UNIVERSITY OF TWENTE.

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PRECISION IRRIGATION TECHNOLOGIES

Effect of fertilizer strategies on the grey water footprint in rain-fed and irrigated agriculture

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PULA/SARDINIA/ITALY

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Introduction

- The water footprint is a comprehensive indicator of freshwater resources appropriation, showing water consumption volumes by source and polluted volumes by type of pollution. It composes the green, blue and grey components. (Hoekstra, 2011).

- Water footprint(WF) reduction is increasingly required in the face of increasing water scarcity and in the move to close supply-demand gap for fresh water.

Introduction

Understanding water resources use by source (rainwater, irrigation water from surface and groundwater, water from capillary rise) is vital for water resources management. Falkenmark and Rockström (2006) and Hoekstra et al. (2011).

Green/Blue WF

$$- \text{Green/Blue}\ \ WF_i = \frac{(ET_a)_i}{(Y_a)_i}$$

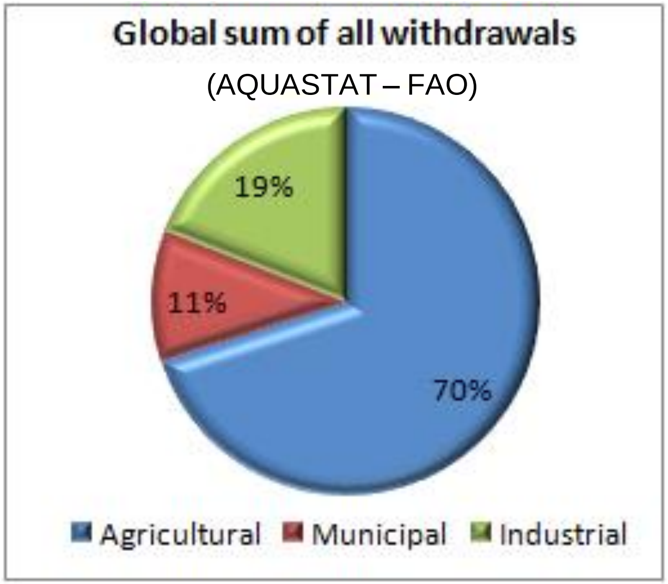
Grey WF for nonpoint source

$$- (WF_{grey})_i = \frac{(\alpha * AR_i)/(C_{max} - C_{nat})}{(Y_a)_i}$$

$$- \text{Total}\ \ WF_i = WF_{Green} + WF_{Blue} + WF_{Grey}$$

Introduction

- Agriculture contributes, 92% of the global fresh water footprint (Mekonnen, M.M. and Hoekstra, A.Y. (2011))
- Irrigation withdraws 70% of fresh water resources (Fischer et al., 2007).



- Plants use only 10 to 30% of the fresh water supply for biomass formation(Howell et al., 2001; Wallace, 2000)

Introduction

Water footprint of irrigated crop production can be reduced by – (1) increasing yield, and (2) minimizing losses (Hoekstra, 2013).

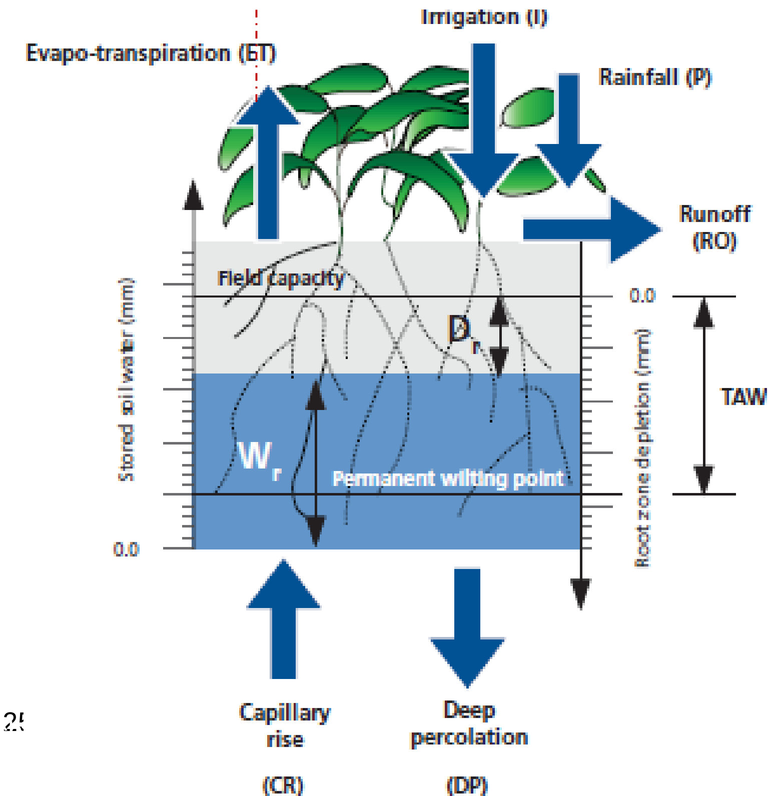
Scale:

Basin,

Farm,

Field

WF =f(managements)



Objective

to explore the scope for reducing the water footprints of growing crops by a systematic model based assessment of management practises at field and basin scale.

(1) to explored the potential for reducing the green-blue water footprints of growing crops (p1).

(2) to explore the effect of fertilizer strategies on the grey water footprint of growing crops (p2).

