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Evaluating uncertainty introduced to MABIA-WEAP-FAO56 soil water balance simulation model by using limited meteorological data

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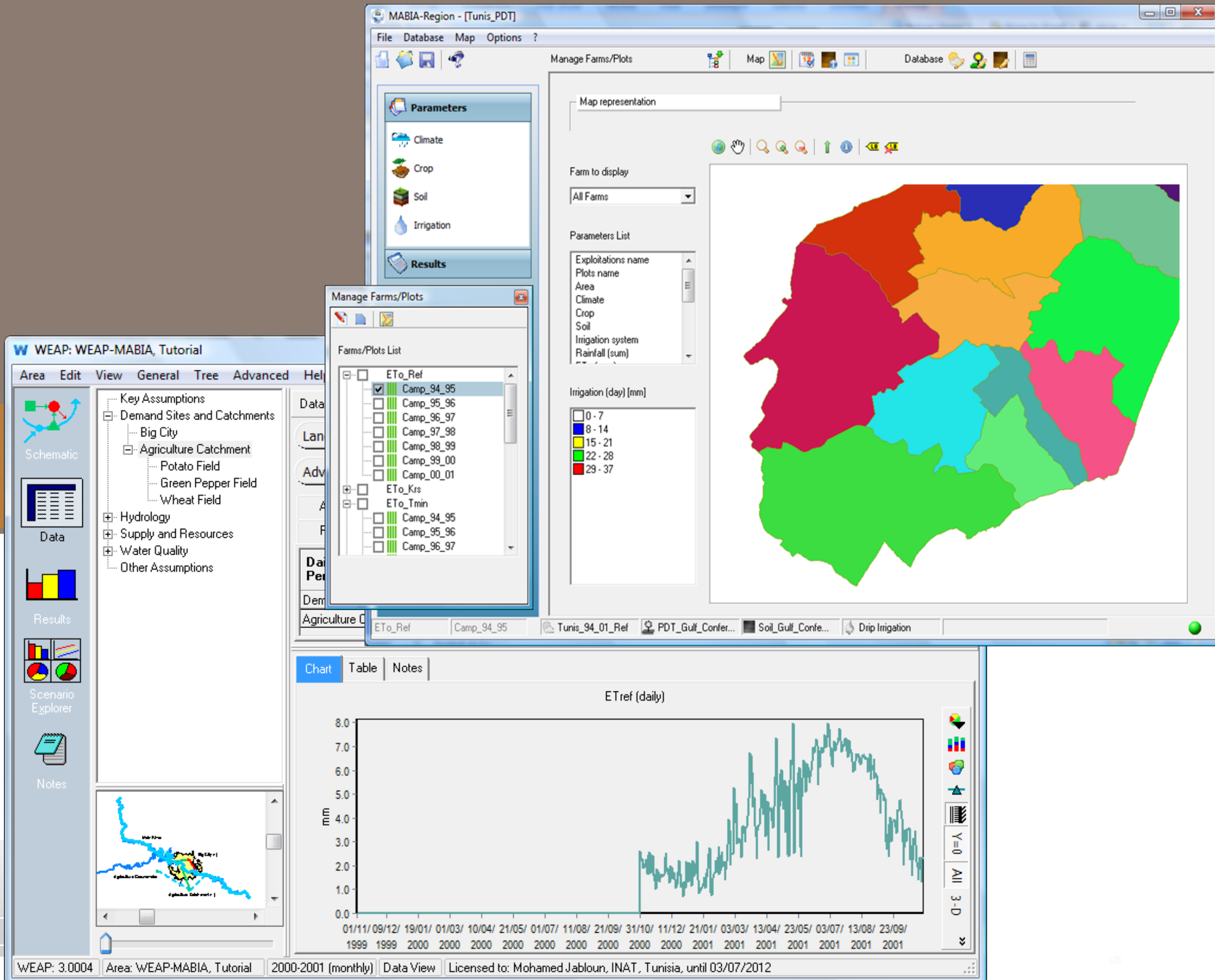

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SEI STOCKHOLM ENVIRONMENT INSTITUTE
BRIDGING SCIENCE AND POLICY SINCE 1989

Irrigated agriculture is the primary user of diverted water globally, reaching a proportion that exceeds 70–80% of the total in the arid and semi-arid zones.

The rapid increase of the world population and the corresponding demand for extra water by sectors such as industries and municipals, forces the agricultural sector to use irrigation water more efficiently.

↓

Particularly in Mediterranean areas where water resources are limited and irrigation is a necessary part of agricultural practices, accurate estimates of the crop water requirement (ET) are critical in order to make informed decisions regarding water management.

Since the ET varies over the growing season, farmers will adjust the irrigation frequency and/or application depth during the growing season.

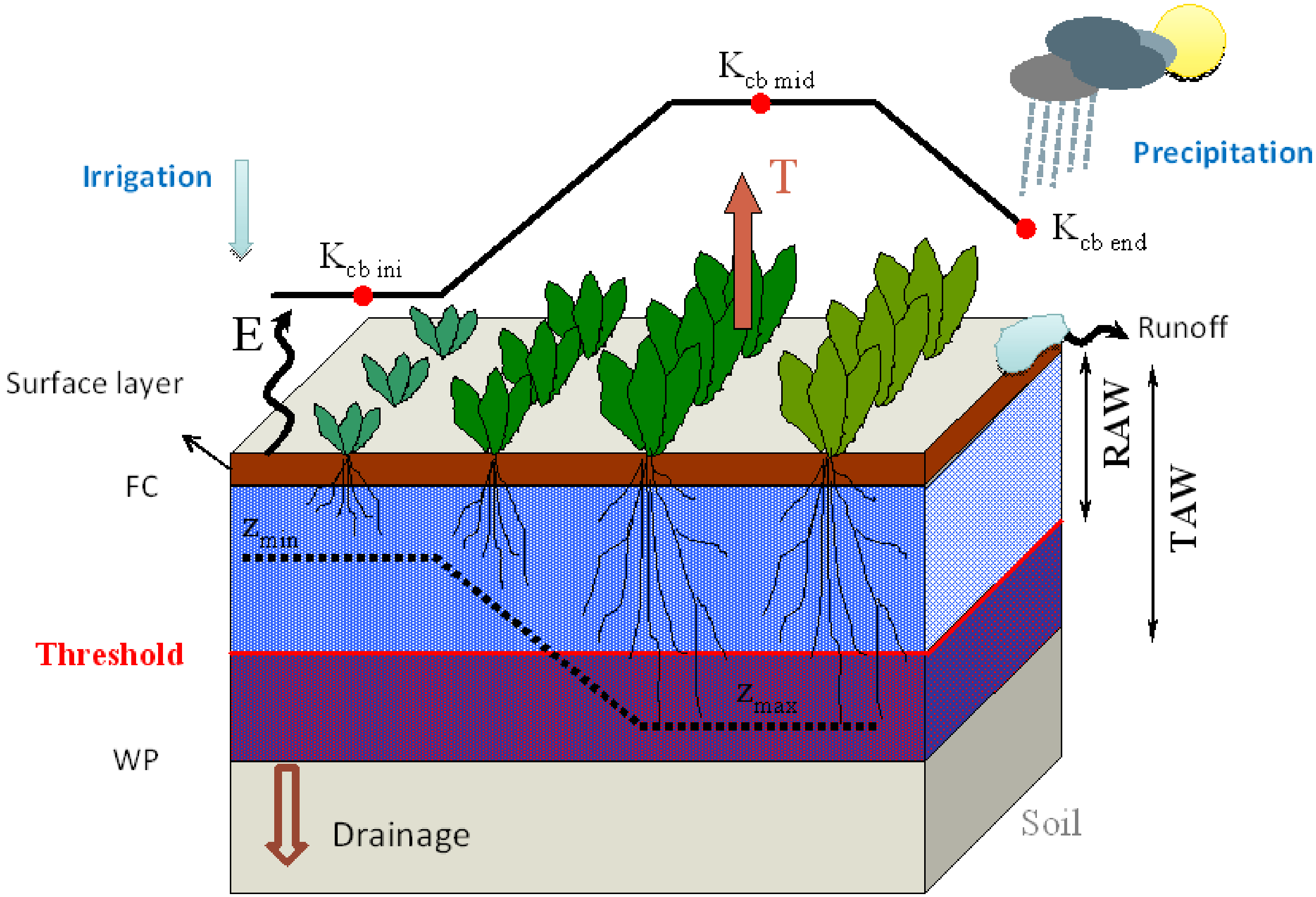
However,

Making regular direct in-field measurements of plant and/or soil water status to schedule irrigation is usually too laborious, time consuming, difficult, or expensive for individual farmers.

