The extreme future of soil moisture in a Mediterranean country: the Portuguese case

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Goals

1)Characterize the pattern of soil moisture in Portugal in present climate; 2) Evaluate the ability of Regional Climate Models (RCMs) from EURO-CORDEX to represent soi moisture; 3) Depict the RCM future projections for soil moisture and aridity; 4) Portray the main drivers associated with such future evolution.

Methods and data (1)

1) EURO-CORDEX regional climate modelling data

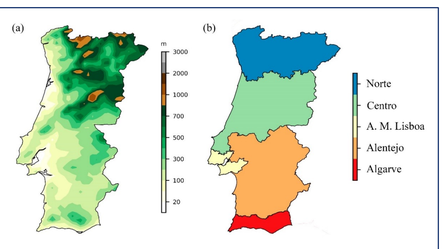
13 EURO-CORDEX simulations (RCP2.6, RCP4.5 and RCP8.5)
Time Periods: 1971-2000, 2011-2040, 2041-2070 and 2071-2100

Total soil moisture content; daily total precipitation; total runoff; evaporation flux; 2-m maximum and minimum daily temperatures; 2-m specific humidity; surface pressure; daily mean 10-m wind speed; upward latent heat flux.

2) GLEAM Observational Dataset

Surface soil moisture, from 1980 to 2020 at 0.25º horizontal resolution

Methods and data (2)



1) Soil moisture and land water balance properties

- Standardised soil moisture anomaly
- Evapotranspiration rate: $ET = \frac{hfls}{\lambda}$
- Potential evapotranspiration (Penman-Monteith equation :

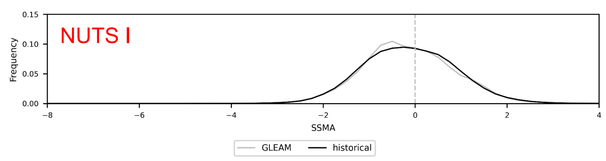
$$PET = [0.408\,\Delta\,(R_n - G) + \gamma[900/(T_m + 373)]\,V_{h2}\,(e_s - e_a)] / (\Delta + \gamma(1 + 0.34V_{h2})$$

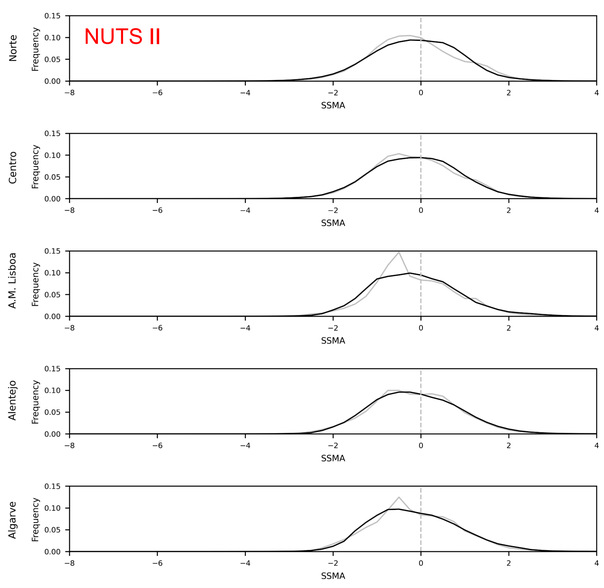
- Near-surface air relative humidity: $RH = \left[\left(\frac{mr}{mr_{sat}}, 1\right), 0\right] x100$
- Aridity Index: $AI = \frac{P}{PET}$

2) Weighted multi-model ensemble (MME) based on precipitation and temperature (Lima et al. 2023a,b).

Evaluation: soil moisture from MME vs GLEAM Dataset

Standardised Soil Moisture Anomaly

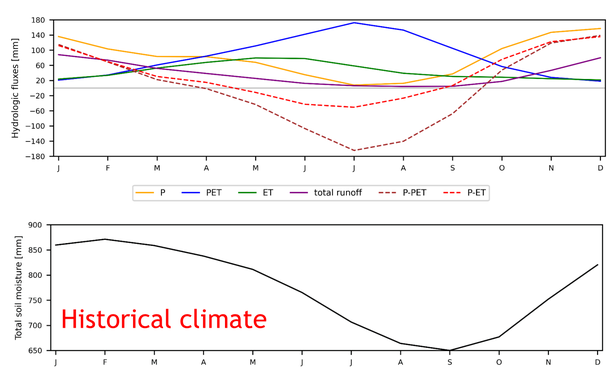




PDFs of Standardised Soil Moisture Anomaly at the daily scale for mainland Portugal NUTS I and II, for GLEAM dataset for the period 1980-2009 (grey) and for the historical period (1971-2000) of multi-model ensemble historical (black). Total soil moisture from the multi-model ensemble against the surface soil moisture from GLEAM dataset.

