Long-term Interactive Effects of Throughfall Exclusion and Fertilization on Physiology of Loblolly Pine (*Pinus taeda* L.)

Charles J. Pell[1], Lisa J. Samuelson[1], Tom A. Stokes[1], Stan M. Bartkowiak[1], Madison K. Akers[2], Michael Kane[2], Daniel Markewitz[2], Mary Anne McGuire[2], and Robert O. Teskey[2]

[1]School of Forestry and Wildlife Sciences, Auburn University

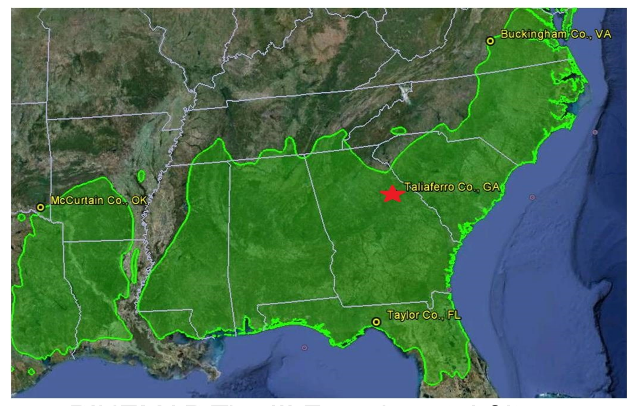
[2]Warnell School of Forestry and Natural Resources, University of Georgia

PINEMAP

AUBURN UNIVERSITY — SCHOOL OF FORESTRY AND WILDLIFE SCIENCES

Introduction

The project presented here takes part in the silviculture and ecophysiology aim. The goal of this aim is to establish a region wide three-tiered monitoring network based on existing cooperative research trials, and develop standardized methods to quantify C, water, and nutrient storage and flux baselines and responses to climate change.



PINEMAP Tier III Experimental Sites

Fertilization can increase loblolly pine productivity by increasing photosynthesis and leaf area index (LAI). However, high LAI in response to fertilization may increase severity of drought effects which may limit photosynthesis. The interactive effects of throughfall exclusion and fertilization will be studied to better understand how the physiology and productivity of loblolly pine is affected by drought.

Objectives and Hypotheses

The objective of this project is to continue to quantify the interactive effects of throughfall exclusion and fertilization on factors that affect the productivity of loblolly pine including LAI, IPAR, and leaf physiology.

Hypotheses

1. Increased LAI in response to fertilization will result in soil water depletion and greater effects of rain exclusion.
2. Reduced net photosynthesis in response to rain exclusion will decrease fertilizer enhancement of LAI and growth.

Experimental Design

- This PINEMAP Tier III experimental site is a 44.5 ha loblolly pine stand located in Taliaferro County Georgia and in 2006 was planted with bare root open pollinated, genetically improved second generation loblolly pine seedlings.
- The experimental design is a 2x2 factorial combination of throughfall manipulation and fertilization treatment replicated in four blocks

Throughfall

- Ambient throughfall
- 30% reduction: trays cover 30% of plot area

Fertilization

- No fertilization
- Fertilization: 224 kg N ha^{-1}, 28 kg P ha^{-1}, 56 kg K ha^{-1}

Throughfall exclusion tray

Materials and Methods

- Leaf Area Index (LAI)
- Intercepted Photosynthetically Active Radiation (IPAR)
- Photosynthesis (P_{net})
- Soil moisture
- Leaf water potential (Ψ_L)
- Foliar nutrients and $\delta^{13}C$