→ it has been suggested that a good precision in the application of irrigation can potentially be obtained by the use of ‘soil water balance calculations’

Soil Water Balance

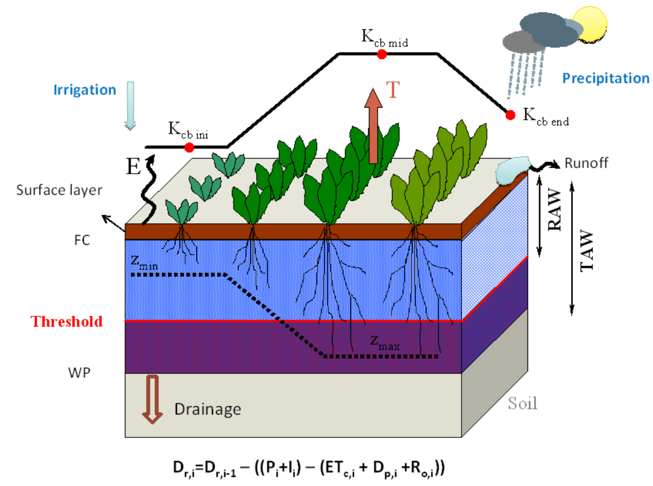
Soil moisture status change is estimated by the difference between the inputs (irrigation plus precipitation) and the losses (runoff plus drainage plus crop evapotranspiration).



$$D_{r,i}=D_{r,i-1} - ((P_i+I_i) - (ET_{c,i} + D_{p,i} + R_{o,i}))$$

FAO-56 Dual Crop Coefficient and Water Balance

FAO 56 Paper is a standard reference for crop evapotranspiration (ETc) and irrigation water requirement (Allen et al. 1998).

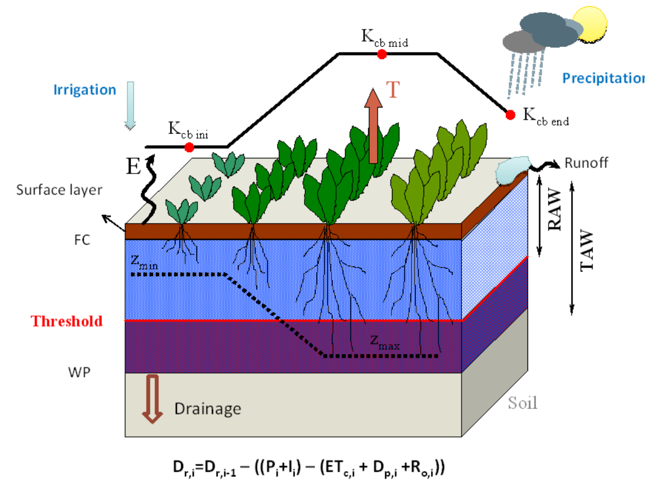


The proposed methodology for computing actual crop evapotranspiration (ETa) was based on the application of a dual soil water balance (DSWB) at the top soil and the root zone layers and the use of the reference evapotranspiration (ETo) and the dual crop coefficient method that separates evaporation from transpiration.

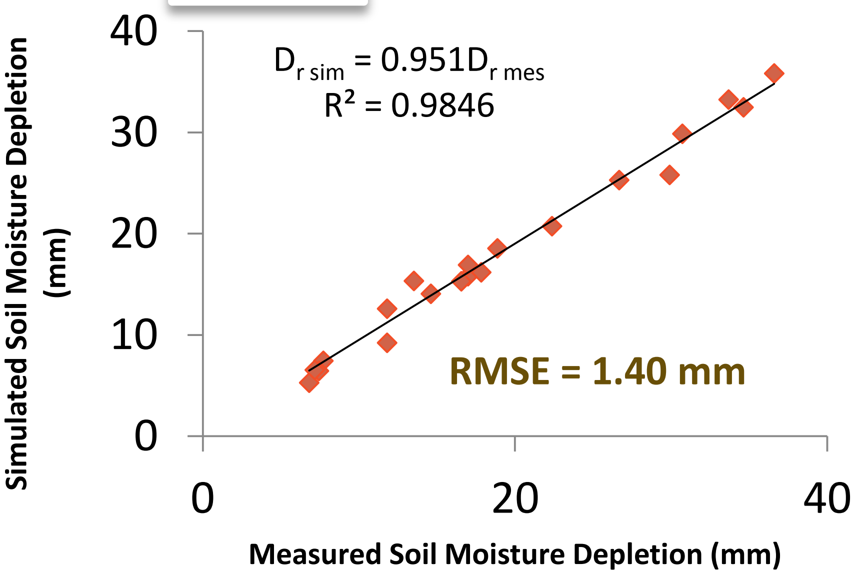
FAO-56 Dual Crop Coefficient and Water Balance - Validation

Subsequent papers have demonstrated the accuracy of the FAO-56 method for several crops and weather conditions

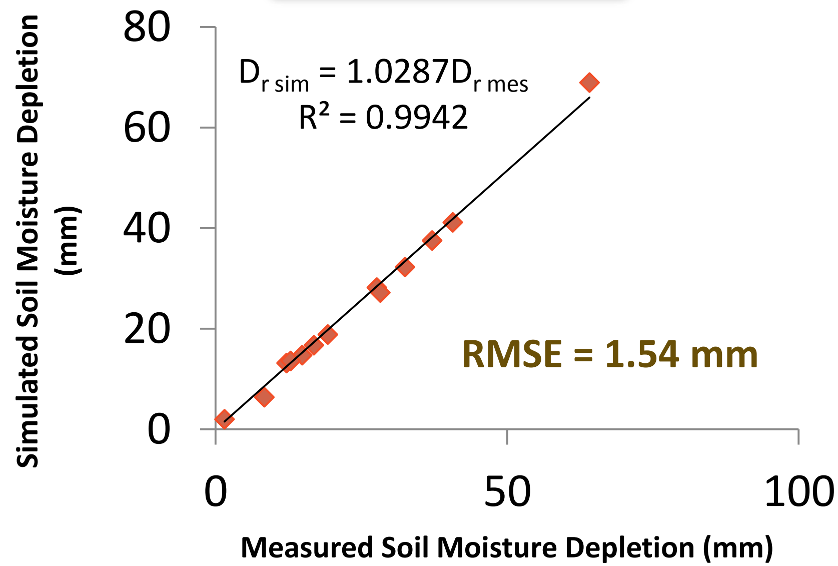
- Cotton (Allen 2000)
- Wheat and Maize (Liu & Pereira 2000)
- Peach (Goodwing et al 2006)
- Potato and Pepper (Jabloun & Sahli 2006)



