Physiological mechanisms related to drought mortality of mid-rotation loblolly pine (*Pinus taeda* L.)

Adam O. Maggard, PhD Student**, Rodney E. Will,** Professor, **Cassandra R. Meek,** Research Specialist, **Casey Ausmus**, MS Student, **Duncan S. Wilson,** Assistant Professor, Department of Natural Resource Ecology and Management, Oklahoma State University, Stillwater, OK 74078.

Introduction

Increasing temperatures and decreasing or more variable precipitation is expected to impact loblolly pine (*Pinus taeda* L.) plantation productivity. The effects are unclear because of the lack of knowledge regarding the physiological mechanisms causal to drought associated mortality. A better understanding of the physiology of drought stressed trees will improve predictions of loblolly pine potential growth and improve management under different climate scenarios.

The objective of this study was to measure physiological attributes of trees until they die due to 100% throughfall exclusion.

Hypothesis

Our hypothesis is that under drought conditions, loblolly pine mortality will be related to increasingly negative xylem water potentials that will lead to hydraulic failure and cessation of photosynthesis.

Methods

- Seven-year old loblolly pine leaf gas exchange, leaf water potential, and sap flow as well as adjacent soil moisture were compared for control trees and trees for which 100% of throughfall was excluded using 3.7 m by 2.7 m rainfall exclusion structures (Figure 1). Trenching to approximately 60 cm deep was conducted to minimize lateral water movement (Figure 2). This study is located in McCurtain county near Broken Bow, Oklahoma.
- Treatments consist of :
  - Excluded (~100% rainfall reduction)
  - Non-excluded (rain throughfall)

Figure 1. Rainfall excluders.

Figure 2. Trenching between rows and between trees to sever roots.

- Net photosynthesis and stomatal conductance were measured with a Li-Cor 6400 portable photosynthesis system (Li-Cor Environmental, Lincoln, NE). Measurements were conducted bi-weekly during the 2013 growing season and monthly during the winter. The first flush of the previous year's foliage was used.
- Mid-day and predawn leaf water potentials were measured with a PMS 600 pressure chamber (PMS instrument company, Corvallis, OR). Water potential measurements coincided with gas exchange measurements listed above starting in April 2013 (predawn morning before measurements, mid-day concurrent with gas exchange).
- Sap flow was measured continuously using thermal dissipation probes. Temperature differences were averaged every 15 minutes and used to calculate the rate of sap flow and whole-tree water use.
- Volumetric soil water content (VWC) was measured using Time Domain Reflectometry (TDR) (Textronix, Inc. Beaverton, OR). Measurements were conducted every 7-10 days during the growing season and every 3-4 weeks during the winter.

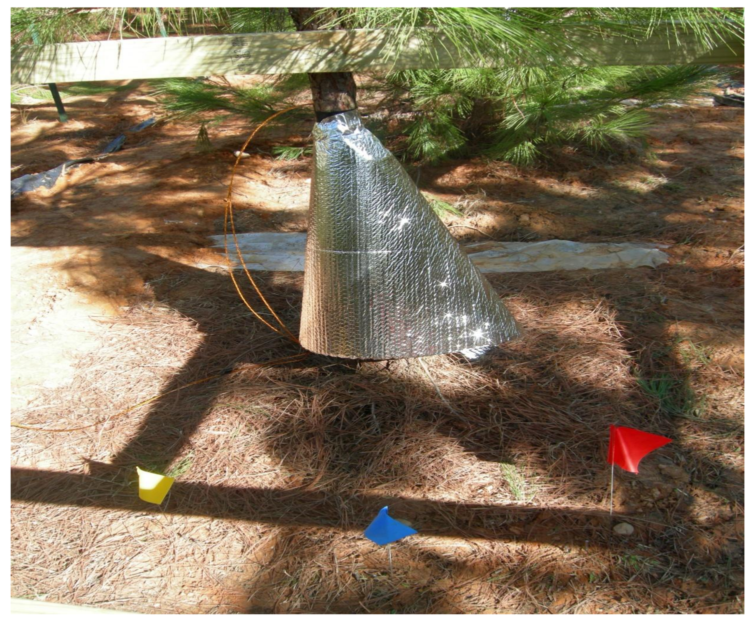

Figure 3. Thermal dissipation probes inserted and wrapped in a measurement tree, along with TDR rods at different depths in the soil.

Figure 4. Measuring leaf gas exchange.

