

Fertilization decreases soil CO₂ efflux and total belowground carbon flux in a loblolly pine (*Pinus taeda*) plantation

Jinyan Yang¹ Cody M. Luedtke¹ Katherine M. Akers¹ Mary Anne McGuire¹ Lisa Samuelson³ Charles Pell³ Doug P. Aubrey² Michael Kane¹ Robert O. Teskey¹

¹ Warnell School of Forestry and Natural Resources, The University of Georgia

² Department of Biology, Georgia Southern University

³ School of Forestry & Wildlife Sciences, University of Auburn, USA

Introduction

- Soil CO₂ efflux (E_S) is an important process influencing net ecosystem CO₂ exchange and forest carbon budgets.
- Autotrophic (E_A) and heterotrophic (E_H) fluxes are main components of E_S.
- The E_A is composed of the CO₂ efflux of roots, mycorrhizal fungi (E_{MH}) and other rhizosphere organisms, while E_H is derived from the activity of free-living microbes and fauna decomposing dead organic matter.
- Total below-ground carbon flux (TBCF) is the sum of metabolic fluxes to support root production, respiration, root exudates, herbivory and symbionts.
- Intensive management and predicted declines in precipitation are likely to affect the carbon budgets of loblolly pine (*Pinus taeda*) plantations in the southeastern United States.
- Little is known about E_S and its components and TBCF will respond to decreasing soil moisture and changes in soil fertility.

Objectives

- To quantify impacts of throughfall reduction and fertilization treatments on E_S and its components (E_A, E_H and E_{MH})
- To determine TBCF response to throughfall reduction and fertilization treatments

Methods: Experimental design and treatments

The study was performed at the Tier III site in Washington, GA (Fig.1a).

The experiment design was a 2 X 2 factorial combination of fertilizer treatment (two levels: no fertilization, C; or one-time fertilizer application, F; Fig.1b) and precipitation throughfall reduction (two levels: no throughfall reduction, C; or 30% throughfall reduction, R; Fig.1c) replicated in four blocks. There are 4 replicate plots for each treatment and 16 plots in total (Fig. 1a).



Fig 1. Map of Washington, GA Tier III site treatments (a). Different blocks are represented by differently colored borders around plots. Fertilization treatment (b) and throughfall reduction (c).

Methods: E_S, E_H and E_{MH} measurements

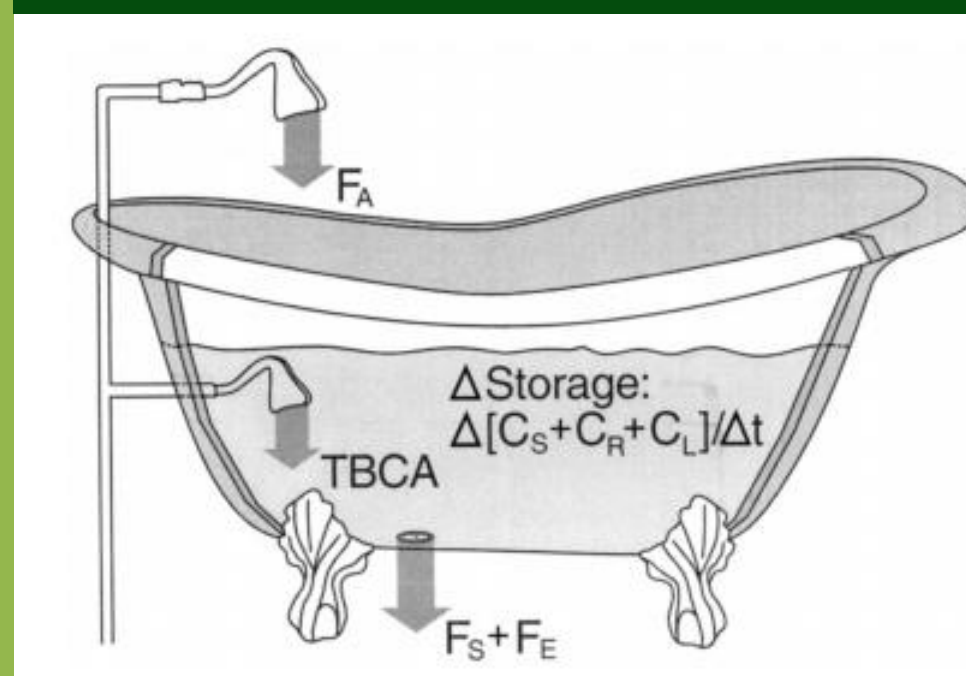
- Monthly E_S along with soil temperature and soil moisture from 2012 to 2014 were measured with a LI-6400 portable gas exchange system (Fig. 2).
- The E_A, E_H and E_{MH} were separated by comparing untrenched plots with trenched plots that prevented root growth. Measurements were taken monthly from April to December in 2014 (Fig. 2).

