EARLY IMPACTS OF RAINFALL MANIPULATION AND FERTILIZATION ON THE ECOPHYSIOLOGY OF LOBLOLLY PINE AT THE GEORGIA PINEMAP TIER III EXPERIMENT

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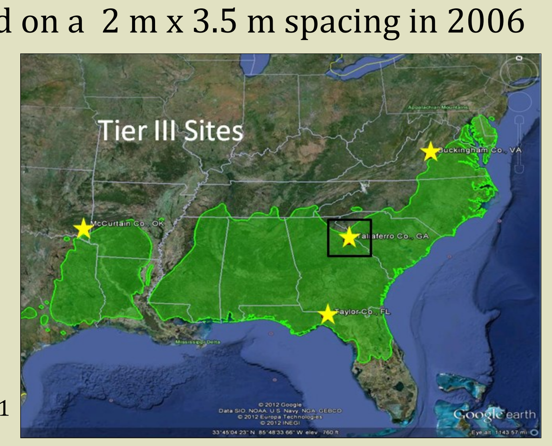
Introduction

Climate change in the southeastern United States may impact productivity and carbon sequestration in loblolly pine. Climate models predict increases in temperatures from 2 to 5°C along with decreases in summer precipitation of 10 to 30% throughout the region over the next century (Christensen et al. 2007). As part of PINEMAP, the Silviculture and Ecophysiology AIM has established four study sites located within loblolly pine's distribution to evaluate the effects of climate, soils and management approaches on planted pine carbon sequestration.

The region wide monitoring network created by the Silviculture and Ecophysiology aim is examining the effects of reduced water availability combined with fertilization on loblolly pine productivity. A key question is whether interactions between water and nutrient availability will develop over time. Fertilization has been shown to have large, positive influences on the aboveground productivity of southern pines, which are mainly attributed to increases in leaf area and intercepted radiation. Decreases in water availability can have negative effects on productivity, including decreases in leaf area, intercepted radiation and photosynthetic capacity. Interactions between reduced water availability and fertilization are not yet fully understood. For example, increased leaf area from fertilization may cause greater water stress during times of drought. **The main objective of this study is to examine the interactive effects of varying water and nutrient availability on leaf area, intercepted radiation, photosynthetic capacity and productivity.**

Methods

The study site is located in Taliaferro County, GA and was planted on a 2 m x 3.5 m spacing in 2006 (1544 trees ha^{-1}). Loblolly pine seedlings were from a second generation open pollinated family. Trees were 6 years-old at study initiation. The experimental design is a 2 x 2 factorial randomized complete block with 4 replications:



Tier III throughfall rain exclusion experiment sites with GA site highlighted

Treatments:

Fertilization treatments:

1) No Fertilization
2) Fertilization- addition of 224 kg ha^{-1} N, 28 kg ha^{-1} P, 56 kg ha^{-1} K and a micro-nutrient blend. Fertilization was applied on March 28th 2012.

Rainfall manipulation treatments:

1) Ambient rainfall
2) Rain exclusion- rain throughfall exclusion trays were installed in early May 2012 to divert 30% of rainfall off of the plot by covering 30% of the ground area.

Field Measurements:

Intercepted Photosynthetically Active Radiation (IPAR)

IPAR was measured using a line quantum sensor (LI-191, Li-Cor Inc., Lincoln, NE) along three permanent transects, with 10 sampling points per transect in each plot.

Leaf Area Index (LAI)

Leaf area index was measured using the LAI-2000 plant canopy analyzer (Li-Cor Inc., Lincoln, NE). Measurements were made along three diagonal transects between rows with eight sample points on each transect within each plot.

Photosynthetic Capacity

Light-saturated net photosynthesis (P_{net}) and stomatal conductance (g_s) were measured using a portable gas exchange system (LI-6400, Li-Cor Inc., Lincoln, NE) at a PAR 1800 µmol m^{-2} s^{-1}. Foliage from the upper third of the canopy was measured on three trees per plot between the hours of 0900 and 1400.

Water Potential

Leaf water potential (Ψ_L) was measured using a pressure chamber (PMS Instrument Corp., Corvallis, OR). Predawn Ψ_L was measured on the same trees selected for gas exchange measurements. Midday Ψ_L was measured on same shoots used for gas exchange measurements.

Soil Moisture

Soil moisture was measured between trees and between rows using the hydro sense II soil-water sensor (Campbell Scientific Inc.). Between row and between tree measurements were averaged to calculate soil moisture. Soil moisture was measured during gas exchange measurement.

Foliar nitrogen and δ^{13} C

Foliar nitrogen and δ^{13} C were measured on foliage produced in 2012 in October of 2012. Shoots from three trees in each plot were cut from the upper third of the canopy. Foliage was separated by flush then dried and ground into powder and sent to Duke Environmental Stable Isotope Laboratory and Auburn Soil Testing Laboratory for δ^{13} C and nitrogen analysis, respectively.

