Impact of deficit irrigation strategies on water use and productivity for vegetable crops in a semi-arid context of Tunisia

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Overview

- Irrigation in Tunisia
- Water deficit context
- Deficit irrigation
- Objectives
- Methodology
- Results
- Conclusion & Recommendation

Irrigation in Tunisia

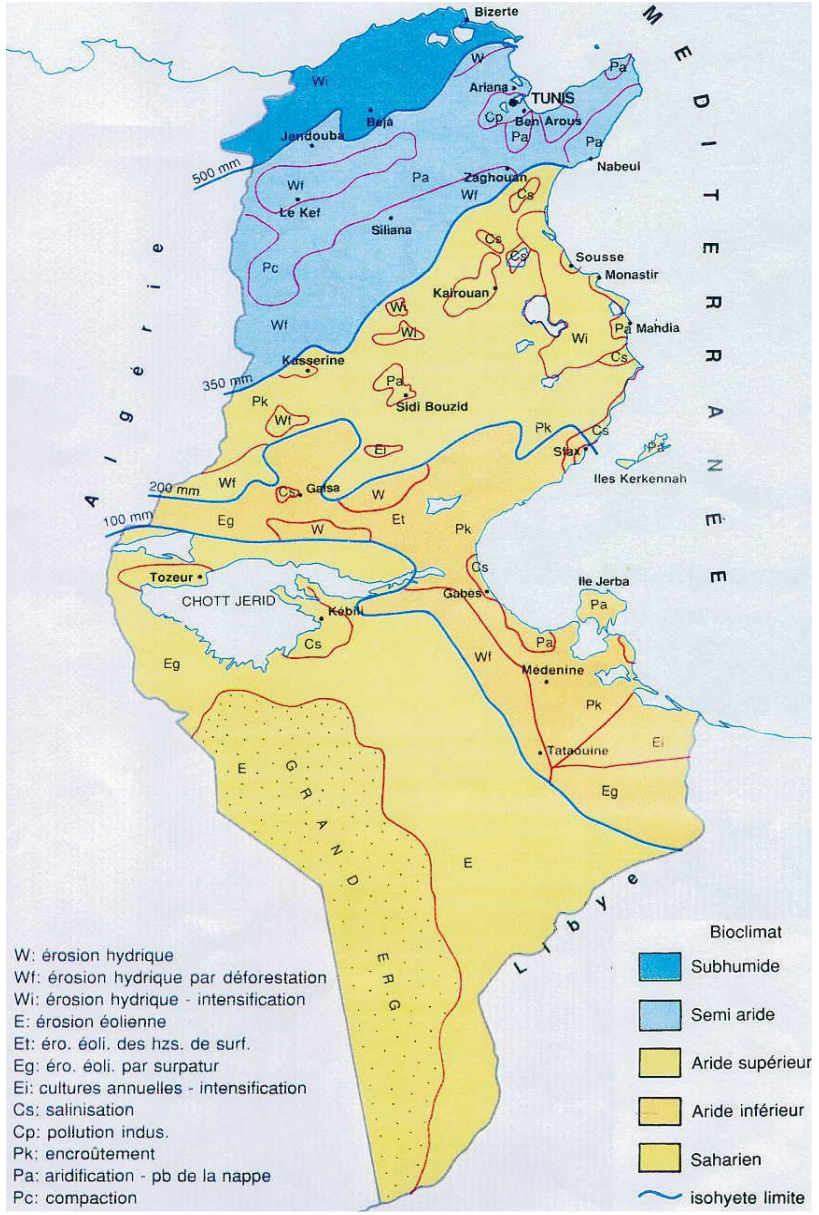
Climate:

- Mediterranean in the north and Saharan in the south
- Irregular rainfall pattern over time and space
  - north: 500-1000 mm/year
  - center: 200-400 mm/year
  - south: less then 100 mm/year

Water resources

- Limited and subject to quality deterioration due to overexploitation and pollution
- Surface water: 2,7 km^3 ; Underground water: 2,1 km^3
- 440 m^3/capita/year in 2018

