Agriculture in Southern Mediterranean areas under climate change: Impacts on irrigated wheat grain yield and irrigation requirements

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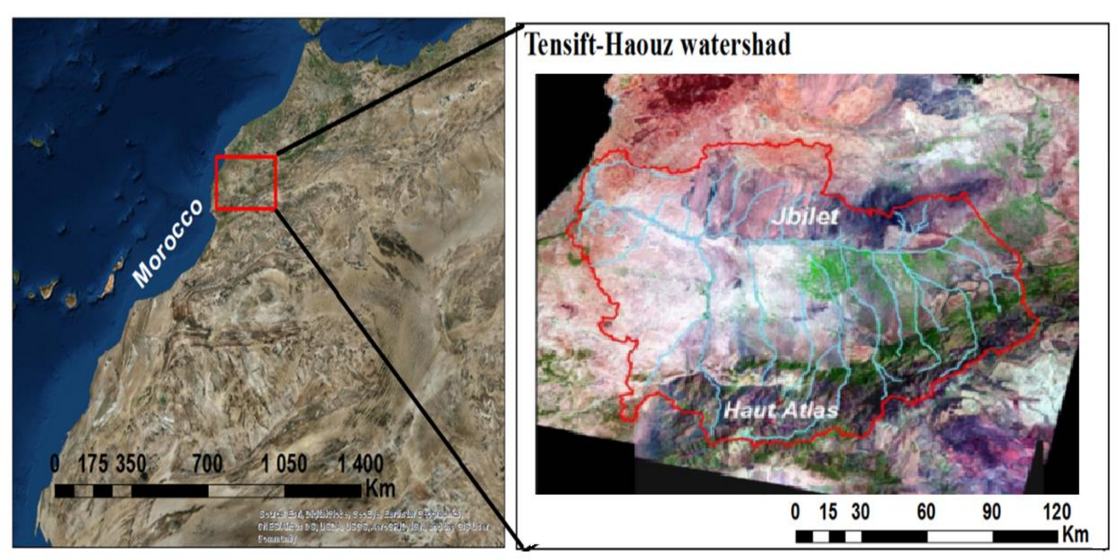
Introduction

The southern Mediterranean regions will face drastic climate changes. Agricultural yields, particularly cereals, could be severely affected, especially if significant changes affect the key phenological stages. In addition, while agriculture is expected to meet around 83% of food demand by 2050 in North Africa, the increase in agricultural water needs due to the intensification of practices, the extension of arable land and the expected warming could jeopardize the water supply of other key economical sectors. This work aims to quantify the impact of climate change on cereal grain yields and water needs in the Tensift-Haouz region of Morocco. The Med-CORDEX ensemble runs under scenarios RCP4.5 and RCP8.5 have first been evaluated and disaggregated using the quantile-quantile approach. The impact of climate change on the duration of the main wheat phenological stages based on the degree day approach is then analysed considering three typical sowing dates (early around November, 15th; intermediate around December 15th and late around January, 15th). The AquaCrop model is used to analyse the impact of climate change (rising in atmospheric CO_2 , temperature and decrease in precipitations) on grain yields and water needs, according to the same sowing dates .

Materials and methods

Study site

The Tensift-Haouz region is located in the center of Morocco. Its climate is semi-arid with about 250 mm of annual rainfall and an evaporative demand that reaches 1600 mm/year. The common wheat is the main crops of the region and it is cultivated both rainfed and irrigated depending on access to water supply and climate conditions. Potential yields is estimated to be around 8t/ha but real yields are usually lower, in particular for rainfed wheat that hardly exceed 1.5t/ha. Cereals are usually sown between November 1st and Janaurry 1st and are harvested by the end of May.