Preliminary Results

Net photosynthesis and stomatal conductance

- Rainfall exclusion caused a decreasing trend in net photosynthesis (Figure 5A) and stomatal conductance. (Figure 5B) during the growing season.

Mid-day and pre-dawn leaf water potential

- Rainfall exclusion led to increasingly negative mid-day leaf water potential towards the end of July 2013 and in February and April 2014 (Figure 6A). Rainfall exclusion led to increasingly negative pre-dawn leaf water potential towards the end of July 2013 through October 2013 and January, February, and April 2014 (Figure 6B).

Sap flow

- Whole-tree water use varied during the growing season. Rainfall exclusion decreased whole-tree water use during several periods (Figure 7).

Growth

- Rainfall exclusion showed a trend of reduced height growth(Figure 8A) and diameter growth (Figure 8B).

Volumetric soil water content

- Rainfall exclusion decreased VWC at 0-90 cm (Figure 9A), at 0-45 cm (Figure 8B), and at 0-12 cm (Figure 8C).

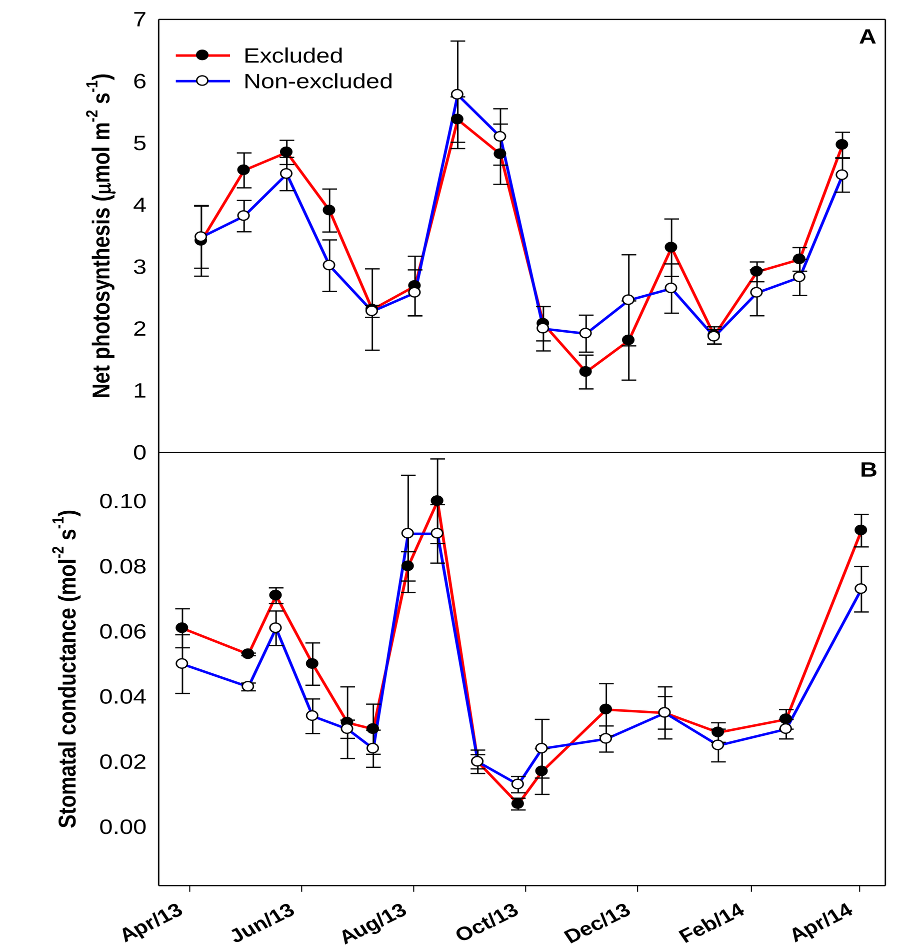

Figure 5. Net photosynthesis rate (A) and stomatal conductance (B) by treatment type.

