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Mediterranean irrigation under climate change: more efficient irrigation needed to compensate for increases in irrigation water requirements

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Table S1: Characteristics, advantages and disadvantages of our water availability/scarcity approach.

Our water scarcity approach	Advantages	Disadvantages
Only renewable surface and groundwater considered	Does not take into account saline fossil aquifers and considers possible depletion of fossil aquifers (currently dropping groundwater tables).	Excludes currently available fossil groundwater.
No consideration of climate change effects on water availability	Avoids adding uncertainty due to high spread of runoff projections.	Might overestimate water availability because the majority of projections point to a reduction of runoff (but the magnitude is uncertain).
No changes in water demand of households and industry	Might be a good balance between the unknown factors leading to potential increases and decreases of these consumptions.	Might be pessimistic if water savings are achieved through implementation of new technologies in industry, environmentally friendly tourism and water pricing and counters in households. Might be pessimistic because does not consider population growth and industrialization in the Southern shores.
Irrigation requirements are compared to water availability at national scale and on an annual basis (as oppose to grid-cell or	Accounts for temporal transportation of water within a country which is especially plausible in the Northern Mediterranean.	Might mask subnational and seasonal water scarcity. Might mask potential up versus downstream

watershed level)	Accounts for possible projects on interbasin water transfers (e.g. channels and pipelines) within a country. Does not exclude the idea of reallocation of production areas within a country. Does not add uncertainty by missing micro-dams and unknown dam management in the river routing of the model.	consumptions.
Does not consider desalinization, water reuse and water recycling.	Does not add uncertainty by the unknown evolution of these sectors. Assumes that high energy consumption and investment costs may limit to a certain degree these potentials.	Might be pessimistic for countries that already use these options, like Israel and Spain.
Includes through different scenarios the current political treaties affecting the inflows and outflows of countries and the water needed for conservation of aquatic ecosystems.	Represents current political agreement and accounts for the environmental flow requirements.	Environmental flow requirements are not spatially explicit and political agreements may change in future.

A. Definition of the study area and irrigated areas

Defining the Mediterranean region is a complex task and a topic that has originated a lot of scientific discussions (e.g. Médail & Quézel 1997[1]). For this study we take a very simple approach aiming to combine socioeconomic and geographical criteria. First, we assumed that following countries belong to the Mediterranean region: Portugal, Spain, France, Italy, Greece, Morocco, Algeria, Tunisia, Libya, Egypt, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Israel, Lebanon, Macedonia, Montenegro, Serbia, Slovenia, Syria and Turkey. And second, we selected river basins from the dataset DDM30 (Döll and Lehner, 2002)[2] that are totally or partly situated in these countries, independently of the location of the river mouth. Fig. S1 shows the absolute and percentage values of irrigated areas in this region.

