Effect of increasing long-term water deficit on maritime pine radial wood growth/density in southern Portugal

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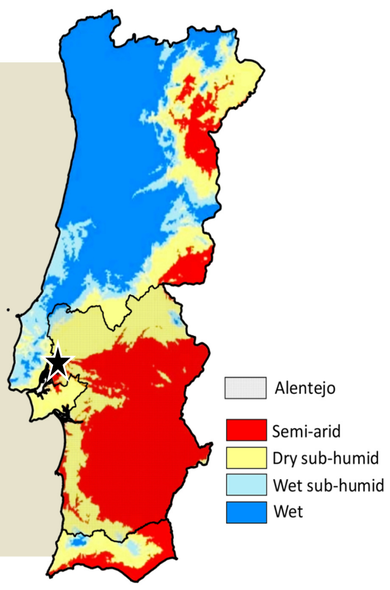
Aim

We investigated whether *Pinus pinaster* (Ait) has been affected by short to long-term droughts in a region who experienced a recent increase of dryness.

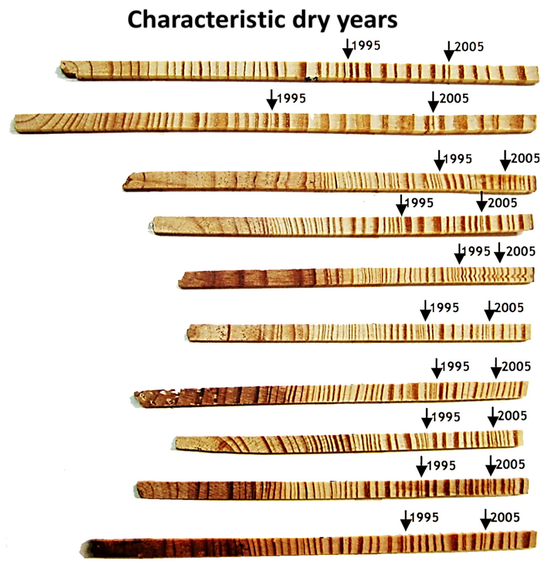
In this study we analyze how wood radial growth and density responded to recent climate changes.



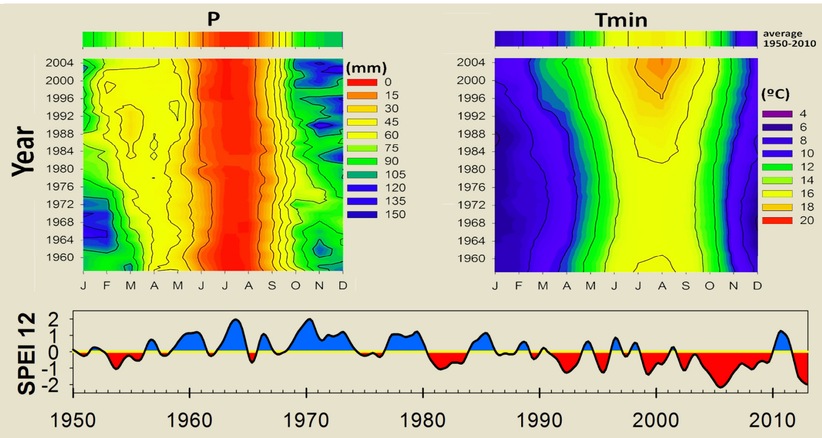
Methods

Wood ring cores were sampled in the northern-east part of the Alentejo region, in Companhia das Lezirias (38º 47' 24.01 N; 8º 54' 11.10 W). Dendrochronological are the average of ten 60-year old maritime pine trees with a mean diameter of 36.9cm and a mean height of 21.3m. See detailed methods in [1].

Meteorological datasets covering the period 1950-2010 were retrieved from ECA&D & ENSEMBLES. Data on Fig1 are 15-yr moving averages. SPEI multi-scalar drought index was calculated according to Vicente-Serrano [2]. The temporal evolution of the climate-growth relationship (Fig3, 4) was analyzed by computing the Pearson correlation coefficients (r) between the dendrochro-nological time-series and the monthly climatic times-series for the period 1958-2011. r values were calculated considering a moving window of 15-yr intervals [1].