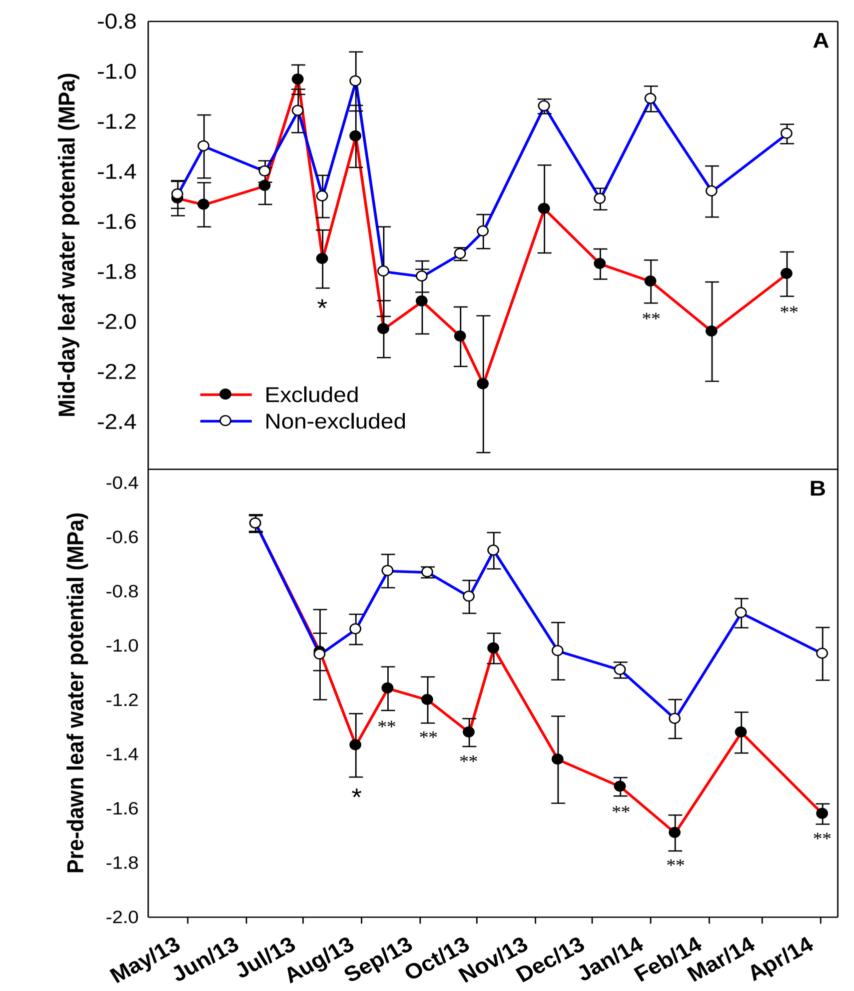

Figure 6. Mid-day leaf water potential (A) and pre-dawn leaf water potential (B) by treatment type. * indicates p<0.05. ** indicates p<0.01.

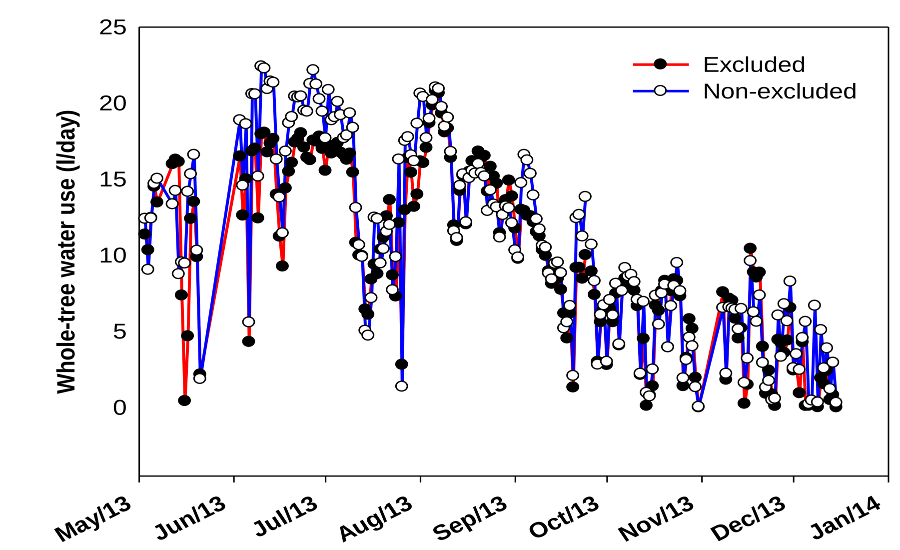

Figure 7. Whole-tree water use per day by treatment type.

