Climate change and durum wheat crop projections in the Capitanata (Apulia, southern Italy)

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Abstract

This study investigates the effect of anthropogenic emissions on the future durum wheat production and phenological cycle. Durum wheat is a fundamental crop for the Apulia agricultural sector and it may be sensibly affected by decreasing precipitation or increasing temperature and evaporation, having important consequences on regional economy. The study focuses on the Foggia area by analyzing the climate conditions for three 30-years periods in autumn, winter and spring. A first part, based on COSMOMed simulations for the medium RCP4.5 and the high RCP8.5 emission scenarios, examines how mean seasonal minimum and maximum temperature and cumulated precipitation will change in the future. Results highlight very substantial minimum and maximum temperature increases. They, further, show that reduction of precipitation is mostly not significant for the medium emission scenario, but significant particularly for spring in the high emission scenario. In the second part, daily meteorological values produced by COSMOMed are used in the CropSyst crop model to estimate future crop productivity and phenology. Results show that negative effects of future warmer temperature and lower precipitation are overcompensated by the carbon dioxide fertilization effect, leading to an increase of yield and biomass production. This outcome needs to be validated in further analyses using other climate and crop models

Data and Methods

Because of the complex morphology, Regional Circulation Models are required to investigate the spatial details of climate change and compute its impacts. This study considers the Capitanata area, which is among the most important areas in Italy for the durum wheat crop production.

Scenarios: RCP4.5, RCP8.5

Periods: 1961-1990 (baseline), 2021-2050 (near-term), 2071-2100 (long-term)

Seasons: autumn (SON), winter (DJF), spring (MAM)

COSMOMed

(regional coupled atmosphere-ocean model)

0.11deg spatial resolution

3-hourly values of:

precipitation, temperature, relative humidity, downwelling SW radiation, wind speed

Assuming an orographically homogeneous area

Climate change analysis

- Mean seasonal minimum temperature [°C]
- Mean seasonal maximum temperature [°C]
- Mean seasonal cumulated precipitation [mm/season]

CropSyst v.4.0.5.5

(multi-year, multi-crop, daily timestep crop growth simulation model)

Settings

Atmospheric CO_2	constant rate (ppm/year)*
Evapotranspiration	from Penman-Monteith formula
Water dynamic	cascading approach
Organic matter	microbial, stable organic matter and residue with carbon decomposition

SOIL and CROP MANAGEMENT

Date	Tillage operations
90 days b.p.	primary Moldboard plow
60 days b.p.	secondary Disc harrow
1 day b.p.	secondary Rotary tiles
0 days b.p.	Planting Aerial seeding
	Nitrogen fertilization
10 days b.p.	Urea
90 days a.e.	Ammonium nitrate
	Residue management
10 days a.p.m.	70% stubble 30% surface residue