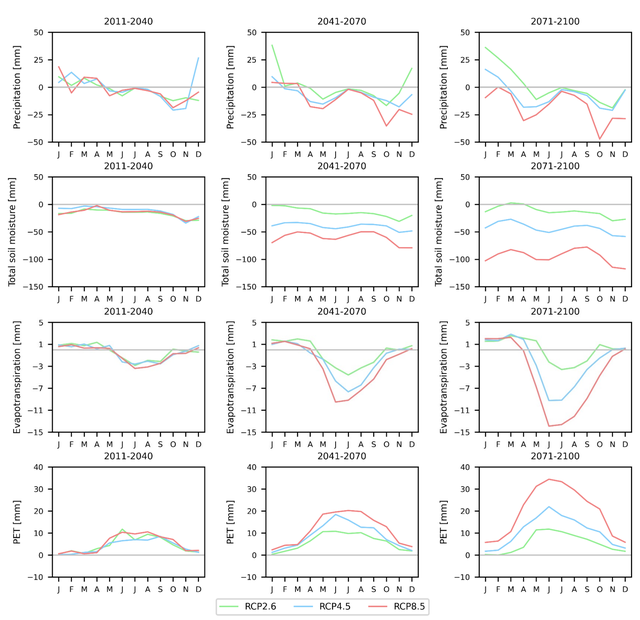
Drivers of soil moisture and humidity depletion