Data

- **Climate**

http://climexp.knmi.nl/selectdailyseries.cgi

- **Crop parameters**

(Potato, tomato and maize

FAO database and

local conditions

- **Soil**

http://eusoils.jrc.ec.europa.eu/ESDB

[and field data measurement]()

- **Groundwater**

Method (p1)

Management options

1. Four irrigation techniques: Furrow, Sprinkler, Drip and Subsurface drip (SSD);
2. Three irrigation strategies: full irrigation, deficit irrigation & supplementary irrigation; + rain-fed;
3. Three mulching practices: no mulching, organic & synthetic mulching.

Modelling

AquaCrop & WF accounting

Effects

Green and **Blue** WF of growing crops

Cases: Four environments, three types of years, three soils and three crops

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Environment (Location)	Soil	Type of years	Crops	Groundwater
Arid (Eilat , Israel)	Loam Sandy loam Silty-clay-loam	Dry Normal Wet	Maize, potato and tomato	Deep
Semi-arid (Badajoz, Spain)	Loam Sandy loam Silty-clay-loam	Dry Normal Wet	Maize, potato and tomato	Deep
Sub-humid (Bologna, Italy)	Loam Sandy loam Silty-clay-loam	Dry Normal Wet	Maize, potato and tomato	average 1.5 m
Humid (Eden, United Kingdom)	Loam Sandy loam Silty-clay-loam	Dry Normal Wet	Maize, potato and tomato	Deep

Method

Green and blue soil water separation

$$\frac{dS_g}{dt} = R - (Dr + ET)\left(\frac{S_g}{S}\right) - RO\left(\frac{R}{I+R}\right)$$

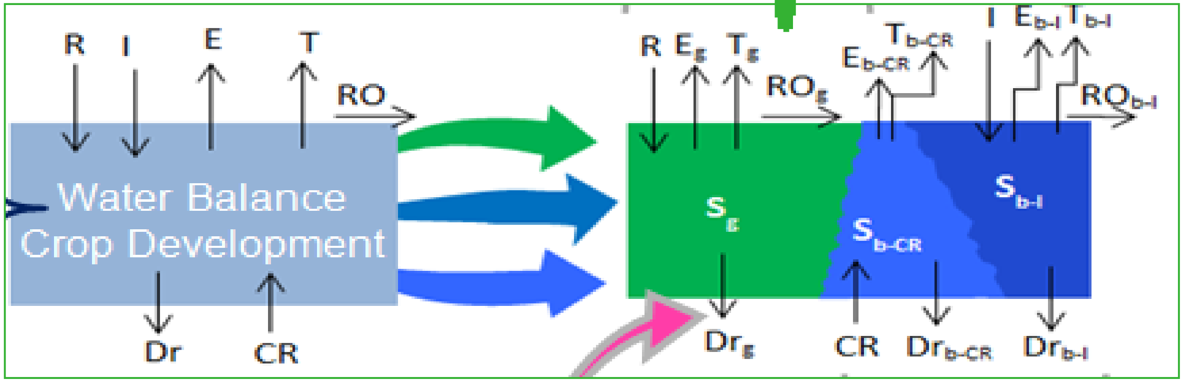
$$\frac{dS_{b\text{-}CR}}{dt} = CR - (Dr + ET)\left(\frac{S_{b\text{-}CR}}{S}\right)$$

$$\frac{dS_{b\text{-}I}}{dt} = I - (Dr + ET)\left(\frac{S_{b\text{-}I}}{S}\right) - RO\left(\frac{I}{I+R}\right)$$

