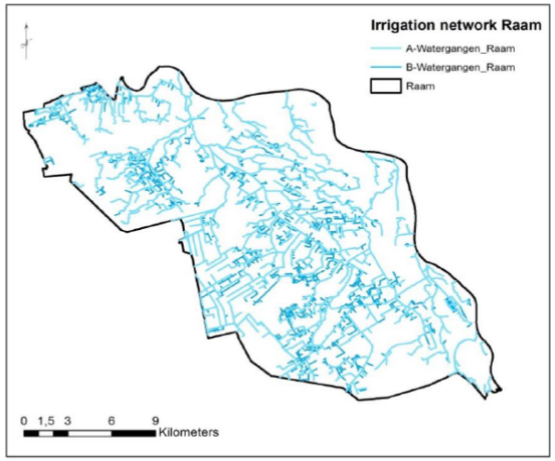
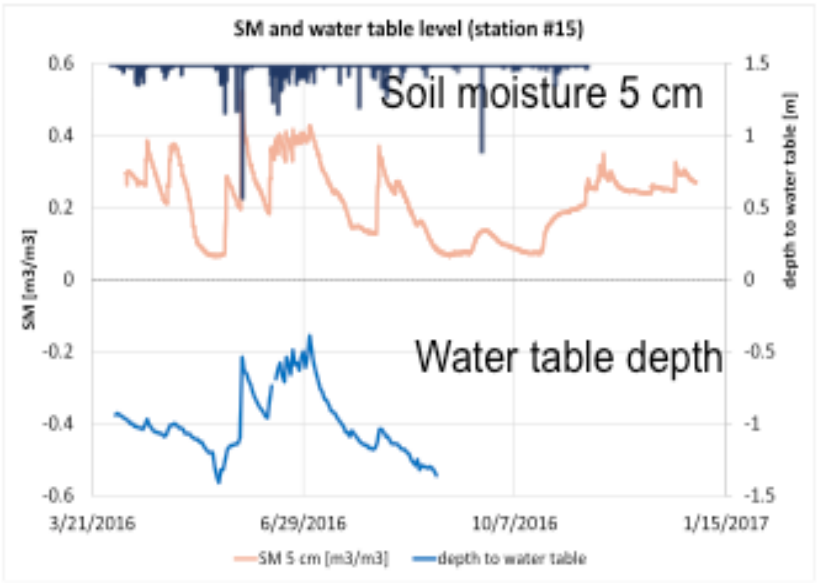
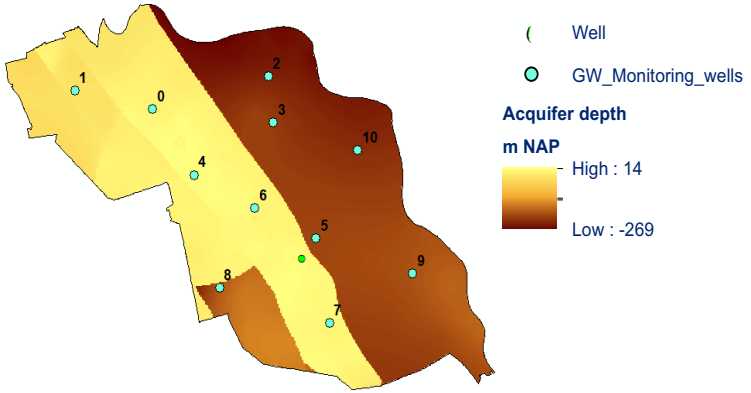