359 m^3/capita/year by 2030



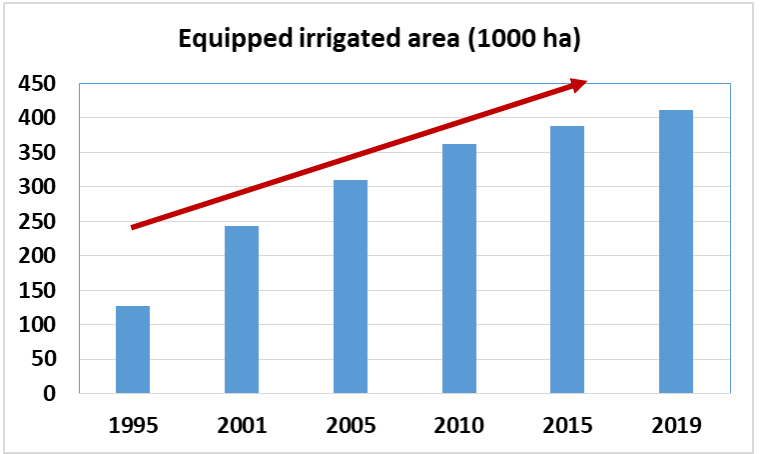
Irrigation in Tunisia

- Irrigated area of 450 000 ha (intensive)

✓ 8% of the arable land
✓ 36 % of total agriculture production

✓ 27% of the workforce
✓ 90% of vegetable production

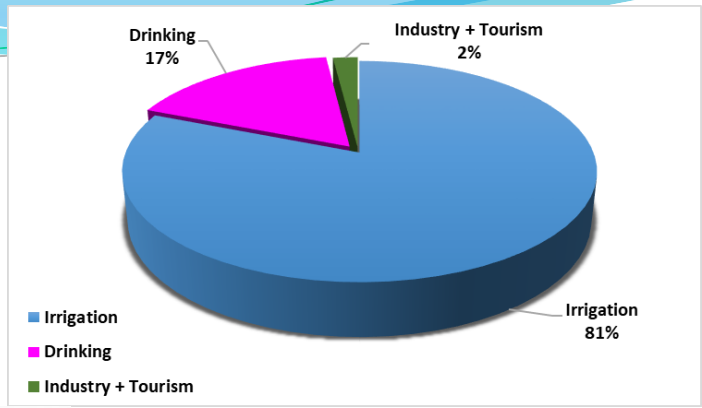
- Mobilization of water resources
- National program for water conservation



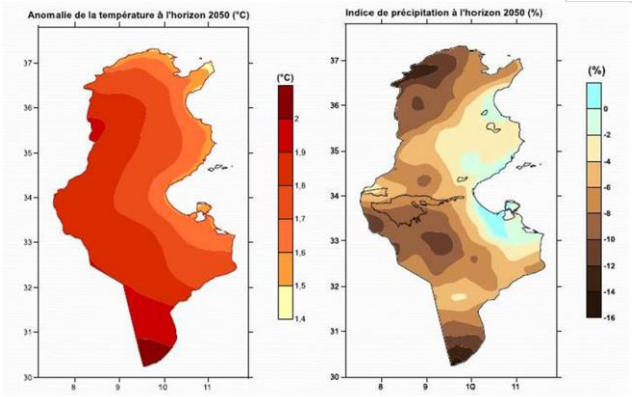
- Water saving technologies and proper irrigation management options are required to guarantee the quality production and to ensure sustainability

Water deficit context

- The increasing pressure of different sectors on water resources augurs a water stress, which should evolve crescendo.



- Climate projections in Tunisia for 2050:
  - a decrease of 2% to 16% for rainfall
  - an increase of 1.4 to 2.1°C



- Droughts events shall increase and could have a serious effect on crop yields
- To cope with water scarcity, Tunisian irrigation managers have even adopted severe restriction measures for water supply.
- **e.g.**in 2017 irrigation volumes were reduced by 20 to 30% of the crop water requirement.