LAI 2000 Canopy Analyzer

LI 6400 Portable Photosynthesis System

Results

- In 2012 precipitation was unusually low (849 mm) and 2013 was higher (1478 mm) than normal. The Palmer Drought Severity Index (PDSI) indicated drought conditions from January 2012 through June 2012 (Figure 1).
- No interactive effects were significant for any variable for any year.
- Foliar N was higher in the first than the second flush in both years and increased by fertilization both years and decreased by throughfall reduction in 2012 (Table 2).
- In 2012 neither treatment influenced DBH, basal area, or stem mass, however throughfall reduction reduced basal area increment and stemwood biomass and each were increased by fertilization (Table 1).
- In 2013 there was no significant effect of throughfall on growth but fertilization increased DBH, basal area, basal area increment, and stemwood biomass (Table 1).
- Fertilization increased peak LAI both years and peak IPAR and APAR in 2013; throughfall had no influence either year (Table 1, Figure 2).
- Throughfall reduction reduced predawn Ψ_L in both years, and fertilization had no influence either year (Figure 3).
- Throughfall reduction decreased average P_{net} in 2012 only (Figure 4).
- Throughfall reduction and fertilization treatments each increased $\delta^{13}C$ in 2012 only (Table 2).

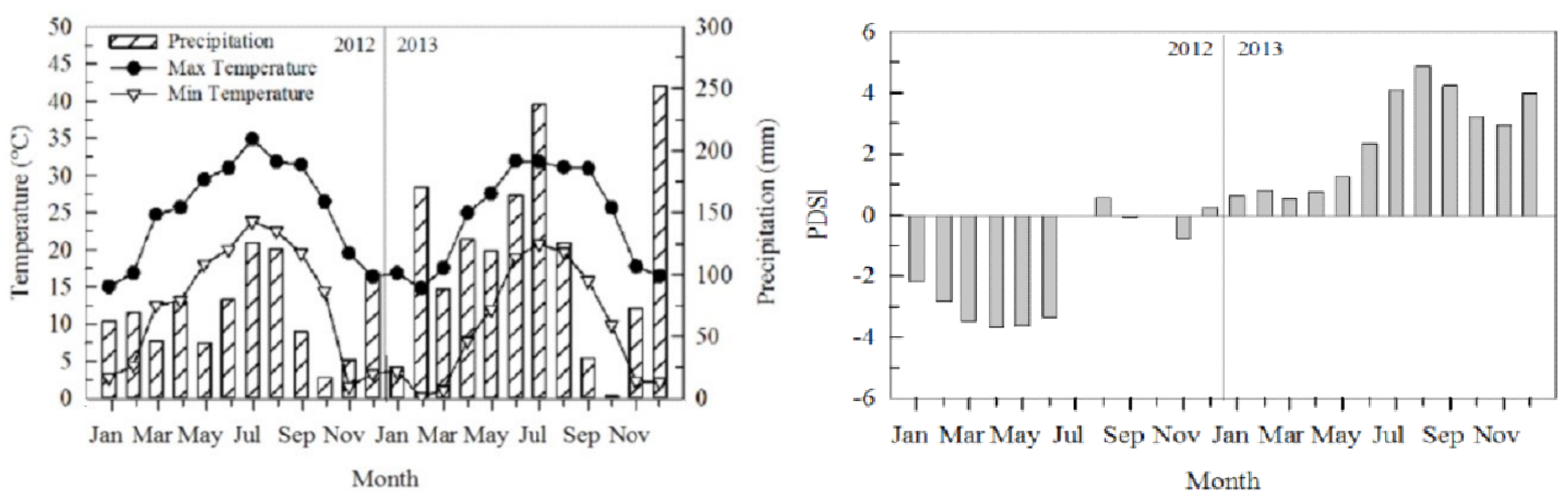


Figure 1. *Monthly precipitation, mean minimum and maximum daily temperatures, and the Palmer Drought Severity Index (PDSI) during the two year study.*

Table 1. *Influence of throughfall reduction (TR_0: no reduction, TR_{30}: 30% reduction) and fertilization ($Fert_0$: no fertilization, $Fert_+$: one-time fertilization) treatments on mean (SEM) stand characteristics, peak leaf area index (LAI), peak intercepted photosynthetically active radiation (IPAR), and absorbed photosynthetically active radiation (APAR).*

