PS 18-41: Measurements of hydrologic and biogeochemical fluxes of stemflow and soil quality from southern pine beetle outbreaks in southern forests

Jacob Landfield
Dr. Courtney Siegert
Department of Forestry, Mississippi State University

MISSISSIPPI STATE UNIVERSITY™
DEPARTMENT OF FORESTRY

Abstract

Widespread use of loblolly pine (*Pinus taeda*) has greatly increased the suitable habitat for southern pine beetle (*Dendroctonus frontalis*). Southern pine beetles(SPB) impact different species in forests as an effect of their wintering habits. This study aims to fill gaps of literature describing the biogeochemical and hydrological fluxes in stemflow and throughfall from southern pine beetle elicited tree death. We hypothesize that affected trees will produce more stemflow than control trees and this stemflow will have different biogeochemical makeup as well. In this study we treated ten trees to simulate bark beetle impacts. This was done by girdling and treating five stems with blue stain fungus, and five stems with nutrient agar, meanwhile five untreated trees acted as controls for this study. Stemflow volume was then collected using collars and collection bins. Stemflow volume was then calculated to quantify hydrological fluxes to give a better understanding of the impacts that bark beetles have on southern watersheds. Water and soil samples were collected, water was filtered, and stored in refrigeration at 2.22°C for future analysis. Soil samples were ground, dried, and stored at room temperature in Whirl-paks. Preliminary results show no significant differences in stemflow or throughfall depths between treatment groups and control specimens. This is probably due to a small temporal scale.

Introduction

Up to 5% of precipitation is partitioned to the forest floor as stemflow, this water moves nutrients into the soils near tree roots by funneling action done by the canopy [4, 6, 9]. The stemflow is enriched by canopy exchange and dry deposition [6]. The preferential funneling of nutrients provides soil microbes near the base of the tree critical resources they need to prepare to break down the leaf litter and other falling debris from the tree. In deciduous stands, dissolved organic matter in stemflow has been seen to be lower during leafless season than the leaf bearing season[5].

Bark beetle species, such as the Southern pine beetle (SPB) (F 1) colonize the bark of trees to as a safe location for laying their eggs during the early spring[1]. Female beetles may then release hormones to attract mates, which can lead to greater, stand wide impacts [9,11,15]. In the United States outbreaks of SPB have been seen to kill large volumes of standing timber (F 2). This leads to increases in organic nitrogen on loblolly pine soils as associated with tree mortality. These impacts could be similar to those seen by Griffin and Turner in stands near Yellowstone[4,7].

This research is part of a multifaceted project aiming to examine the effects of SPB on southern forests. For this study we hypothesize that: (1) trees affected by SPB will produce less stemflow per storm event on average as crown die-off occurs. (2) Trees impacted by SPB will have higher concentrations of organic nitrogen, and dissolved organic matter in their stemflow over the first few years of study. (3) Higher CO_2 flux concentrations will occur near the base of treated trees (F3).

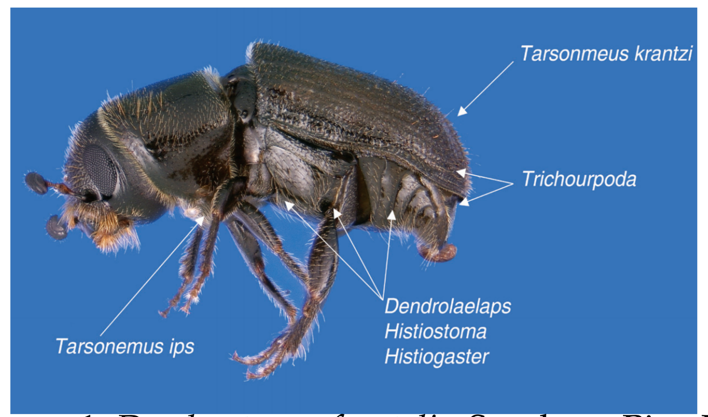

Figure 1. *Dendroctonus frontalis*, Southern Pine Beetle[2]

