

# Interactive Effects of Throughfall Reduction and Fertilization on Water Use of 8-Year-Old Loblolly Pine

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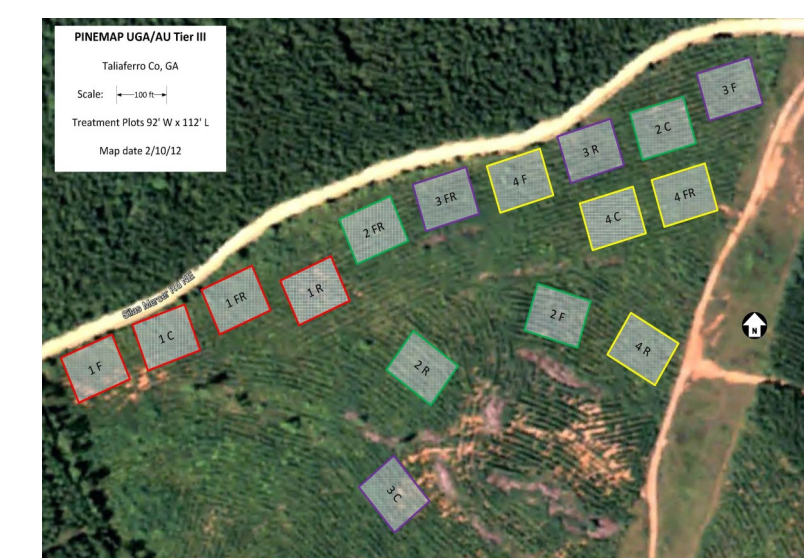
## INTRODUCTION

The southeastern United States has experienced a 1-2°C increase in average annual temperature over the last 30 years. Future climate projections indicate the duration and intensity of summertime droughts are expected to increase with the rate of warming in the southeastern United States. Conversely, the frequency of extreme precipitation events (ie. days with precipitation greater than 25.4 mm) may increase with the water-holding capacity of a warming atmosphere. Precipitation events such as these are likely to result in surface water runoff and therefore less net soil water availability, which may affect loblolly pine water use.

Reduced soil water availability has been shown to decrease stand productivity and associated physiological mechanisms including canopy stomatal conductance and transpiration whereas fertilization has been shown to increase stand productivity and transpiration, which may be attributed to leaf area production. Increased leaf area with fertilization may decrease the sapwood-to-leaf area ratio ( $A_S:A_L$ ) resulting in greater soil water depletion and plant water stress. **The objective of this research is to examine the interactive effects of reduced precipitation and fertilization on water use of loblolly pine. We hypothesize that greater leaf area index (LAI) with fertilization will decrease soil water availability resulting in reduced canopy stomatal conductance ( $G_S$ ) and subsequently transpiration per unit leaf area ( $E_L$ ) to limit water loss.**

The results from this research will be used by PINEMAP to provide (1) transpiration data input for the 3-PG and Water Supply and Stress Index (WASSI) models, and (2) physiological understanding of stand-level water use under varying climate conditions.

## MATERIALS AND METHODS



The PINEMAP Tier III Experimental Site is located in Taliaferro Co., Georgia and was planted with a second generation open-pollinated family of loblolly pine in 2006.

The experimental design is a 2x2 factorial combination of throughfall reduction and fertilization treatments replicated in four blocks.