$$WF_{b-I} = \sum_{i=1}^{n} \frac{(ET_{b-I})_i}{Y}$$

$$WF_{b-CR} = \sum_{i=1}^{n} \frac{(ET_{b-CR})_i}{Y}$$

$$WF_g = \sum_{i=1}^{n} \frac{(ET_g)_i}{Y}$$



(Results (p1): green – blue soil water separation

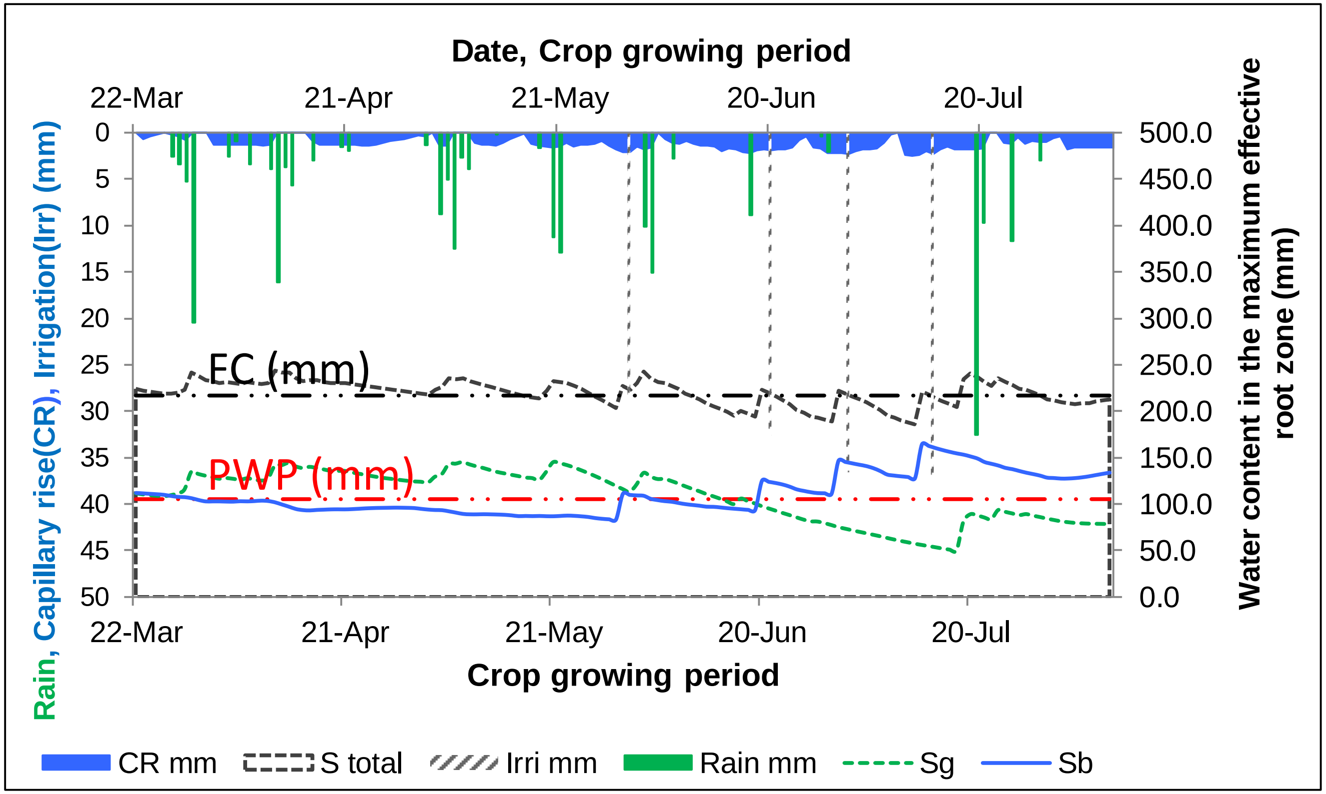


Figure : The green (Sg) and the blue (Sb) soil water stocks/storages at Bologna, Semi-humid environment, for average year/2001/