Methods: Stem CO₂ efflux (E_{ST}) measurement

We also measured monthly E_{ST} and stem temperature at 1cm depth below the bark, from April to December in 2014 with LI-6400-09 chamber (Fig. 3).

Methods: Total belowground carbon flux (TBCF)

- TBCA = F_S + F_E - F_A + ΔC_S + ΔC_R + C_L
- F_S = soil surface CO₂ efflux
- F_E = leached C
- F_A = litterfall
- ΔC_S = change in C in mineral soil
- ΔC_R = increment of C in root biomass
- C_L = Litter layer mass



Results: Seasonal means and Q₁₀ for E_S, E_H, E_A and E_{MH}

- Except E_A, there were no significant differences for seasonal means of E_S, E_H and E_{MH} in all treatments (Table 1).
- E_H was dominant contributor to E_S in all treatments, ranging from 62 to 67%, and E_{MH} was < 15% for E_S.

Table 1. Seasonal means and Q₁₀ for E_S, E_H, E_A and E_{MH} in 2014. The different lower case letters indicate significant difference among treatments. The significant level is at p < 0.05.

Treatment	E _S		E _H		E _A		E _{MH}	
	Mean	Q ₁₀	Mean	Q ₁₀	Mean	Q ₁₀	Mean	Q ₁₀
C	2.32 ± 0.55	1.65	1.53 ± 0.39	1.69	0.68 ± 0.26 ab		0.22 ± 0.09	
F	1.70 ± 0.53	1.65	1.22 ± 0.48	2.19	0.41 ± 0.22 b		0.12 ± 0.17	
FR	1.90 ± 0.37	1.46	1.29 ± 0.41	1.96	0.51 ± 0.28 ab		0.15 ± 0.14	
R	2.05 ± 0.46	1.56	1.27 ± 0.32	1.68	0.78 ± 0.29 a		0.21 ± 0.16	

Results: P values for effects of treatments on E_S, E_H, E_A, E_{MH} and E_{ST}

- Significant F effects on E_S and E_A while no significant R effects on all effluxes (Table 2).
- Significant measurement by date effects on all effluxes except E_{MH}.

Table 2. P values for effects of treatments on E_S, E_H, E_A, E_{MH} and E_{ST}. The significant level is at p < 0.05.

Source	E _S	E _H	E _A	E _{MH}	E _{ST}
F	0.0287	0.4328	0.0325	0.8085	0.4298
R	0.8846	0.0657	0.4779	0.3141	0.7546
F X R	0.1597	0.1107	0.9442	0.8825	0.5900
Date	<0.0001	<0.0001	0.0047	0.0653	<0.0001
Date X F	0.4571	0.7258	0.4566	0.1926	0.1217
Date X R	0.6907	0.3658	0.7419	0.0402	0.0004
Date X F X R	0.8525	0.9784	0.4125	0.3689	0.0572

Results: E_S vs soil temperature and soil moisture

- Significant temperature effects (R²:0.51-0.72) on E_S and weak soil moisture effects on E_S (Fig. 4).