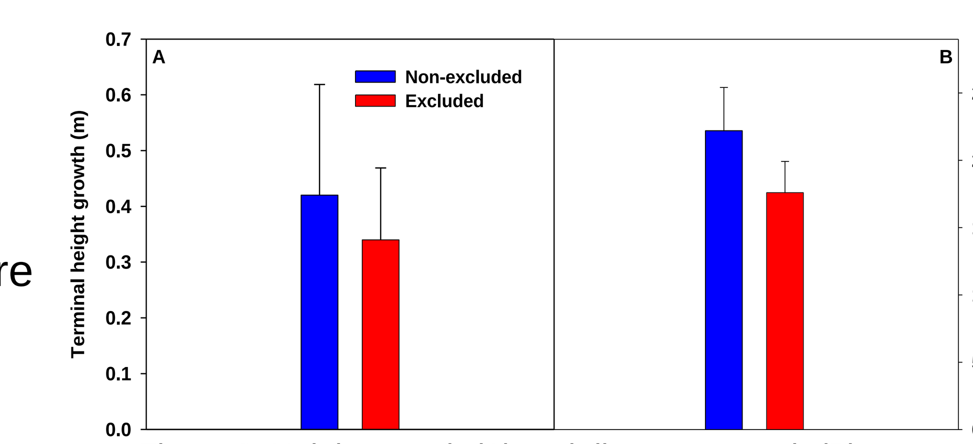

Figure 8. Height growth (A) and diameter growth (B) by treatment type.

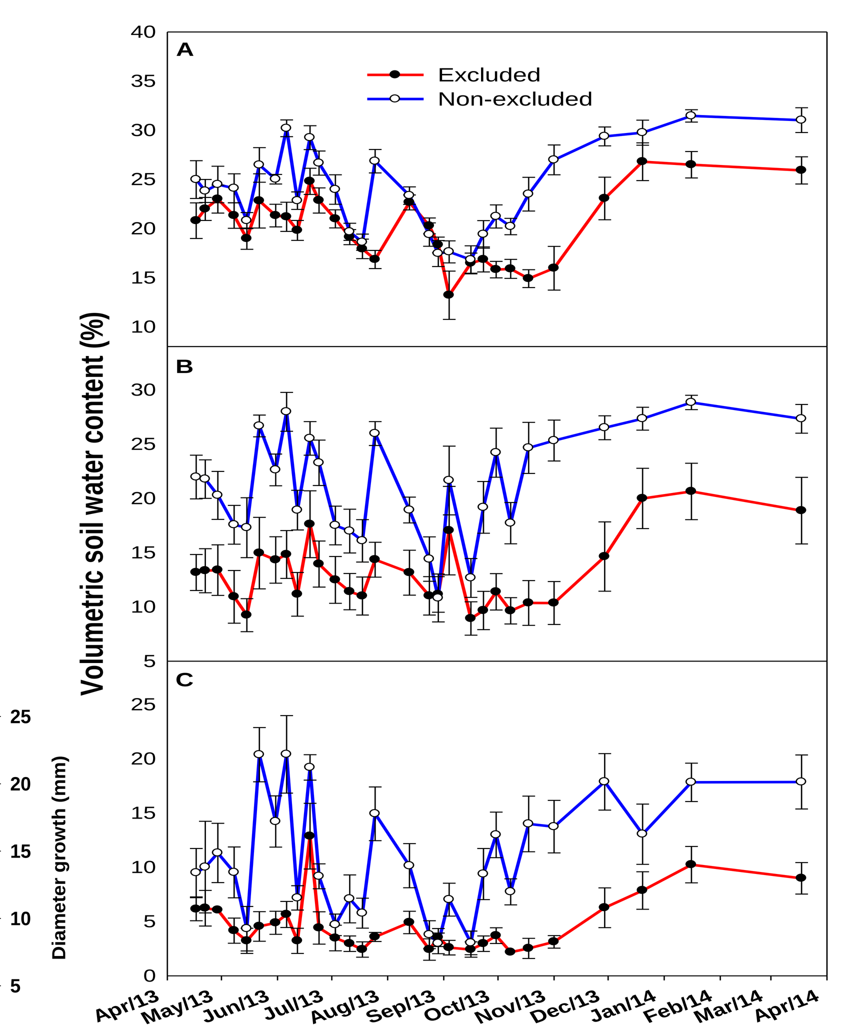

Figure 9. Volumetric soil water content at 0-90cm (A), 0-45cm (B), and 0-12cm (C) by treatment type.

Conclusion

Not surprisingly, preliminary results suggest that drought causes a reduction in net photosynthesis and stomatal conductance, more negative leaf water potential, and decreased water use associated with decreased availability of soil water content. Even an entire growing season after treatment, drought stressed trees are still physiologically active and not yet showing signs of severe drought stress. Given the increase in soil moisture this winter, soil may be receiving moisture from deep movement of water or overland flow.

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USDA United States Department of Agriculture National Institute of Food and Agriculture