Potato

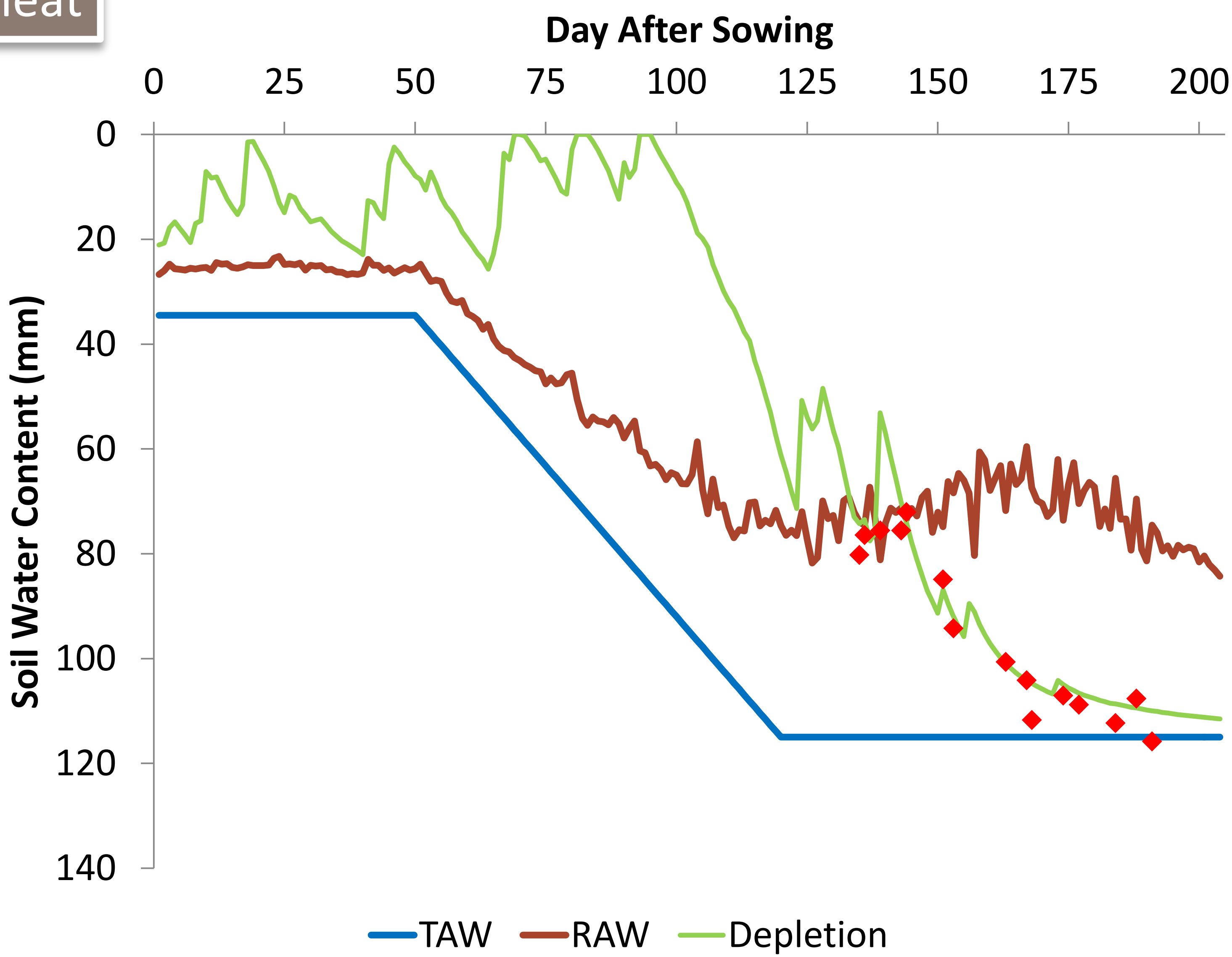


Green Pepper



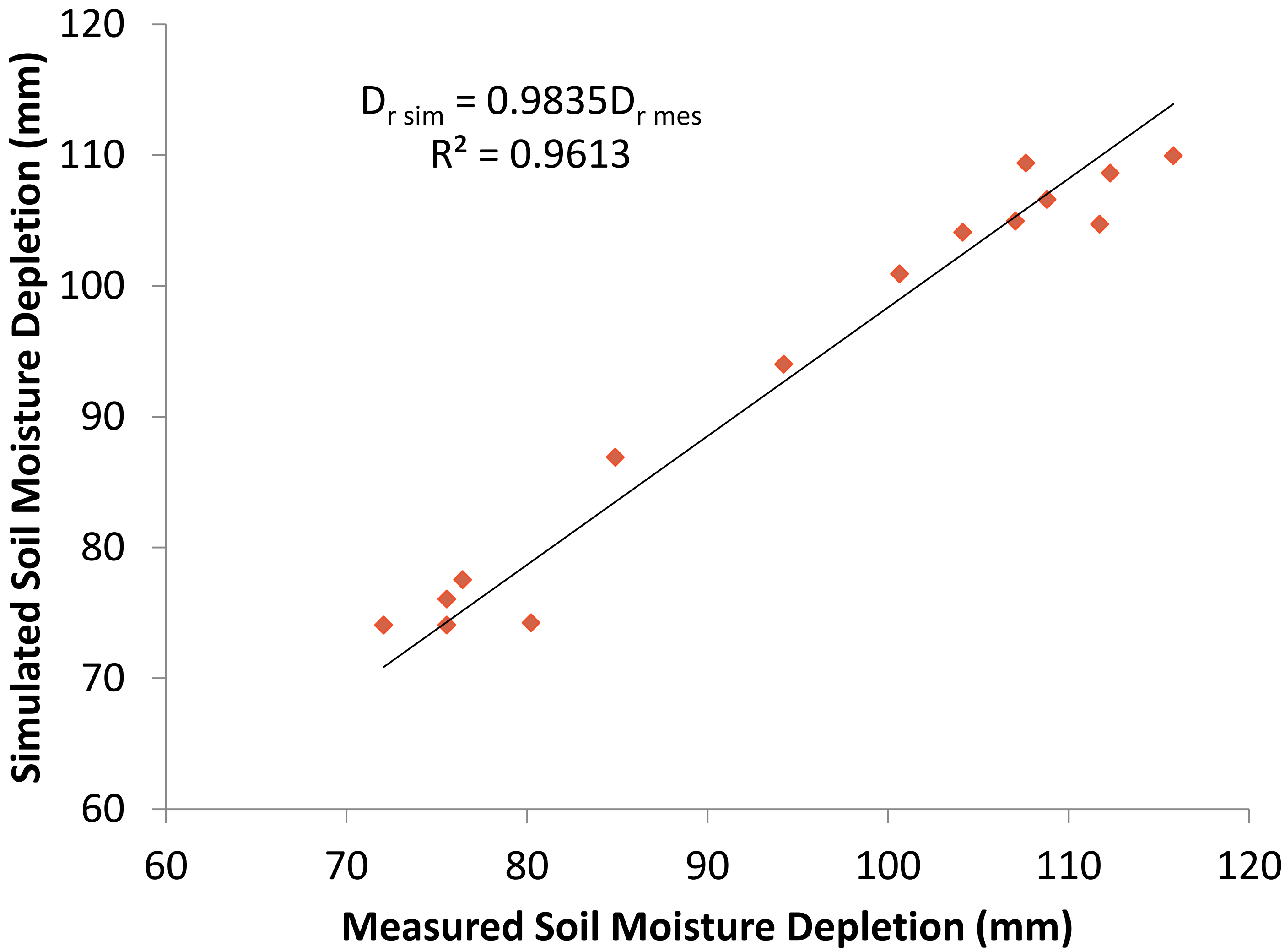
FAO-56 Dual Crop Coefficient and Water Balance - Validation

Wheat



Wheat

RMSE = 3.23 mm



Different tools operating on the basic principle of the FAO56 water balance model have been developed to save on water use in agriculture.

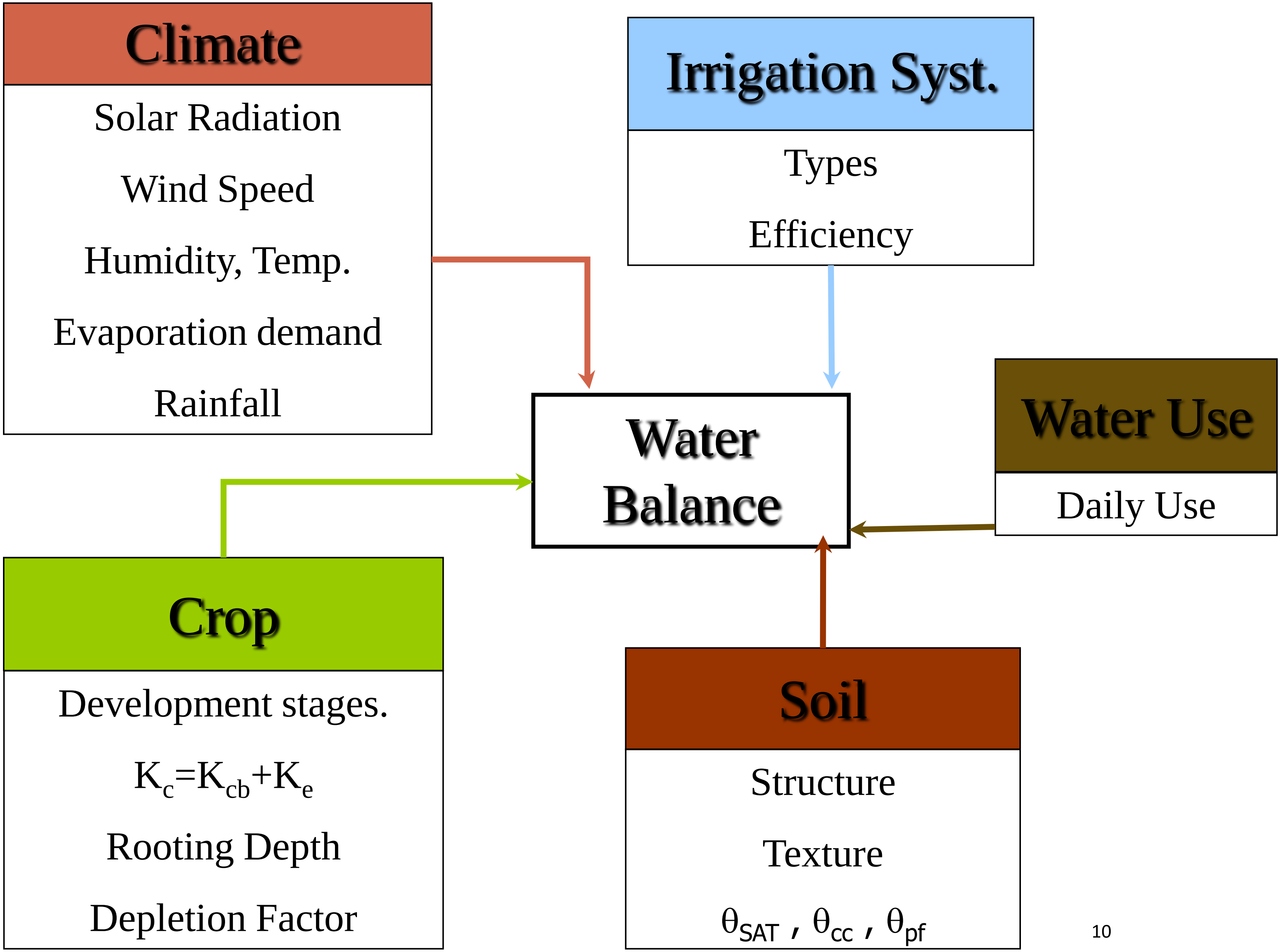
At Field Scale :

- MABIA-ETc by Jabloun & Sahli 2005
- SIMDualKc by Rolim et al. 2007
- AQUACROP by Raes et al. 2009
- Ect...