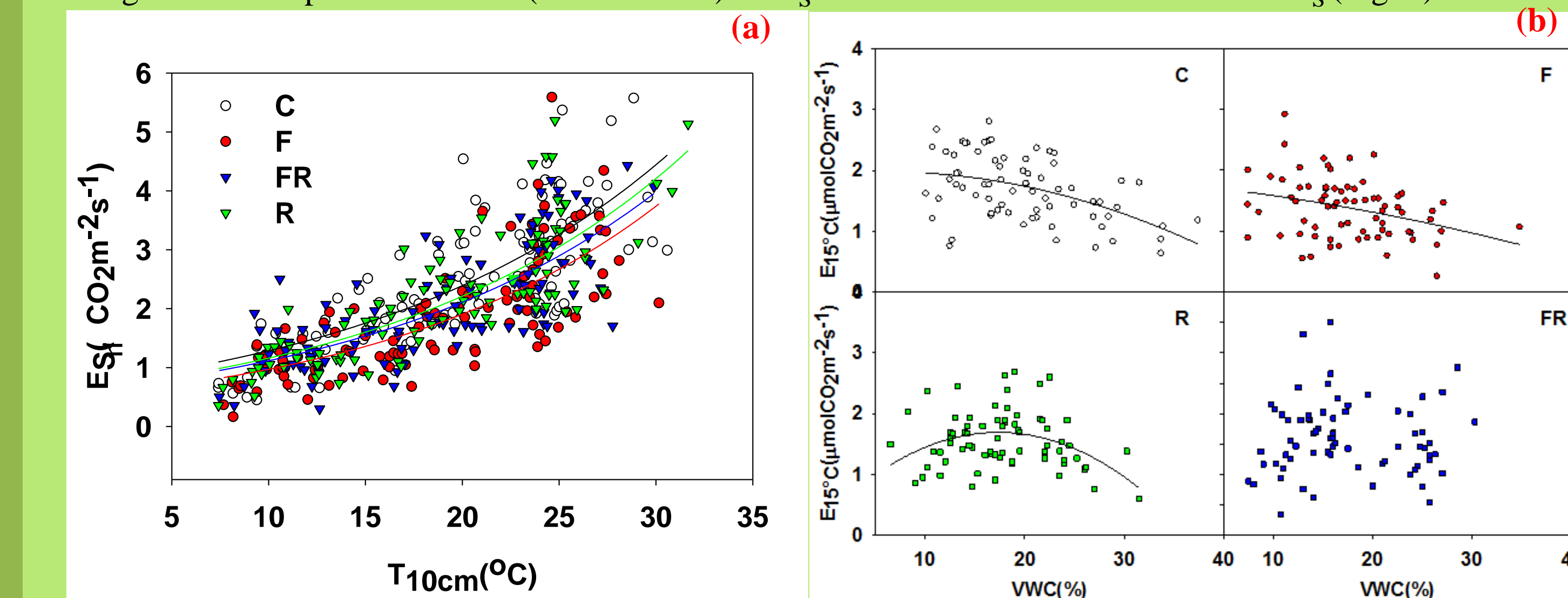


Fig 4. Relationships between E_S and soil temperature (a) and moisture (b)



- E_S
- E_R
- E_{R-MH}
- E_{ST}
- 4 replicates/treatment
- Excluded roots (E_R)
- Excluded roots & MycorHyphae
- 4 PVC collars/plot
- Mesh screen (41μm)
- Thick plastic
- Monthly measurement

Fig 2. E_S, E_A, E_H and E_{MH} measurement

Fig 3. E_{ST} measurement

Results: Seasonal patterns of E_S, E_H, E_A and E_{MH}

- Fertilization significantly decreased E_S (by 22%) and E_A (by 37%) (Fig.5).
- Seasonal patterns of E_H were similar to those of E_S while there were less obvious seasonal patterns of E_A.
- E_{MH} in the R treatment was significantly higher than in control at the early spring and early fall.