AquaCrop model description

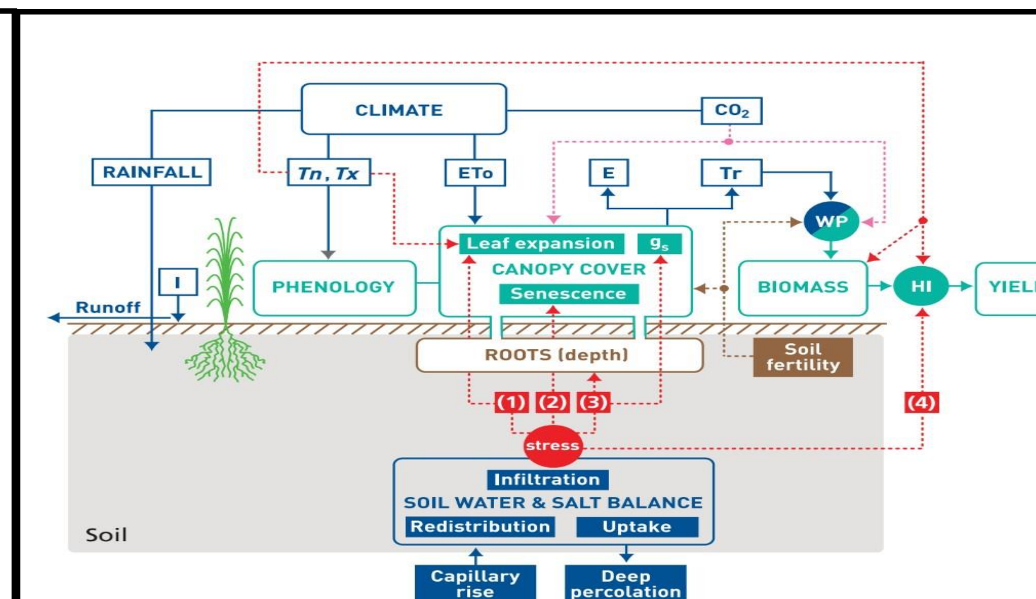
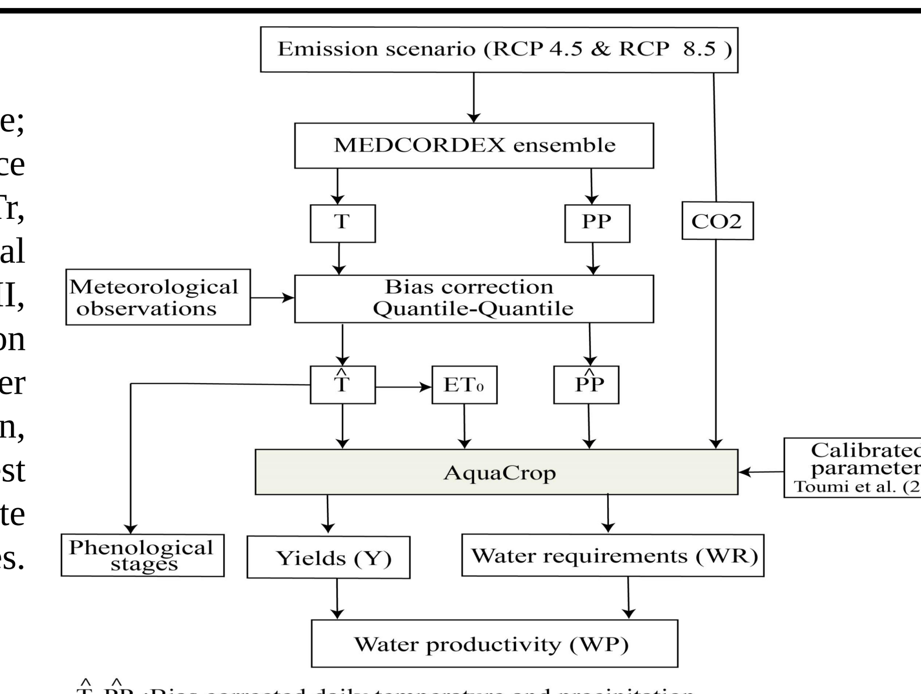


Chart of *AquaCrop* indicating the main components of the soil–plant–atmosphere, continuum and the parameters driving phenology, canopy cover, transpiration, biomass production, and final yield