At Regional Scale :

- MABIA-Region by Jabloun et al. 2011
- WEAP-MABIA by Seiber 2011

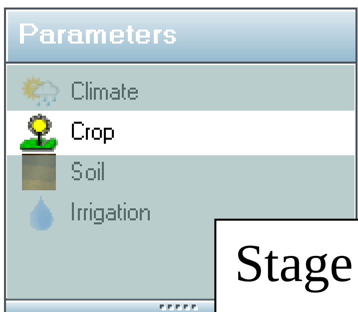
FAO-56 Dual Crop Coefficient and Water Balance – Use Requirements



FAO-56 Dual Crop Coefficient and Water Balance – MABIA Facilities

To overcome the need to fill all the requested data, MABIA-Region & WEAP-MABIA tools come with an integrated :

- Crop Data Base : Built from the available data in the literature



Stage duration

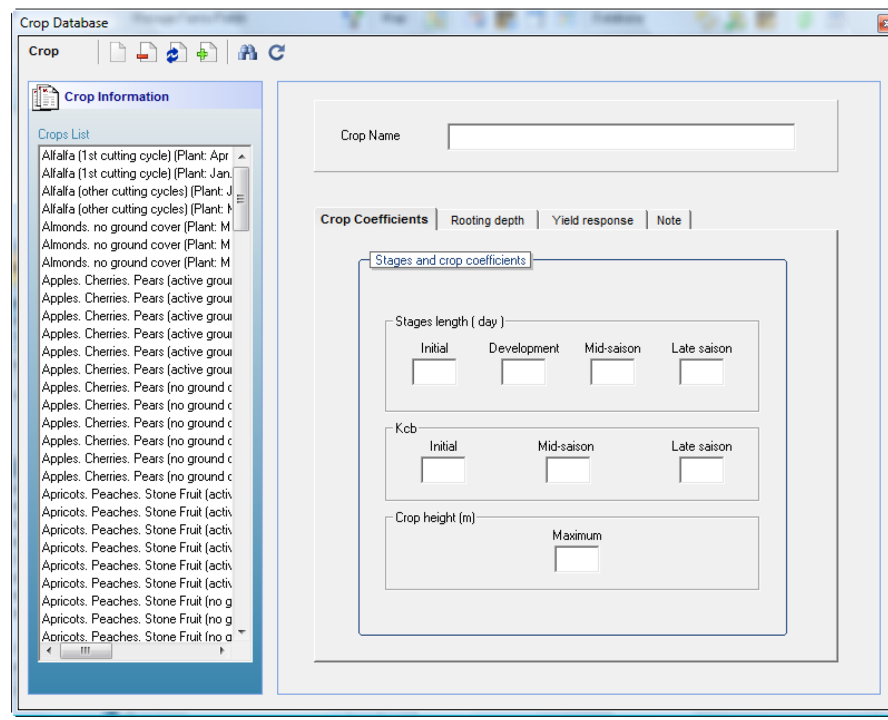
K_{cb}

Crop height

Rooting depth

Depletion factor

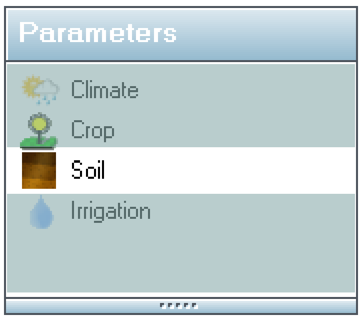
Ky



FAO-56 Dual Crop Coefficient and Water Balance – MABIA Facilities

To overcome the need to fill all the requested data, MABIA-Region & WEAP-MABIA tools come with an integrated :

- Soil Data Base : Built for the 12 FAO textural classes



SAT

FC

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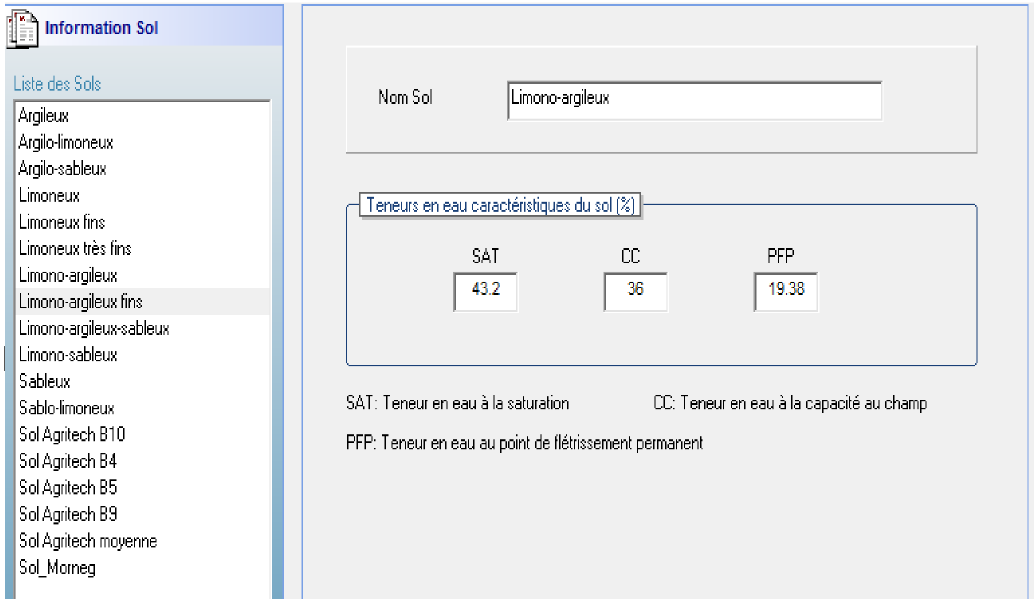
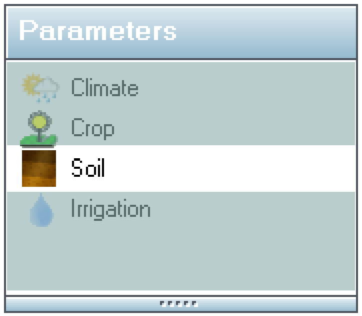


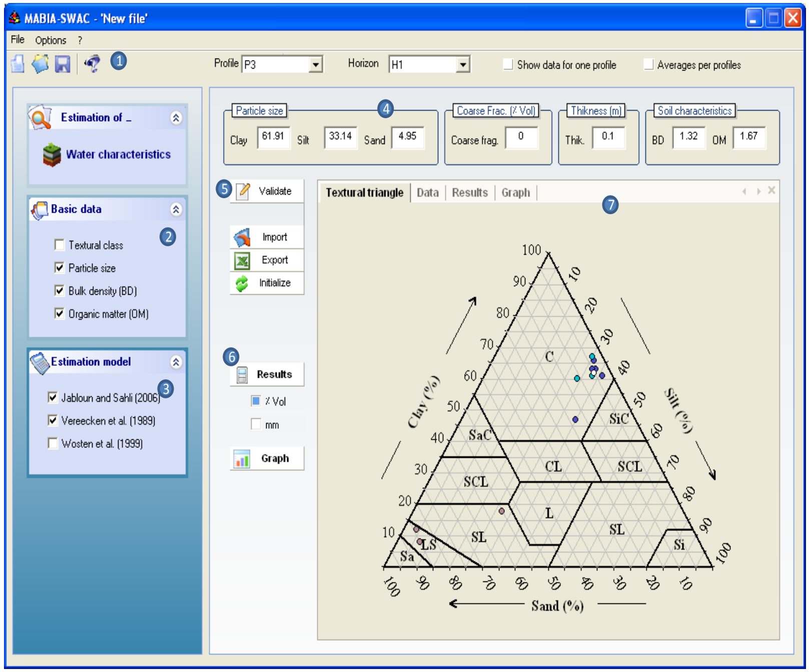
To overcome the need to fill all the requested data, MABIA-Region & WEAP-MABIA tools come with an integrated :

- Soil WAter Characteristics Module: Based on different hydraulic pedotransfer functions



Data about soil components.

