Intrinsic Water Use Efficiency of Loblolly Pine in Southeastern United States is affected by Drought

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INTRODUCTION

Contributing to 36% of the sequestered forest carbon in the conterminous United States (USA), the southern forests of the USA are dominated by loblolly pine (*Pinus taeda* L.) plantations. As the future climate may increase drought frequency and intensity (Will et al., 2015), it is crucial to evaluate the effect of drought on loblolly pine plantation ecosystems. As a key parameter in carbon and water cycles of terrestrial ecosystems, water use efficiency is affected by climate, species- and site characteristics (Barbour et al., 2010), and stand structure (Moreno-Gutierrez et al., 2012). However, the magnitude of these effects and interactions are not well understood. The objective of this study is to understand the response of loblolly pine to drought in terms of intrinsic water use efficiency (iWUE) and establish a relationship between the iWUE and environmental variables among 85 sites in the southeastern USA.

MATERIALS AND METHODS

Loblolly pines from 84 loblolly pine plantations established from 1984 through 2002 in 10 states in southeastern USA (AL, AR, FL, GA, LA, MS, NC, SC, TX, VA) were sampled. Eight trees per site were cored at breast height from 2012 through 2014. Cores were cross-dated using the identification of signature years and the program COFECHA. The Palmer's drought index (PDSI) was used to identify meteorological wet and dry years for each climatological division where sites are located. For sites established later than 1995, recent years were chosen to avoid juvenile effects on stable isotope signatures. Latewood α-cellulose was extracted using a modified version of the method developed by Wieloch et al (2011). The ^{13}C and ^{18}O stable isotope ratios of the extracted α-cellulose were determined at the Cornell University Stable Isotope Laboratory.

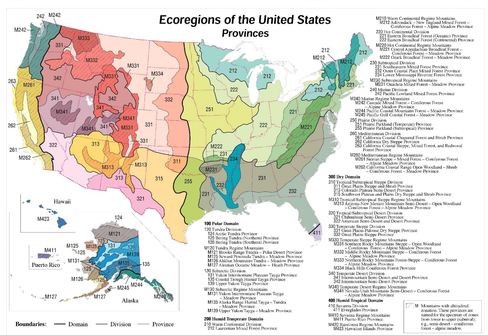
iWUE is calculated with δ13C values of the extracted α-cellulose ($\delta 13C_{plant}$)

$$iWUE = 0.625 * c_a[1 - \frac{\delta^{13}C_{plant} - \delta^{13}C_{air} + a}{b - a}]$$

where a is the discrimination against $^{13}CO_2$ during diffusion through the stomata (–4.4‰), b is the net discrimination due to carboxylation (-27‰), c_a is ambient CO_2 concentrations, and $\delta 13C_{air}$ is the isotopic signature of the air.

Geographic variation in loblolly pine is complex. According to Ecoregions in conterminous United States (Omernik 1987) and seed transfer zone (Schmidtling 2001), the study area encompasses 5 regions: 231_1, 231_2, 232_1, 232_2, and 232_3.

Linear mixed-effect linear model was used to assess the influence of PDSI on iWUE, with site identity considered as a random factor. Models were fitted based a restricted maximum likelihood method and the analyses were performed using lme4 package in R software (version R 3.2.2; R development Core Team 2015).

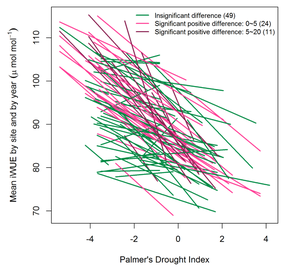


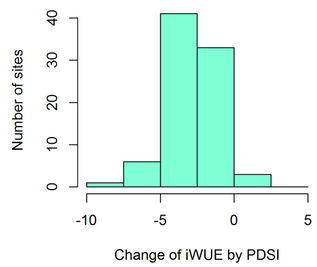
Ecoregions of the United States

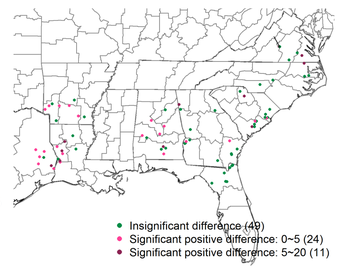
RESULTS

iWUE response to drought

- iWUE ranged from 50.7 to 126.2 μmol/mol, and differed as much within each ecoregion as across them.
- The change of iWUE by 1 unit of PDSI varied from -9.66 μmol/mol to 0.95 μmol/mol, with an overall mean of -2.82 μmol/mol. The change of iWUE in 74 sites (88% of the sites) is between -5 and 0 μmol/mol.
- 42% of the 84 sites showed a significant response to drought in their iWUE. Less sites responded to drought significantly in the eastern than the western area, especially on the eastern coast.
- Local variability indicate genetics and local site attributes such as topography and soils types affected the response of iWUE.





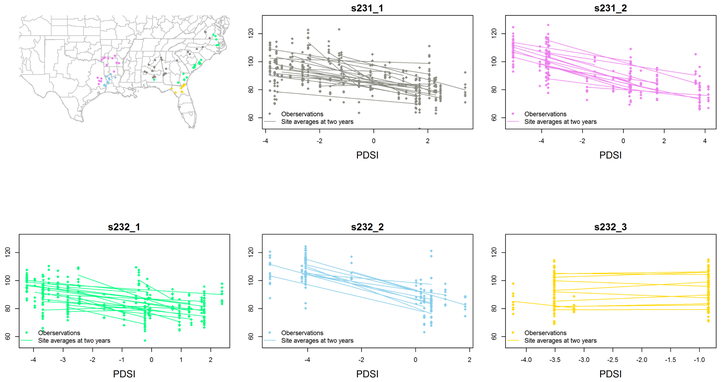


Regional differences

- The drought sensitivity of iWUE differed between ecoregions, with the greatest response per unit PDSI in the more continental climates in ecoregions 231_1, 231_2 and 232_2 compared to the east coast regions 232_1 and 232_3.

The fixed effects of PDSI at each region

Regions	n	Intercept	Slope
231_1	24	86.93	-3.44
231_2	16	87.72	-3.25
232_1	22	83.84	-2.86
232_2	11	87.54	-4.31
232_3	11	91.26	-0.23



FUTURE WORK

- Combine analysis of both $\delta^{13}C$ and $\delta^{18}O$ to understand how loblolly pine respond to drought in southeastern USA.

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