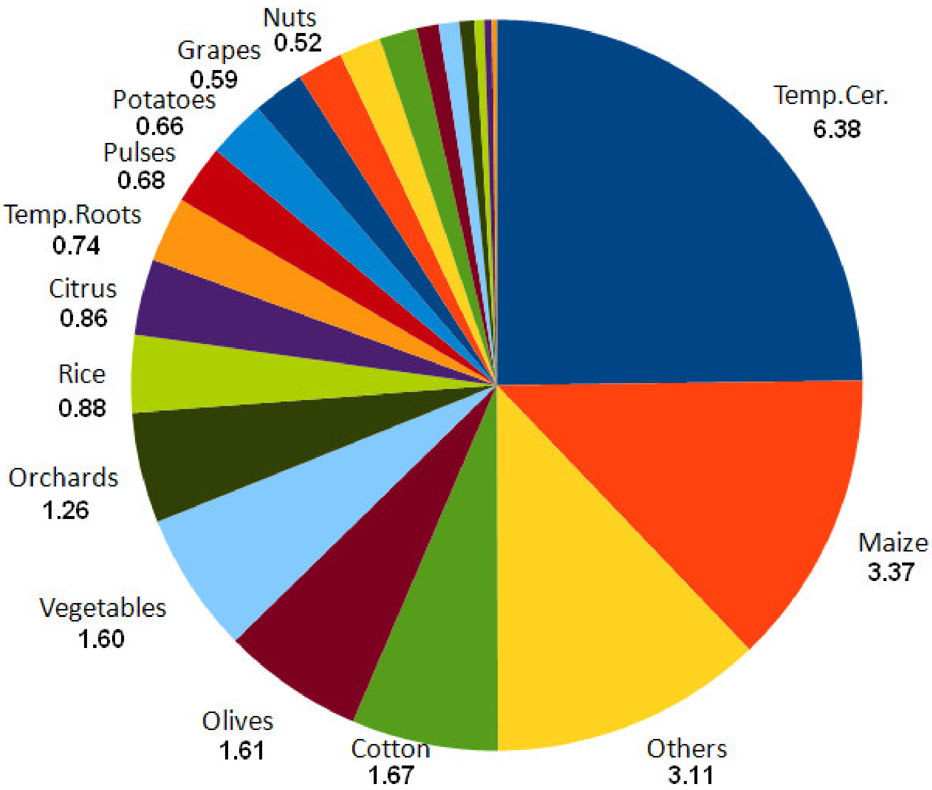

Figure S1: Crop-specific irrigated areas in the Mediterranean region. The portions in the pie graphic represent the percentage to total irrigated area; the numbers below the label represent the total areas in 10^6 ha.

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[1] Médail F, Quézel P. 1997. Hot-spots analysis for conservation of plant biodiversity in the Mediterranean Basin. Ann. Missouri Bot. Gard 84:112-127.

[2] Doell P, Lehner B (2002). Validation of a new global 30-min drainage direction map. Journal of Hydrology, 258(4-Jan), pp.214-231.

B. Scenarios of CO2-fertilization effect

Figure S2 shows the CO_2 concentrations used in each scenario.

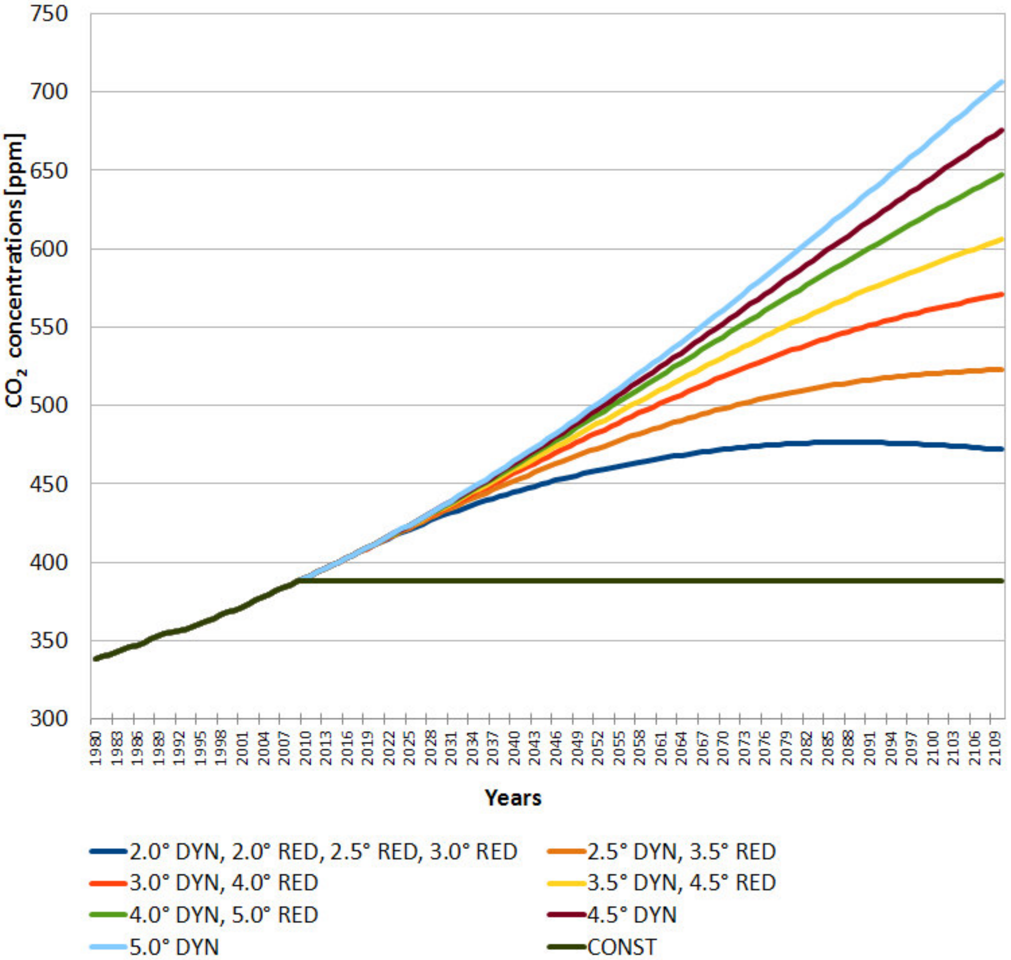


Figure S2: CO_2-fertilization scenarios used in this study (see section 2).