Deficit irrigation

- Deficit irrigation (DI) = application of water below the crop ET requirements

- Water demand for irrigation can be reduced and the water saved can be diverted for alternative use

- To cope with water scarcity, adoption of DI stands as an important tool to reduce water use and potentially improve water productivity (WP)

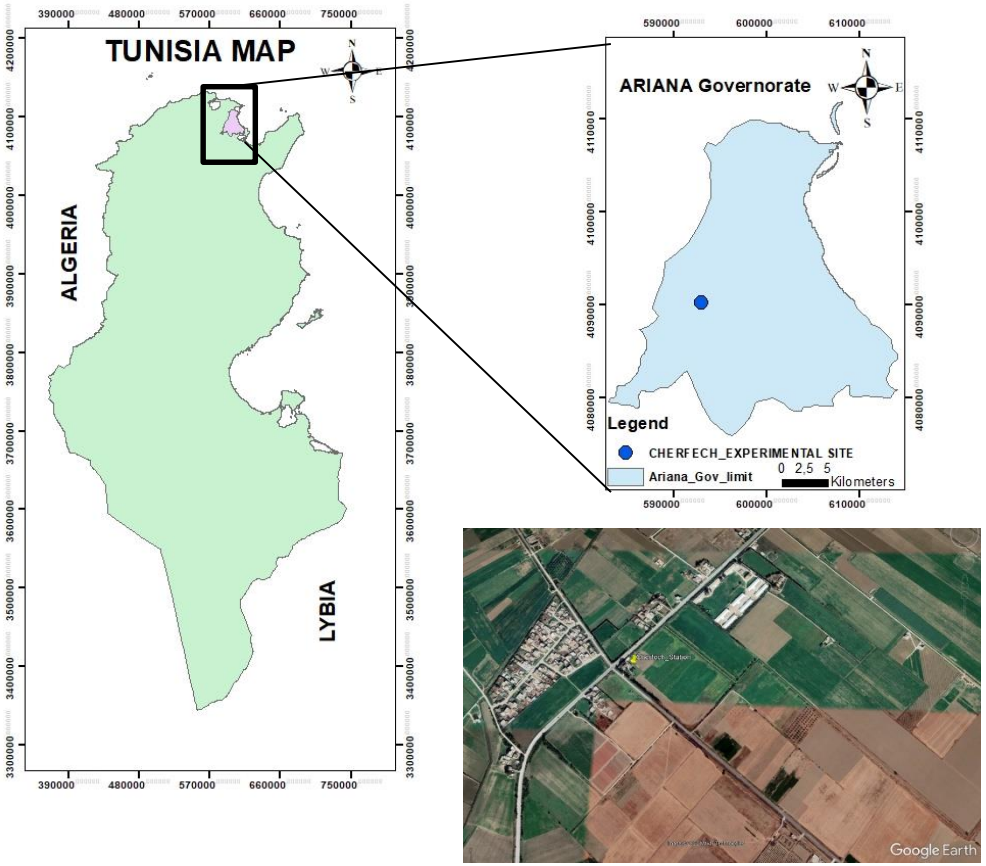
- Increase in WP and saving of water resources are becoming of strategic importance in the arid and semi-arid conditions of Tunisia

Objectives

- Assess the effect of deficit irrigation on crop water requirements, yield and water productivity under different water demand conditions.
- Identify appropriate deficit irrigation strategies that allow water conservation with acceptable impact on yields and thus ensuring sustainability of irrigation systems

Methodology

1. Study area



- Climate: Semi-arid Mediterranean
- Average yearly precipitation (P): 443 mm
- Average yearly reference evapotranspiration (ET_0) Penman-Montheith: 1105 mm
- Water deficit ($P-ET_0$) : from March to October (8 months) with a peak in July.
- Soil texture : silty clay loam
- Total available water (TAW): 160 mm/m
- Average electrical conductivity EC_e of the irrigation water: 2.6 dS m^{-1}.