Treatment	Mean DBH (cm)	Mean height (m)	Basal area (m^2 ha^{-1})	Basal area increment (m^2 ha^{-1} yr^{-1})	Stemwood biomass (Mg ha^{-1})	Stemwood production (Mg ha^{-1} yr^{-1})	LAI	IPAR (%)	APAR (MJ m^{-2})
2012 Year-end stand and growing season attributes									
TR_0	10.6 (0.4)	7.2 (0.2)	12.4 (0.7)	3.8 (0.2)	16.3 (1.4)	6.8 (0.5)	2.0 (0.1)	66.3 (3.8)	-
TR_{30}	10.4 (0.3)	7.2 (0.2)	12.2 (0.6)	3.3 (0.2)	15.8 (1.3)	5.9 (0.4)	1.9 (0.2)	64.9 (3.3)	-
$Fert_0$	10.3 (0.3)	7.1 (0.2)	11.7 (0.6)	3.0 (0.1)	15.1 (1.3)	5.6 (0.3)	1.8 (0.1)	62.4 (3.8)	-
$Fert_+$	10.7 (0.3)	7.3 (0.2)	12.9 (0.6)	4.0 (0.2)	17.0 (1.4)	7.2 (0.4)	2.1 90.2)	68.7 (2.9)	-
P > F									
TR	0.361	0.656	0.657	**0.038**	0.599	**0.015**	0.627	0.761	-
Fert	0.084	0.437	0.054	**<0.001**	0.063	**<0.001**	**0.013**	0.2	-
TR x Fert	0.664	0.945	0.89	0.79	0.88	0.93	0.116	0.683	-
2013 Year-end stand and growing season attributes									
TR_0	12.6 (0.4)	9.1 (0.3)	17.4 (0.9)	5.0 (0.3)	29.6 (2.3)	13.3 (1.0)	3.1 (0.2)	87.6 (1.9)	1936.0 (107.2)
TR_{30}	12.3 (0.3)	8.8 (0.2)	16.8 (0.7)	4.7 (0.4)	27.6 (1.9)	11.8 (0.8)	2.7 (0.2)	85.3 (1.5)	1897.9 (99.2)
$Fert_0$	12.0 (0.3)	8.8 (0.2)	15.8 (0.6)	4.0 (0.2)	25.8 (1.8)	10.7 (0.7)	2.5 (0.1)	83.1 (1.2)	1727.3 (68.8)
$Fert_+$	12.9 (0.3)	9.1 (0.3)	18.5 (0.7)	5.7 (0.2)	31.4 (1.9)	14.4 (0.7)	3.4 (0.2)	89.8 (1.1)	2106.7 (80.1)
P > F									
TR	0.218	0.059	0.413	0.348	0.203	0.088	0.068	0.231	0.707
Fert	**0.002**	0.139	**0.003**	**<0.001**	**0.004**	**0.001**	**0.002**	**0.005**	**0.004**
TR x Fert	0.937	0.915	0.944	0.493	0.954	0.942	0.951	0.443	0.678