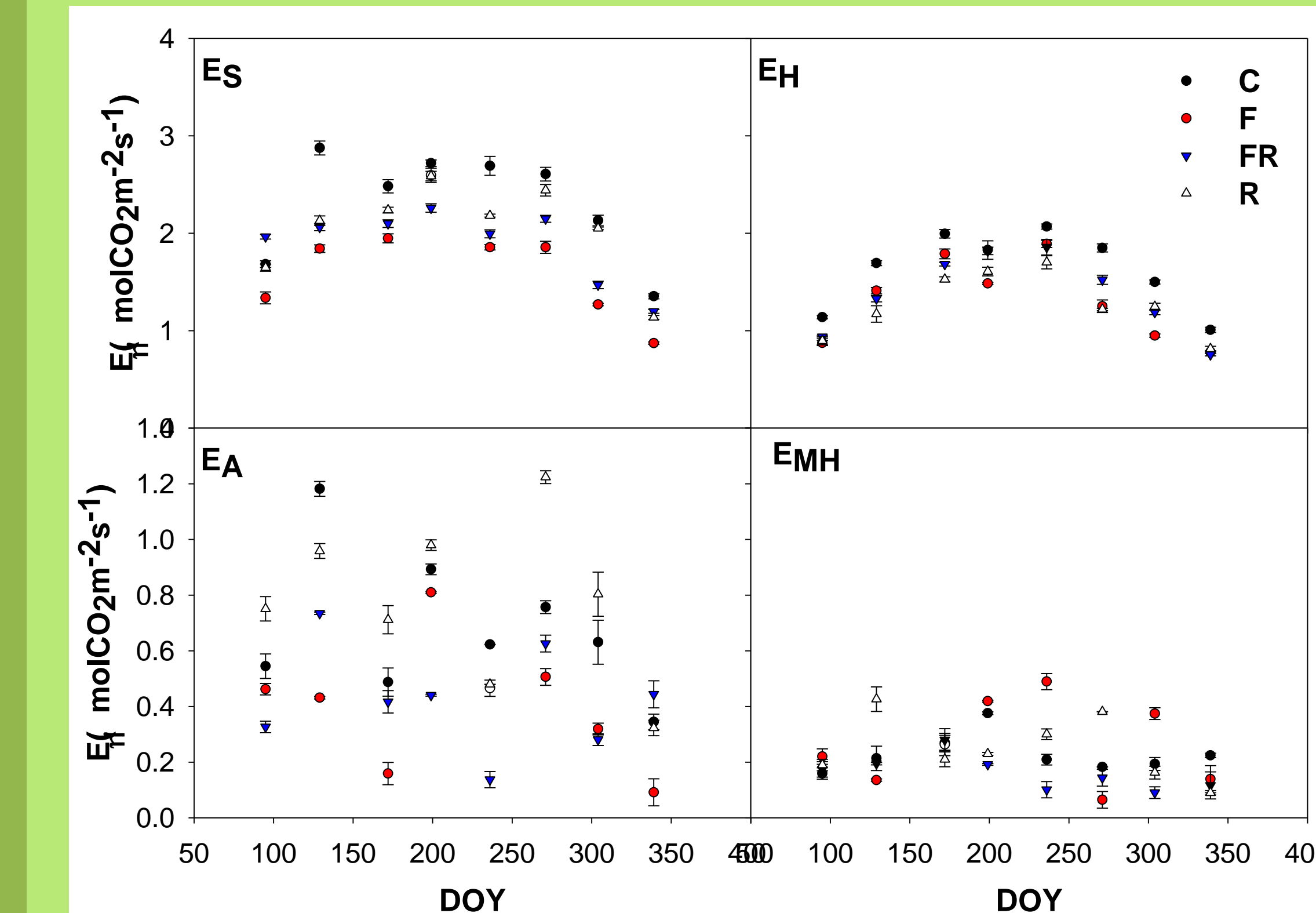


Fig 5. Seasonal patterns of E_S, E_H, E_A and E_{MH}

Results: Correlation between E_A and E_{ST}

- Mean E_{ST} was 3.53, 3.37, 3.71 and 3.18 μmolCO₂m⁻²s⁻¹ for C, F, FR and R treatments, respectively.
- After controlling for temperature effect, a weak correlation was found between the residuals of E_{ST} and E_A in control plots (Fig.6a).