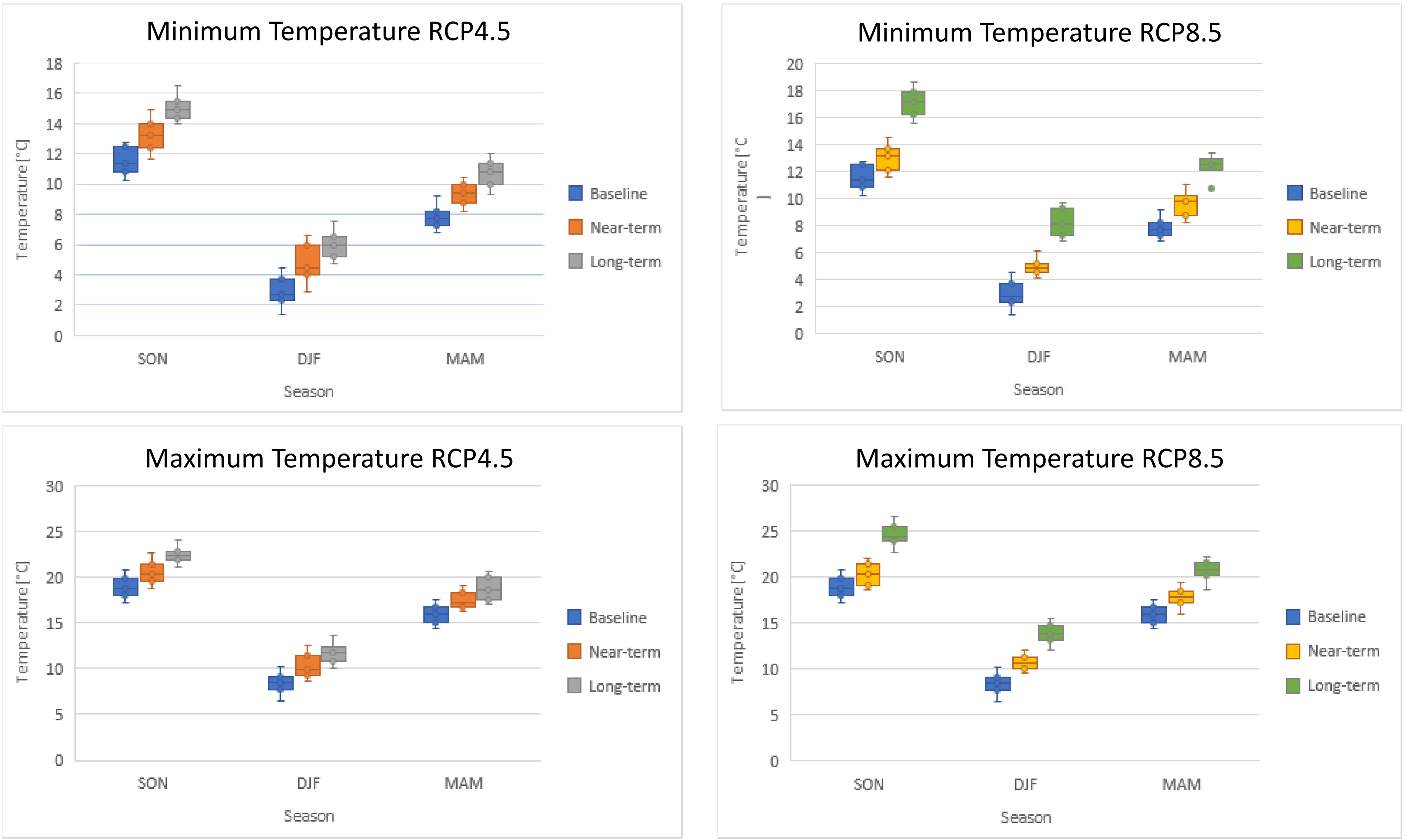
**A constant rate is calculated from the initial and final CO_2 concentration values of every simulation (Meinshausen, M. et al., "The RCP Greenhouse Gas Concentrations and their Extension from 1765 to 2300.", Climatic Change (Special Issue), 2011)*

Impacts of anthropogenic emissions on climate and wheat

Negative effects of temperature increase and precipitation decrease will be overcompensated by the CO_2 concentration increase (fertilisation effect) with a better efficiency in water use and an increase in crop yield