Fig 3.60 –Irrigation network in Raam district

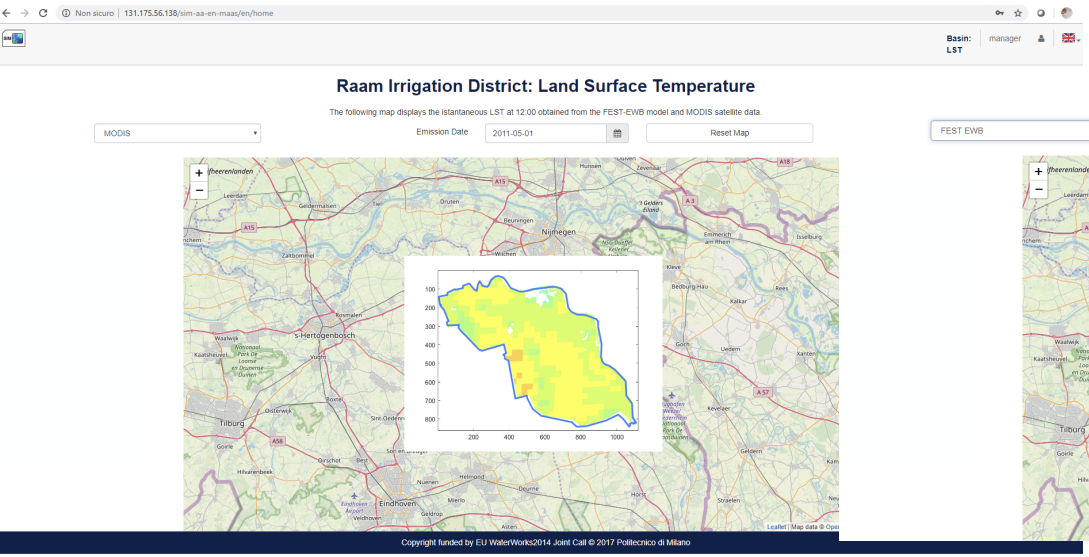
VARIABLE		2011	2012	2013	2014	2015	2016
Irrigation	MAX (mm/d)		2.8	3.9	8.3	10.3	
	MIN (mm/d)		0.0	0.0	0.0	0.0	
	AV (mm/d)		0.2	0.5	0.2	0.7	
	Total Vol (Mmc/y)	6,00	2,87	7,58	2,60	10,74	
	Area of Raam irrigated		16%	29%	18%	26%	
Precipitation cum (mm)		342.3	353.0	205.2	440.8	233.0	373.6
Classification (R.Haskoning report)		Normal-Dry	Normal	Dry	Normal	Dry	Normal