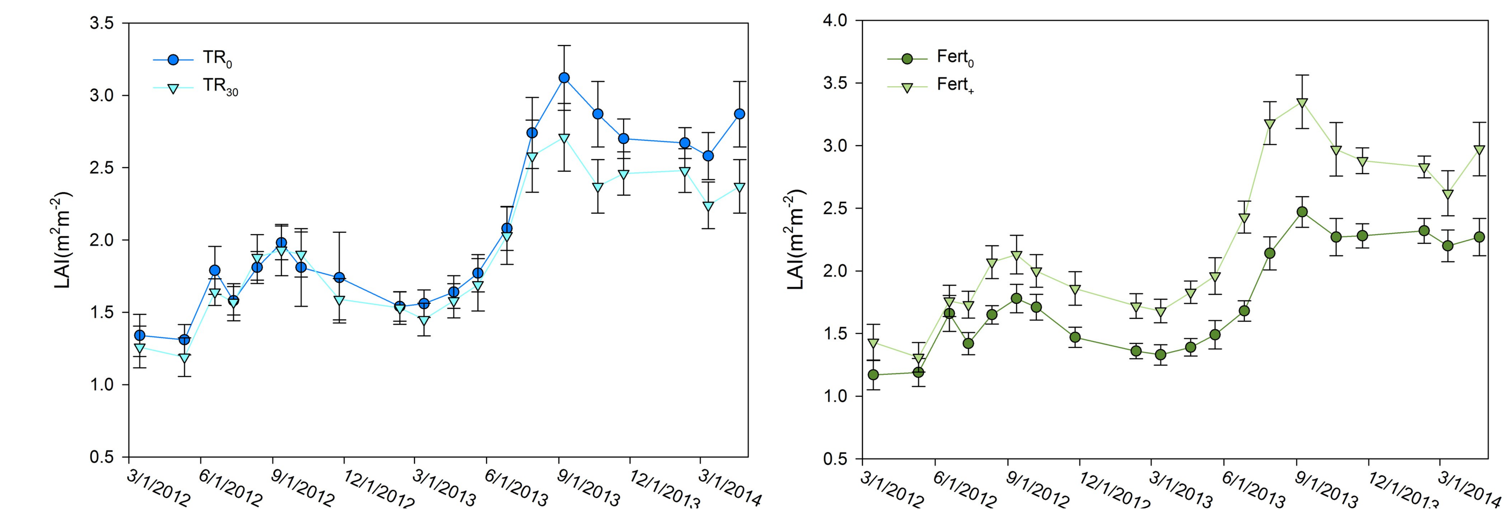


Figure 2. *Mean (SEM) leaf area index (LAI) in response to throughfall reduction (TR_0: no reduction, TR_{30}: 30% reduction) and fertilization ($Fert_0$: no fertilization, $Fert_+$: one-time fertilization) treatments.*

Table 2. *Mean (SEM) foliar nitrogen (N) concentration, foliar $\delta^{13}C$ in response to flush and throughfall reduction (TR_0: no reduction, TR_{30}: 30% reduction) and fertilization ($Fert_0$: no fertilization, $Fert_+$: one-time fertilization) treatments.*

Treatment	N 2012 (mg g^{-1})	N 2013 (mg g^{-1})	$\delta^{13}C$ 2012 (‰)	$\delta^{13}C$ 2013 (‰)
Flush1	17.4 (0.6)	14.0 (0.2)	-28.8 (0.1)	-30.6 (0.1)
Flush2	13.0 (0.4)	14.8 (0.3)	-28.8 (0.1)	-30.3 (0.2)
TR_0	15.7 (0.8)	14.6 (0.3)	-29.0 (0.1)	-30.4 (0.2)
TR_{30}	14.6 (0.7)	14.1 (0.3)	-28.5 (0.1)	-30.5 (0.1)
$Fert_0$	13.8 (0.6)	13.9 (0.2)	-28.9 (0.1)	-30.4 (0.1)
$Fert_+$	16.6 (0.7)	14.8 (0.2)	-28.6 (0.1)	-30.5 (0.2)
P > F				
Flush	**<0.001**	**0.016**	0.619	0.115
TR	**0.016**	0.102	**0.003**	0.384
Fert	**<0.001**	**0.009**	**0.049**	0.635
TR x Fert	0.508	0.833	0.185	0.086
Flush x TR	0.508	0.771	0.542	0.787
Flush x Fert	0.112	0.129	0.853	0.753
Flush x TR x Fert	0.137	0.616	0.619	0.421

