Micro- and macromorphological responses in foliage of Scots pine to changes in soil water availability

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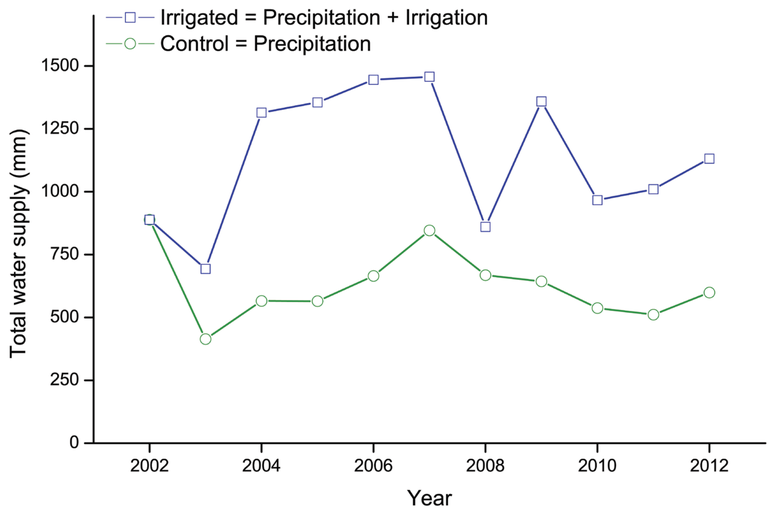
Introduction

In central Europe the last few decades have shown parallel increases in average temperature, drought frequency and in the number of declining stands of Scots pine trees. Since 2003, an irrigation experiment was established in central Valais (615 m a.s.l.), to test whether re-occurring drought is pre-disposing or triggering Scots pine decline.

Objective

Analyze cell to canopy-level responses in tree foliage in response to an increased water supply.

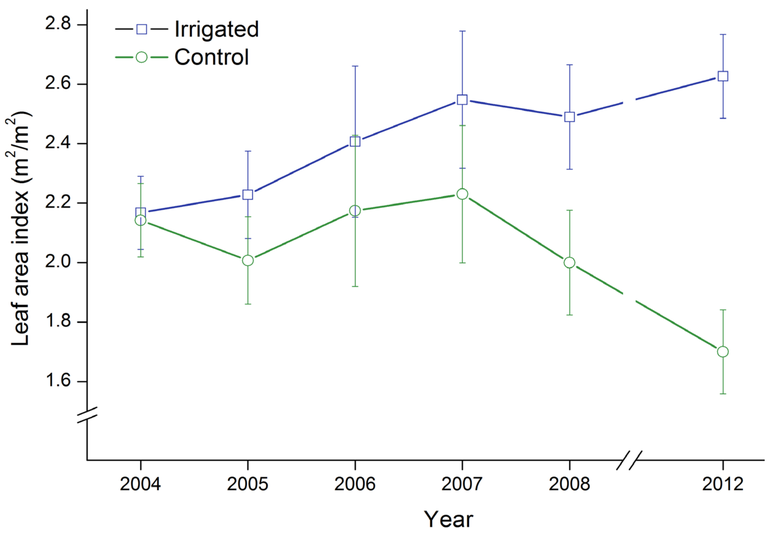


Method

- Leaf area indices were measured using hemispherical pictures.
- Shoot and needle growth were determined using branches with at least three needle generations from two harvests taken in Autumn 2006 and 2012.
- Histological structures in needle cross-sections were measured under the optical microscope using three needle generations collected in the harvest 2006.

