The Effects of Increasing Atmospheric CO_2 Levels on Tree Growth and Carbon Isotope Uptake

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Background

- Atmospheric CO_2 levels have increased by over 20% in the last 50 years (NASA, 2017), driving increased temperatures and drought (Swann et al., 2016)
- High atmospheric CO_2 can also lead to decreased drought sensitivity due to increased CO_2 uptake per unit water loss (Fig 1)
- Using isotopic carbon uptake recorded by $\delta^{13}C$ in tree rings, we can better understand whether changes in atmospheric CO_2 has affected tree growth and drought sensitivity

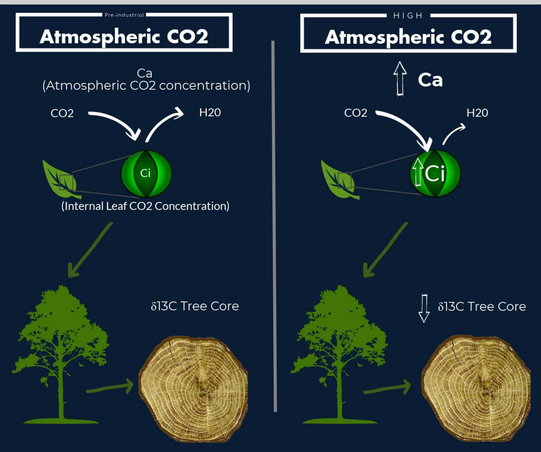


Figure 1. Changes in carbon uptake due to increased atmospheric CO_2 are recorded in $\delta^{13}C$ of tree rings. (Heilman, 2018)

Question

- Has increased atmospheric CO_2 altered tree growth and isotopic carbon uptake ($\delta^{13}C$) measured in annual tree rings?

Hypothesis

- Rising CO_2 levels will increase carbon isotope discrimination (decrease $\delta^{13}C$) , potentially leading to enhanced tree growth or decreased drought sensitivity

Methods

- Determining tree growth: Trees were cross dated, measured with Tellervo, and statistically confirmed with COFECHA software
- Stable Isotope Analysis: EA IRMS used to quantify $\delta^{13}C$ isotopic ratio and adjusted to account for Seuss Effect
- Compared detrended tree growth data from Bonanza Prairie trees to Palmer Drought Severity Index (PDSI) and atmospheric CO_2 levels

Results

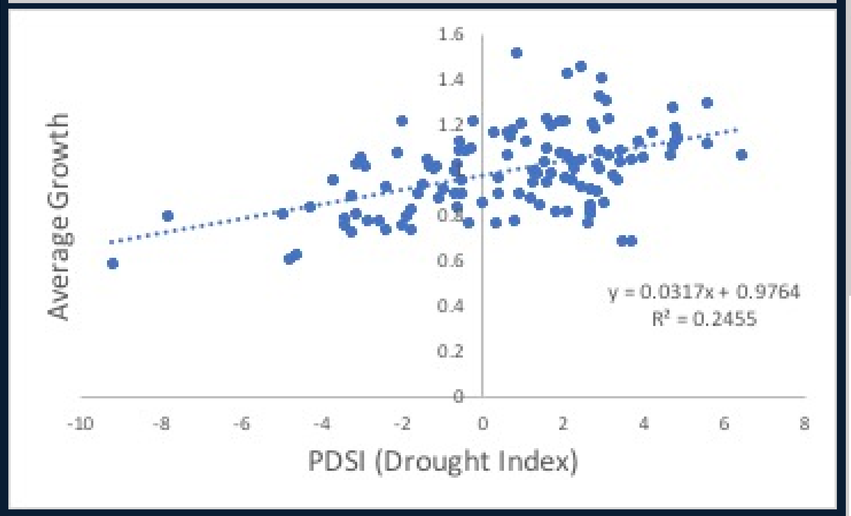


Figure 2 : Comparison of average growth to PDSI. PDSI values from July of years 1895 – 2017 were obtained from the National Climate Data Center. There was a significant correlation between average growth and PDSI (R^2= 0.2455, p=7.5645E-09). There was no significant correlation between PDSI and $\delta^{13}C$ levels.