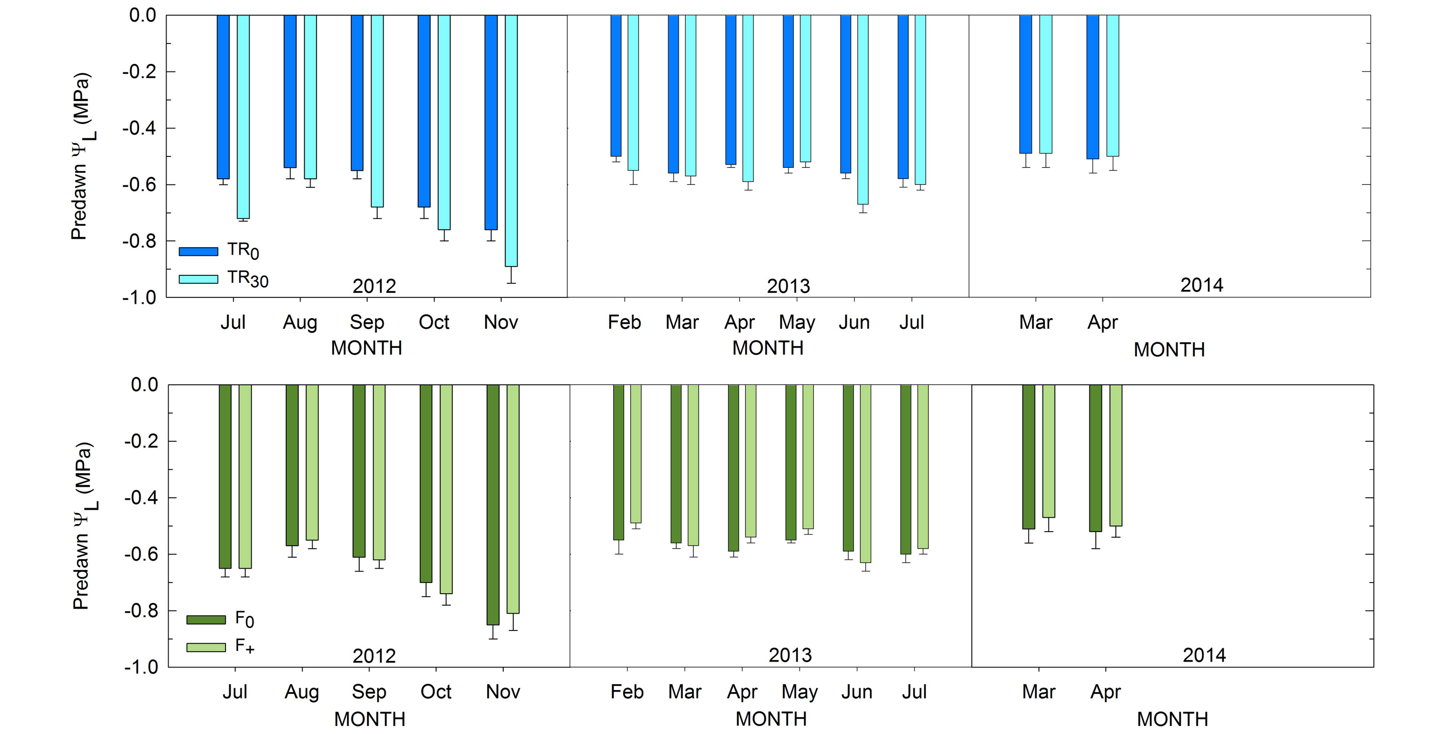


Figure 3. *Mean (SEM) predawn leaf water (Ψ_L) potential in response to throughfall reduction (TR_0: no reduction, TR_{30}: 30% reduction) and fertilization ($Fert_0$: no fertilization, $Fert_+$: one-time fertilization) treatments.*