Trends of recent climate changes



1 There was a sharp decline of spring precipitation (P) from 1950 to 2012, progressively spreading from spring to the previous late winter. Over the same period a significant raise of minimum temperature (Tmin, **Fig1**) affected all months of the year.

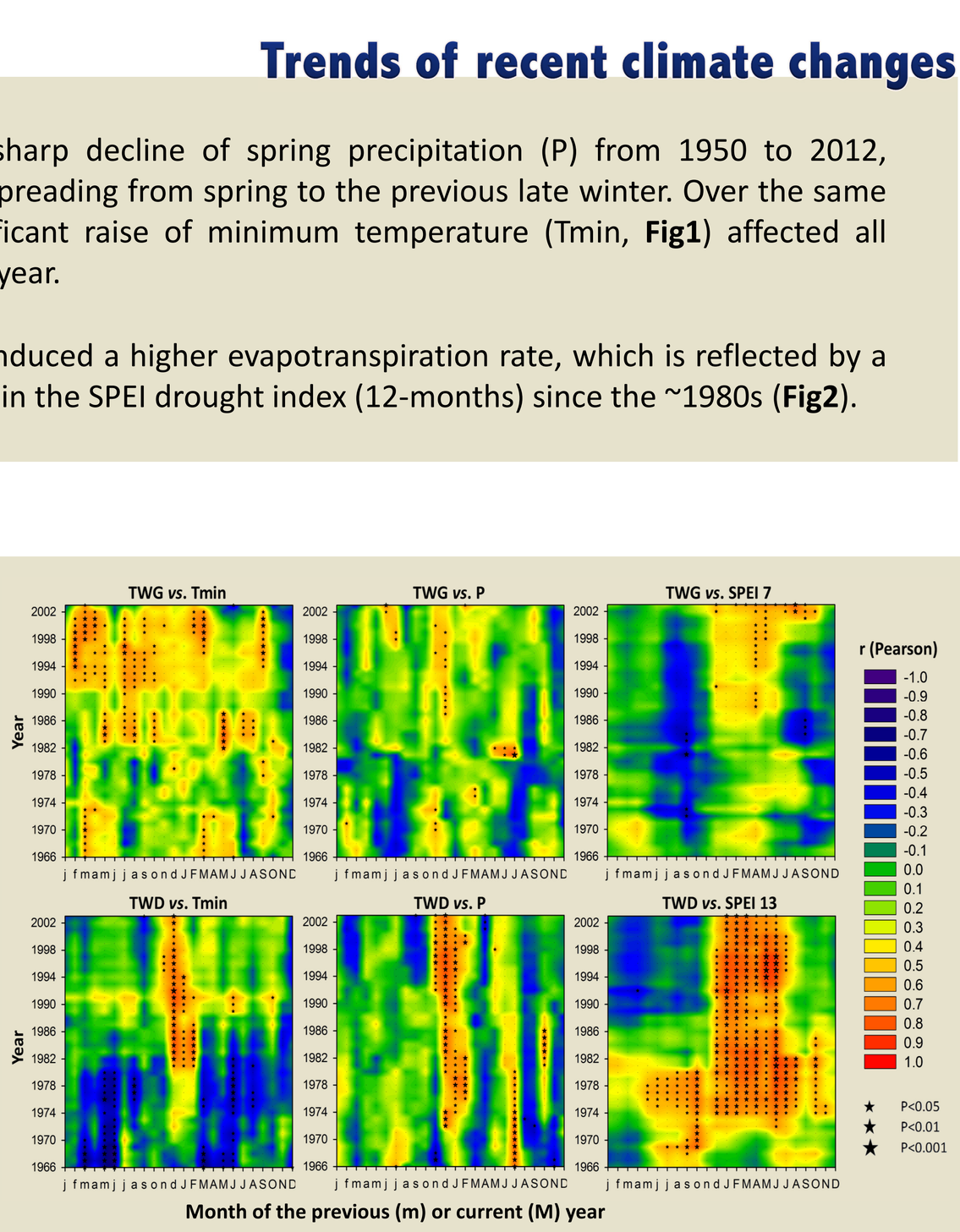
2 Those trends induced a higher evapotranspiration rate, which is reflected by a negative trend in the SPEI drought index (12-months) since the ~1980s (**Fig2**).