(Results (p1): Effect of the management options on ET, Y and WF

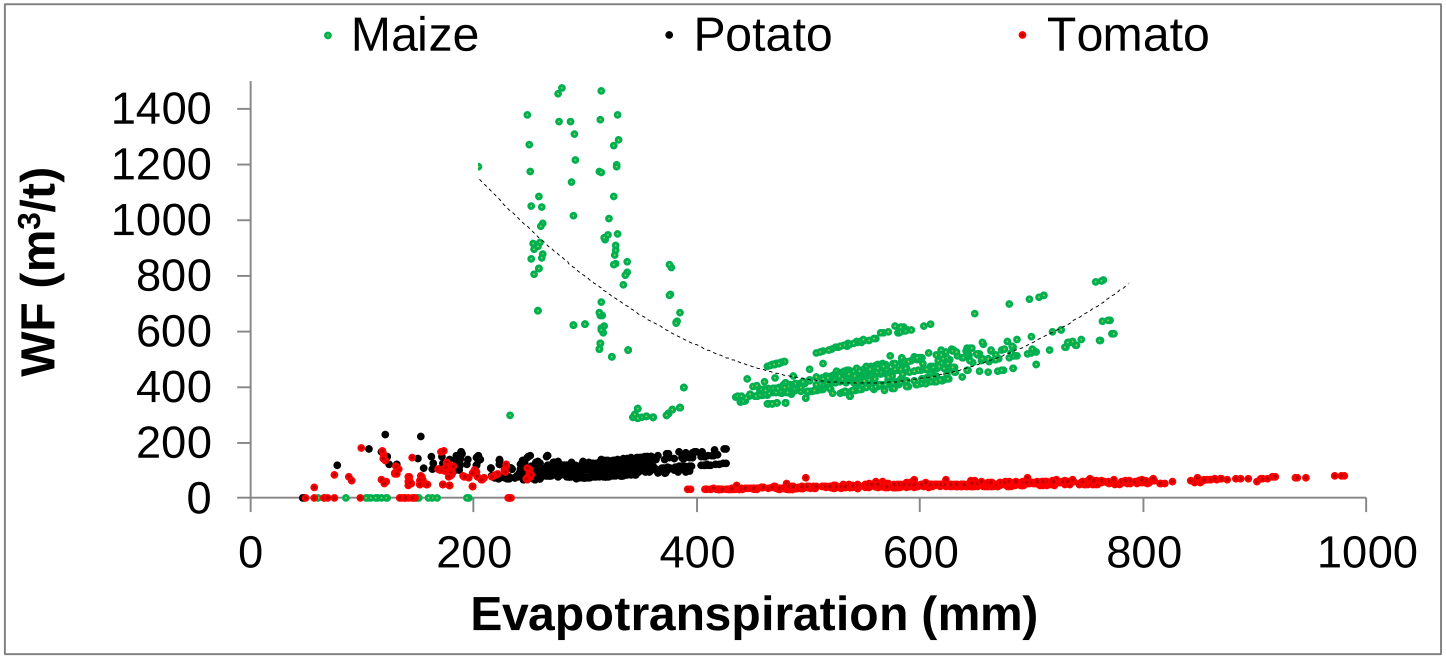


Figure: Effects on WF from the whole experiment

Results (p1): Effect of the management options on ET, Y and WF

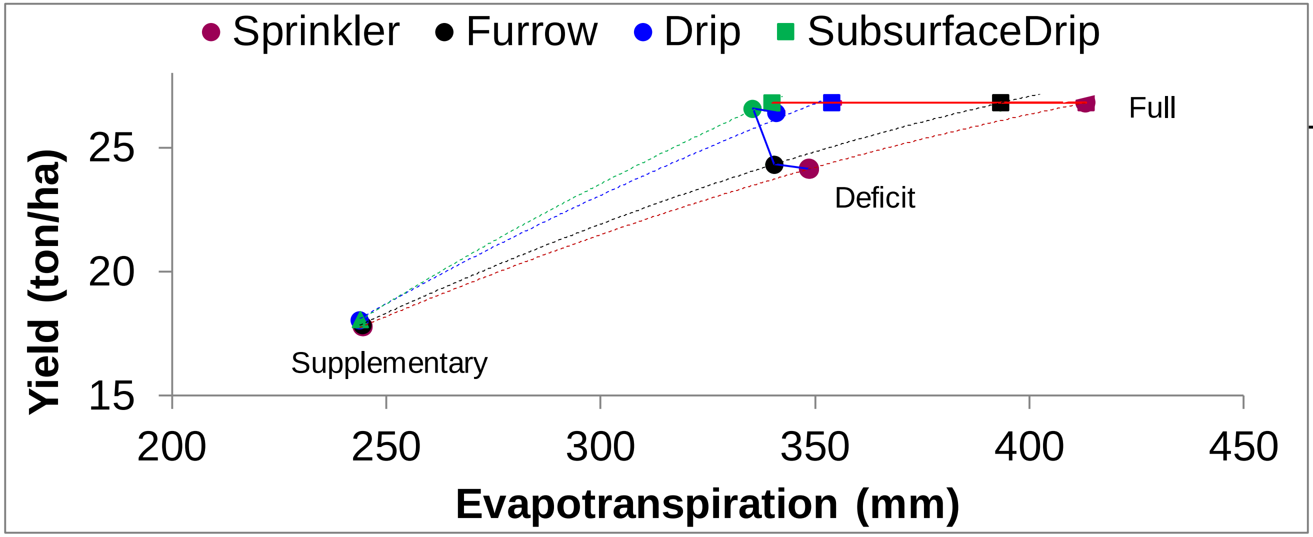


Figure: ET-Y relationship for irrigation techniques with no mulching practice.

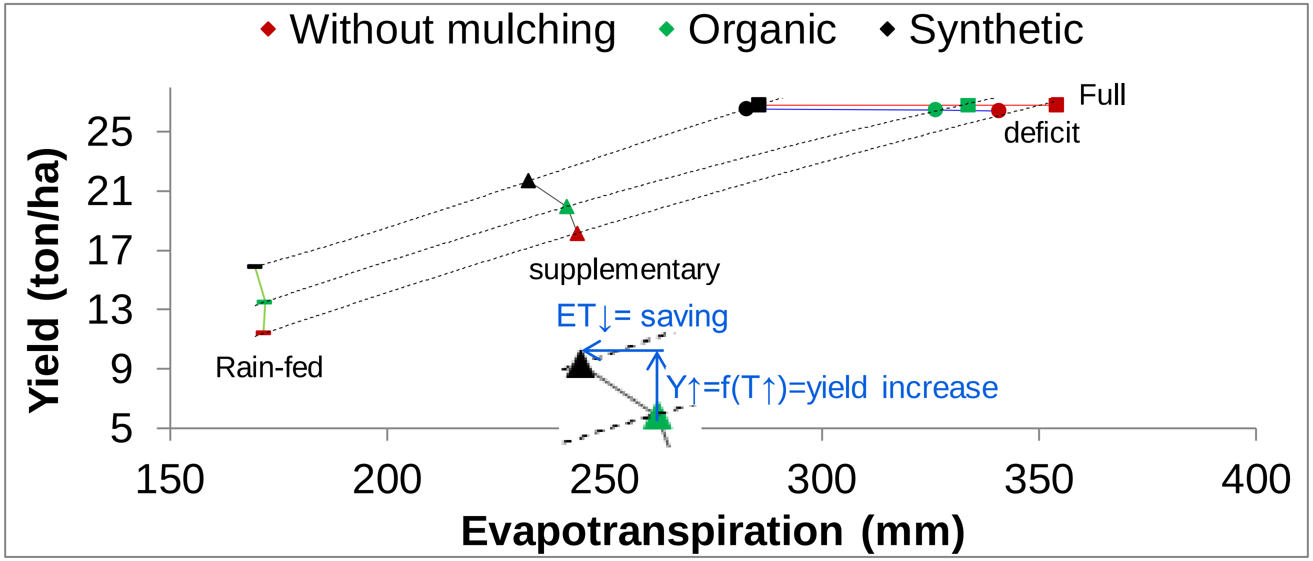
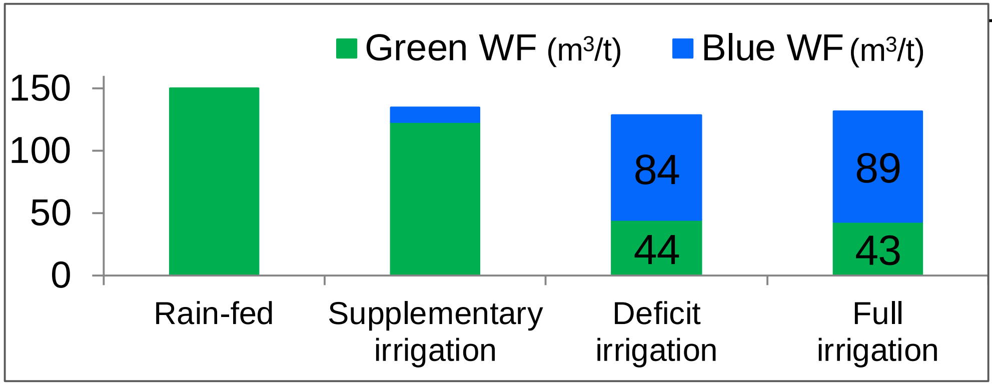
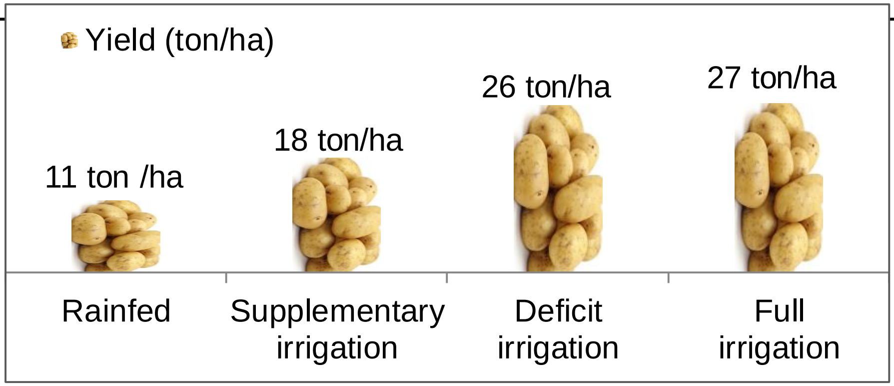