C. Complementary results

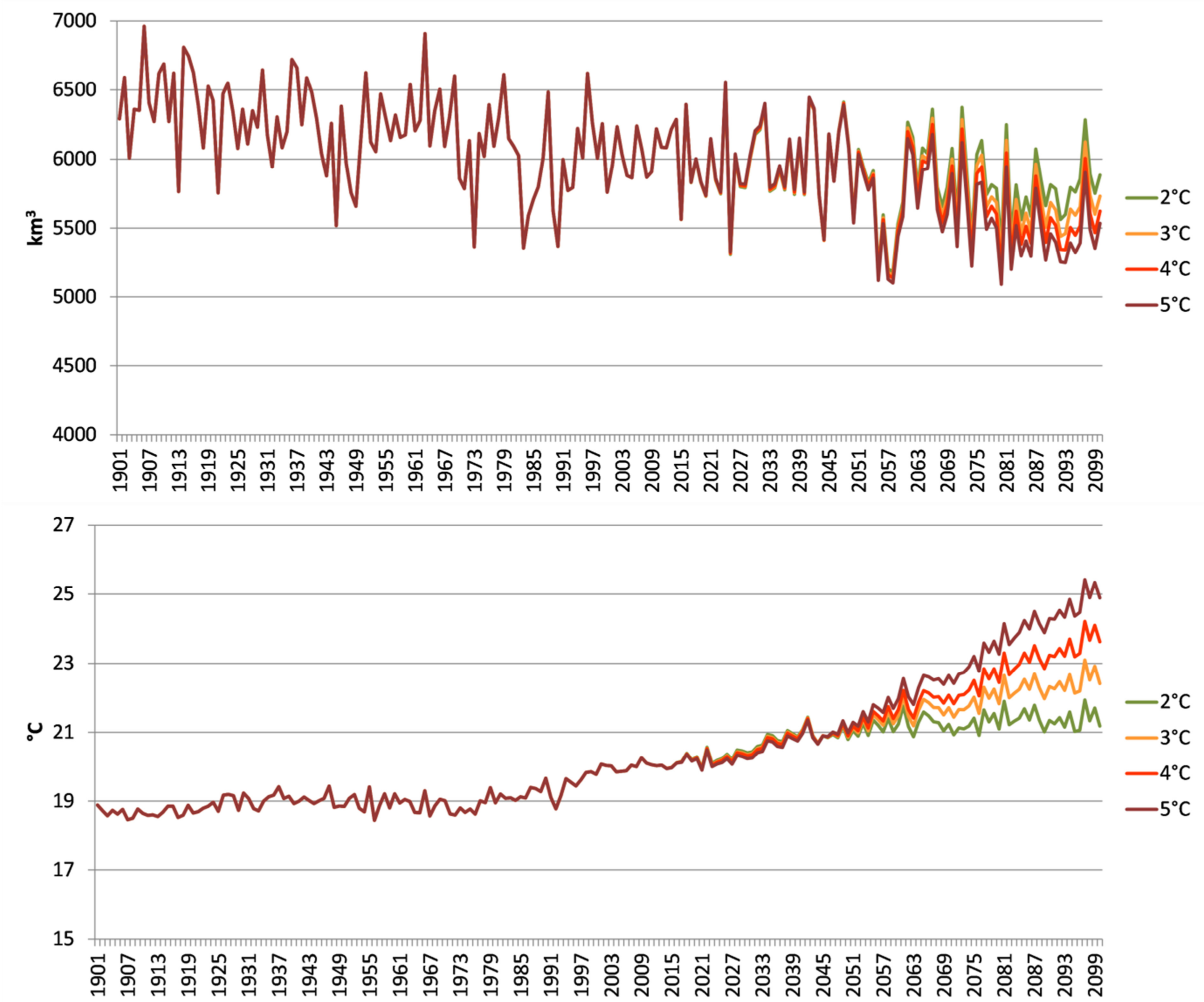


Figure S3: Time series of annual precipitation (upper panel) and mean temperature (lower panel) over the Mediterranean region. From 2010 to 2100 the values displayed are the ensemble median of 19 global climate models for 2, 3, 4 and 5 °C global warming.