### Throughfall Treatments

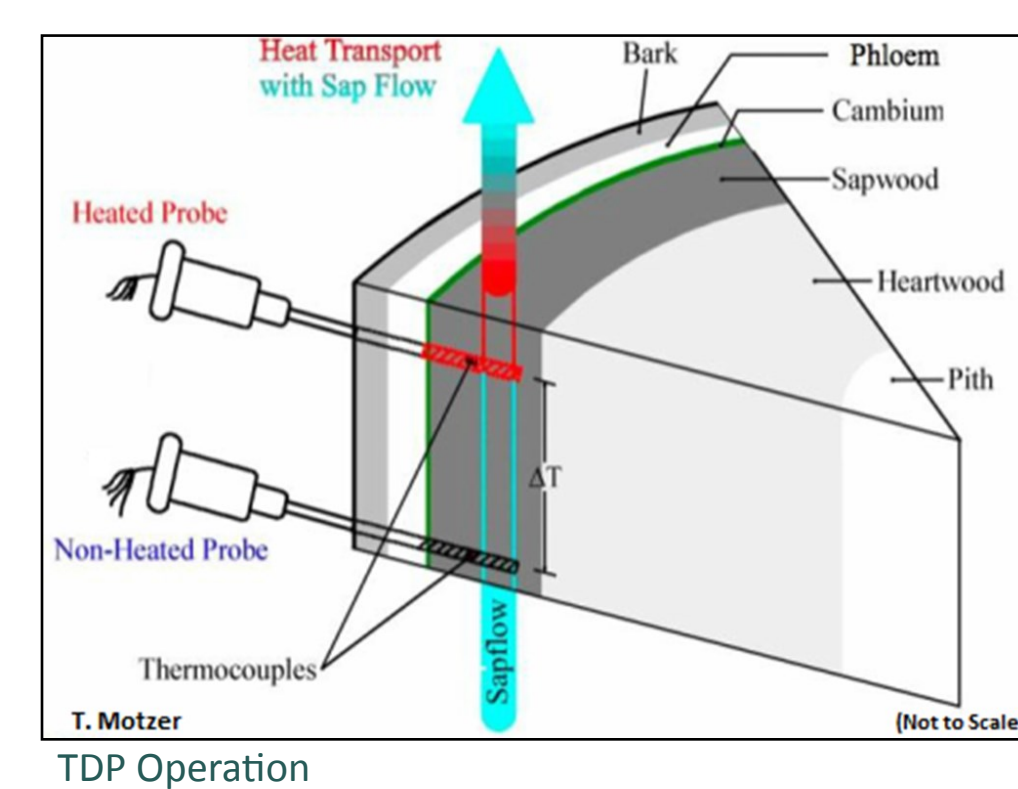
- Ambient Throughfall ( $TR_0$ )
- Throughfall Reduction ( $TR_{30}$ ; installed under tree canopy to divert ~30% of rainfall from the treatment plots)

### Fertilization Treatments

- No Fertilization (Fert<sub>0</sub>)
- Fertilization (Fert.; 224 kg N ha<sup>-1</sup>, 28 kg P ha<sup>-1</sup>, 56 kg K ha<sup>-1</sup>, 1.1 Kg B ha<sup>-1</sup> applied March, 2012)



Throughfall Exclusion Trays



Five trees in each measurement plot (80 trees total) were randomly selected based upon basal diameter distribution. Sap velocity was determined using 20 mm thermal dissipation probes (TDP), modified after Granier (1987).

A cellular networked weather station with a data logger is collecting continuous environmental data (precipitation, wind speed, photosynthetic active radiation, global radiation, temperature and relative humidity).

Whole tree transpiration on a leaf area ( $E_L$ ) and ground area ( $E_G$ ) basis were calculated following Domec et al. (2009).

Canopy stomatal conductance ( $G_S$ ) was calculated following Samuelson et al. (2007).

The sensitivity of  $G_S$  to vapor pressure deficit (D) was examined by fitting the data to the functional form:  $G_S = G_{S,REF} - \delta \log D$  (Oren et al., 1999), where  $G_{S,REF}$  is  $G_S$  at D = 1 kPa and  $-\delta$  is the rate of stomatal closure and reflects the sensitivity of  $G_S$  to D.

Due to power failure, missing data (ie. daily sums of transpiration) in January 2013 and March 2013 were gap-filled on a monthly basis using regressions against environmental drivers, specifically D.