Figure: ET-Y plot for mulching practices at rain-fed and drip irrigated field.

Case: potato, loam soil, normal year, Semi-arid environment (Badajoz – Spain).

Results (p1) Effect of the management options on ET, Y and WF





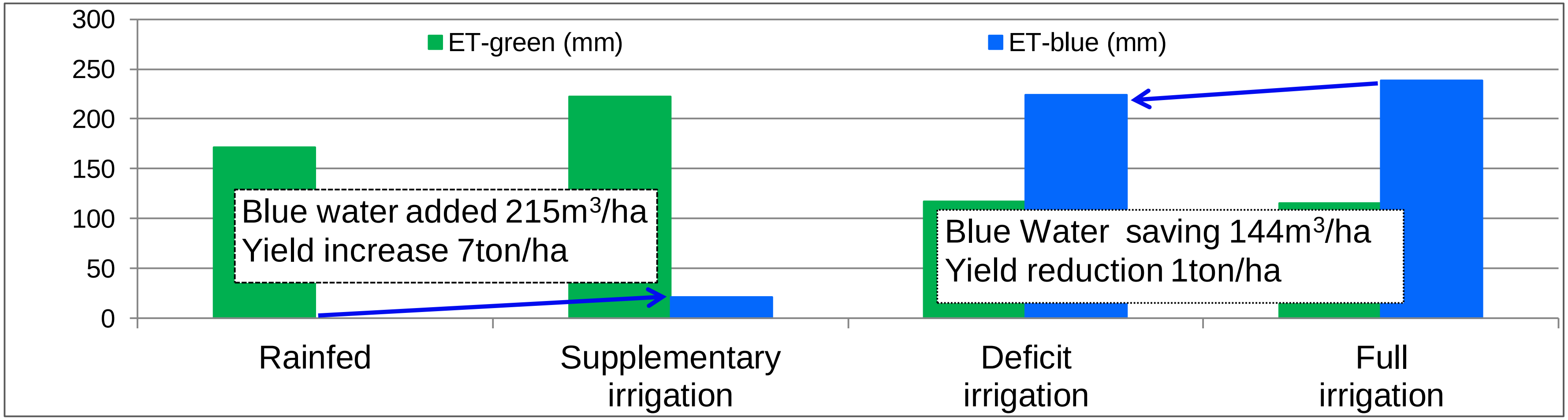


Figure: Effects of the irrigation strategies with drip on Yield, green and blue WF.

Case: potato, loam soil, normal year, Semi-arid environment i.e. Badajoz – Spain.