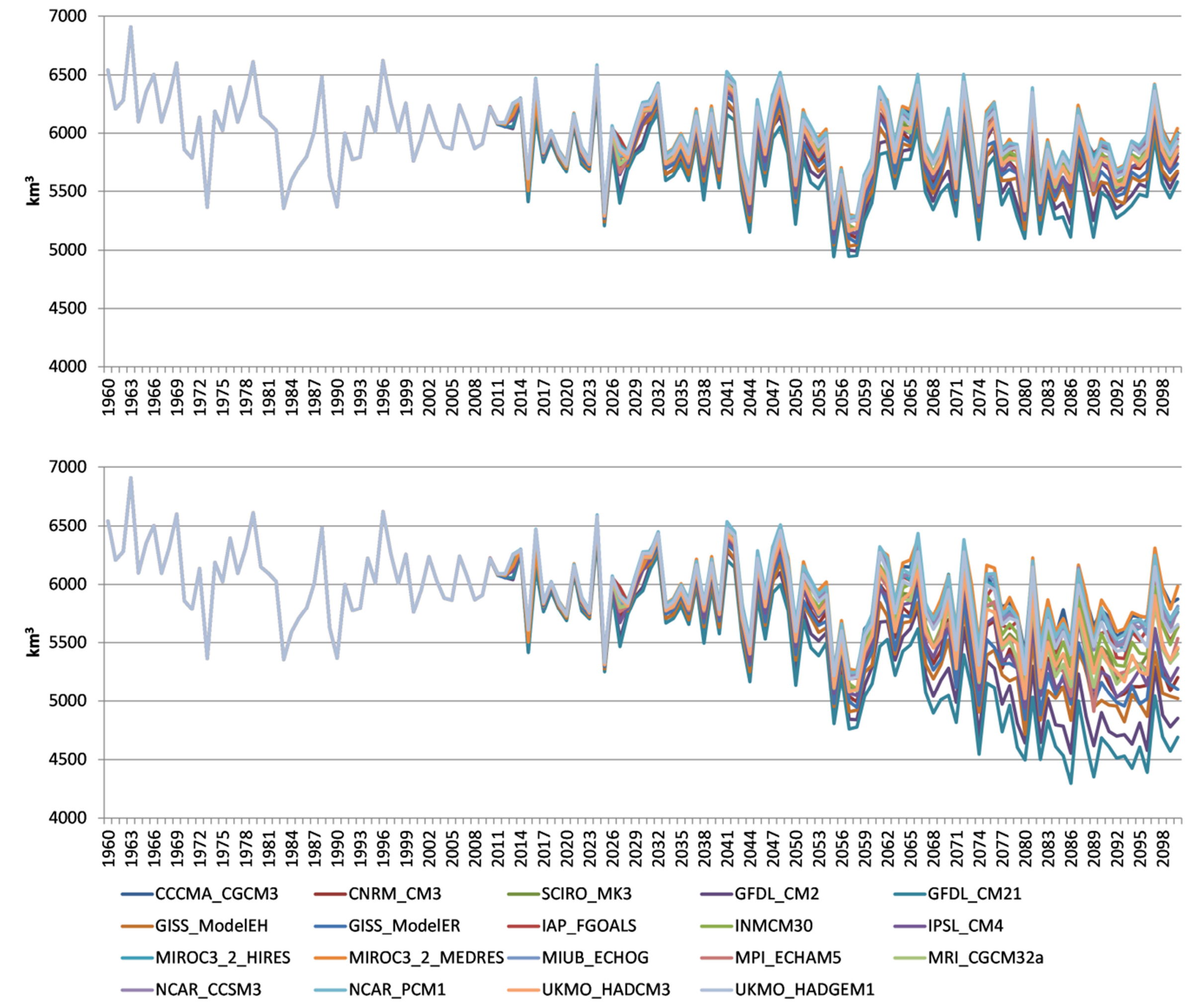


Figure S4: Time series of annual precipitation for 2°C global warming (upper panel) and 5°C global warming (lower panel) over the Mediterranean region. From 2010 to 2100 the values displayed correspond to 19 global climate models.