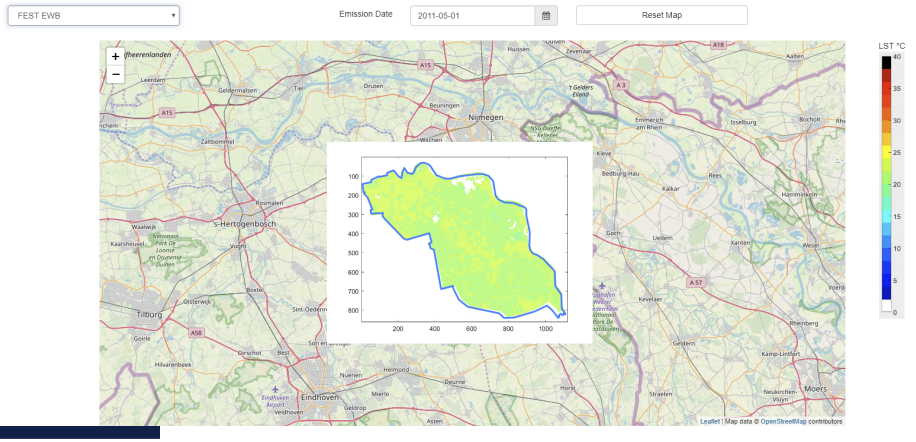


AQUIFER DEPTH with **MONITORING WELLS**
chosen for groundwater level analysis

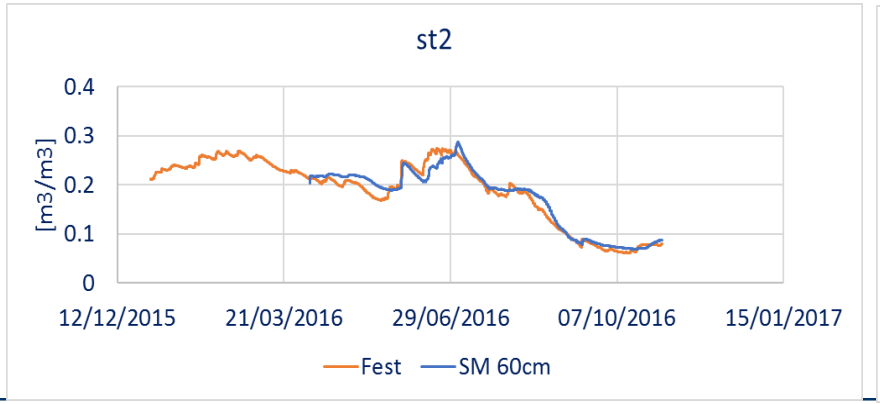


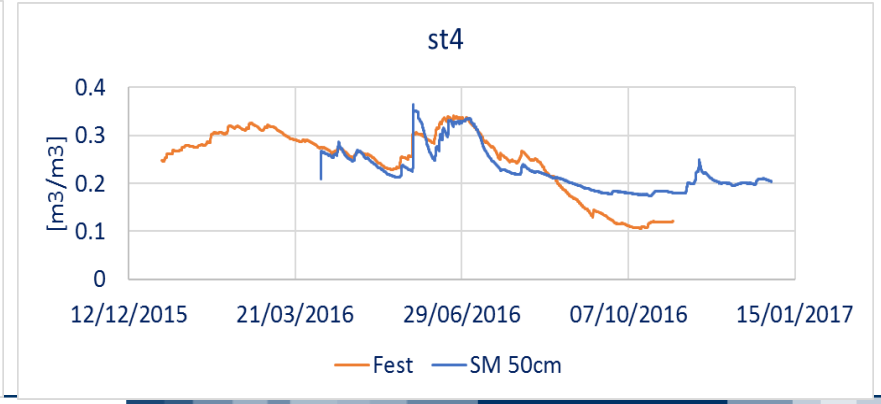
The SIM reanlysis dashboard



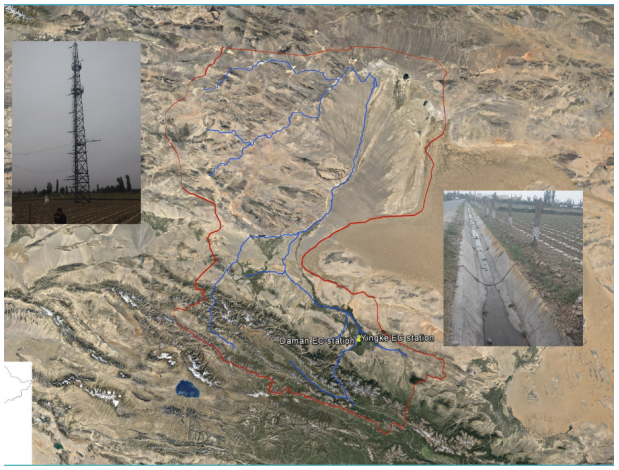


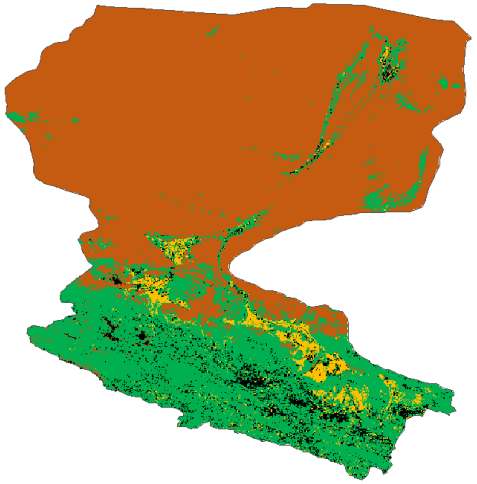
FEST-EWB is calibrated against MODIS LST images