Statistical Analysis:

Gas exchange variables were separated into two groups: growing season (April-Oct) and non growing Season (Nov-March). All statistical analyses were performed using SAS and the PROC MIXED procedure (SAS Statistical Institute, Cary, NC). All data were averaged by month, block and treatment. Main effects and interactions were considered significant at α=0.05.

Results

Growth

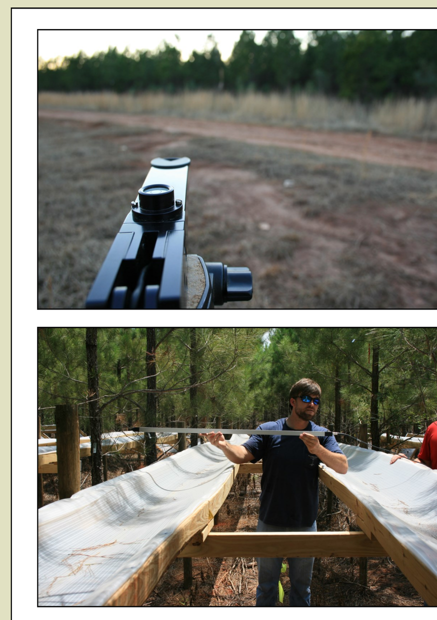
- No interactive effects of rainfall manipulation and fertilization on growth have been observed.
- Fertilization increased Ht, DBH, BA and BAI (Table 1).
- The rainfall exclusion treatment had lower DBH, BA and BAI when compared to ambient rain treatment (Table 1)
- Height was not affected by the rainfall manipulation treatment (Table 1).

Table 1. Influence of fertilization and rainfall manipulation treatments on mean (±SE) diameter at breast height (DBH), height (Ht), basal area (BA) , and Basal Area Increment (BAI) of loblolly pine after one year of treatment . Asterisks indicate significant difference between treatments.

Treatment	DBH (cm)	Ht (m)	BA (m^2 ha^{-1})	BAI (m^2 ha^{-1} yr^{-1})
No Fertilization	10.4 (0.3) *	7.1 (0.2) *	11.7 (0.6) *	3.1 (0.1) *
Fertilization	10.8 (0.3)	7.3 (0.2)	12.5 (0.6)	3.9 (0.2)
Ambient Rain	10.8 (0.3)*	7.3 (0.2)	12.3 (0.7) *	3.9 (0.2) *
Rain Exclusion	10.5 (0.3)	7.2 (0.2)	11.9 (0.5)	3.2 (0.2)

LAI, IPAR

- No interactive effects of rainfall manipulation and fertilization treatments on LAI or IPAR have been observed.
- Peak LAI occurred in September. At peak LAI, fertilized plots had 16% greater LAI than non-fertilized plots (Figure 1).
- No significant differences between rainfall manipulation treatments were detected for LAI and IPAR in any month (Figure 1).
- IPAR was also highest in September and fertilized plots intercepted more radiation when compared to non-fertilized plots in August 2012, September 2012 and March 2013 (Figure 1).