MABIA-SWAC



SAT

FC

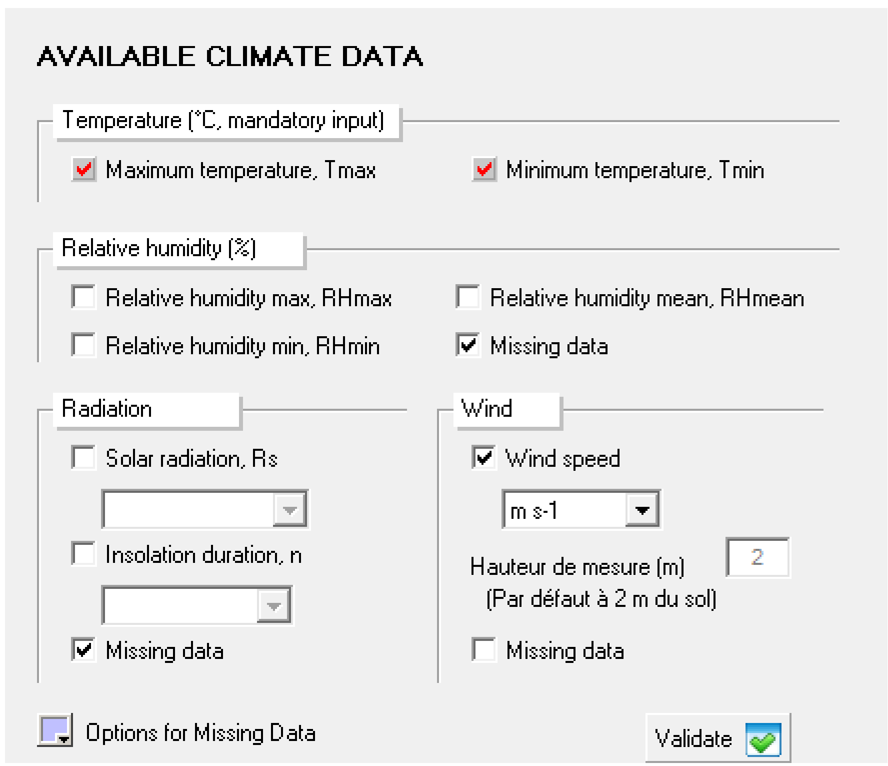
WP

FAO-56 Dual Crop Coefficient and Water Balance – MABIA Facilities

To overcome the need to fill all the requested data, MABIA-Region & WEAP-MABIA tools come with an integrated :

- Reference Evapotranspiration ETo-Module :
  - Based on the FAO Penman-Monteith equation
  - And using different scenarios of climatic data availability

MABIA-ETo



ASKED QUESTION

QUESTION

What is the error that arises in the water balance terms i.e. crop evapotranspiration, irrigation requirement and drainage when some site-specific climate data are missing

METHODOLOGY USED

Location : Five different sites in Tunisia

	Beja	
	P	ETo
Mean	551	1240
Minimum	339	1157
Maximum	802	1292
CV	27%	4%

	Tunis	
	P	ETo
Mean	408	1490
Minimum	260	1401
Maximum	605	1547
CV	31%	3%

	Zaghouan	
	P	ETo
Mean	444	1323
Minimum	246	1247
Maximum	663	1380
CV	32%	3%

	Sidi Bouzid	
	P	ETo
Mean	239	1371
Minimum	88	1331
Maximum	332	1403
CV	37%	2%

	Kairouan	
	P	ETo
Mean	293	1344
Minimum	133	1279
Maximum	448	1384
CV	33%	3%

Climate and Data Availability scenarios:

- Daily data records during 7 years :
  - Daily maximum and minimum temperatures
  - Daily maximum and minimum relative humidity,
  - Daily sunshine duration
  - Daily mean wind speed
  - Daily Rainfall

- Scenarios of climatic data availability and ETo estimating methods :

ETo estimation Methods	Temperature (°C) T_{max} & T_{min}	Humidity (%) HR_{max} & HR_{min}	Sunshine Duration (hours) n	Wind Speed (m/s) u_2
ETo-Ref	+	+	+	+
ETo-K_{rs}	+	+	-	+
ETo-T_{min}	+	-	+	+
ETo-T_{ure}	+	-	-	+
ETo-Hargreaves	+	-	-	-

Crops, Soil and Field Parameters

- Four irrigated crops :
  - Wheat,
  - Potato,
  - Tomato
  - Olive tree

- Trials base information referring to crop, soil and irrigation system

Crop Parameter	Wheat	Potato	Tomato	Olive
date	15^{th} November	15^{th} February	01^{st} March	01^{st} March
Initial Stage (d)[a]	55	20	30	30
Dev. Stage (d)	70	25	40	90
Mid. Stage (d)	50	35	50	60
Late Stage (d)	35	25	30	90
Root length (m)	1.0	0.6	0.8	1.5
TAW (mm/m)	145	145	145	145
Initial WC	FC	FC	FC	FC
Irrigation f_w	1.0	0.6	0.6	0.2

Calculation Tool, Estimated Parameters and Performed Analysis

- Used Tool to estimate soil water balance terms : MABIA-Region

- Estimated Parameters

  - Irrigation Requirement,
  - Drainage

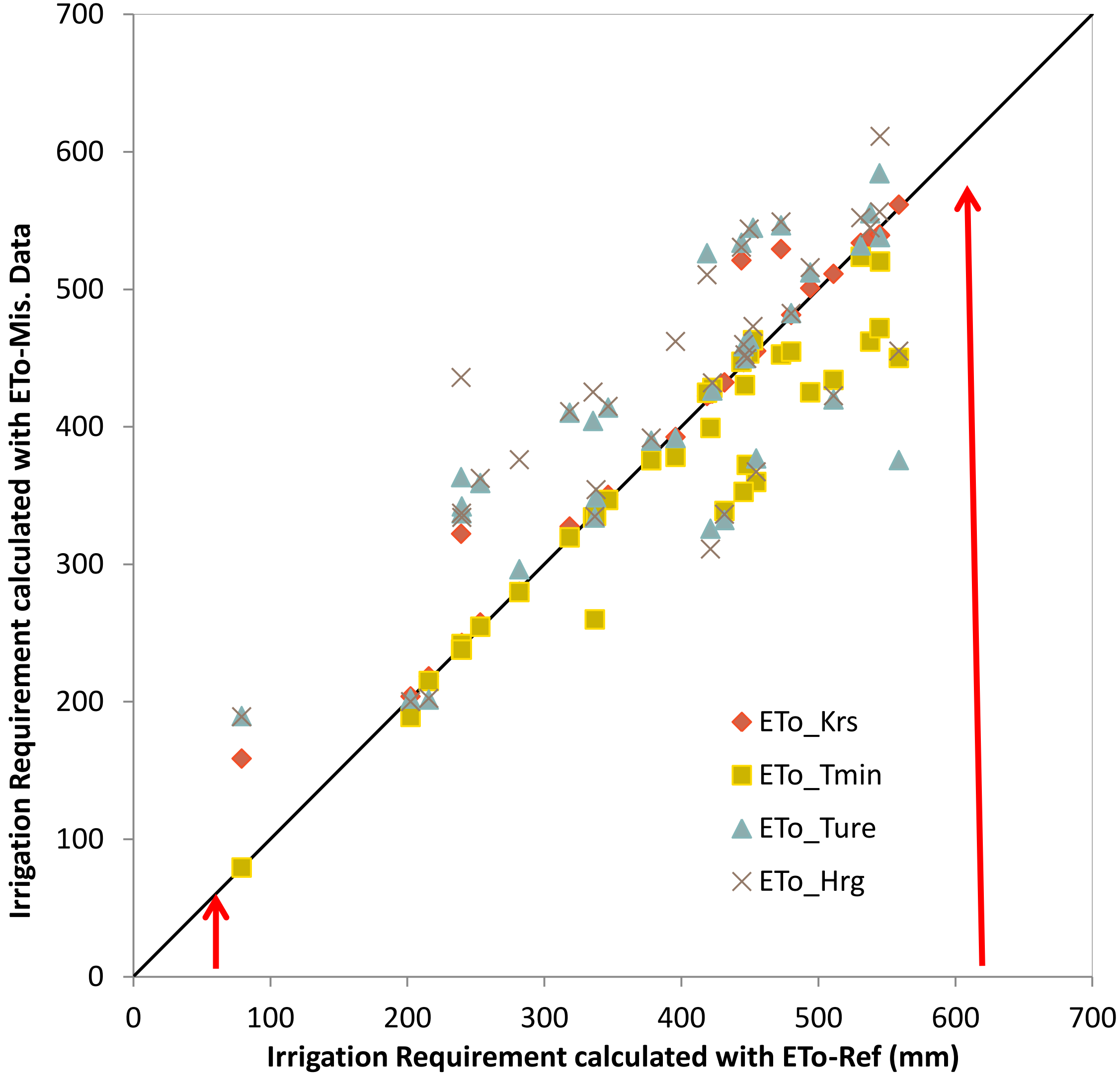
- The impact of the ETo calculation method on the estimated parameter was evaluated using the Mean Beas Error and the Root Mean Square Error between results based on ETo-Ref and ETo-Missing Data

$$MBE = \frac{1}{n}\sum_{i=1}^{n}\left(R_{ETo-mis} - R_{ETo-Ref}\right)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(R_{ETo-mis} - R_{ETo-Ref}\right)^2}$$