TDP Installation



Installed TDP

## RESULTS

- Fertilization treatment increased LAI but no difference was detected in response to throughfall treatment. No interaction effects were detected (Figure 1).
- Daytime averaged  $q$  and  $G_S$  demonstrated typical seasonal patterns and  $q$  and  $G_S$  rates were as high as 73.9 g m<sup>-2</sup> s<sup>-1</sup> and 194 mmol m<sup>-2</sup> s<sup>-1</sup>, respectively (Figure 2).
- An interaction effect of throughfall reduction and fertilization treatment was detected for  $q_{MAX}$ ,  $G_S$ ,  $G_{S,REF}$ ,  $-\delta$ , and  $E_L$ . Fertilization decreased  $A_S:A_L$  (Table 1).
- In the throughfall reduction treatment, fertilization decreased  $G_S$  and  $E_L$ . On average  $G_S$  was reduced from 90.9 to 63.6 mmol m<sup>-2</sup> s<sup>-1</sup> and  $E_L$  was reduced from 18.6 to 13.4 mm month<sup>-1</sup> (Figure 3).
- Fertilization decreased  $G_{S,REF}$  and  $-\delta$  by 37% and 44%, respectively, in the throughfall reduction but not ambient throughfall treatment (Figure 4).

### Leaf Area Index

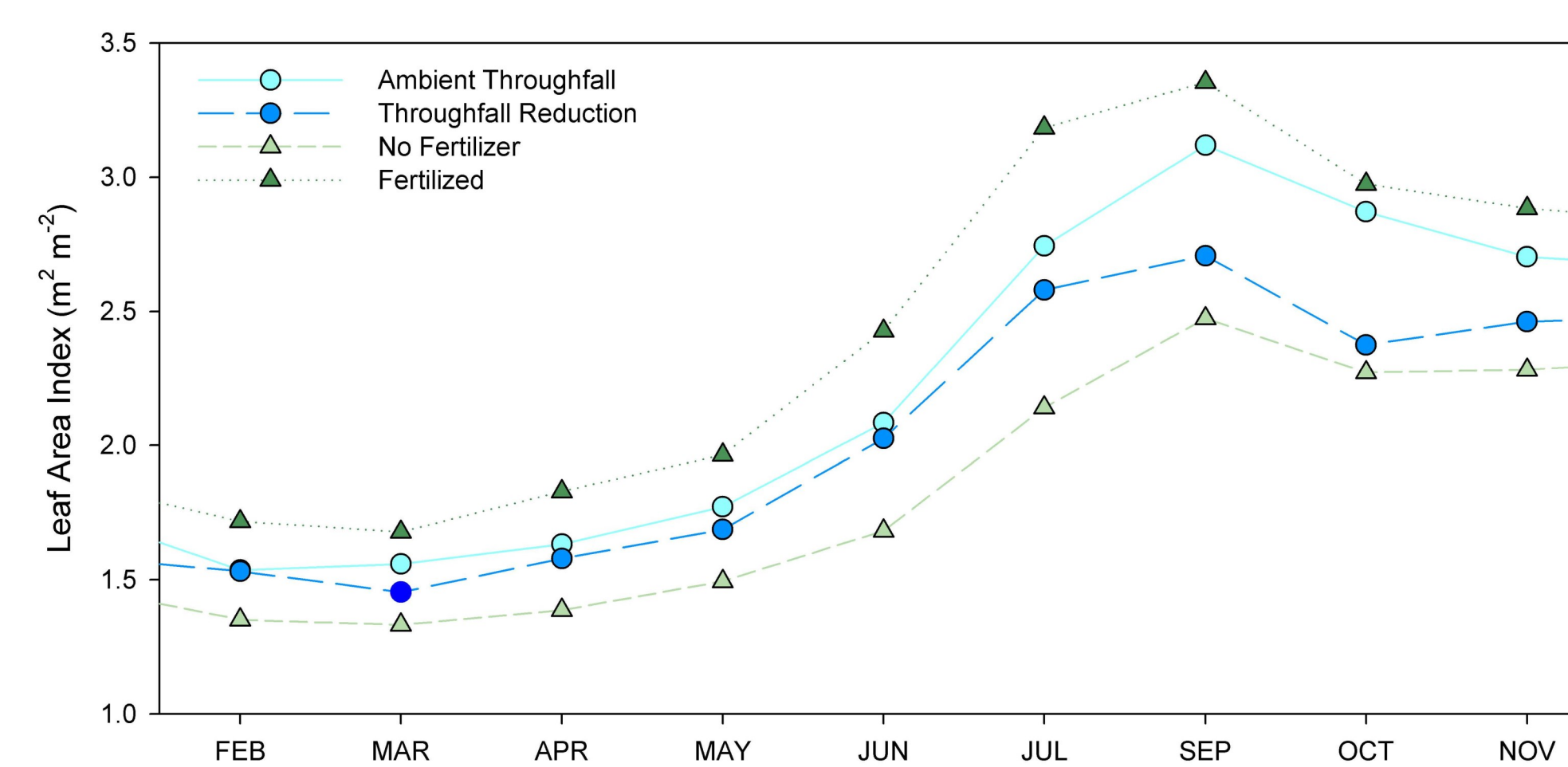


Figure 1. Response of leaf area index (LAI) to throughfall reduction and fertilization treatments in 8-year-old loblolly pine from February 2013 to November 2013 (see poster by Pell et al.).