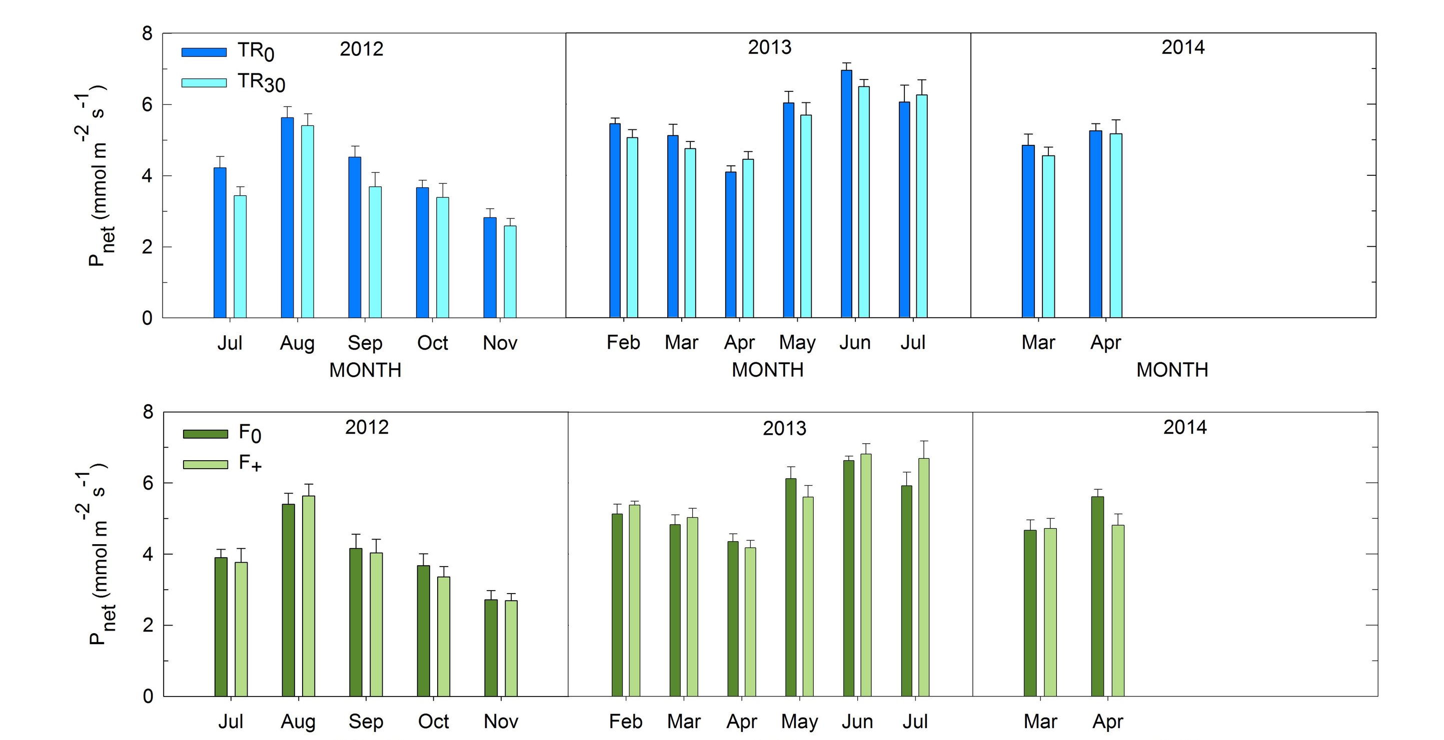


Figure 4. *Mean (SEM) leaf-saturated net photosynthesis (P_{net}) in response to throughfall reduction (TR_0: no reduction, TR_{30}: 30% reduction) and fertilization ($Fert_0$: no fertilization, $Fert_+$: one-time fertilization) treatments.*

Conclusions

- No interactions between throughfall and fertilization treatments were observed possibly due to high inter-annual variability in climate.
- Throughfall reduction reduced P_{net}, growth, and increased leaf water use efficiency during a dry but not a wet year.
- Fertilization had the greatest impact on growth, LAI, IPAR, and APAR.
- Long-term study of the effects of nutrient availability and changing precipitation under a range of climate conditions is needed.

Acknowledgments

The Pine Integrated Network: Education, Mitigation, and Adaptation project (PINEMAP) is a Coordinated Agricultural Project funded by the USDA National Institute of Food and Agriculture, Award #2011-68002-30185.

USDA NIFA