Climate indices and return period analysis to assess the long-term impact of climate change on olive crops in Peloponnese, Greece

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Introduction

The olive tree (Olea europaea L.), a perennial evergreen, is one of the most important crops in the Mediterranean basin, where almost 95% of the world olive oil supply is produced (EC, 2012). Greece - the third largest producer worldwide behind Spain and Italy - contributes 15% in olive production in Southern Europe; however the olive yield (kg/ha) is much higher when compared to the rest countries (Fraga et al., 2020). Almost 40% of the olive production in Greece comes from Peloponnese, Southern Greece.

The optimum climate conditions for the cultivation of the olive tree are long, warm, dry summers and rainy winters. The plant can tolerate some frost, but sustained extremely low temperatures can destroy it. Since southern Europe has been identified as a climate change hotspot region by the Intergovernmental Panel on Climate Change (IPCC), the olive fruit production may be subjected to unfavourable meteorological conditions due to climate change.

The objective of this study is to employ tailored climate indices and the return period method to communicate the effect of climate change on the olive crops in the long-term in Peloponnese.

Climatic data and return period analysis

Climatic data: A three member GCM-RCM sub-ensemble simulations from the Euro-Cordex database with a horizontal resolution of 0.11° was used for the area of interest (Fig. 1). Daily climate data (precipitation and temperature) for three climate periods –historical (1971-2000), near future (2031-2060) and distant future (2071-2100) – and under two future emission scenarios - RCP4.5 and RCP8.5 - were used. The model data has been evaluated using observational data from meteorological stations and was found suitable for our study.

Fig. 1: Area of interest (Peloponnese, Southern Greece) in red

Institute	RCM	GCM
SMHI	RCA4	HadGEM2-ES
SMHI	RCA4	MPI-ESM-LR
KNMI	RACMO22E	HadGEM2-ES

Return period analysis: The return period of a particular event is defined as the inverse probability of this event's occurrence in any given year. NOAA also uses the term 'annual exceedance probability' (AEP) (Bonnin et al., 2004). The return period analysis is a mean for more interpretable results by the general public. In brief, if the selected threshold of the studied variable x is x_o, the return period is $T=1/F(x_o)$, where F(x) is the cumulative distribution function (CDF)

Olive yield and precipitation

Precipitation index

WINRR (*total precipitation from October to May*) is one of the most important indices for olive yield. Winter precipitation and olive production are strongly connected and has been shown that reduced precipitation over the months prior to flowering leads to low flower and fruit-setting (e.g. Ribeiro et al., 2006).

WINRR, is overall expected to decrease. Strong regional dependency is illustrated, with significant changes reaching almost 20% in western and southern Peloponnese (Fig. 2).

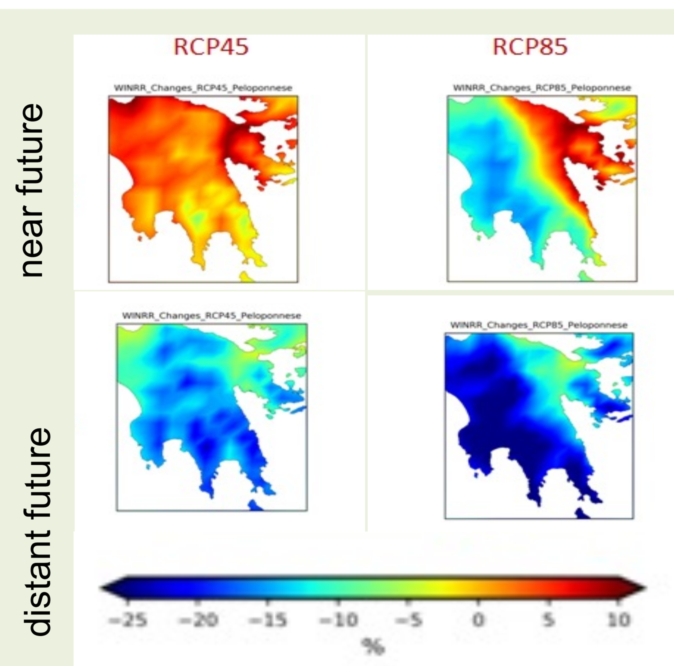

Fig. 2: Relative differences for total winter (Oct-May) precipitation (WINRR)

Occurrence probabilities of bad years

The threshold for defining a bad year in terms of olive yield has been set to **300 mm** for the total winter precipitation (October to April), in accordance to several detailed studies (e.g. Gratsea et al., 2022)