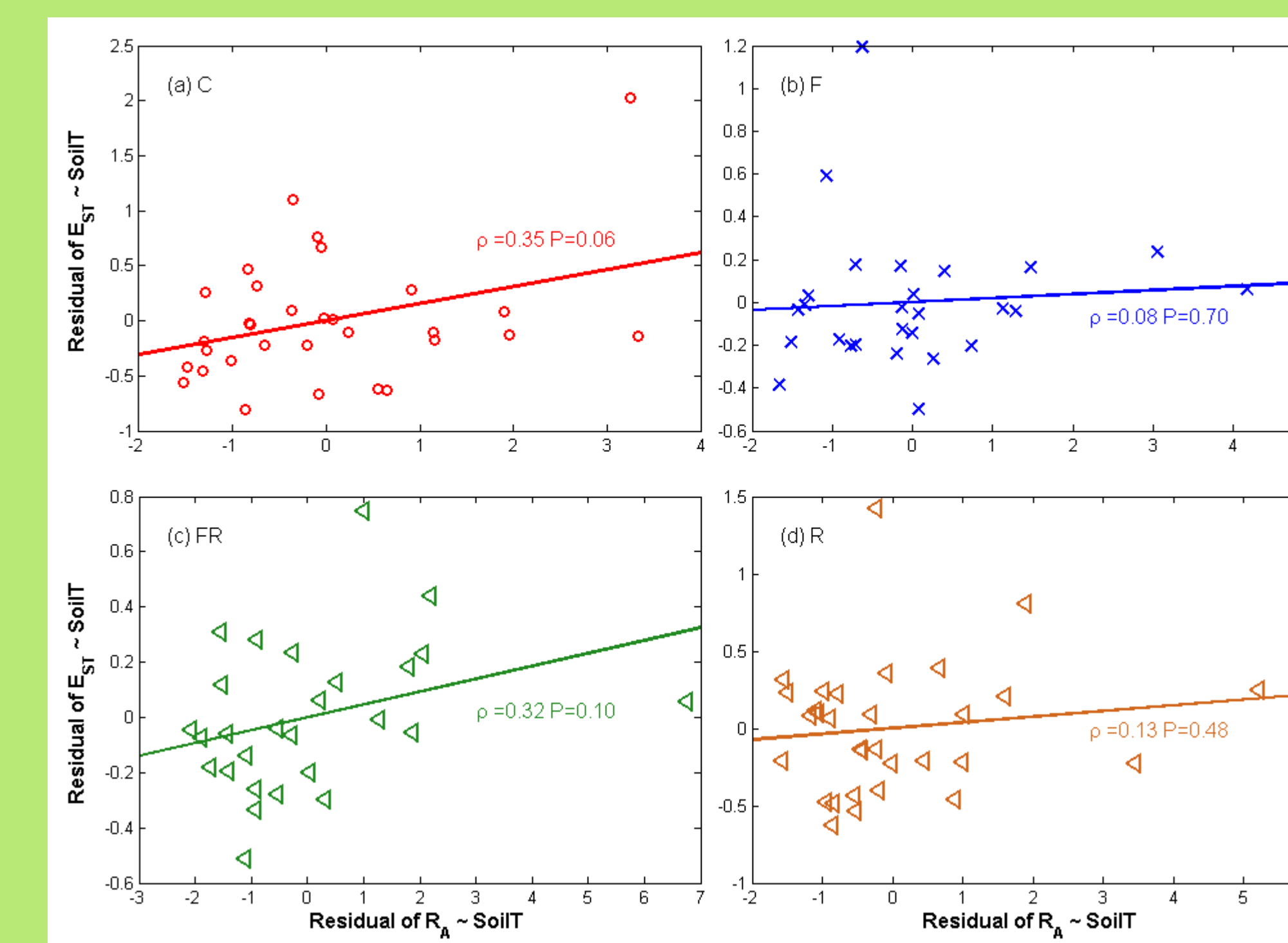


Fig 6. Relationships between residuals of E_{ST} and E_A in different treatments.

Results: Annual E_S, E_A and E_H flux

- Fertilization decreased annual E_S and E_H flux in 2012 and 2013 (Fig. 7).
- There was no significant difference between FR and R treatment for annual E_S, E_A and E_H.