### Physiological Parameters

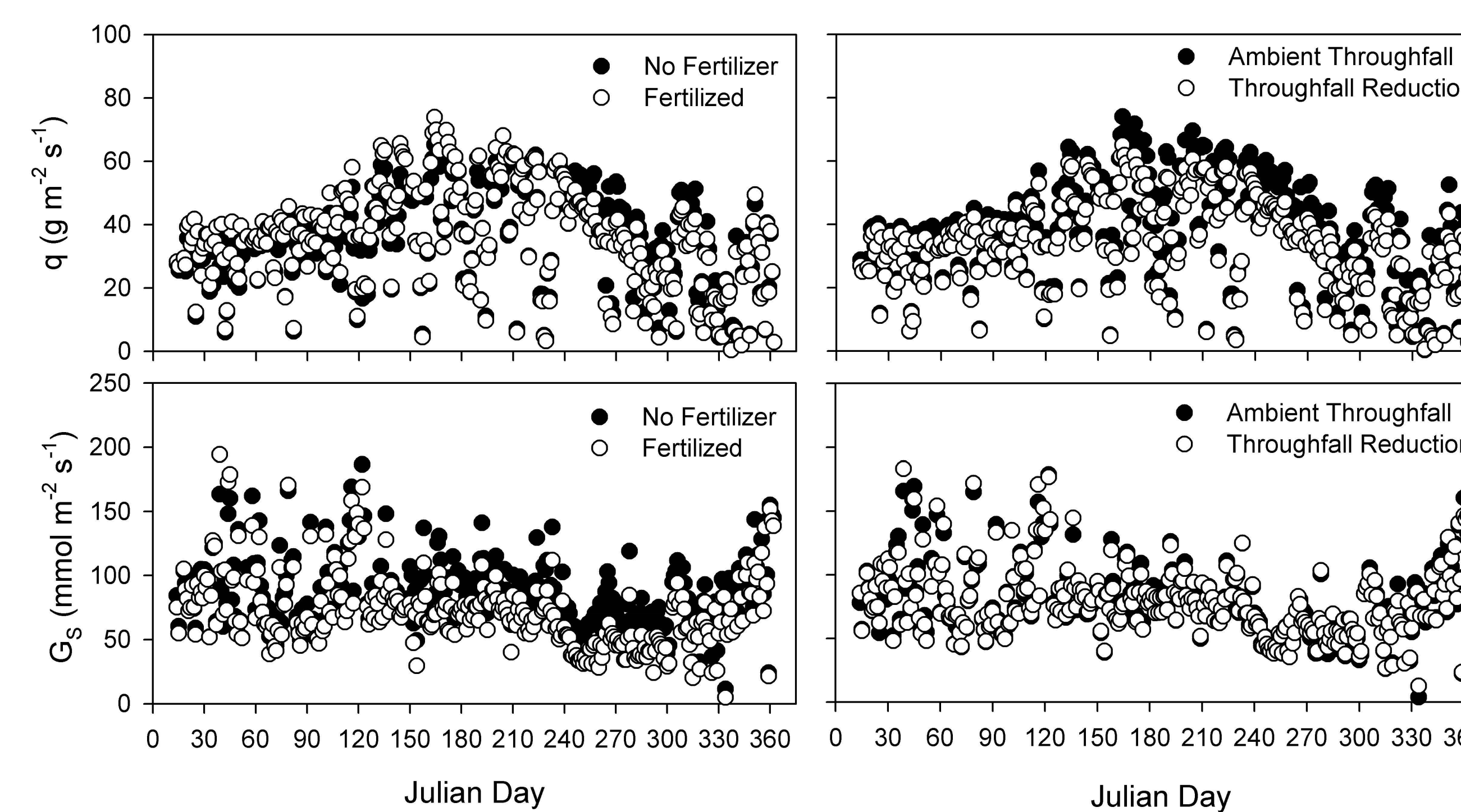


Figure 2. Daytime averaged sap flux density ( $q$ ) and canopy stomatal conductance ( $G_S$ ) in response to throughfall reduction and fertilization treatments from January 2013 to December 2013 in 8-year-old loblolly pine.

Table 1. Mean ( $\pm$ SE) by treatments and observed probability values for the effects of month, throughfall reduction ( $TR_0$ ;  $TR_{30}$ ) and fertilization (Fert<sub>0</sub>; Fert.) treatments on monthly daytime averaged sap flux density ( $q$ ), midday maximum sap flux density ( $q_{MAX}$ ), daytime averaged canopy stomatal conductance ( $G_S$ ), reference  $G_S$  at D = 1 kPa ( $G_{S,REF}$ ), sensitivity of  $G_S$  to D ( $-\delta$ ), monthly daytime transpiration on a ground area ( $E_G$ ) and leaf area ( $E_L$ ) basis, and sapwood-to-leaf area ratio ( $A_S:A_L$ ) in 8-year-old loblolly pine.