Methodology

2. Crop water-yield simulations:

Irrigation simulations were performed for **potato** and **tomato** crops in **2016** and **2017** using **CROPWAT FAO model**

3. Deficit irrigation strategies

- Selected by adopting soil moisture depletion levels inducing water stress and yield reduction
- Evaluation of DI strategies : $\left(1-\frac{Y_a}{Y_m}\right)=K_y\left(1-\frac{ET_a}{ET_m}\right)$

ET_a/ET_m (%): relative ET, $ET_m = Kc \times ET_0$, where Kc: crop coefficient

RYL (%) = $(1-Y_a/Y_m)$: relative yield loss, Y_a : actual yield (kg/ha), Y_m: maximum Yield

4. Water productivity (Kg/m³)

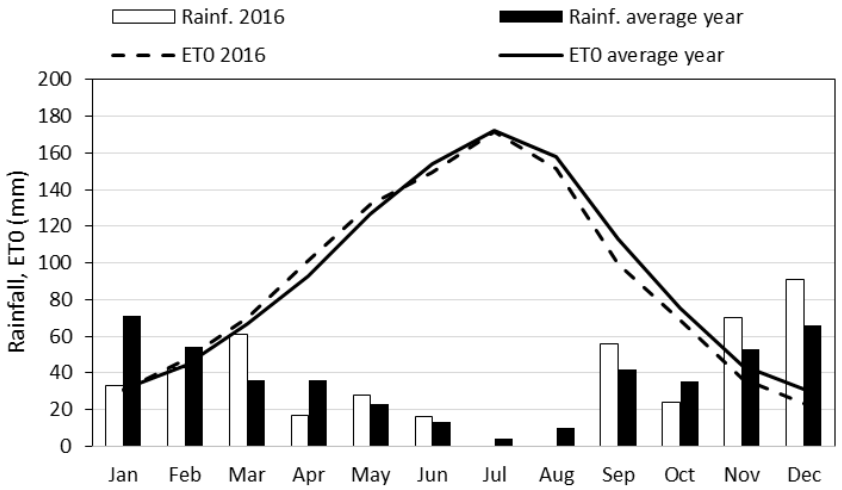
$WP = \frac{Y_a}{IWU}$, IWU: gross irrigation (m^3/ha).

5. Economic water productivity (DT/m³): $EWP = \frac{Monetary\ value\ of\ Y_a}{IWU}$

Results

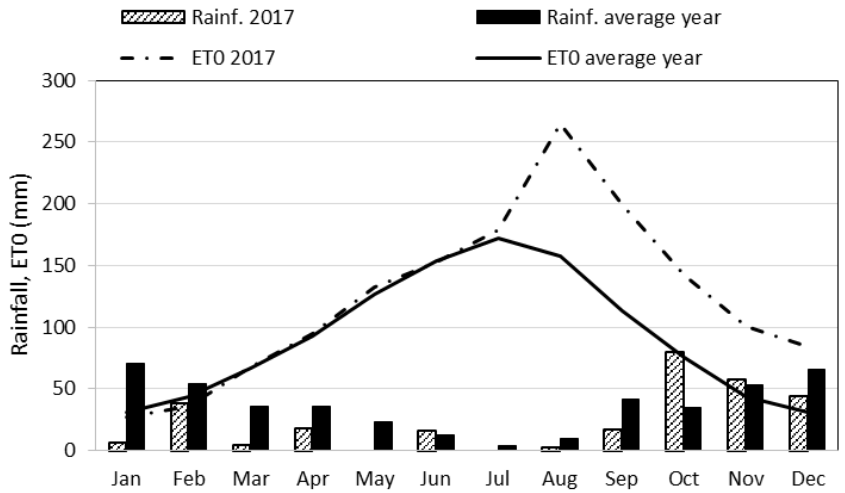
Climate analysis

2016: P = 439 mm, ET0 = 1083 mm



Average year (time serie of 30 years) :
P = 443 mm, ET0 = 1105 mm

2017: P = 283 mm, ET0 = 1481 mm



Season rainfall

- For 2016, rainfall was very close to the average year for potato growing season (Feb - Jun) and relatively deficient (shortage ≈ 30 %) for tomato growing season (Apr – Aug)
- For 2017: rainfall deficit of 60% for both potato and tomato