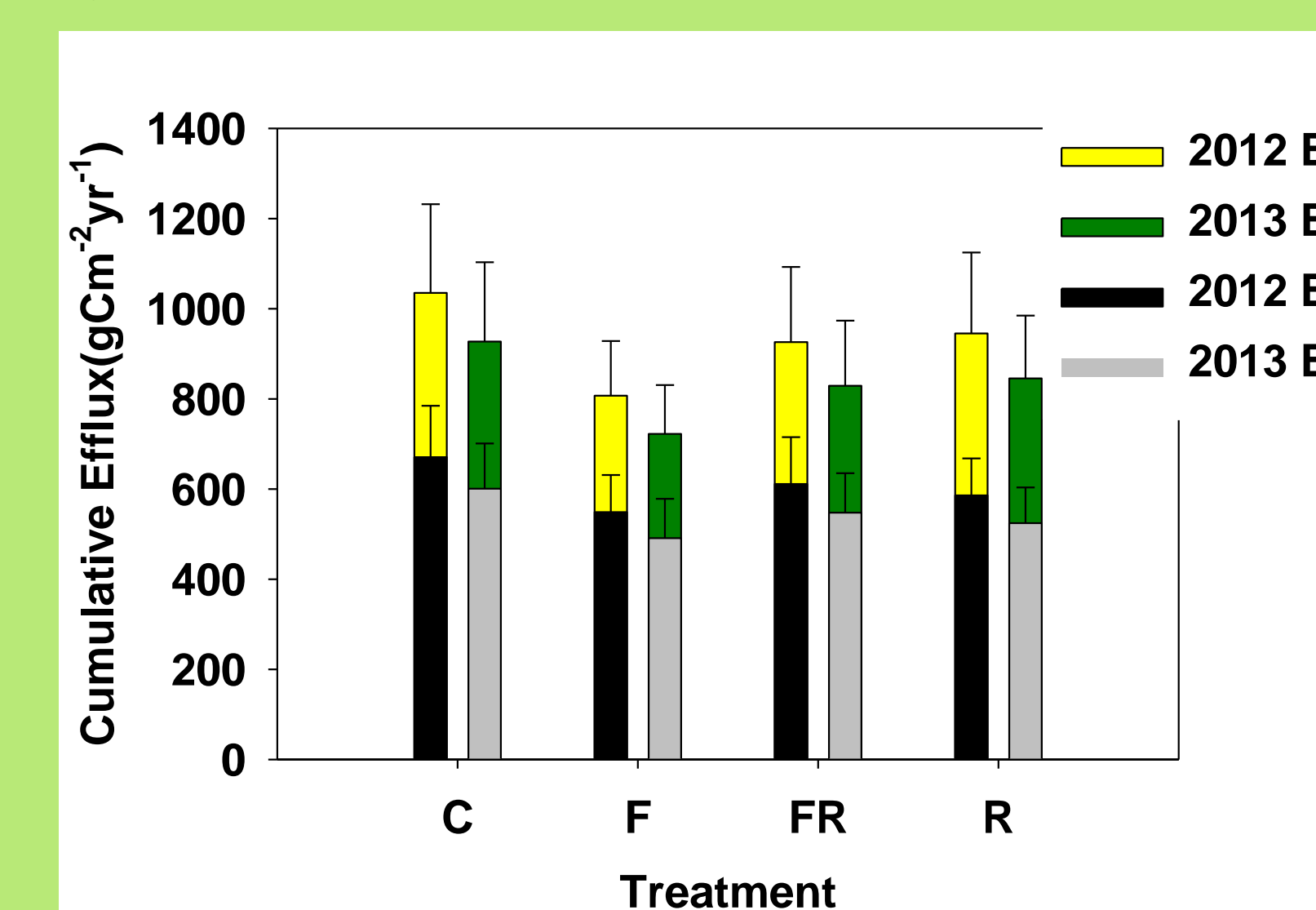


Fig 7. Annual E_S, E_A and E_H flux in different treatments.

Results: Total belowground carbon flux (TBCF)

- Fertilization significantly decreased TBCF in 2012 (Fig.8).
- There was no difference in TBCF between 2012 and 2013.