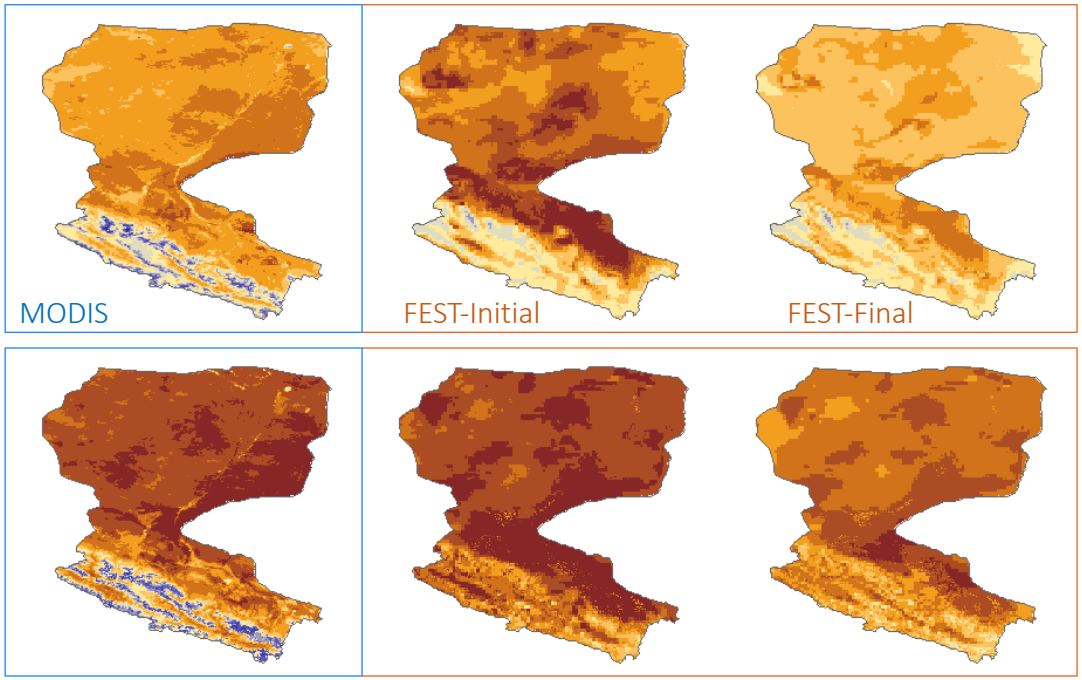


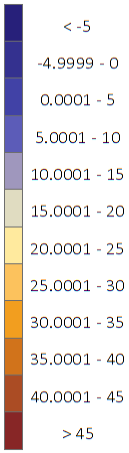
Heihe River (黑 河) basin, PR China





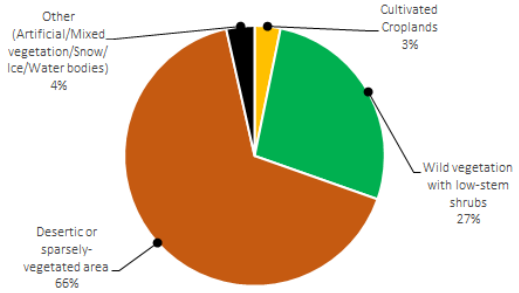
FEST-EWB LST calibration results





Land Surface Temperature [°C]