Effect on wood growth and density

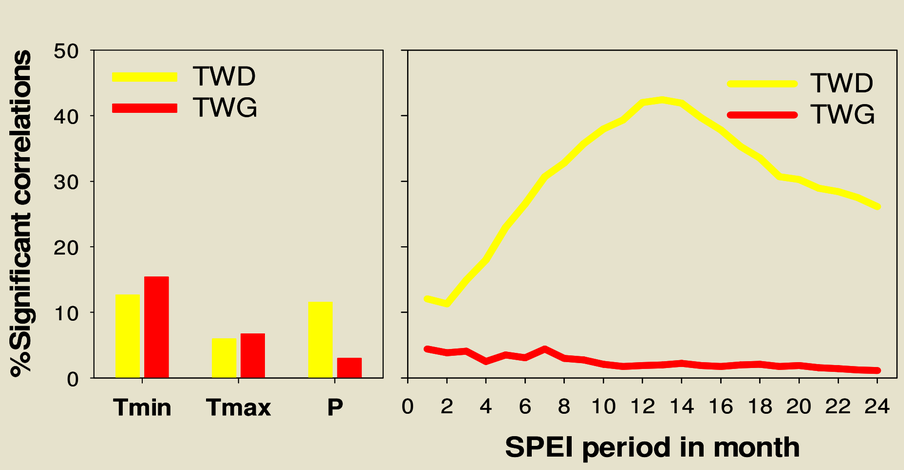
Tree radial growth was consistently and positively correlated to winter total precipitation, namely in November-January preceding the ring formation (P, **Fig3**). This shows that mature *P. pinaster* trees rely on deep water sources to cope with semi-arid droughts and are favored by better groundwater recharge at the end of the winter period [1, 3, 4], when maritime pine's xylogenesis is still dormant [5].

Tree-ring width (TWG) appears to benefit from Tmin increase since the 1980s (**Fig3**), whereas the negative effects of long-term droughts significantly prevailed on tree-ring density (TWD, **Fig3)** increasingly affected by more common long-term water deficit since the 1980s (**Figs2-4**).

The accumulation of recent inauspicious years with negative SPEI indexes and insufficient stored water at the beginning of the growing season tended to decrease the length of the growing period and consequently resulted in thinner cell walls, lower wood growth, density and quality. This trend will most probably exacerbete until 2100, with a 20-30% precipitation decline [6] and 3ºC mean temperature increase [7] according to climate predictions of scenarios A1B and RCP 8.5 for the Southern Mediterranean.



3 Contour plot representation of 15-yr moving correlations of annual radial growth (TWG, top) and mean ring density (TWD, bottom), versus minimum temperature (Tmin), monthly precipitation >0.1mm (P) and SPEI drought index. Months of the current year are in upper case letters (M) while months of the year preceding the annual ring growth are in lower case letters (m). The stars are scaled according to the level of statistical significance of correlations (n=15), with p<0.05 for |r|>=0.515 , p<0.01 for |r|>=0.637 and p<0.001 for |r|>=0.818, respectively.



4 Comparison of climate variable effects on *P. pinaster*'s dendrochronological traits, calculated as the percentage of significant correlations (P<0.05) obtained over the total number of correlations calculated in each subplot of Figure 3 as well as coorelations obtained with monthly maximum temperature (Tmax). Total annual ring width (TWG, red), mean ring density (TWD, yellow).

Conclusions

Our results underline an antagonist response of wood formation to the combined effects of the recent temperature and precipitation changes. While thriving under the disappearing of cold days and the increase of minimum temperature, *P. pinaster* xylogenesis suffers from prolonged water deficit (7-13 months) that has become more common since the 1980s.

The climate predicted in 2100 in the Alentejo region is likely to induce lower groundwater recharges as well as acute drops of the capillary fringe and groundwater levels [8]. According to our results, *P. pinaster*'s productivity and suitability for commercial purposes could be severely affected in the near future in the semi-arid area of Southern Portugal.

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Aknowledgments:
This work was partially supported by the ongoing PIEZAGRO project (PTDC/AAG-REC/7046/2014) and former projects (PTDC/AAG-GLO/4155/2012, PTDC/AGR-CFL/099614/2008) funded by the portuguese Fundação para a Ciência e a Tecnologia (FCT). Ana Russo thanks FCT for granted support (SFRH/BPD/99757/2014)

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