Results (p1): Reduction in the total WF

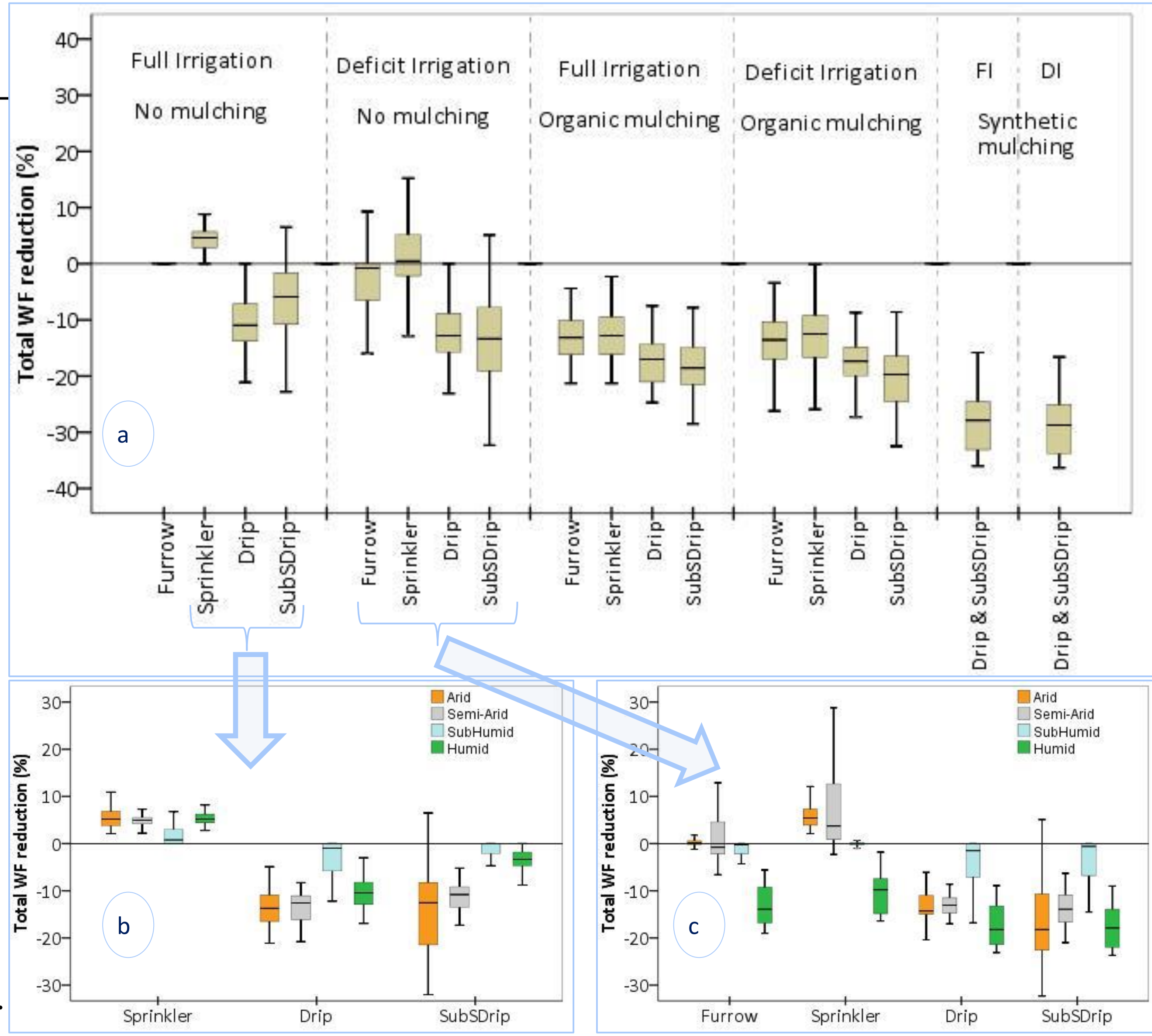
Reference (furrow irrigation with full irrigation and without mulching practice)

The box and whisker plot shows the WF-reduction values for the whole cases:

(a) whole management practices;

(b) four irrigation techniques, with FI and NoML; and

(a) four irrigation techniques, with DI and NoML.