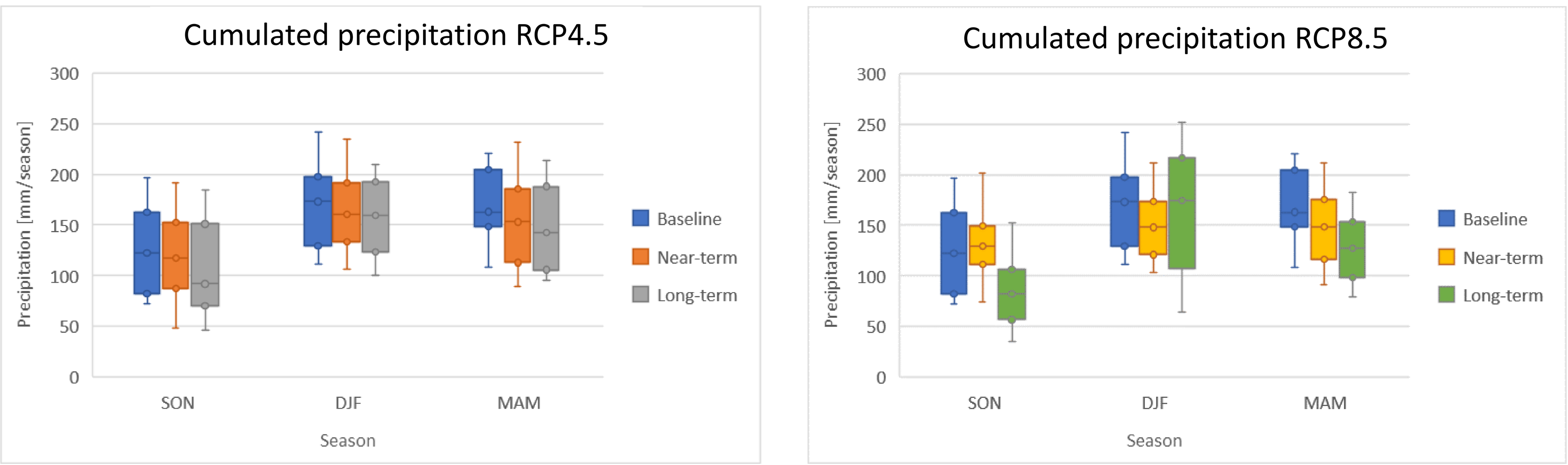
Climate change

Large increase of **minimum** and **maximum temperature**



Upper panels show mean seasonal minimum temperature in °C for autumn (SON), winter (DJF) and spring (MAM) seasons for baseline (blue), near-term (orange) and long-term (grey) periods in RCP4.5 (left) scenario and for near-term (yellow) and long-term (green) in RCP8.5 scenario . Each diagram represents 10th percentile, first quartile, median, third quartile and 90th percentile. Bottom panels: same as upper panels for mean seasonal maximum temperature in RCP4.5 (left) and RCP8.5 (right) scenario. Increase is larger in winter and reaches 5°C in high emission scenario long-term.

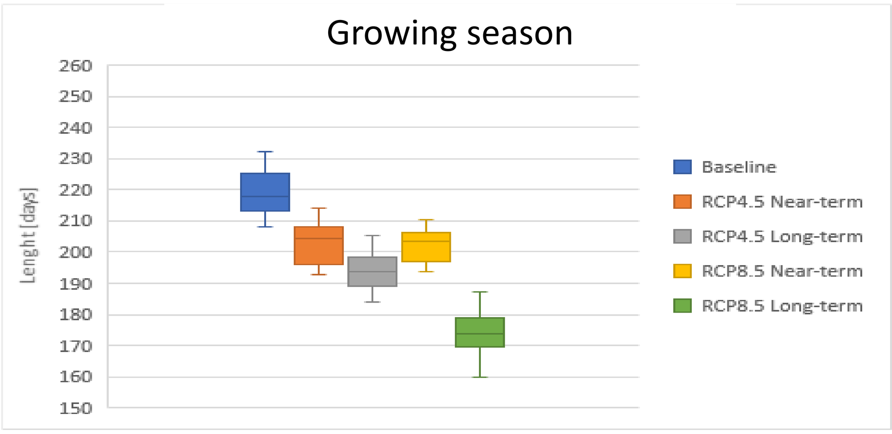
Significant decrease of **precipitation** in spring for high emission scenario