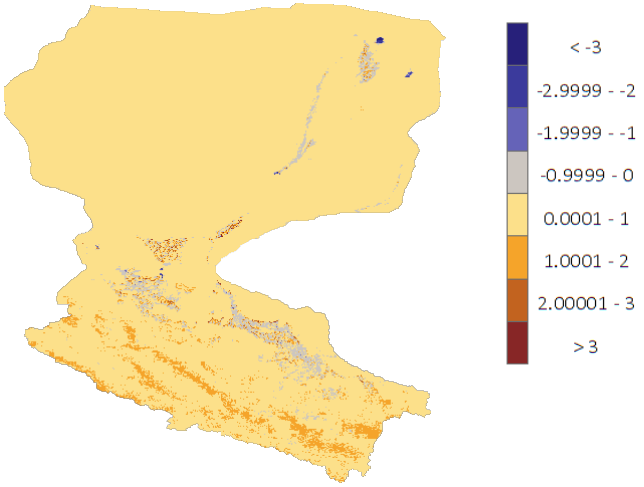
Land cover classification



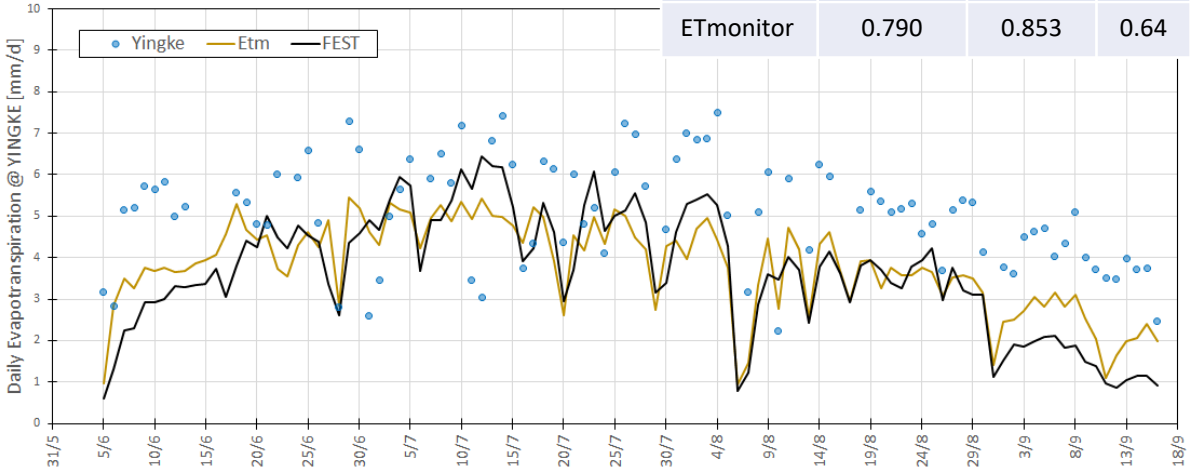
	Calibration statistics (FEST v. MODIS)			
Parameter configurations	Avg. RMSE	Avg. RMSE/σ	Average Bias (FEST-MODIS)	Avg. Nash-Sutcliffe Efficiency (NSE)
Initial	7.7°C	2.96	+2.88°C	+0.067
Final	8.1°C	3.01	-2.69°C	-0.039

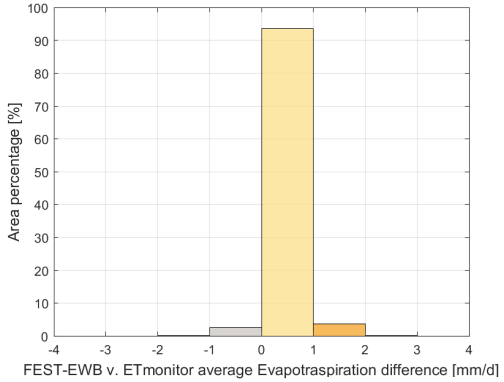
FEST-EWB v. Etmonitor: Average differences

FEST-EWB v. ETmonitor average Evapotranspiration difference [mm/d]

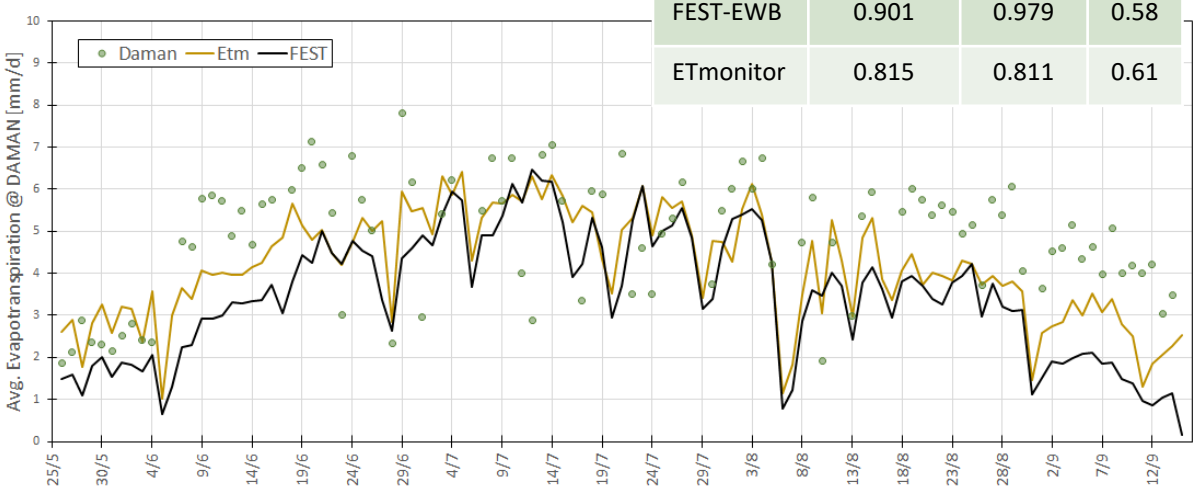


Model	RMSD/σ_O	σ_{mod}/σ_O	ρ
FEST-EWB	0.990	1.202	0.61
ETmonitor	0.790	0.853	0.64





Model	RMSD/σ_O	σ_{mod}/σ_O	ρ
FEST-EWB	0.901	0.979	0.58
ETmonitor	0.815	0.811	0.61



Thanks!

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MILANO 1863

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