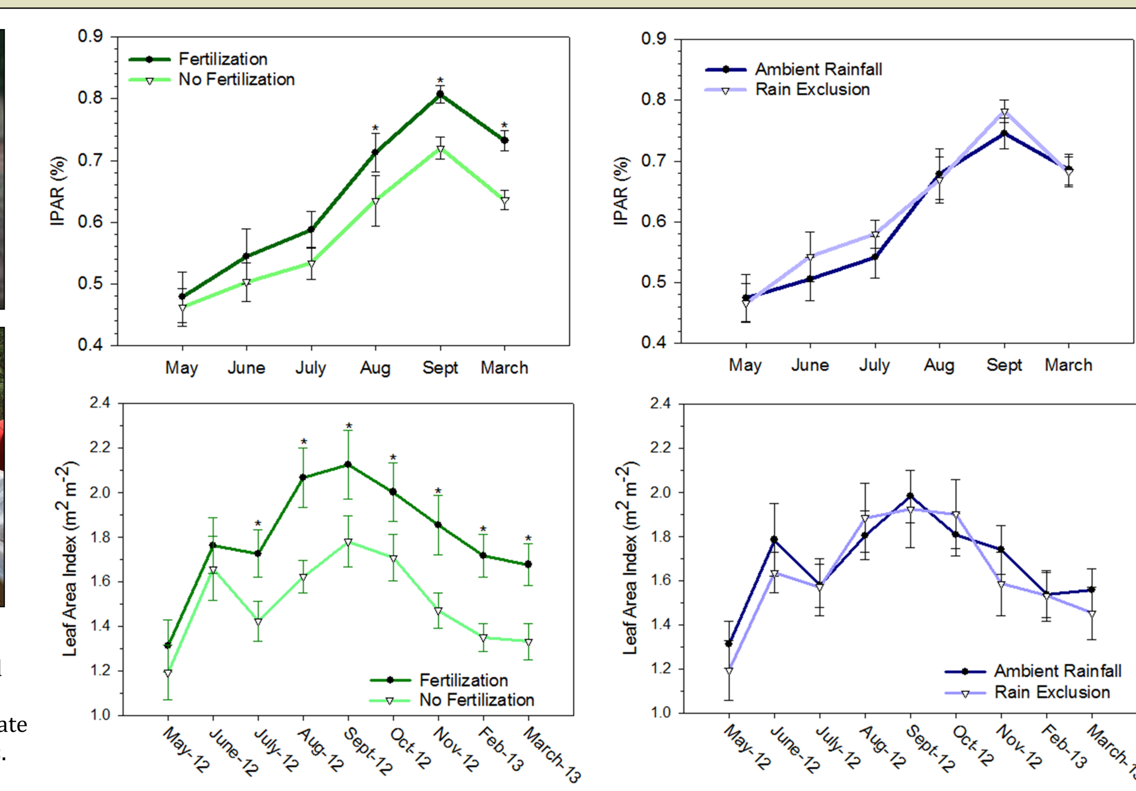


Figure 1. Mean (±SE) response of LAI and IPAR to fertilization and rainfall manipulation treatments. Asterisks indicate significant difference between treatments.

Soil Moisture

- No interactive effects between rainfall manipulation and fertilization treatments on soil moisture have been observed.
- On average the fertilization treatment decreased soil moisture by 12% when compared to the non-fertilization treatment (Figure 2).
- On average soil moisture decreased from 16.4% in the ambient rain treatment to 14.8% in the rain exclusion treatment (Figure 2).

Figure 2. Mean (±SE) response of soil moisture to fertilization and rainfall manipulation treatments. Asterisks indicate a significant treatment effect.

Leaf Physiology

Growing Season (Jul 2012-Oct 2012)

- No interactions between rain manipulation and fertilization treatments or treatments and month of measurement were detected for any leaf physiological variable.
- During the growing season predawn Ψ_L decreased from −0.60 in the ambient rain treatment to −0.69 in the rainfall exclusion treatment (Figure 3).
- Average P_{net} decreased from 4.49 µmol m^{-2} s^{-2} in the ambient rain treatment to 4.05 µmol m^{-2} s^{-2} in the rainfall exclusion treatment (Figure 3).
- Average g_s decreased by 19% in the rainfall exclusion treatment (Figure 3).
- Significant month effects were observed for P_{net}, g_s, and predawn Ψ_L (Figure 3).
- There was a trend (P= 0.167) towards an increase in P_{net} in the fertilization treatment.

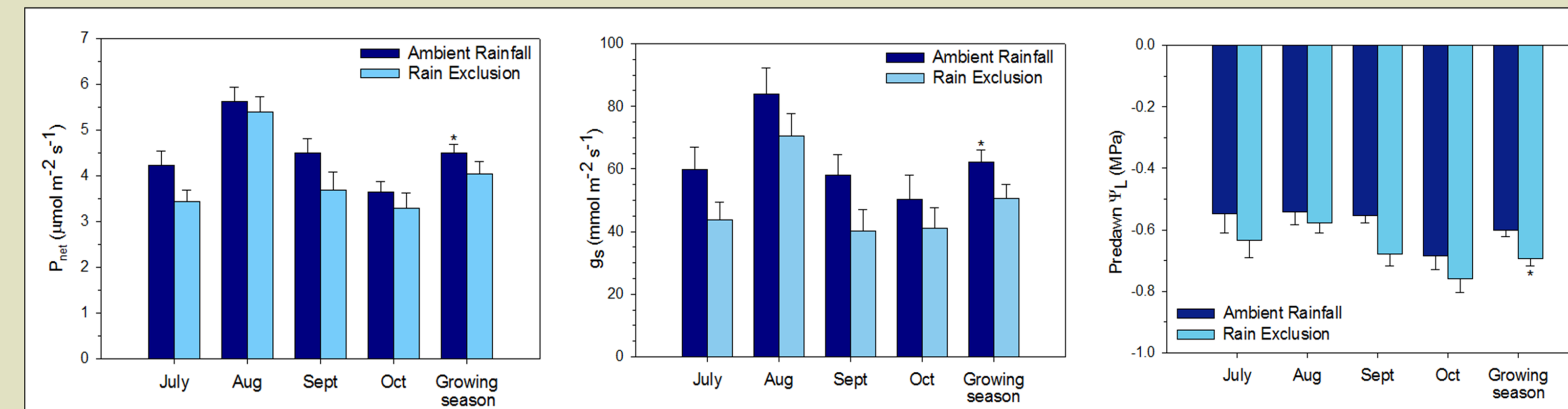


Figure 3. Mean (±SE) P_{net}, g_s, and predawn Ψ_L in response to rainfall manipulation treatments during the growing season of 2012. Asterisks indicate a significant treatment effect.