Results (p1): Reduction in the total WF

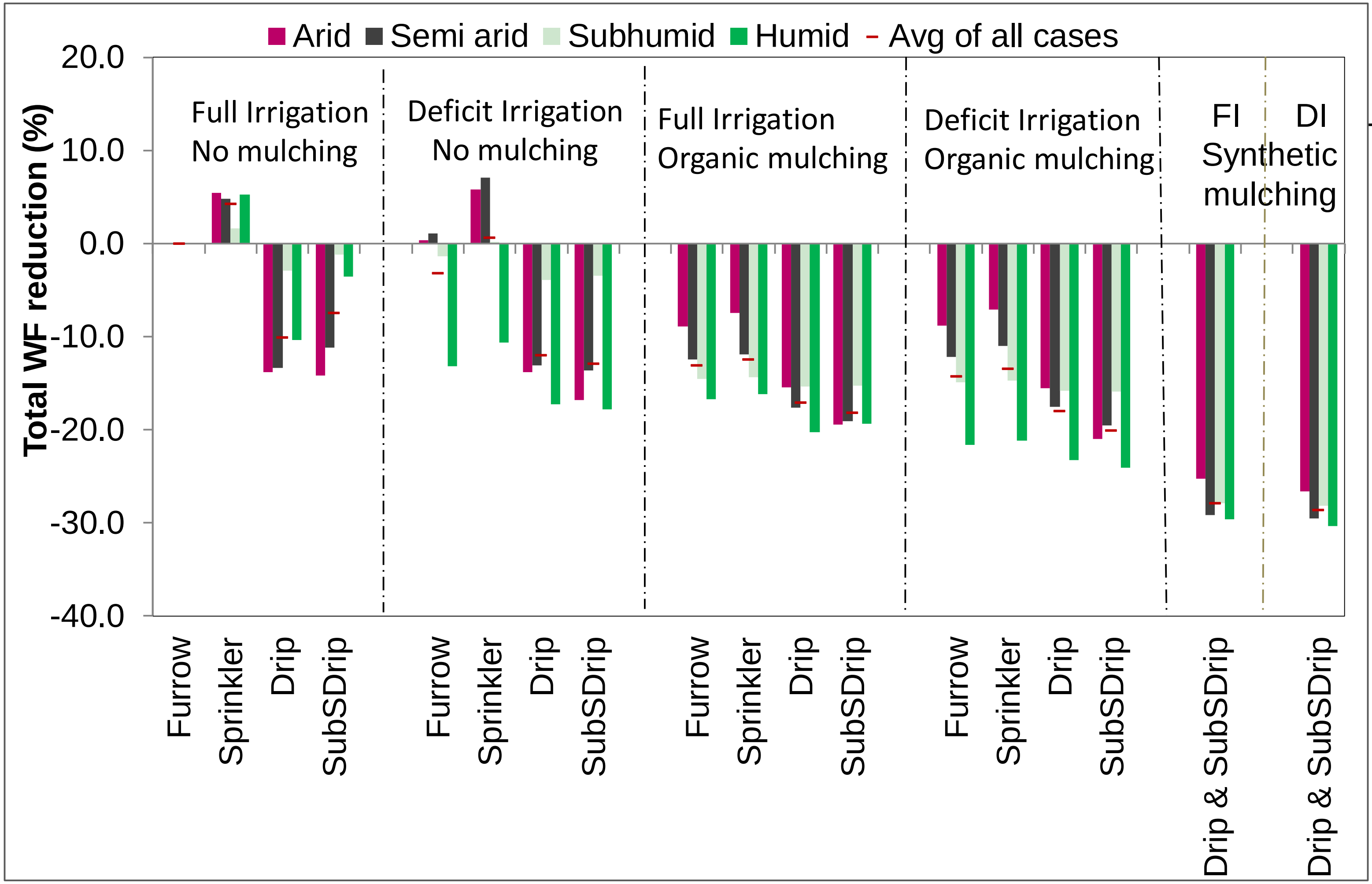


Figure: The mean total WF reduction categorized by the environments for the whole cases