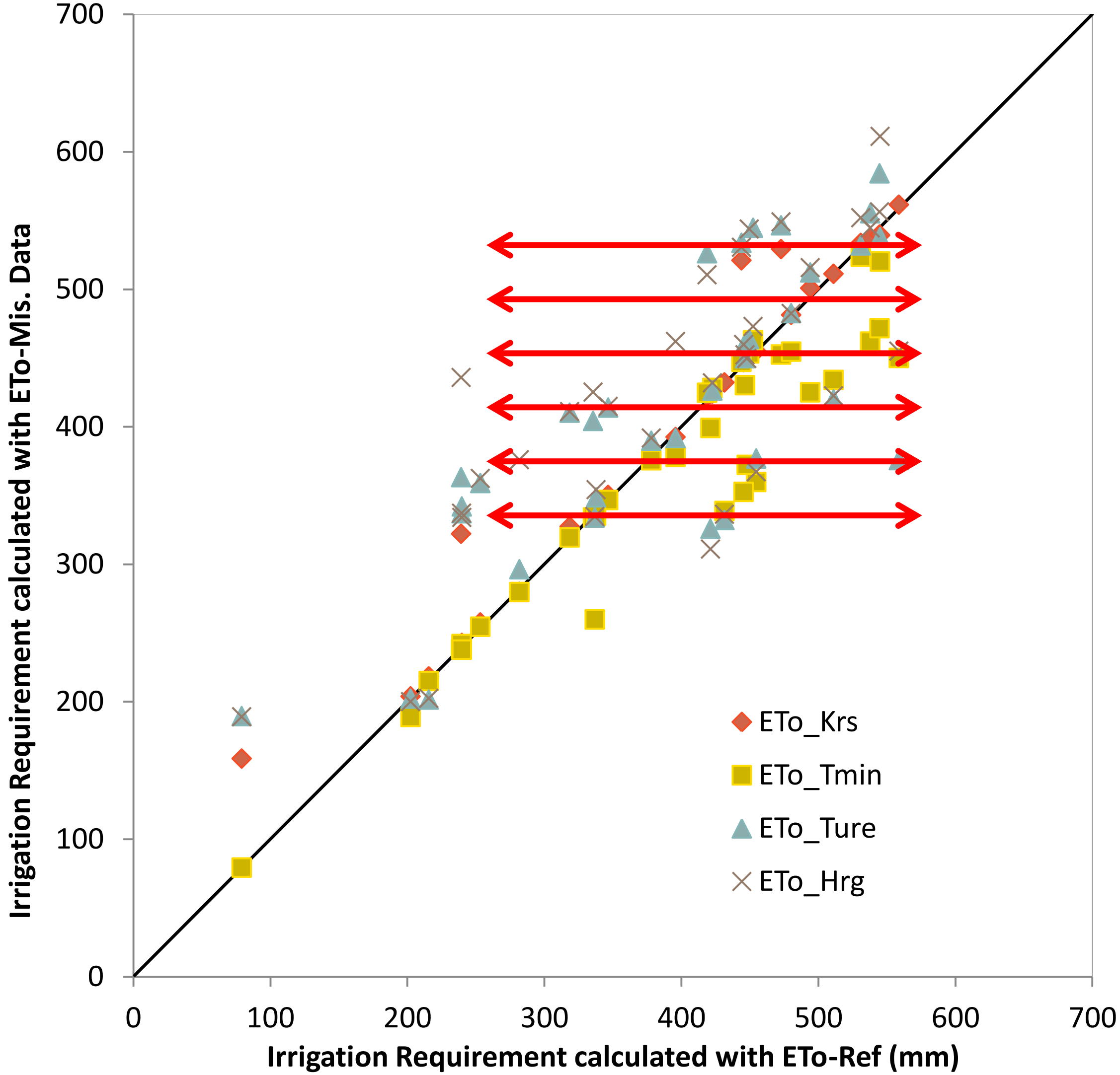
RESULTS

Case of Wheat – Irrigation Requirement



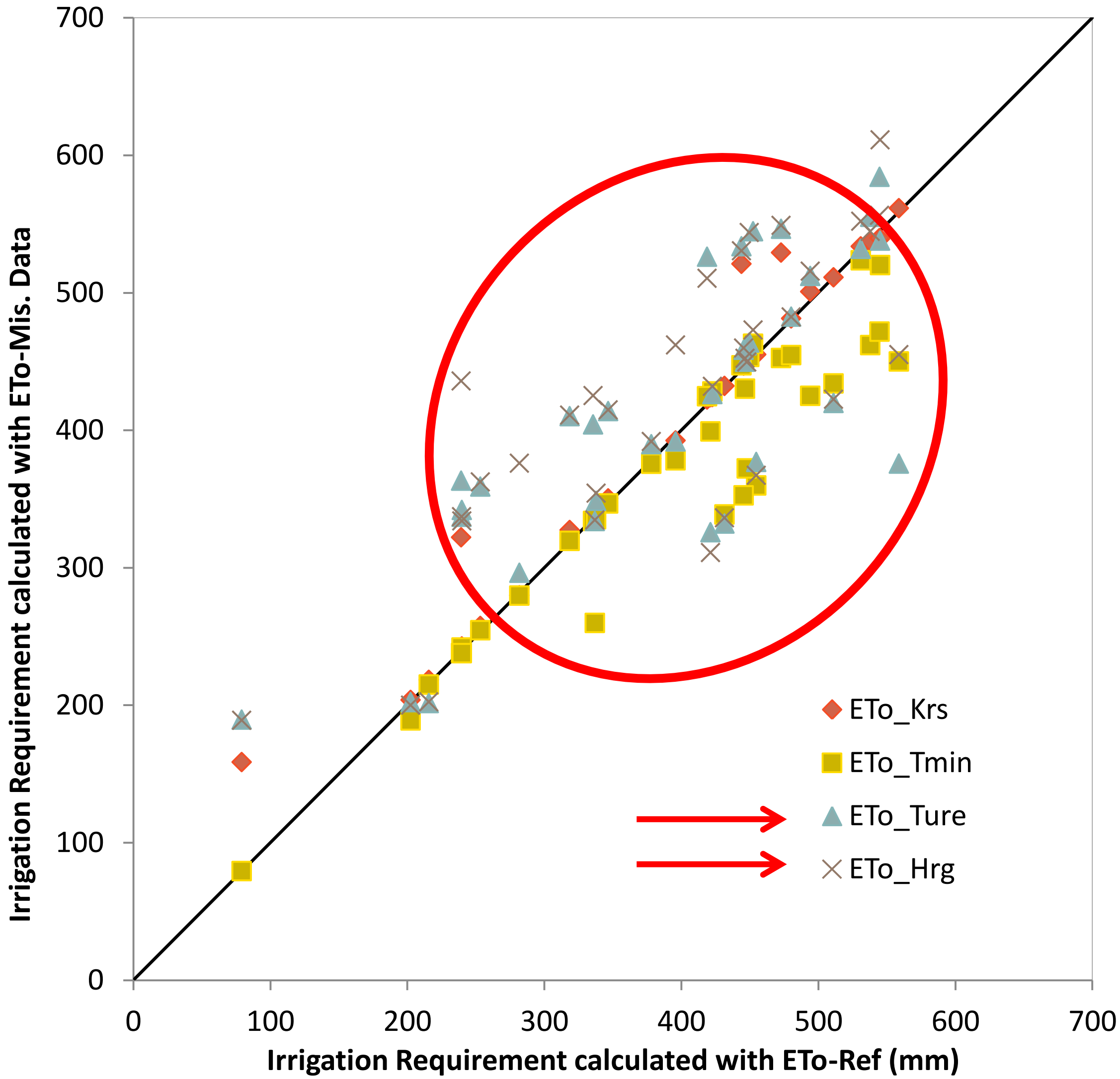
Regarding weather condition, Wheat Irrigation Requirement can vary from 100 to 600 mm with an overall mean of about 400 mm