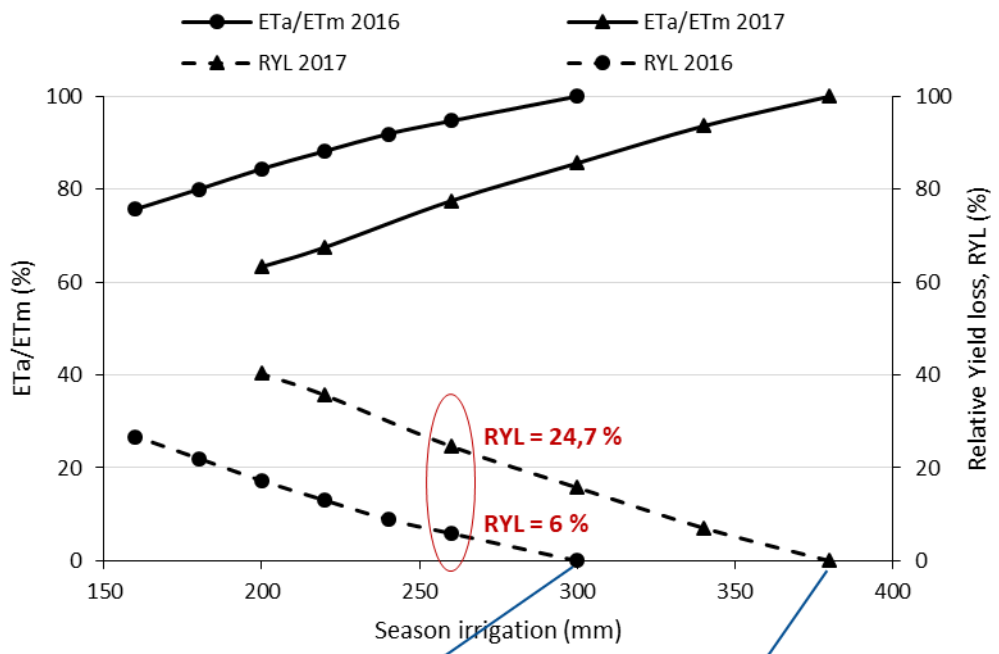
Evaporative demand (ET0)