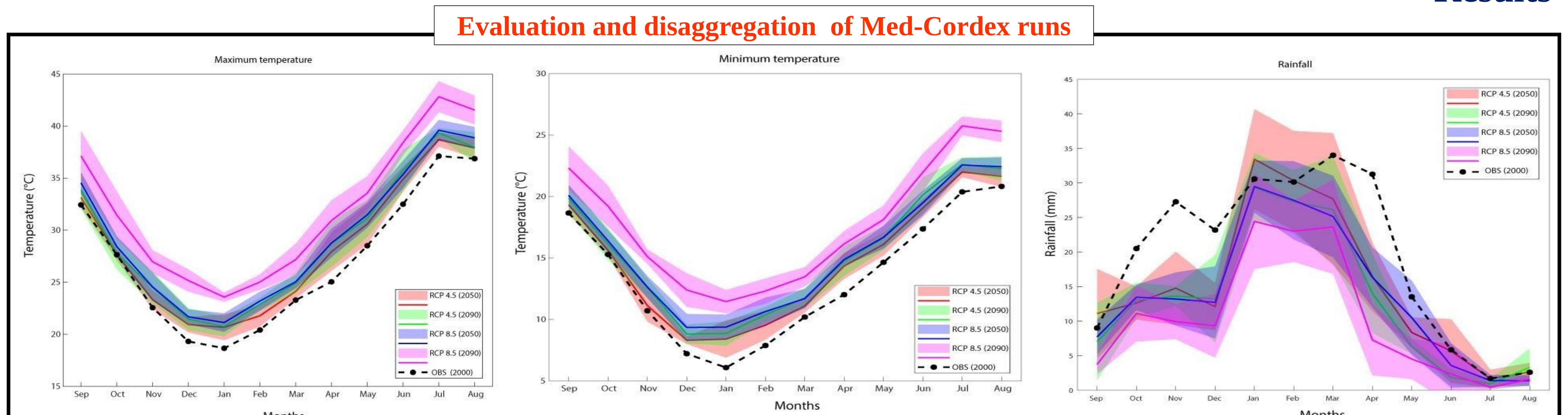
[I, irrigation; Tn, minimum air temperature; Tx, maximum air temperature; ETo, reference evapotranspiration; E, soil evaporation; Tr, canopy transpiration; gs, stomatal conductance; WP, water productivity; HI, harvest index; CO2, atmospheric carbon dioxide concentration; (1), (2), (3), (4), water stress response functions for leaf expansion, senescence, stomatal conductance and harvest index, respectively]. Continuous lines indicate direct links between variables and processes. Dashed lines indicate feedbacks.



Methodological flowchart of this study

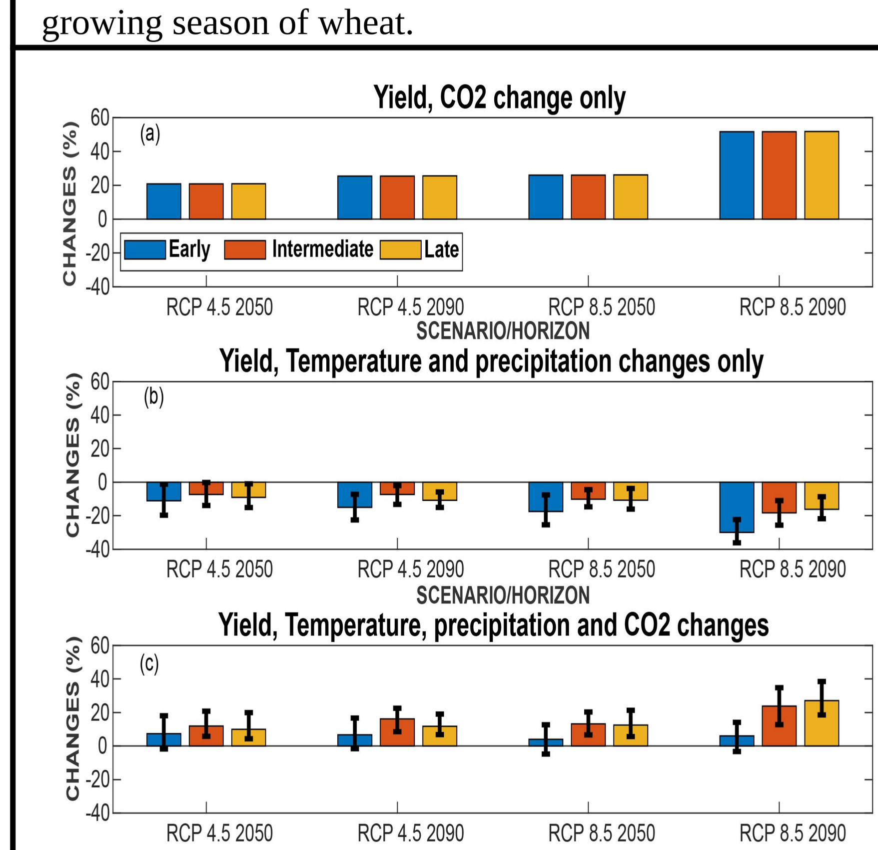
Results

Evaluation and disaggregation of Med-Cordex runs



The med-cordex scenarios have been disaggregated using the quantile-quantile approach and the observations from the synoptic station of Marrakech. The figure shows the monthly change for temperature (left) et precipitation (right) between future scenarios (RCP 4.5 and RCP 8.5 in the middle and end of the century and the historical period. Both maximum and minimum temperature are considered. An increase of up to 3° is observed, in particular during the growing season of wheat.