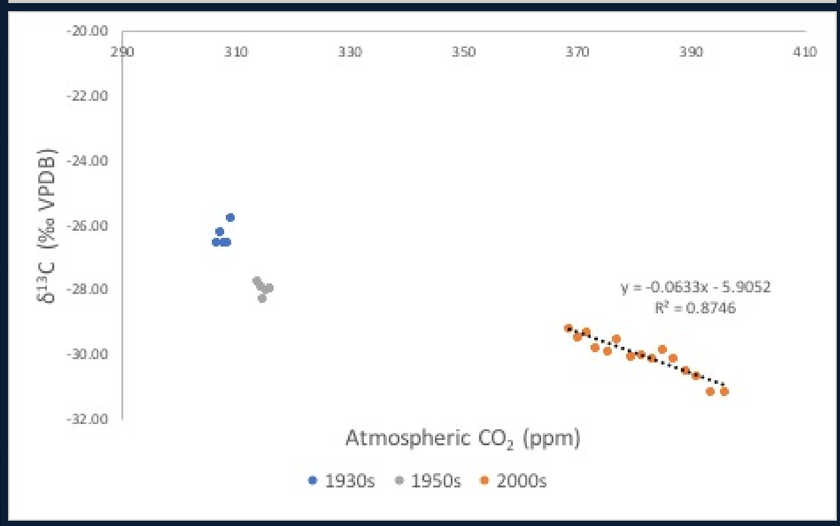
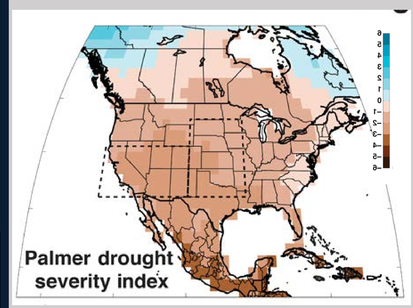


Figure 3. Comparison of isotopic CO_2 to atmospheric CO_2 in the 1930s, 1940s, and 2000s. Atmospheric CO_2 values were obtained form the Mauna Loa Station. In the 1930s, $\delta^{13}C$ is strongly related to atmospheric CO_2 (R^2= 0.302, p=0.002). In the 1950s, $\delta^{13}C$ is only marginally related to CO_2 concentration (R^2=0.131, p=0.6188). In the 2000s, $\delta^{13}C$ is strongly related to atmospheric CO_2 (R^2 =0.7808, p=0.0055). Overall, $\delta^{13}C$ decreases with increasing atmospheric CO_2.

Discussion

- As atmospheric CO_2 increases, the $\delta^{13}C$ levels also decrease, leading to trees that are less sensitive to drought because the trees require less water for the same carbon intake, supporting our hypothesis
- While these results indicate potential drought resilience from high atmospheric CO_2, whether this increase resilience can outweigh the impacts of future increased drought severity (Fig 4) remains unknown.



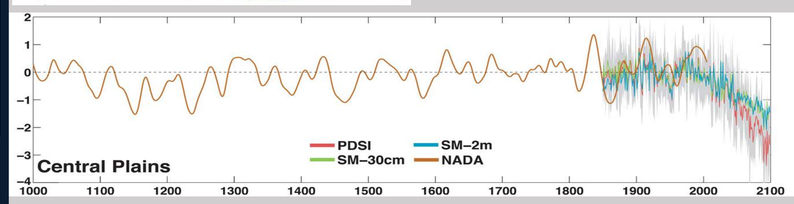


Figure 4. (a) Projected PDSI of North America. (left) **(b) Projected PDSI relative to historically observed summer droughts.** (below) (Cook et al., 2015)

- Future experimentation would include determining how much drought resilience is needed to offset future droughts in the region and measuring studying the $\delta^{13}C$ of trees in areas facing more extreme drought scenarios than trees in Minnesota

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