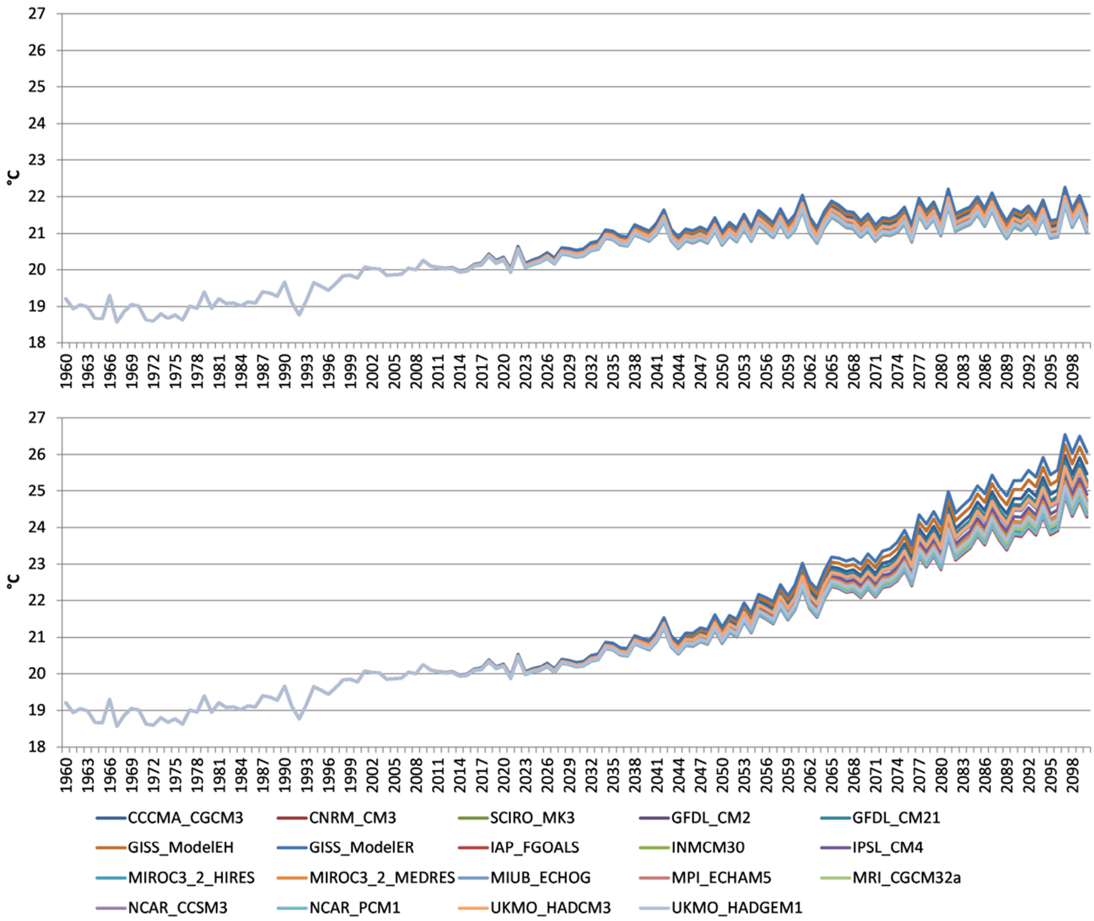
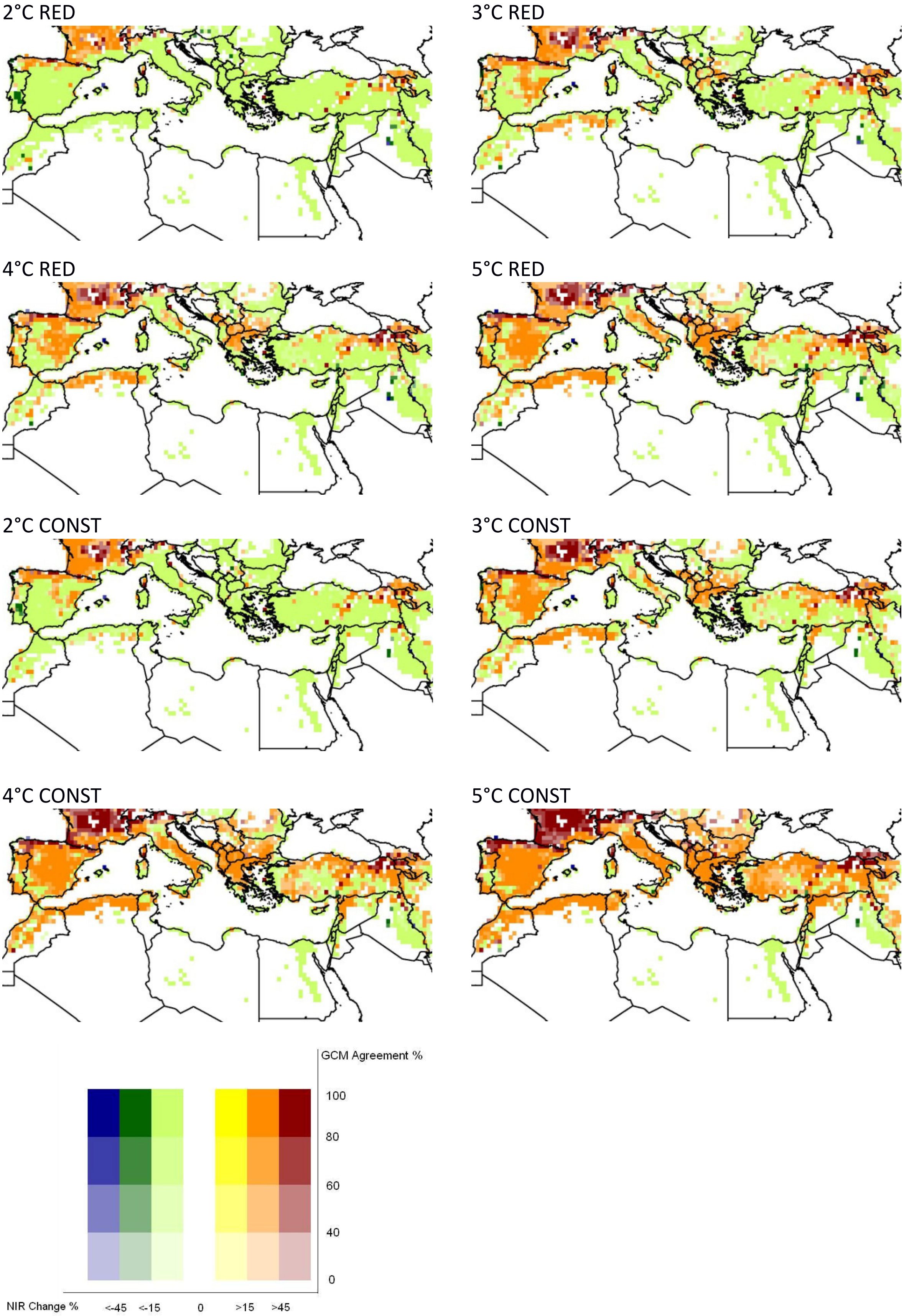