Impact on grain yields



(a): Relative change in yield for CO2 only scenario.

in 2050 yield increase by 21 to 26% for RCP4.5 and RCP8.5 when $[CO_2]$ reach to 487 and 534 ppm

in 2090 when $[CO_2]$ reach to 845 ppm for RCP 8.5 yield are expected to increase by 52%

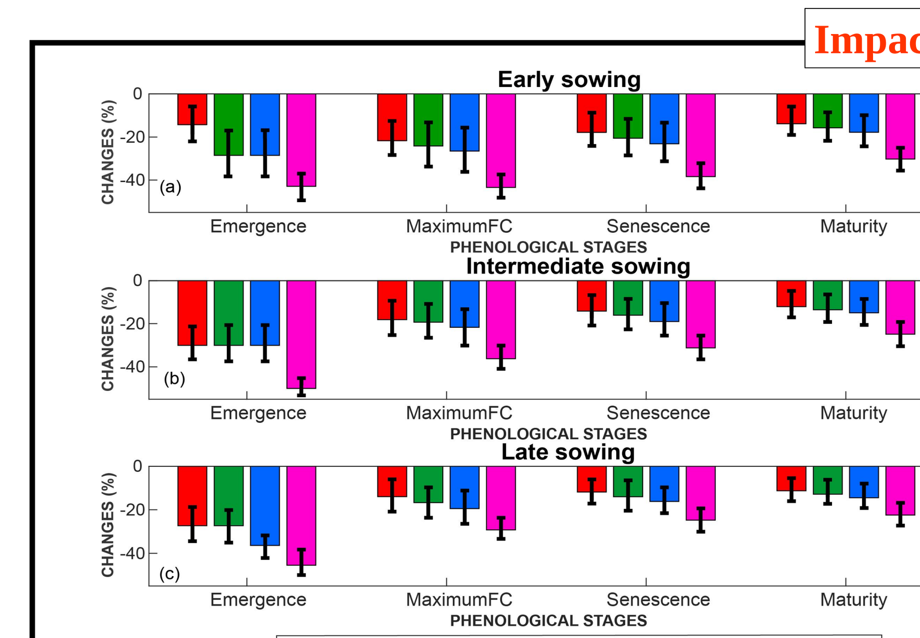
(b): Relative change in yield for climate change only scenario.

When change in temperature and rainfall the optimal yield tends to decrease for all sowing date and all RCP scenarios and horizon.

(c) : Relative change in yield for CO2 + climate change scenario.

With increase in temperature and atmospheric $[CO_2]$ due to CC, yields will increase for all RCPs scenarios and horizon. elevated $[CO_2]$ ameliorate negative effects of above-optimal temperatures.

Impact on the phenological stage durations



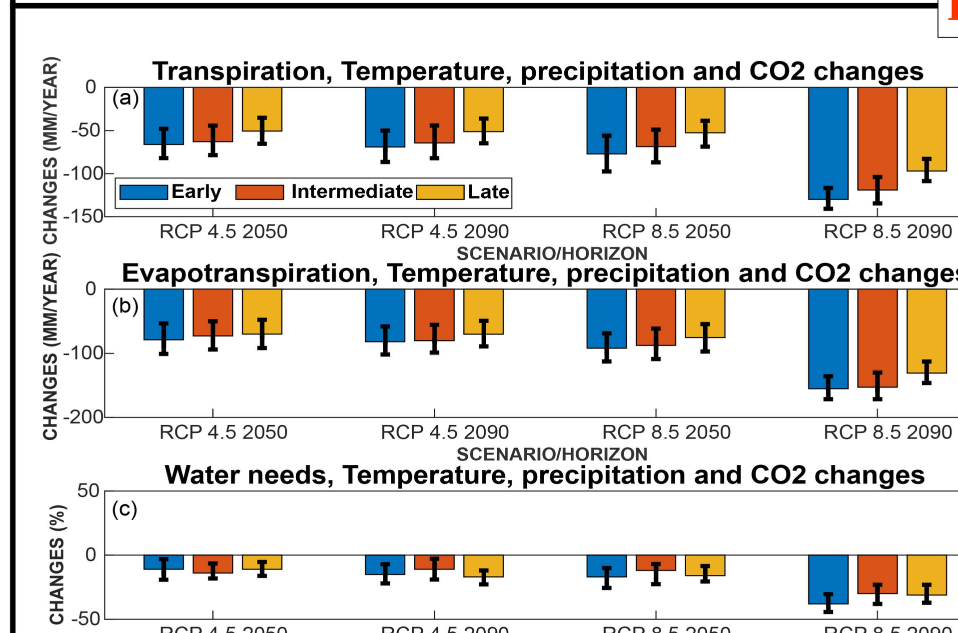
Reduction in the durations of the phenological stages of wheat (in %) for different climatic scenarios and for the three sowing dates