Treatment	$q$ (g m <sup>-2</sup> s <sup>-1</sup> )	$q_{MAX}$ (g m <sup>-2</sup> s <sup>-1</sup> )	$G_S$ (mmol m <sup>-2</sup> s <sup>-1</sup> )	$G_{S,REF}$ (mmol m <sup>-2</sup> s <sup>-1</sup> )	$-\delta$ (mmol m <sup>-2</sup> s <sup>-1</sup> kPa <sup>-1</sup> )	$E_G$ (mm month <sup>-1</sup> )	$E_L$ (mm month <sup>-1</sup> )	$A_S:A_L$ (cm <sup>2</sup> m <sup>-2</sup> )
$TR_0$	36.1 (1.2)	77.2 (2.0)	77.7 (2.3)	101.8 (5.6)	51.8 (3.6)	85.3 (4.2)	16.2 (0.7)	3.1 (0.1)
$TR_{30}$	32.1 (1.1)	98.3 (1.7)	77.2 (2.5)	98.1 (8.2)	50.7 (5.1)	75.9 (3.6)	16.1 (0.7)	3.2 (0.1)
Fert <sub>0</sub>	34.0 (1.1)	72.0 (1.8)	83.9 (2.2)	116.3 (5.1)	62.7 (2.9)	75.4 (3.5)	17.5 (0.7)	3.4 (0.1)
Fert.	34.2 (1.2)	73.6 (2.1)	70.9 (2.4)	83.6 (6.2)	39.8 (3.6)	85.9 (4.3)	14.8 (0.7)	2.9 (0.1)

P > F								
M	<.0001	<.0001	<.0001	<.0001	0.0002	<.0001	<.0001	<.0001
TR	0.0706	0.0334	0.9380	0.5363	0.7816	0.2514	0.8426	0.3078
Fert	0.9534	0.7585	0.0277	<.0001	<.0001	0.2204	0.0134	0.0039
TR x Fert	0.0950	0.0484	0.0147	0.0249	0.0310	0.1284	0.0269	0.7783
M x TR	0.5975	0.7765	0.9964	0.9597	0.8435	0.6626	0.9956	0.4530
M x Fert	0.0122	0.0816	0.6446	0.3150	0.5280	0.0387	0.1596	0.0039
M x TR x Fert	0.7985	0.7647	0.2227	0.9130	0.6023	0.8390	0.4630	0.7518