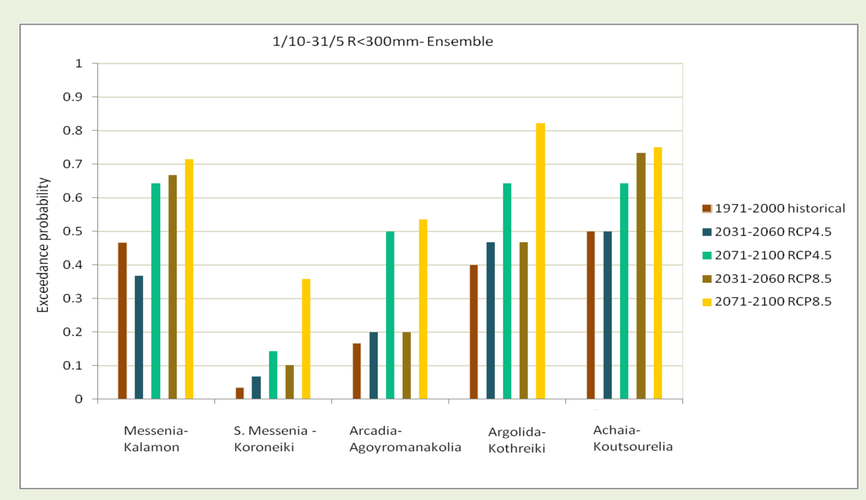

Fig. 3: Occurrence probabilities of total precipitation (October to April) < 300 mm for five regions

A regional dependency is illustrated (Fig. 3), with overall higher probabilities of bad years in north-eastern regions (Argolida), exceeding a probability of 0.8 for reduced olive yield in any given year in the distant future. An overall tendency for increased probability of bad years occurrence in terms of olive yield is projected for the whole Peloponnese.

Temperature related climatic indices

SPRTX

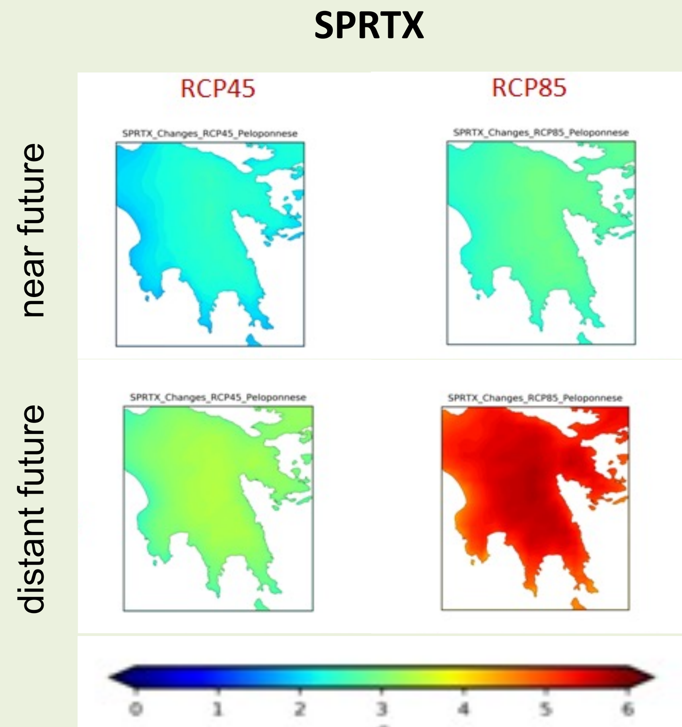

Fig. 4: Absolute differences of spring (April-May) maximum temperature

SPR32

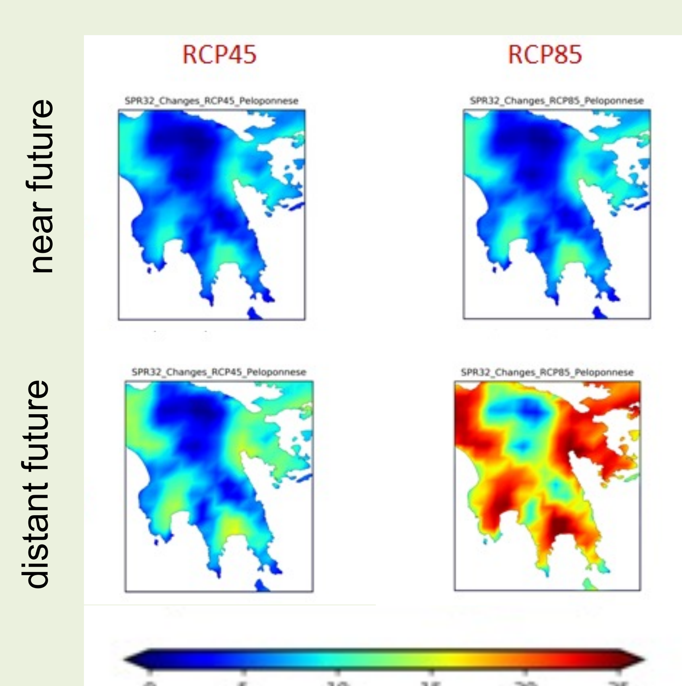

Fig. 5: Absolute differences of the number of spring heat days (Tmax>32°C)