	Emergence	Maximum canopy Cover	Start of senescence	Maturity
Early sowing	7 days	83 days	112 days	152 days
Intermediate sowing	9 days	83 days	106 days	141 days
Late sowing	11 days	72 days	93 days	125 days

Actual durations of phenological stages for all sowing date (2000)

For scenario RCP 4.5 mid-century the shortening reach 11 , 11, 10%.(early, intermediate, late). For scenario RCP 8.5 end of century the shortening reach 32, 28, 26%.(48,40,32 days). On average, the results showed that the rise in air temperature causes a shortening of the development cycle up to 50 days (around 30%) and that this decrease is stronger when wheat is sown early.

Impact on water needs and water productivity



Relative change net irrigation requirement.

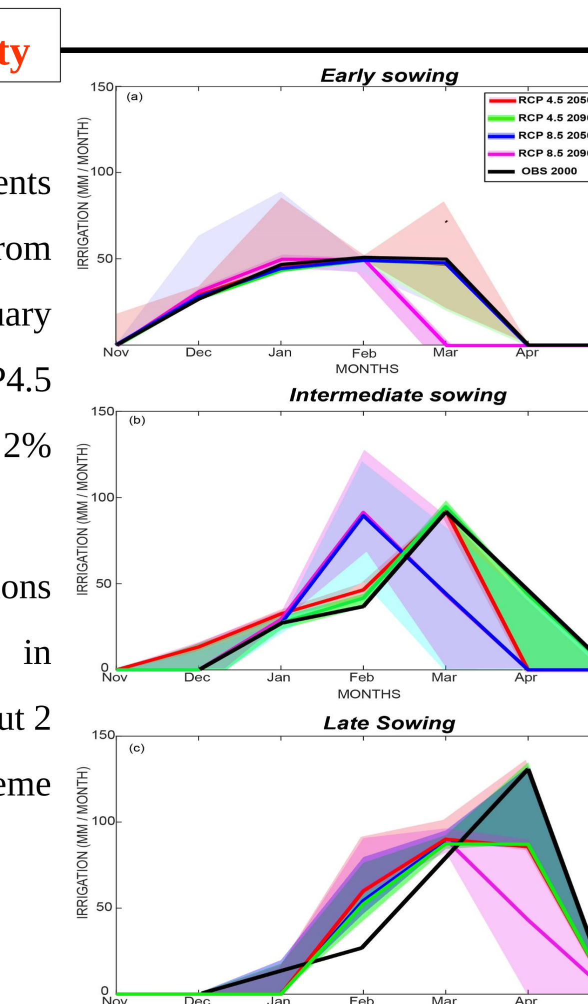
for actual NIR are 171, 244 and 259 according to early, intermediate and late sowing respectively. NIR was simulated for CO2 and climate change scenarios.

Relative change in transpiration .

the relative change of transpiration under CO2 and climate change scenarios.

For early sowing, current irrigation requirements (IRs) are about 160 mm distributed from December to March with a maximum in February (48 mm). In 2050 according to the RCP4.5 scenario, IR requirements should increase by 2% to 164 mm, again with a peak in February.

For late and intermediate sowing, the projections of IR follow the same decreasing trend in irrigation. The shift in peak requirement is about 2 months for late sowing in the more extreme scenario and for the later horizon.



Conclusion

This study provides some details on the impact of climate change on agricultural production in the southern Mediterranean area that not very positive considering the food security of the countries in this region. It leaves also some open issues that are to be analyzed among which: (1) the ability of a simple model such as Aquacrop to accurately simulate the fertilizing effect of CO2 on the plant physiological processes; (2) the potential effects of nutrients that could become a limiting factor for wheat growth and production.