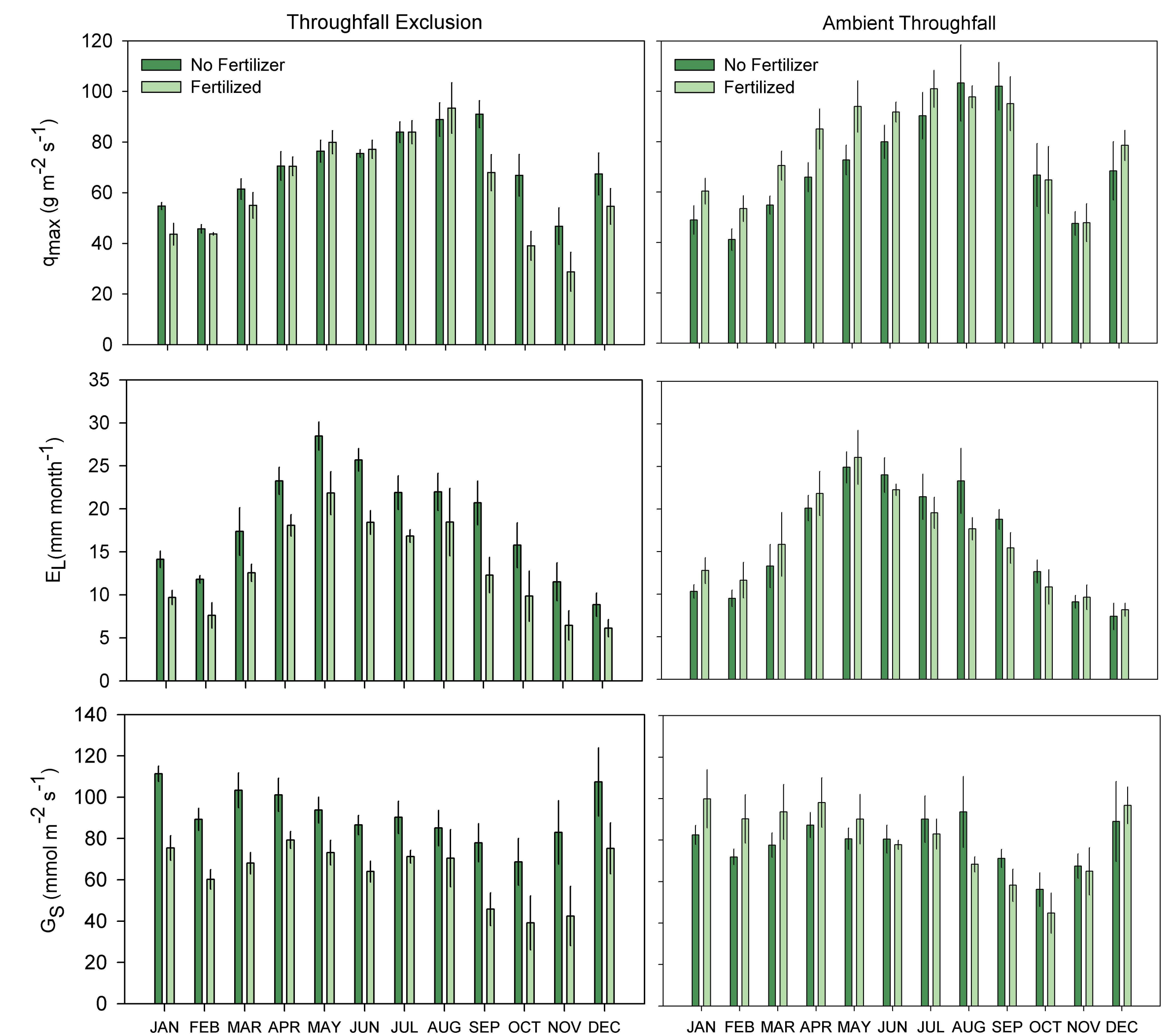


Figure 3. Average midday maximum sap flux density ( $q_{MAX}$ ), canopy stomatal conductance ( $G_S$ ), and monthly transpiration per unit leaf area ( $E_L$ ) of 8-year-old loblolly pine in response to fertilization treatment within the throughfall reduction and ambient throughfall treatments from January 2013 to December 2013.