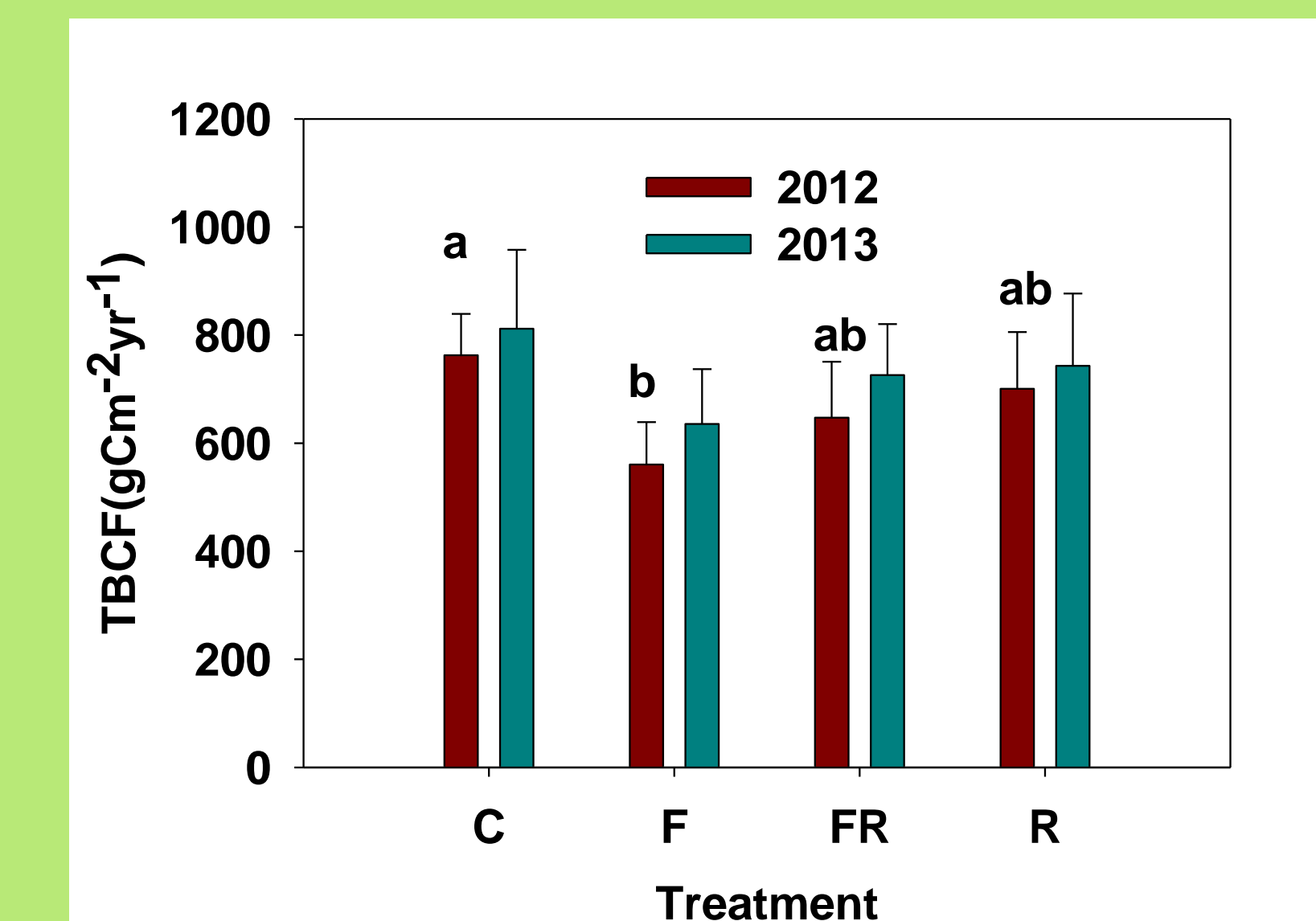


Fig 8. TBCF in different treatments.

Discussion and Conclusion

- E_H was the dominant contributor to E_S in all treatments, ranging from 62 to 67% of E_S.
- E_{MH} contributed less than 15% to E_S in all treatments.
- Fertilization significantly reduced E_S and E_A probably due to decreased carbon partitioning to roots.
- There was a weak relationship between E_A and E_{ST} in control plots that might be related to the upward transport of CO₂ derived from roots via sapflow.
- Fertilization decreased annual E_S and E_H flux in 2012 and 2013.
- Fertilization tended to decrease TBCF due to soil resource availability. The lack of consideration of fine roots may underestimate TBCF.
- The link between aboveground E_{ST} and belowground E_A should be considered in assessing and modeling E_S.

Acknowledgments

Thanks to J. Tyler Manley and others for helping with field work.

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

For further information

Please contact yangjy@uga.edu