Results (p1): Reduction in the green-blue WF

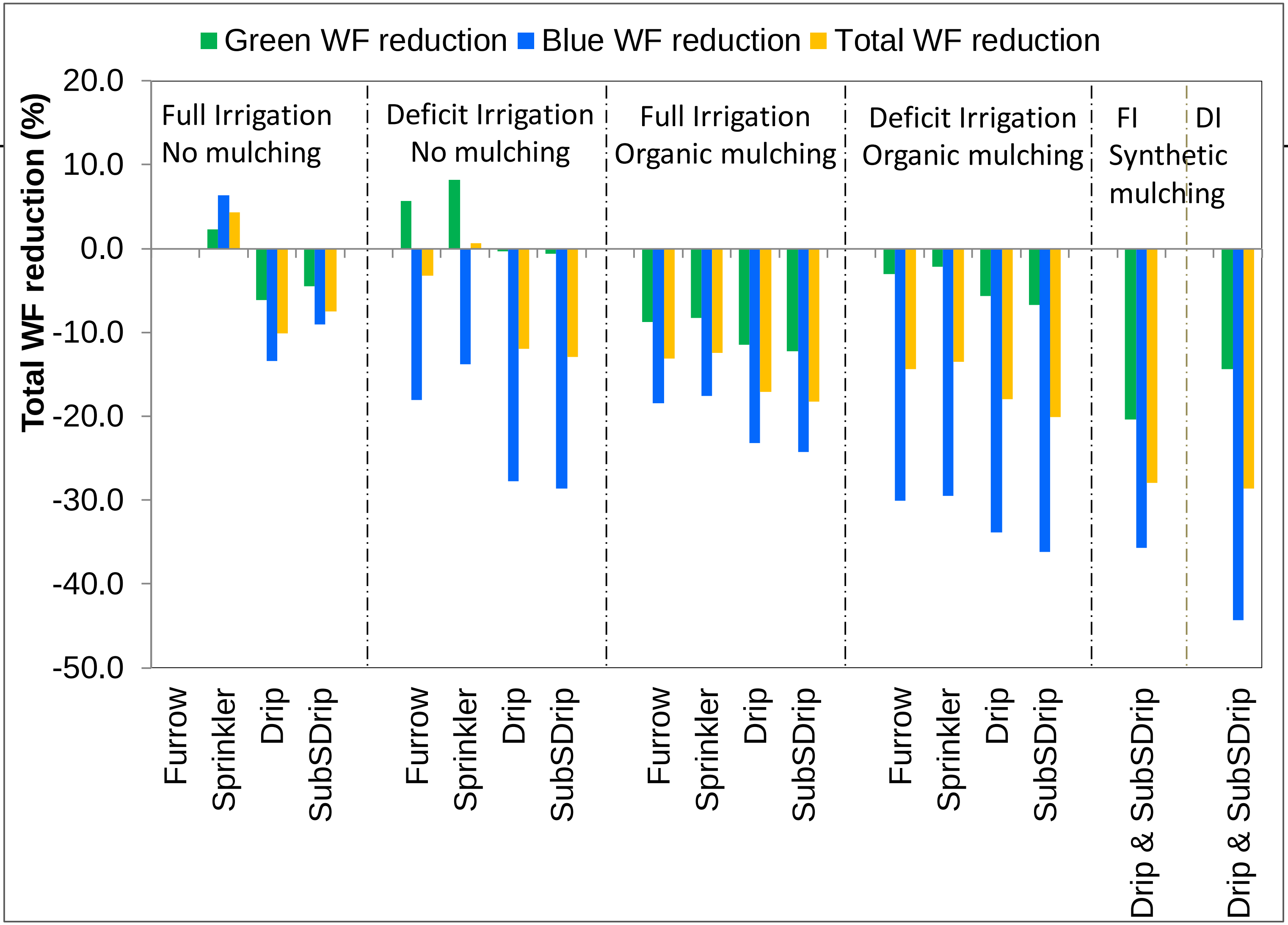


Figure: The mean green, blue and total WF reduction; for the whole cases

Conclusions

- The average reduction in the consumptive WF is: 8-10% if we change from the reference to drip or SSD; 13% when changing to OML; 17-18% when moving to drip or SSD in combination with OML; and 28% for drip or SSD in combination with SML.
- Reduction in overall consumptive WF always goes together with an increasing ratio of green to blue WF.
- The WF of growing a crop for a particular environment is smallest under DI, followed by FI, SI and rain-fed.

Conclusions

- Growing crops with sprinkler irrigation has the largest consumptive WF, followed by furrow, drip and SSD.

- Furrow irrigation has a smaller consumptive WF compared with sprinkler, even though the classical measure of ‘irrigation efficiency’ for furrow is lower.

Grey water footprint component

Simulating the effect of fertilizer strategies on the grey water footprint of growing crops (p2).

Method (p2)

Management practices	Modelling	Effects
1. Moisture supply strategies: irrigated (full irrigation) and rain-fed; 2. Fertilizer strategies: types: mineral and organic fertilizer Quantity: without, existing,	Apex & Global WF accounting standard	Grey WF of growing crops

Cases: Semi-arid environment, three types of years, three soils and potato crop

Method (p2)

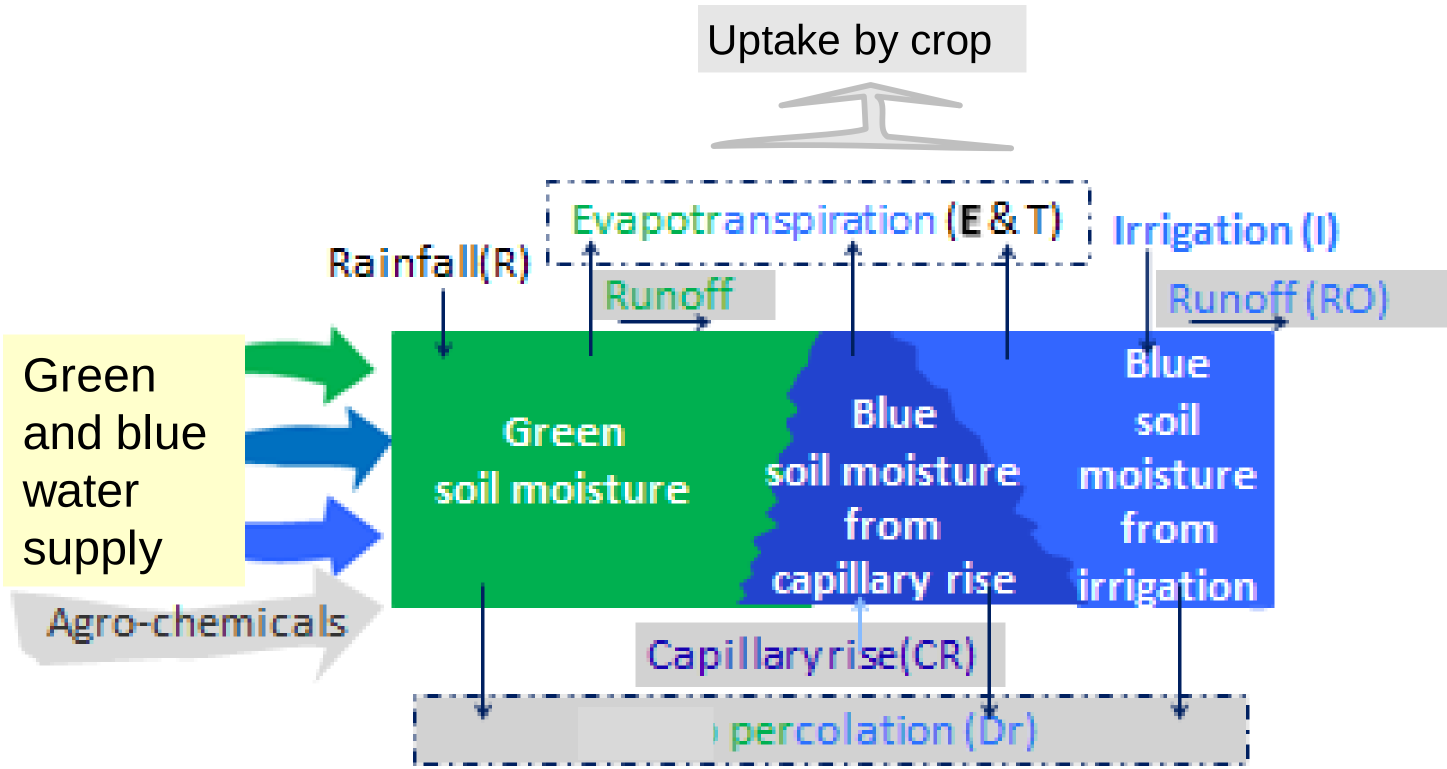


Figure: soil water nutrient balance

Thank You