Figure S5: Time series of mean temperature for 2°C global warming (upper panel) and 5°C global warming (lower panel) over the Mediterranean region. From 2010 to 2100 the values displayed correspond to 19 global climate models.


2°C RED
3°C RED
4°C RED
5°C RED
2°C CONST
3°C CONST
4°C CONST
5°C CONST
GCM Agreement %
100
80
60
40
0
NIR Change %
<-45
<-15
0
>15
>45

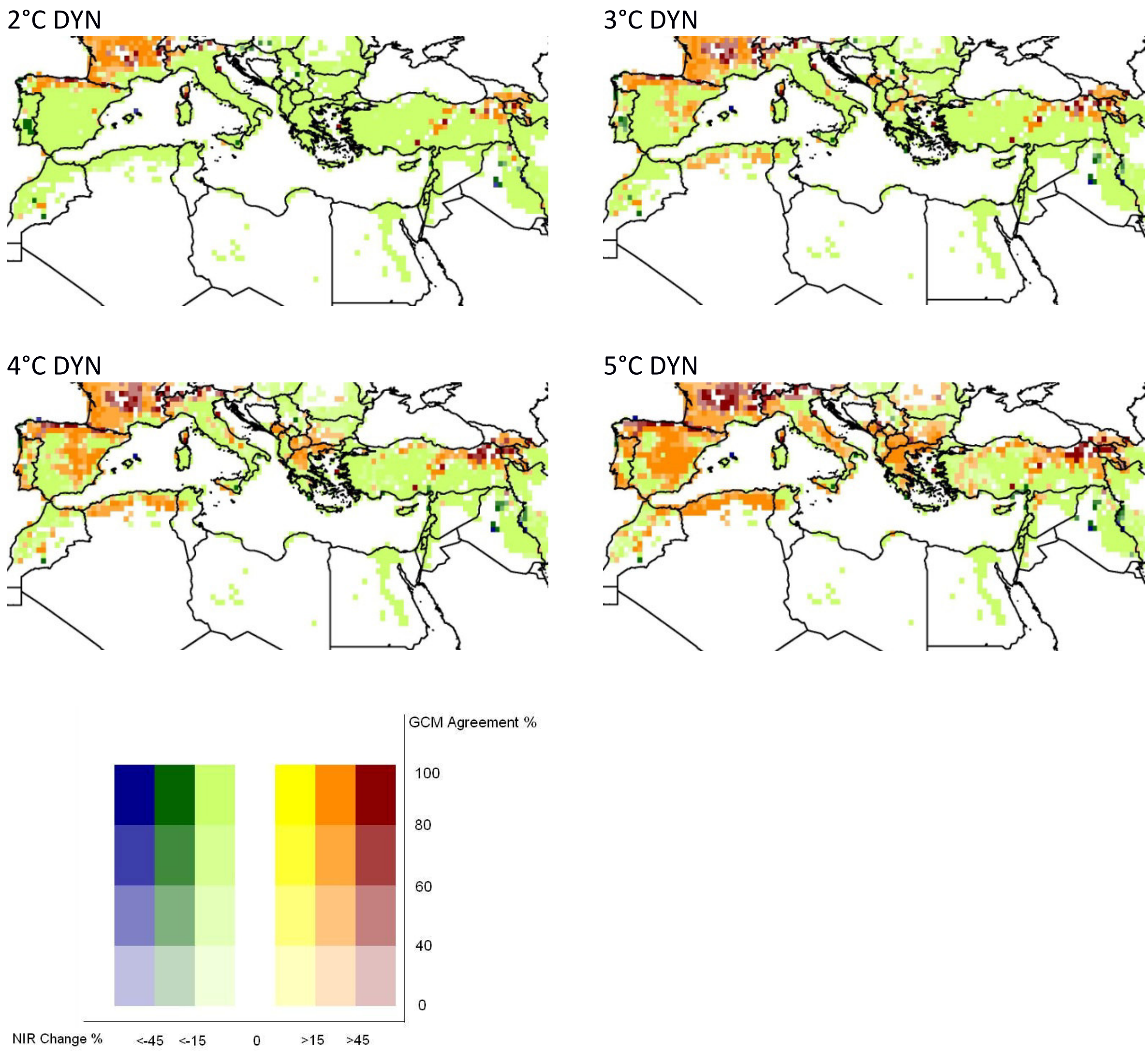


Figure S6: Change in per unit of area net irrigation water requirements NIR from 2000-2009 