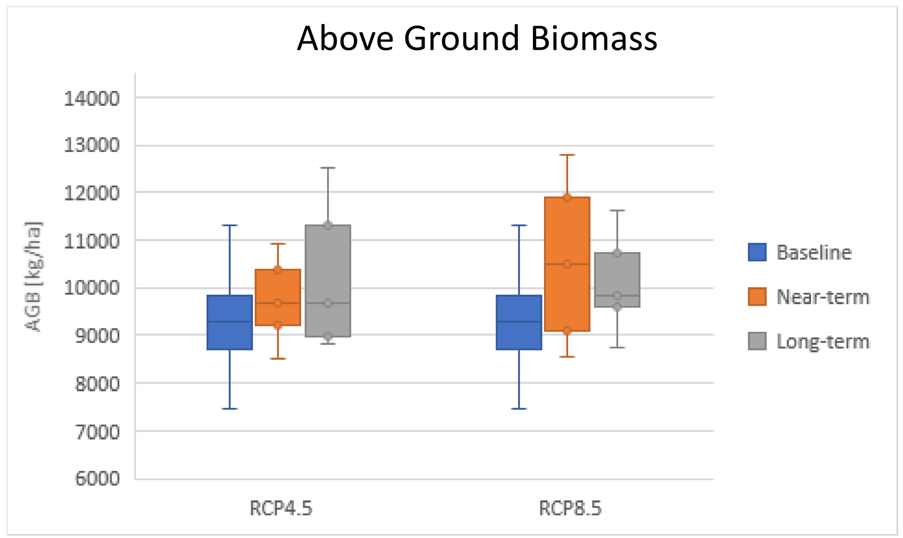


Left panel: mean seasonal cumulated precipitation in mm/season for autumn (SON), winter (DJF) and spring (MAM) seasons for baseline (blue), near-term (orange) and long-term (grey) periods for RCP4.5 scenario. Each diagram represents 10th percentile, first quartile, median, third quartile and 90th percentile. Right panel: same as left panel for RCP8.5 scenario. Baseline (blue), near-term (yellow) and long-term (green) periods are examined. Changes in RCP4.5 are not significant, while in the worst projection (RCP8.5 long-term MAM) decrease can reach -36 mm/season.

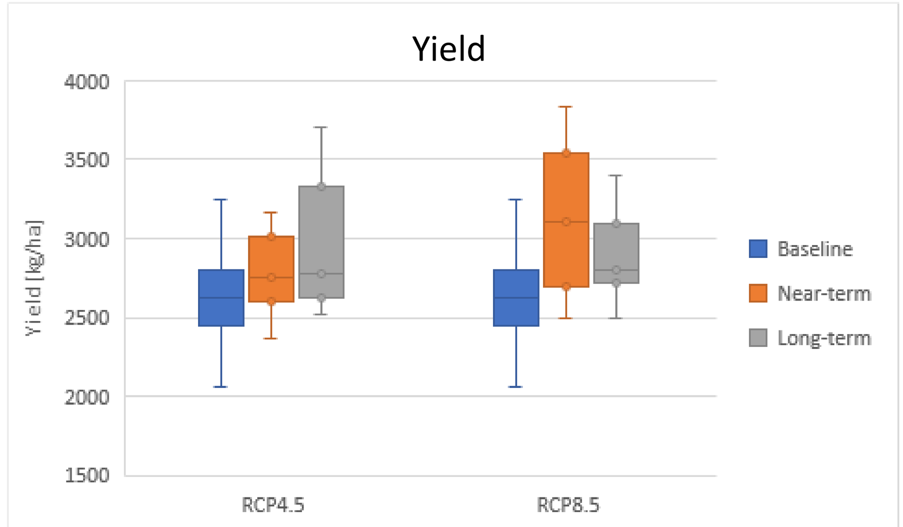
Effects on durum wheat

Reduced **growing season** while **above ground biomass** and **yield** are increased but with larger variability