- Average water demand for 2016
- Very high water demand for 2017

Results

Crop response to deficit irrigation strategies

Potato crop



Average demand (2016): Irrig.= 300 mm, Ya = Ym

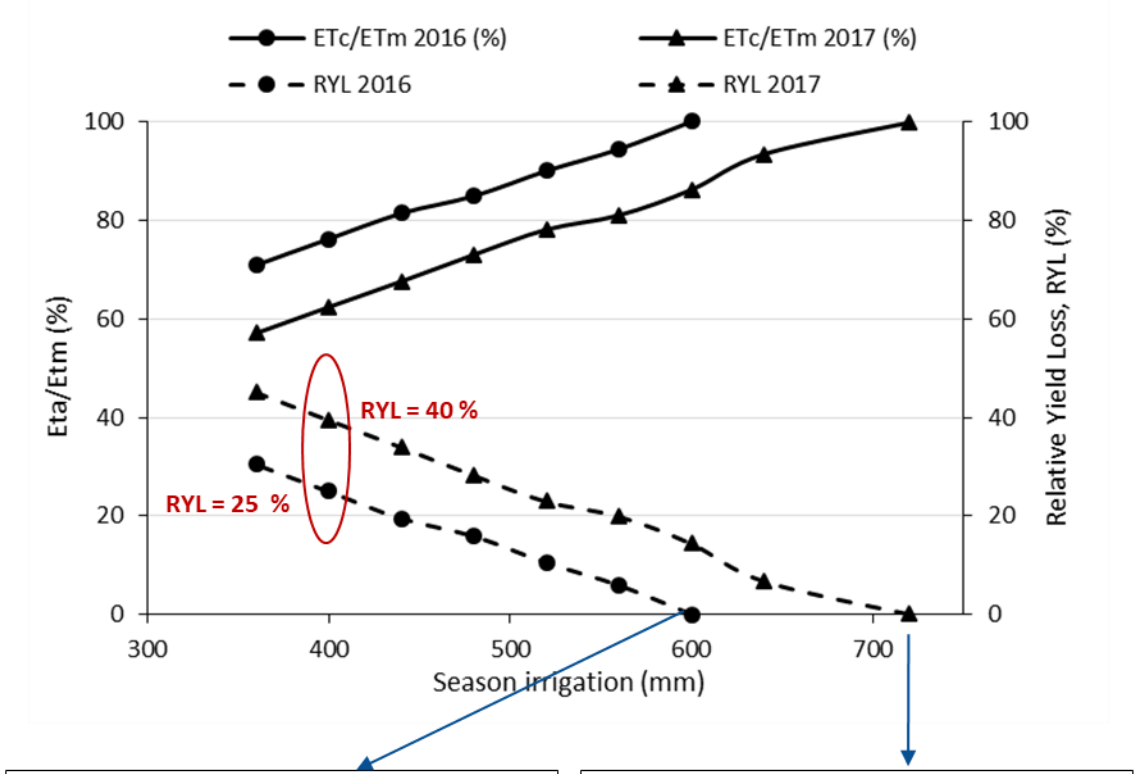
Very high demand (2017): Irrig.= 380 mm, Ya = Ym

- For average water demand, small irrigation reduction (300 to 260 mm) induces a RYL of 6%, easily acceptable by farmers.
- Under very high demand, 260 mm would generate a much higher RYL (24.7%).
- Adoption of DI is more practical for average water demand of 2016.
- For very high water demand of 2017, only low to moderate water shortage are tolerated.

Results

Crop response to deficit irrigation strategies

Tomato crop



Average demand (2016): Irrig.= 600 mm, Ya = Ym

Very high demand (2017): Irrig.= 720 mm, Ya = Ym

- Under average demand of 2016, decreasing season irrigation from 600 to 400 mm generates a RLY of 25 %.
- Under very high demand of 2017, applying 400 mm would result in a RYL of 40 %
- Adoption of DI is more difficult particularly under water scarcity conditions

Results

Crop response to deficit irrigation strategies

- The difference in crop response to DI can be explained mainly by the season rainfall.

Potato crop

- Under average water demand, precipitation beneficially reduces irrigation compared to very high water demand.
- When water is limited, adoption of DI with acceptable RYL (<25 %) will be more feasible under average demand than under very high conditions.