to 2080-2090, and GCM agreement, for different combinations of warming levels and CO_2-fertilization scenario.

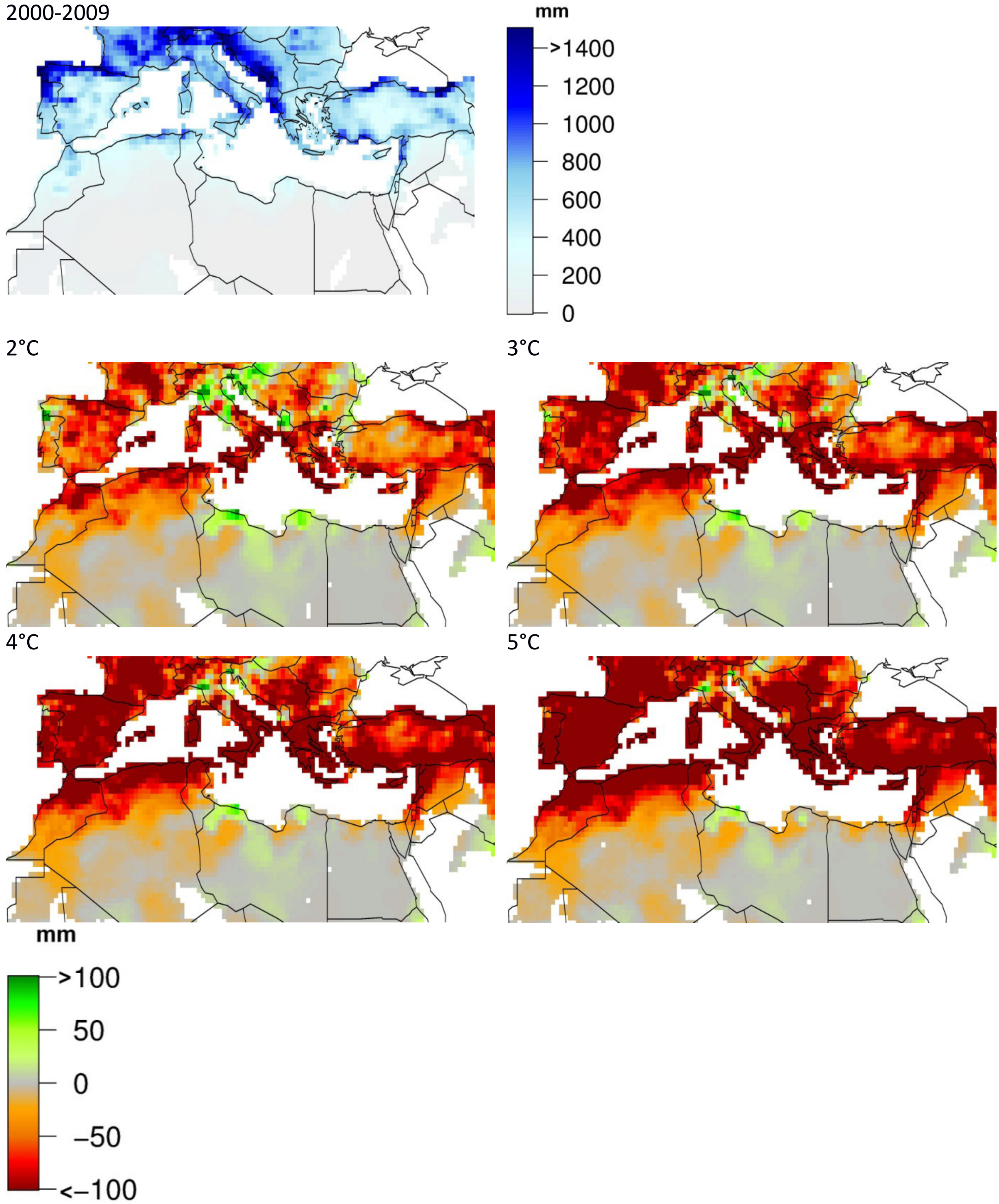


Fig. S7: Current annual precipitation as average for the period 2000-2009 (upper panel), and difference between the ensemble median of annual precipitation as average for the period 2080-2090 for 2, 3, 4 and 5 °C global warming and current annual precipitation. Negative (positive) values indicate a decrease (increase) in annual precipitation.