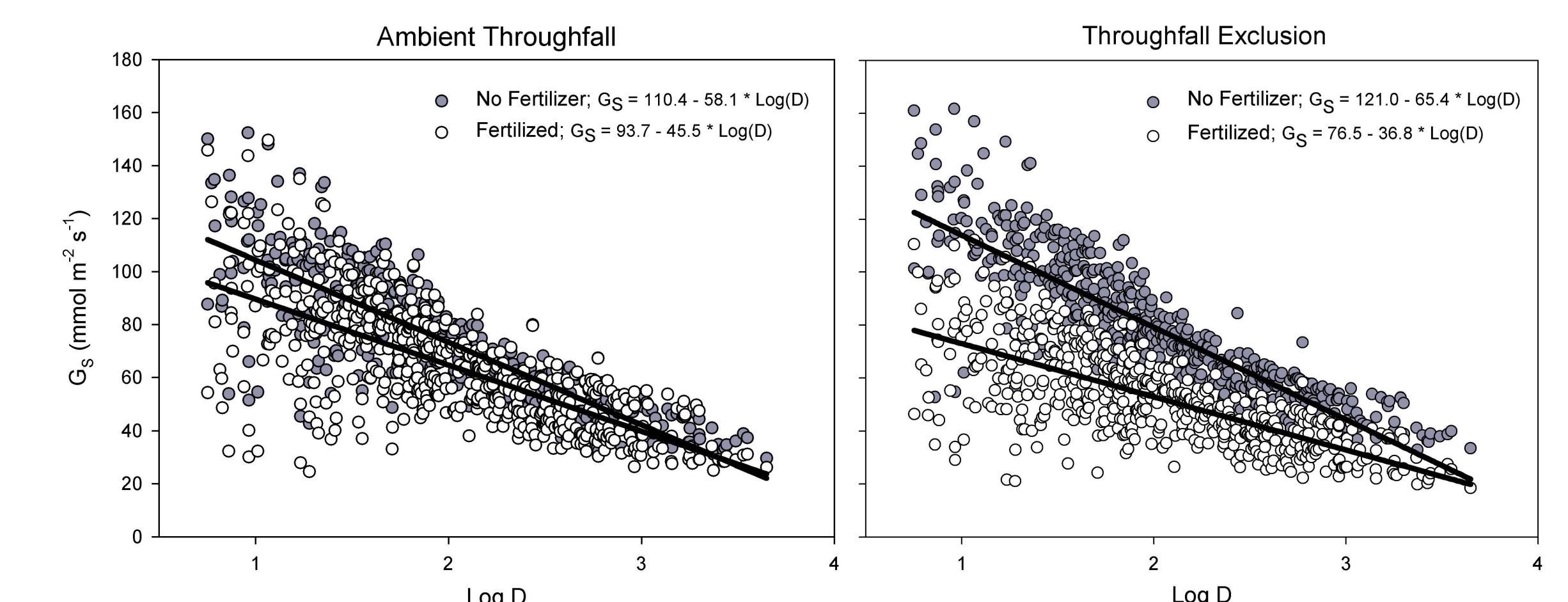


Figure 4. The relationship between  $G_S$  and  $\log(D)$  of 8-year-old loblolly pine in response to fertilization treatment within the throughfall reduction and ambient throughfall treatments.

## CONCLUSIONS

- Fertilization decreased  $A_S:A_L$  but only increased  $E_G$  in the ambient throughfall treatment. In the throughfall reduction treatment, fertilization reduced  $G_S$ ,  $\delta$ , and  $E_L$  which limited  $E_G$  with increased LAI.
- Growth was not influenced by throughfall reduction in 2013 (see poster by Pell et al.).
- These results indicate a more conservative water use strategy at the whole tree level such that increased leaf area with fertilization results in a greater sensitivity to water availability defined by reduced  $G_S$ ,  $\delta$ , and  $E_L$ .
- Annual precipitation was unusually low in 2012 (831 mm) and was at the higher end of normal in 2013 (1413 mm) (see poster by Pell et al.). Due to high inter-annual variability in climate, continued investigation is needed to quantify the influence of reduced soil moisture availability on stand level physiology.

## ACKNOWLEDGEMENTS

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