Annual cycle of the water budged terms and related variables

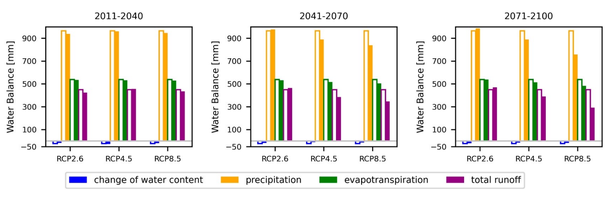


$$\frac{dS}{dt} = P - ET - R_t$$

Future differences on Annual cycle

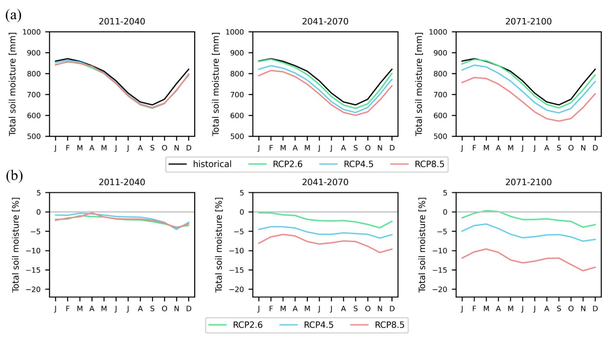


Land water balance components

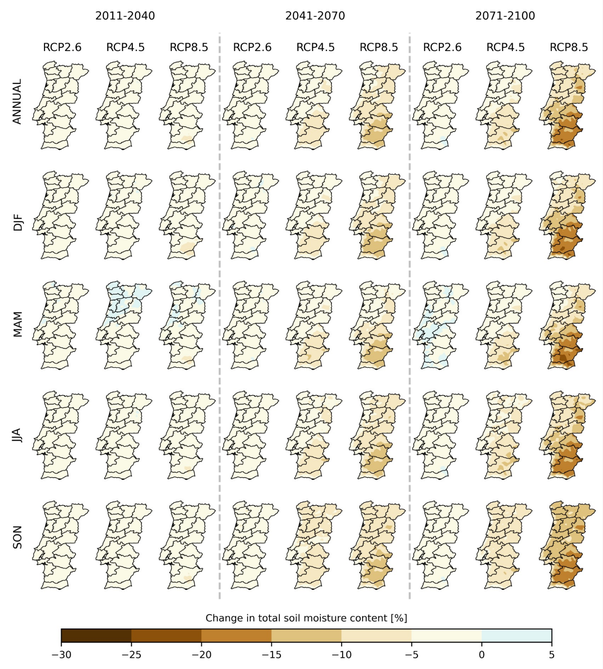


Future climate soil moisture

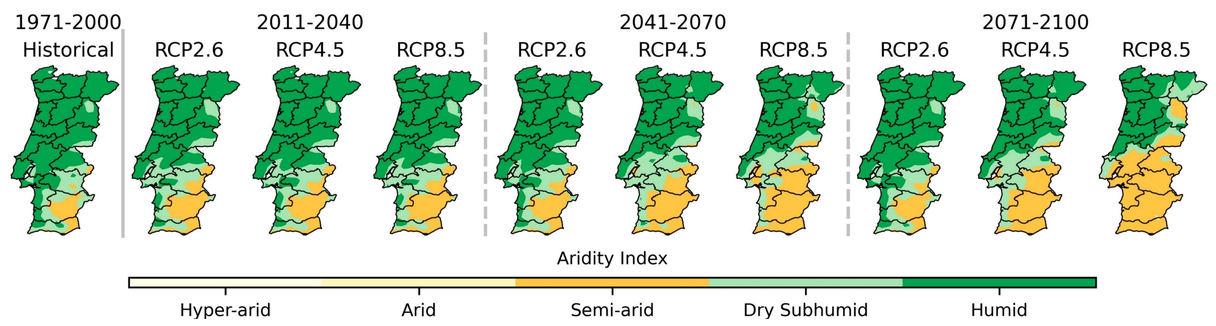
Annual cycle of total soil moisture



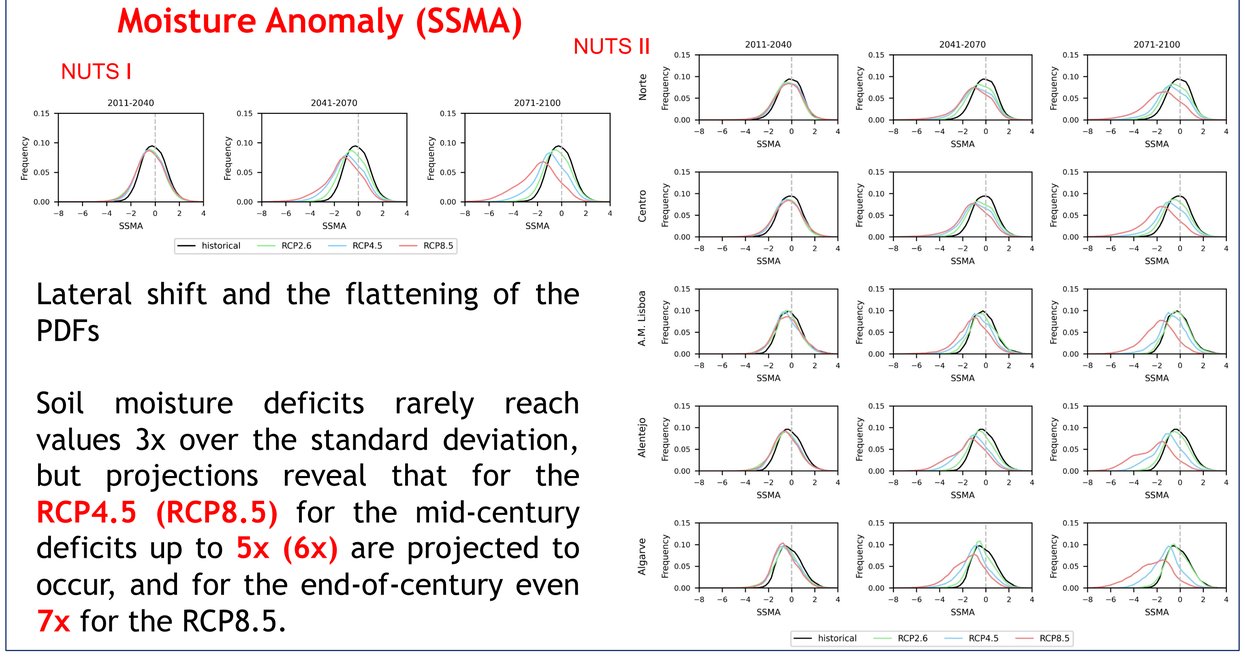
Projected soil moisture changes



Aridity Index



PDFs of Standardised Soil Moisture Anomaly (SSMA)



Lateral shift and the flattening of the PDFs

Soil moisture deficits rarely reach values 3x over the standard deviation, but projections reveal that for the **RCP4.5 (RCP8.5)** for the mid-century deficits up to **5x (6x)** are projected to occur, and for the end-of-century even **7x** for the RCP8.5.

Conclusions

- An impressive decrease in soil moisture is projected;
- The shift for lower values and the flattening of the soil moisture PDFs is projected – more severe for the two southern regions, Alentejo and Algarve;
- future total soil moisture reductions are determined as the precipitation decreases and the augment of potential evapotranspiration throughout the full annual cycle;
- Semi-arid climate overtaking Portugal
- The future panorama of water scarcity here depicted will impact dramatically many Portuguese ecosystems and economic sectors dependent on them, such as agriculture, forests, and tourism.

References
Lima DCA, Gil Lemos; Virgílio A. Bento; Miguel Nogueira; Pedro M.M. Soares (2023) A multi-variable constrained ensemble of regional climate projections under multi-scenarios for Portugal – Part I: an overview of impacts on means and extremes. Climate Services, 30 (100351). DOI: https://doi.org/10.1016/j.cliser.2023.100351.
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