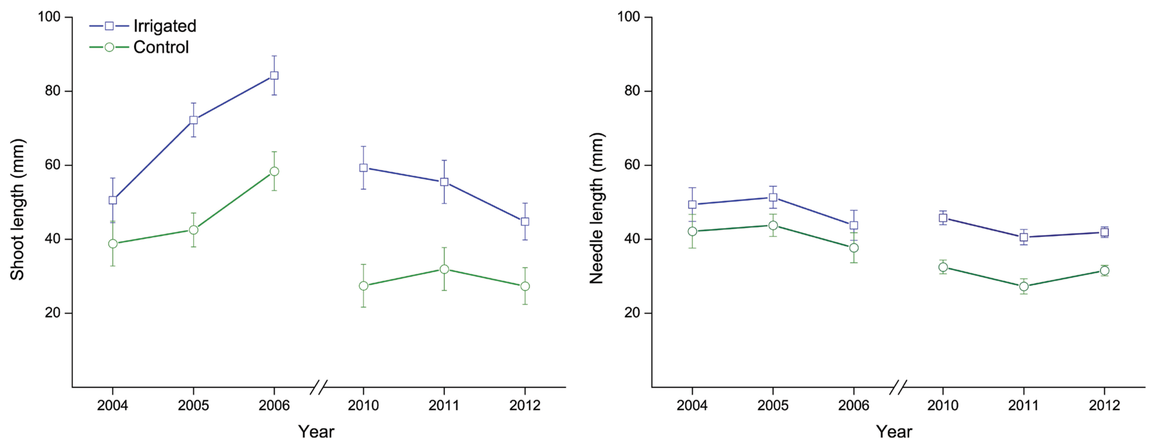
Result 1: Leaf area indices

- The irrigation treatment positively influenced leaf area index from 2005 on.
- Using ANOVA to analyze yearly effects, the results show a significant ($p < 0.05$) difference between treatments in 2008 and a highly significant ($p < 0.01$) difference in 2012.
- Using GLM to analyze processes over time, the irrigation treatment has significantly ($p < 0.01$) increased leaf area indices.
- On average, the canopy density of the irrigated trees more than doubled in 2012.



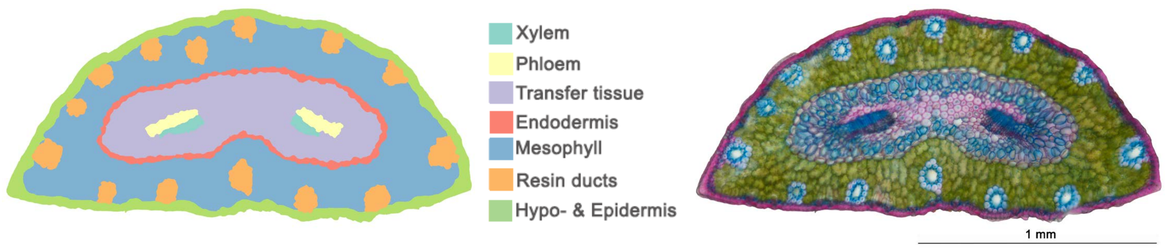
Result 2: Shoot and needle growth

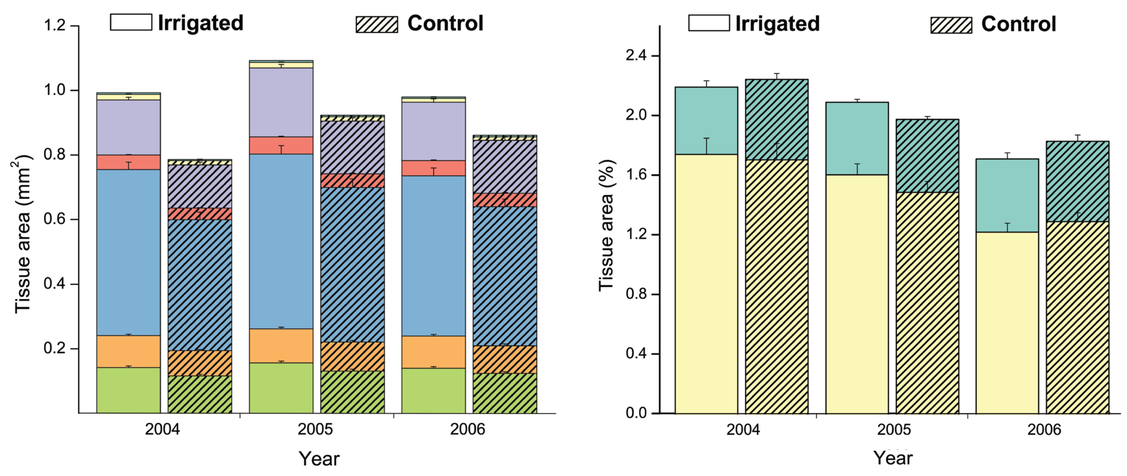
- Since 2004, shoot and needle growth have positively responded to increased water availability.
- Shoot length significantly ($p < 0.01$) increased through the irrigation treatment (ANOVA with repeated measures).
- Needle length showed the same effect ($p < 0.05$).



Result 3: Needle histology

- Similarly, the surface area of all tissues in needle cross-sections significantly increased on irrigated plots (ANOVA with repeated measures).
- However, cuticle thickness remained the same (not shown), as did the relative area of each tissue type.





Conclusion

- Irrigated trees show a positive response in shoot and needle growth which resulted in significantly higher leaf area indices.
- Needle cross-sections showed that all tissues profited equally from an elevated water supply.

However:

- Needle xeromorphic traits did not respond to the irrigation treatment.
- We expected a physiological response of foliage to drought, e.g. a thicker cuticle to prevent water loss through transpiration.

→ Water shortage is limiting the growth of Scots pine trees via carbon shortage

→ Competition for limited water supply, rather than a physiological response to drought, triggers Scots pine decline.