Non-Growing Season (Nov 2012-Mar 2013)

- No interactions between rain manipulation and fertilization treatments or treatments and month of measurement were detected for any leaf physiological variable.
- Predawn Ψ_L was 10% lower in the rain exclusion treatment (Figure 4).
- Average P_{net} and g_s were reduced by 9% and 15%, respectively in the rain exclusion treatment (Figure 4).
- Significant months effects were observed for P_{net}, g_s, and Ψ_L (Figure 4).

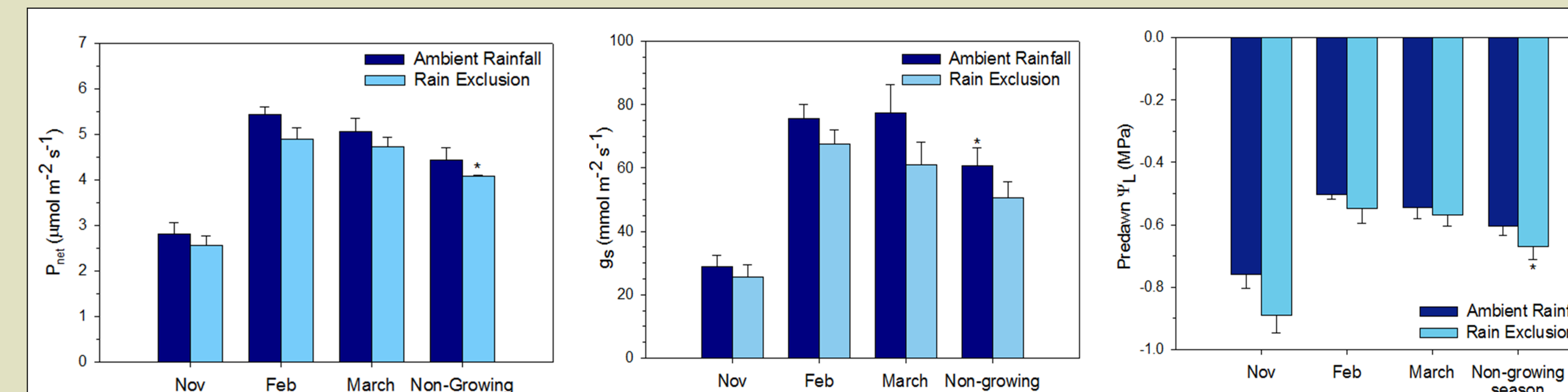


Figure 4. Mean (±SE) P_{net}, g_s, and predawn Ψ_L in response to rainfall manipulation treatments during the non-growing season of 2012-2013. Asterisks indicate a significant treatment effect.

Foliar δ^{13} C and Nitrogen

- No interactions between treatments or foliage age were observed.
- Fertilization decreased the amount of discrimination against δ^{13} C, most likely due to small increases in P_{net} (Table 2).
- Foliar δ^{13} C increased from −29.03% in the ambient rainfall treatment to −28.54% in the rain exclusion treatment, indicating an increase in water use efficiency (Table 2).
- Foliar nitrogen increased in fertilized plots and decreased in rain exclusion plots (Table 2).

Table 2. Influence of fertilization and rainfall manipulation treatments on mean (±SE) foliar δ^{13} C and foliar nitrogen (N) of the 1st and 2nd flushes produced in 2012. Asterisks indicate significant difference between treatments.

Treatment	δ^{13} C (%)	N (%)
Fertilization	-28.63 (0.1) *	1.66 (0.1) *
No Fertilization	-28.94 (0.1)	1.38 (0.1)
Ambient Rain	-28.54 (0.1) *	1.56 (0.1) *
Rain Exclusion	-29.02 (0.1)	1.46 (0.1)

Conclusions

No interactive effects of rainfall manipulation and fertilization treatments on LAI, IPAR, or leaf gas exchange have been observed. Fertilization increased foliage production, while the rain exclusion treatment decreased P_{net}, g_s and predawn Ψ_L. Water use efficiency increased in both fertilization and rain exclusion treatments. We have observed early effects of treatment on loblolly pine physiology and growth. Unless hydraulic adjustments occur over time, these results suggest that future increases in drought will impact loblolly pine productivity and carbon

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