Case of Wheat – Irrigation Requirement



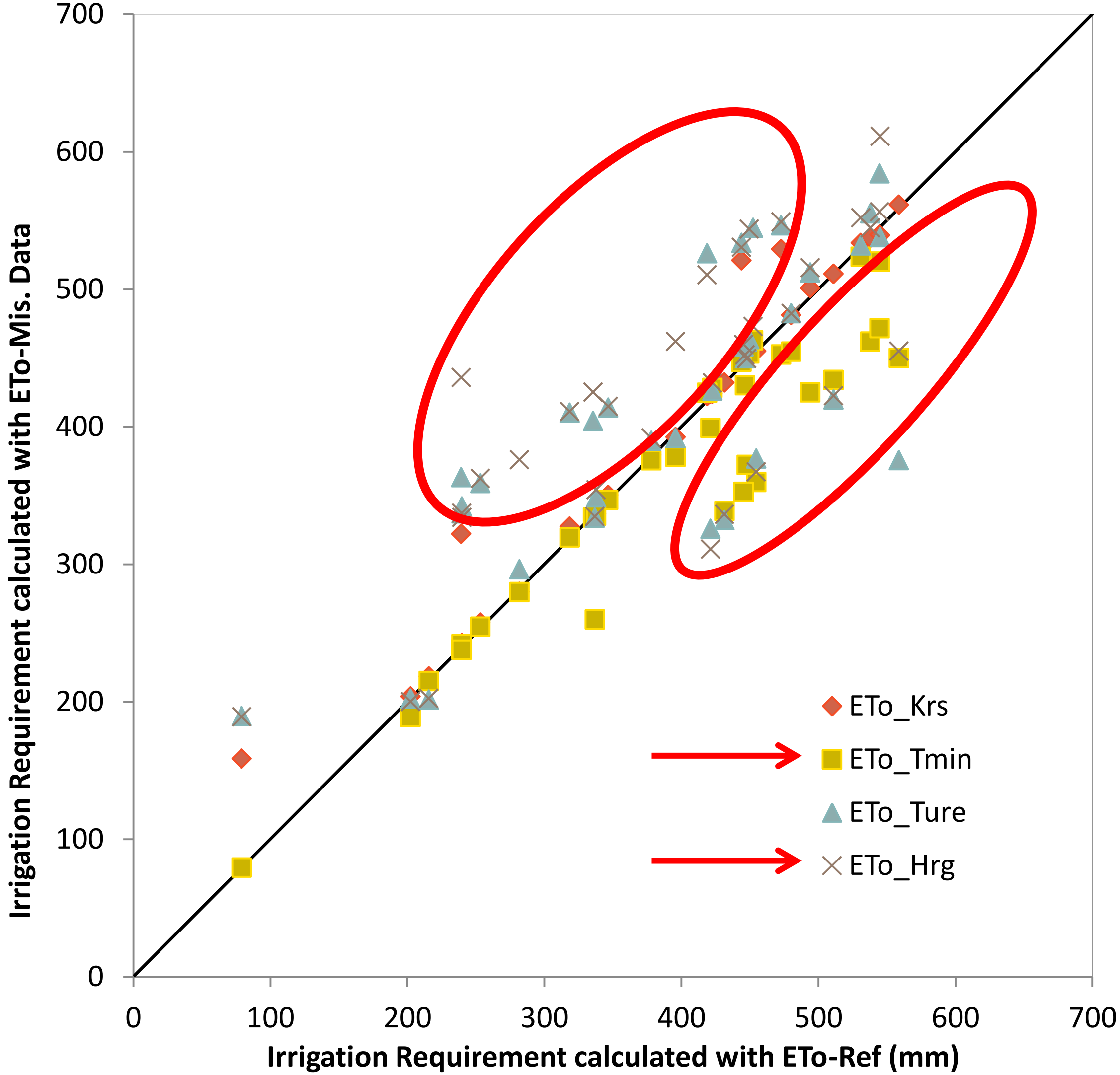
The deviations on WIR is more pronounced during dry growing seasons

Case of Wheat – Irrigation Requirement



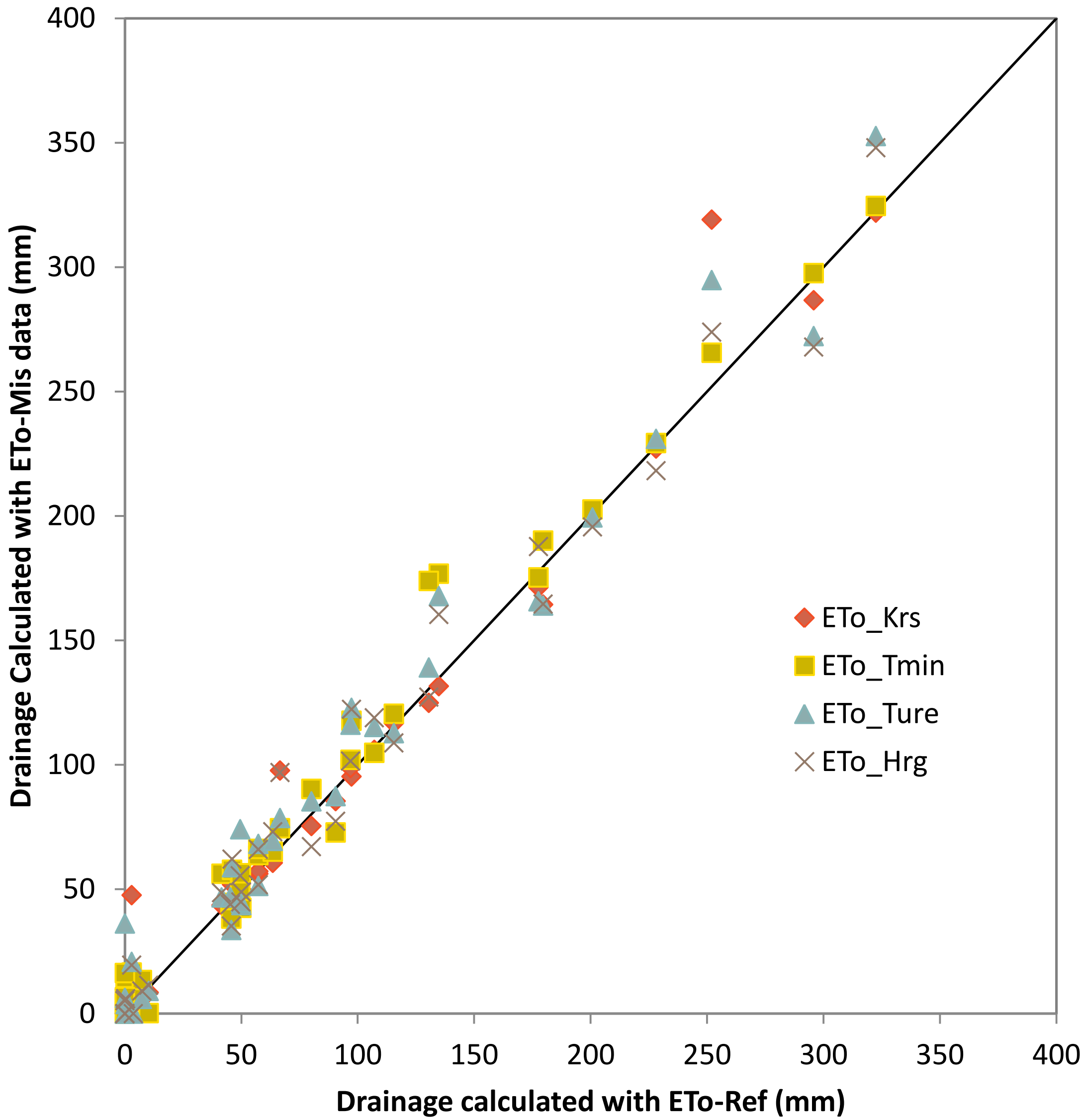
The higher deviations on WIR occur when only available information is minimum and maximum air temperature and when using the Hargreaves equation