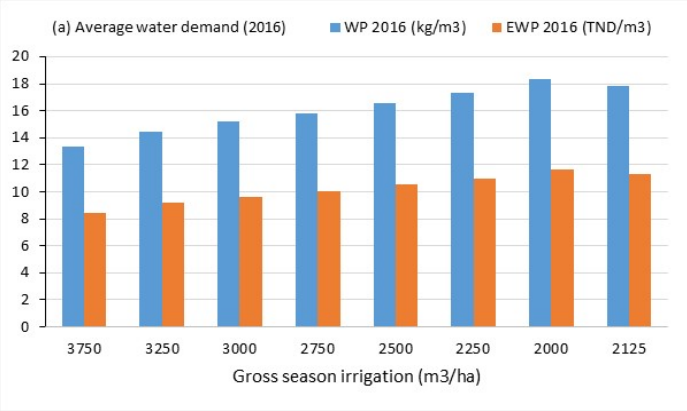
Tomato crop

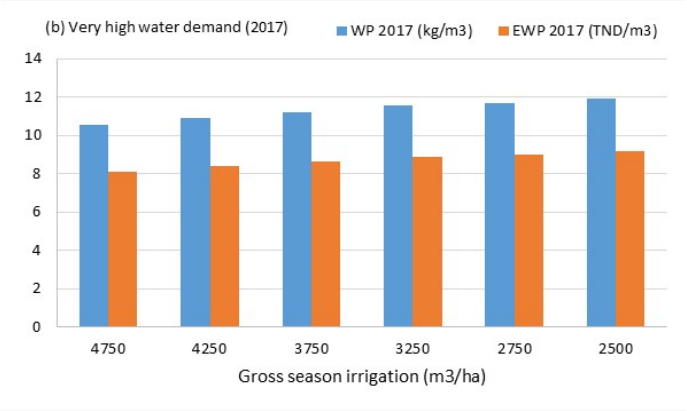
- Rainfall faintly contributes to crop ET of tomato (summer crop).
- For both average and very high demands, irrigation decrease generates a reduction in crop ET and crop yield making more difficult adoption of DI

Results

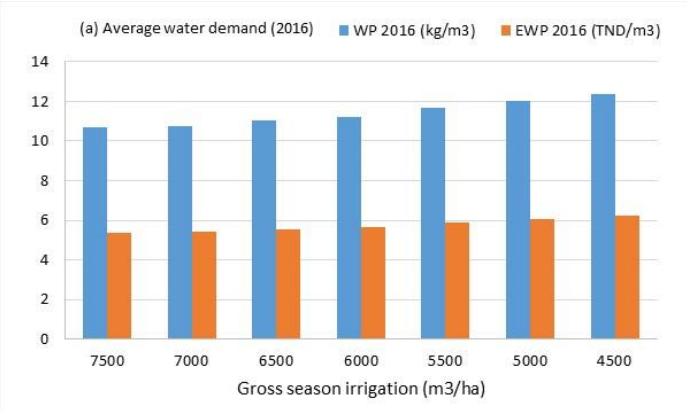
Water productivity (WP)

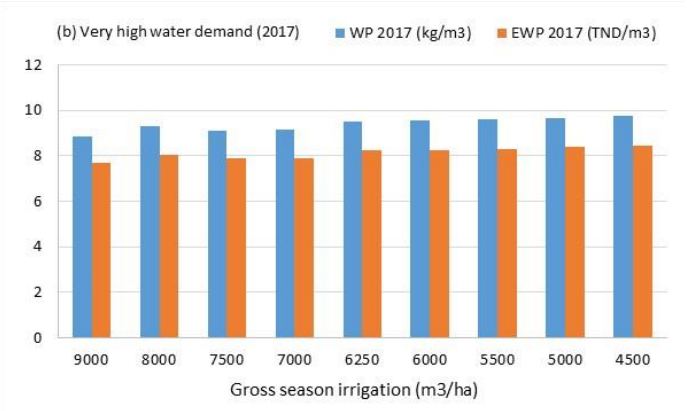
Potato crop





Tomato crop





- Water savings due to DI improves WP under average water demand more than very high demand
- WP improvement was more noticeable for potato (+30% with-150 mm) than tomato (+12,5 % with -250 mm)
- EWP is dependent on the crop market price
- e.g. For tomato, with a RYL = 25%, although WP decreased by 20.7% from average to very high water demand, EWP have even increased by 35.8% due to substantial increase in tomato prices

Conclusion and Recommendations

- Results indicate that potato and tomato crops differently react to deficit irrigation strategies for the climatic conditions of the study area.

- Although the deficit irrigation strategies has been demonstrated as an appropriate water management choice under average water demand, the socioeconomic implications need to be more assessed under different climatic and water availability conditions.

- Additional research on coupling the crop model with an economic optimization model needs to be explored in order to evaluate the impact of deficit irrigation on the farmer’s income

Credits and Acknowledgements

- **Co-authors:**
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Thanks for your attention