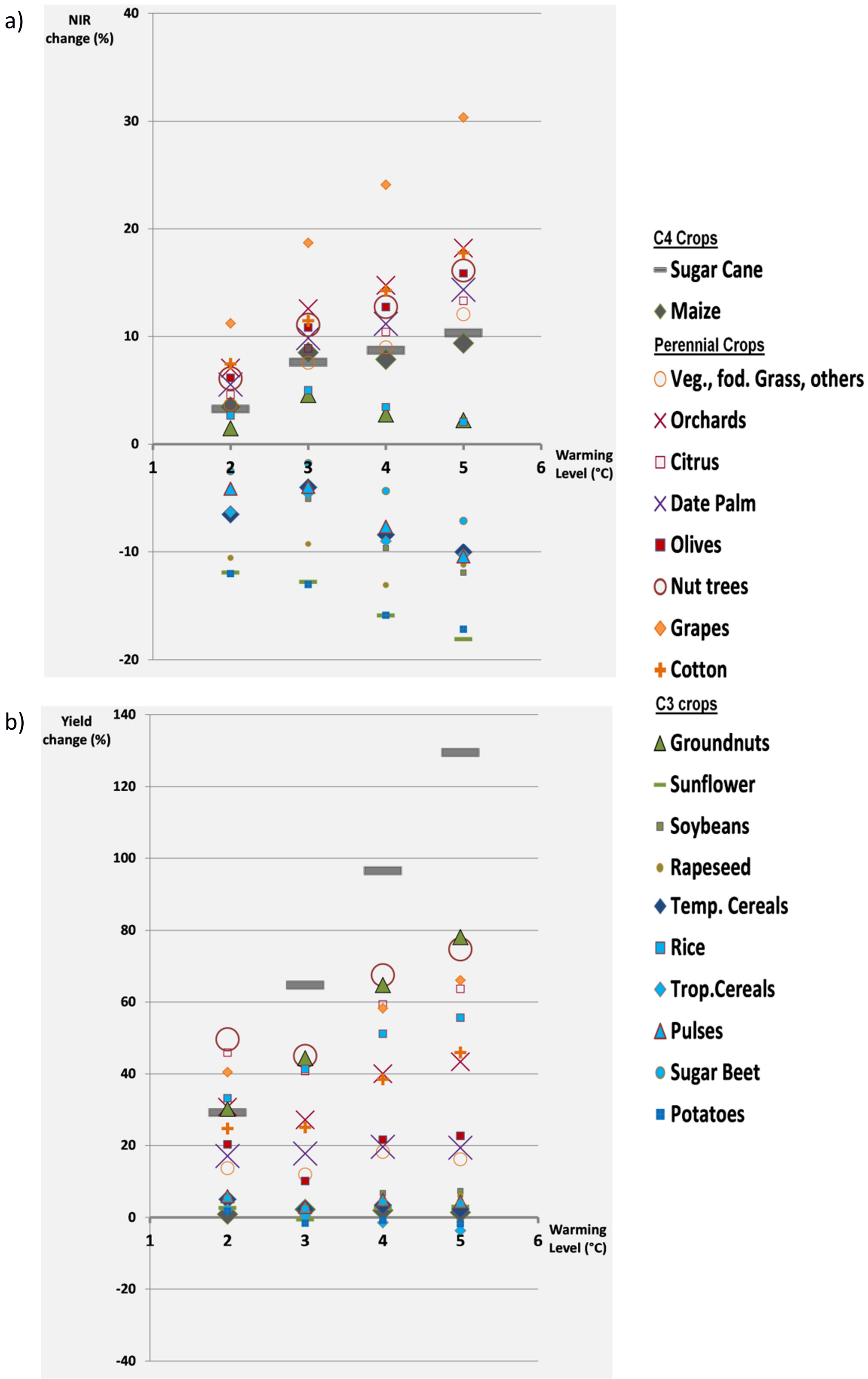


Figure S8: Change in net irrigation water requirements (a) and yields (b) from 2000-2009 to 2080-2090 for different crops' classes and the RED CO_2-fertilization scenario. See Fig. 6 and Fig. 7 for additional scenarios.