Case of Wheat – Irrigation Requirement



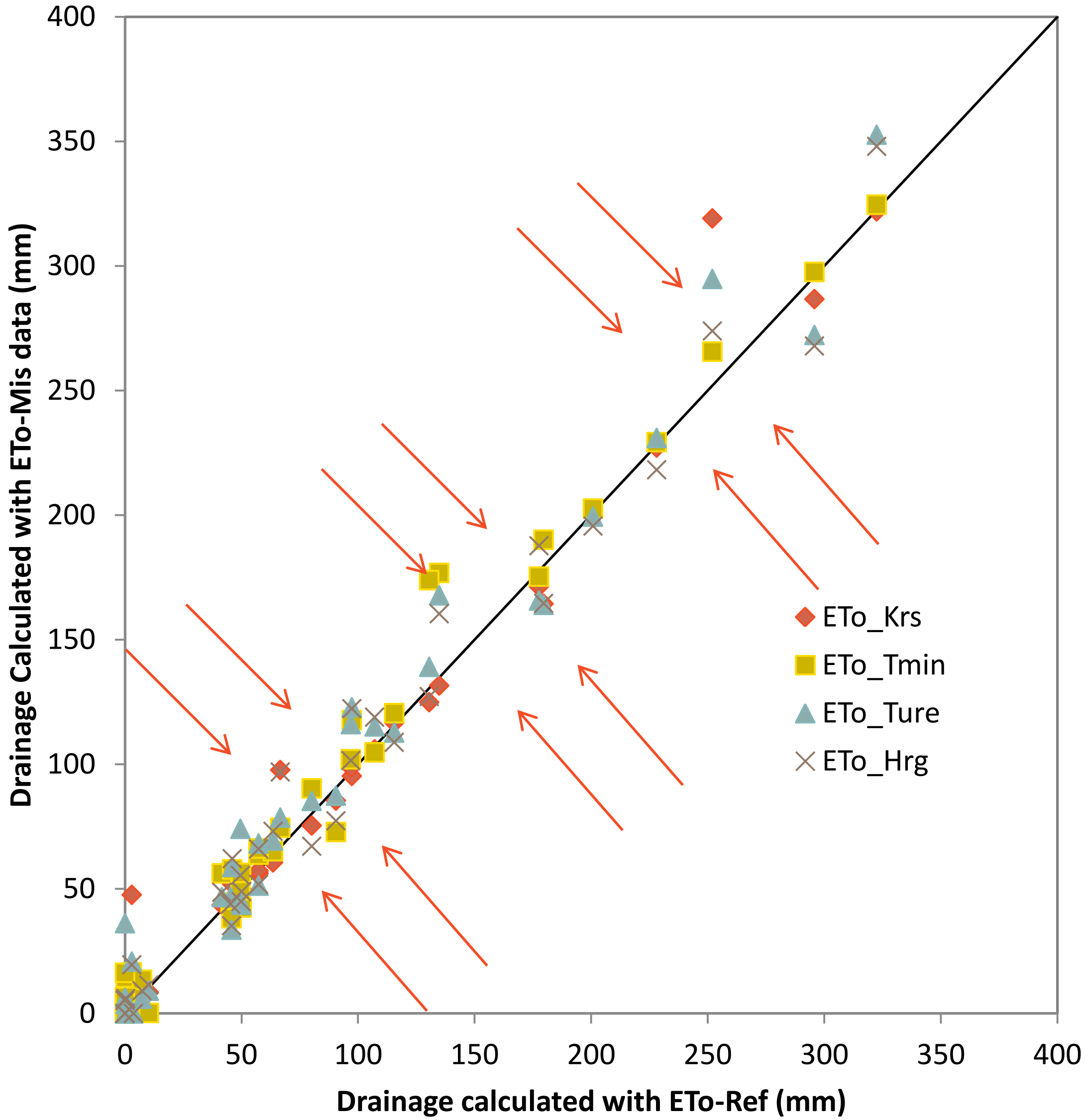
- Hargreaves equation tends to overestimate Wheat Irrigation Requirement
- FAO PM equation tends to underestimate Irrigation Requirement when air relative humidity was not considered

Case of Wheat – Drainage



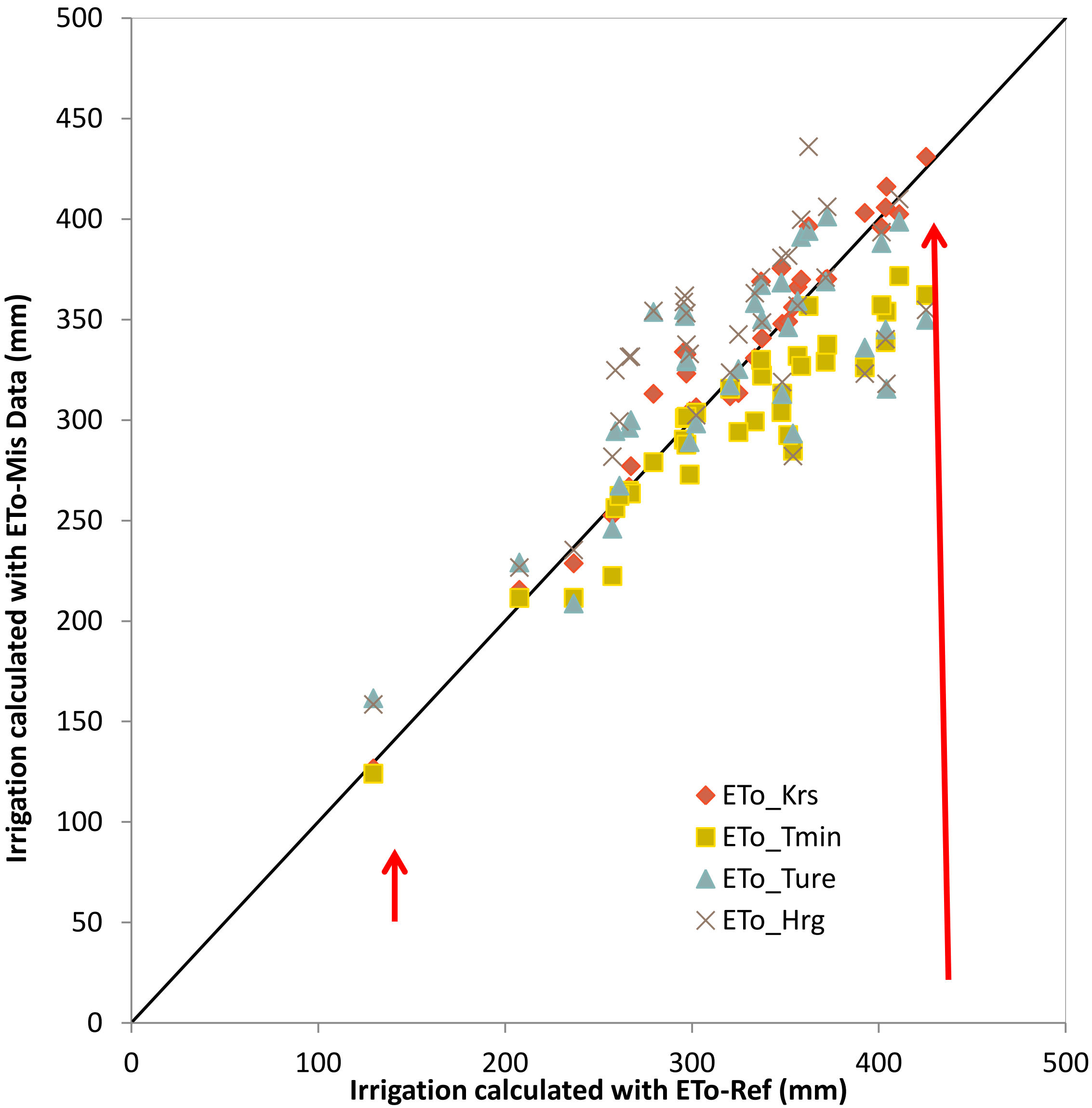
Regarding weather condition, deep percolation under the wheat root depth can vary from 0 to 350 mm with an overall mean of about 90 mm

Case of Wheat – Drainage



As drainage is more related to precipitation events, deviation on deep percolation is less pronounced than one obtained for irrigation requirements regarding ETo estimation method

Case of Potato – Irrigation Requirement



Quantitative Aspect :

- Min PIR : 130 mm
- Max PIR : 425 mm
- Average PIR : 320 mm

Same trends as for wheat :

- Large deviation when using Tmax and Tmin only and with Hargreaves equation
- Overestimation by Hargreaves equation
- Underestimation when air relative humidity was not considered

All Cases – Estimated Errors

Comparison between Irrigation (I) and Drainage (D) computed by the FAO 56-DSWB from ETo estimated with full data set and when ETo is estimated by considering different scenarios of climatic data availability for the different crops

		ETo estimation Methods							
		ETo-K_{rs}		ETo-T_{min}		ETo- T_{ure}		ETo-Harg.	
		MBE	RMSE	MBE	RMSE	MBE	RMSE	MBE	RMSE
Wheat	ETo (mm)	17	19	-36	44	25	68	38	78
	I (mm)	10	26	-27	46	21	72	31	76
	D (mm)	3	15	7	14	6	16	3	13
Potato	ETo (mm)	12	14	-21	26	10	38	23	47
	I (mm)	8	17	-25	34	4	38	16	47
	D (mm)	-3	8	-2	10	-2	10	-3	12
Tomato	ETo (mm)	23	26	-42	48	12	67	43	87
	I (mm)	24	37	-37	49	15	69	44	88
	D (mm)	-2	9	1	7	0	9	-1	12
Olive	ETo (mm)	25	31	-72	82	16	115	53	139
	I (mm)	15	60	-42	72	16	105	39	120
	D (mm)	-4	10	3	24	4	21	4	22

- Large deviation when using T_{max} and T_{min} only and with Hargreaves equation
- Overestimation by Hargreaves equation
- Underestimation when air relative humidity was not considered

CONCLUSION

Conclusion

This initiative aimed to lead use of irrigation management tools in semi arid and arid region, bearing in mind that for many locations, as is the case for Tunisia, the meteorological variables are often incomplete and/or not available

Uncertainty that arises in the water balance terms i.e. crop evapotranspiration, irrigation requirement and drainage when site-specific climate data are missing is larger when Hargreaves equation is used to compute ETo compared to the case when the FAO Penman-Monteith approach is considered;

This approach may be an alternative until the price and maintenance costs of automatic weather stations become affordable in the socioeconomic context of arid and semiarid

WORDS OF THE END

Just for the history

This work is a collaboration between BGR, SEI-US and INAT conducted as part of the ACSAD / BGR Project: "Management, Protection and Sustainable Use of Groundwater and Soil Resources"

Thanks to the project team which has enabled us to live a very rewarding human and scientific experience with a single driving force "sharing"

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Thank You For Your Attention

www.mabia-agrosoftware.net 

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