SU38

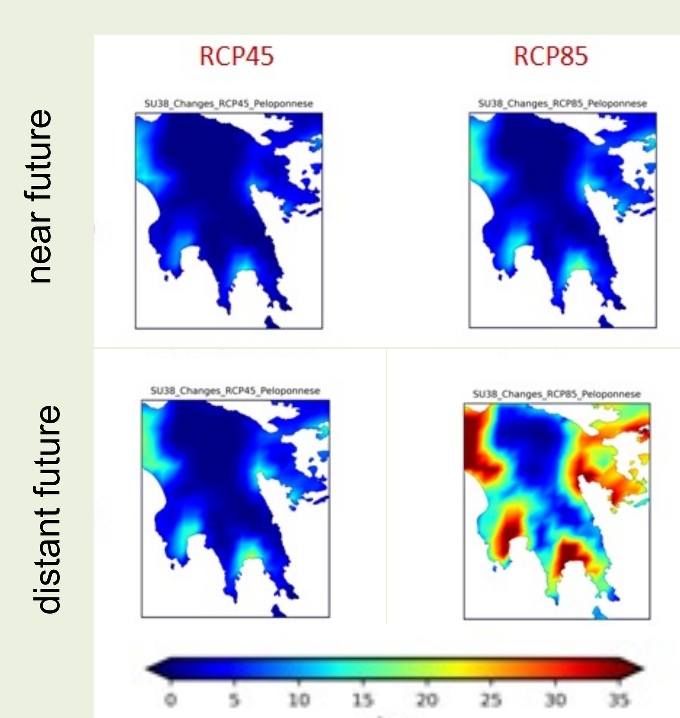

Fig. 6: Absolute differences of the number of summer heat days (Tmax>38°C)

SU40

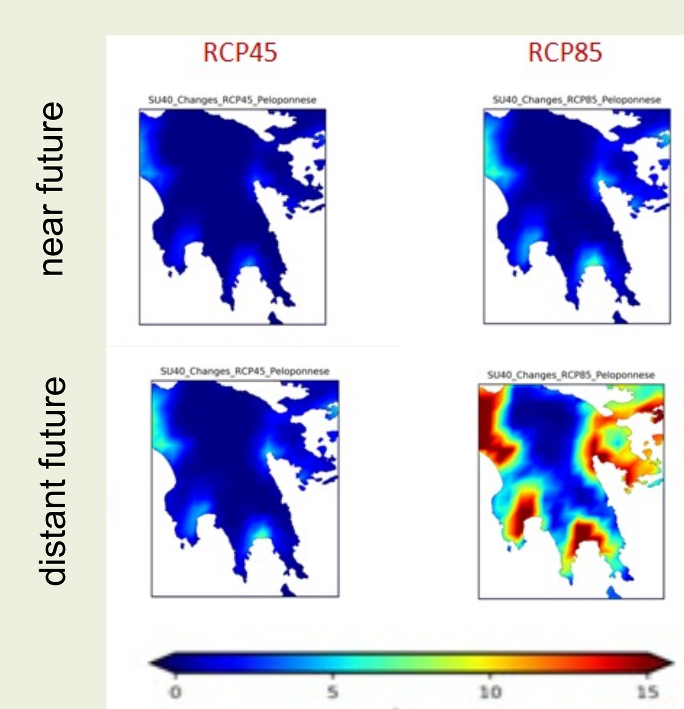

Fig. 7: Absolute differences of the number of summer heat days (Tmax>40°C)

Climate change is expected to decrease the suitability of olive orchards in Peloponnese due to projected excessive heat and water stress in the future.

SPRTX, SPR32 ⟹ related to early flowering dates in spring

The projections for the SPRTX index, indicate increases for the whole area of interest both for the near and distant future and under both RCP scenarios.
Robust increases are projected for the SPR32 index for the larger part of Peloponnese and especially the coastal areas. The impact of climate change on the flowering dates is expected to be significant.

SU38, SU40 ⟹ related to extra irrigation and pest control during summer

High summer temperatures favour an earlier ripening of the olives and affects negatively the fruit weight (Garcia-Inza et al., 2014). Thus the projected increase of SU38 and SU40 may imply the need of extra irrigation, which increases the fruit size and flesh-to-stone ratio. The changes will mostly affect the coastal areas.

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