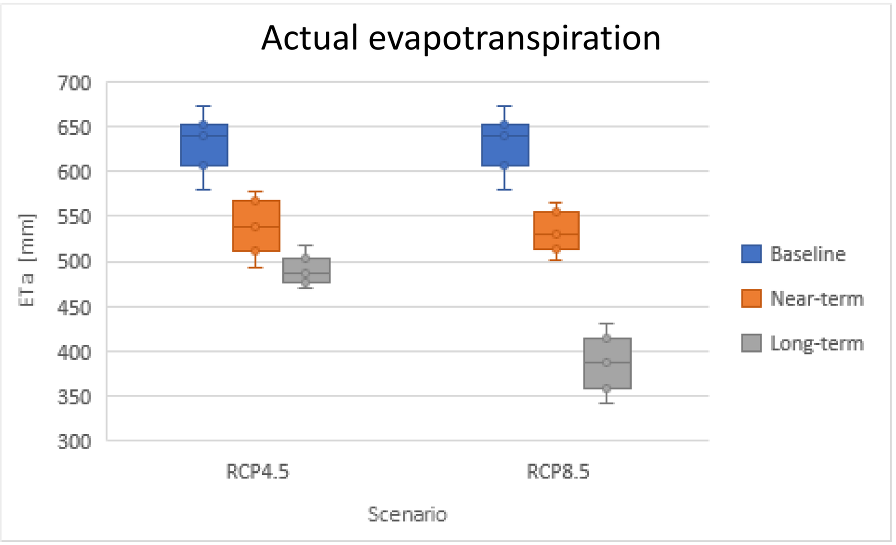


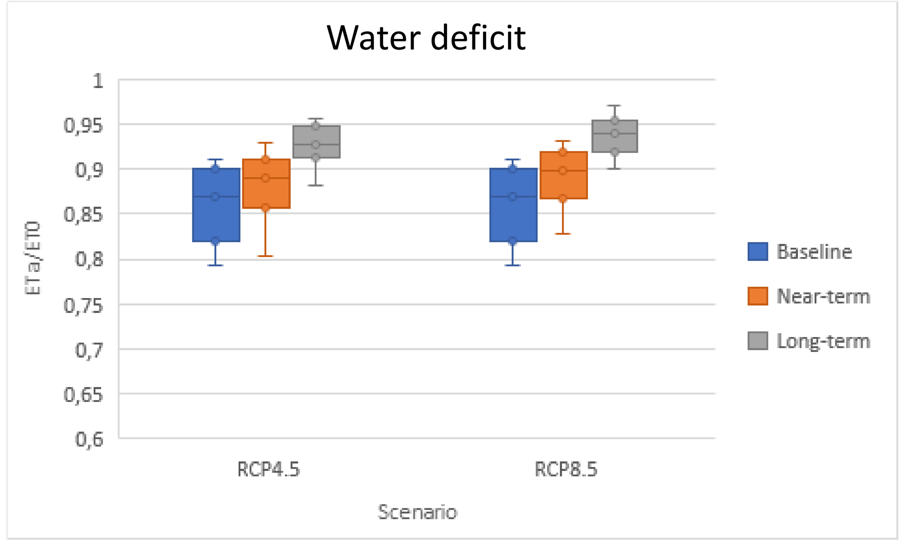


Left panel: growing season length in days for baseline (blue), RCP4.5 near-term (orange) and long-term (grey), RCP8.5 near-term (yellow) and long-term (green) projections. Each diagram shows 10th percentile, first quartile, median, third quartile, 90th percentile.Right panels: above ground biomass (upper) and yield (bottom) in kg/ha for RCP4.5 (left) and RCP8.5 (right) Near-term (orange) and Long-term (grey). Baseline (blue) is duplicated for an easier comparison. The greatest increase is expected for RCP4.5 near-term but with large variability.



Substantial decrease in **actual evapotranspiration**, but increase in **water deficit** and **water use efficiency**





Left panel: actual evapotranspiration for the growing season (in mm) for RCP4.5 (left) and RCP8.5 (right) Near-term (orange) and Long-term (grey). Baseline (blue) is duplicated for an easier comparison. Right panels: same as left panel for water deficit (upper) and water efficiency (bottom) in kg/mm. Water losses are reduced and the same quantity of biomass is produced.