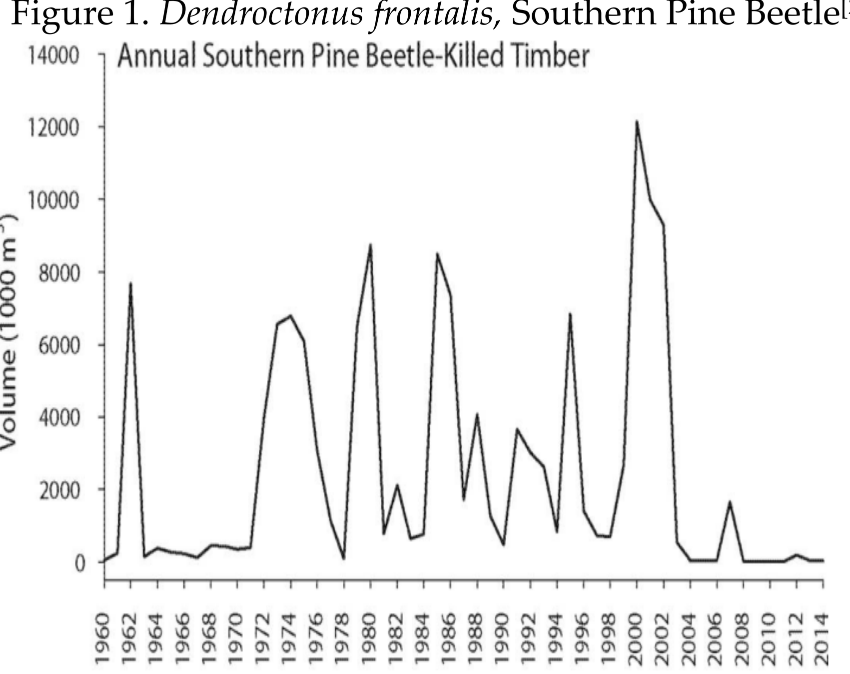

Figure 2. Volume of trees killed by SPB by Year[1]

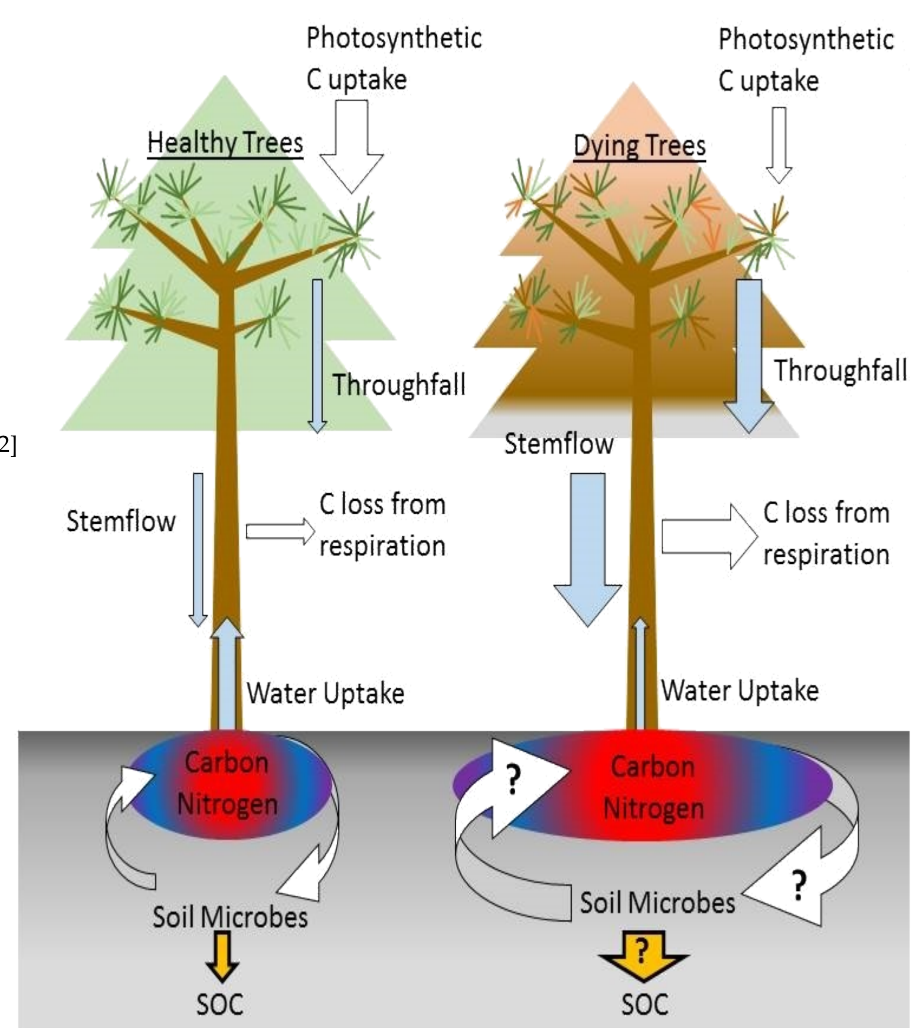

Figure 3. A hypothetical diagram of what we expect to happen to water and nutrient fluxes as trees undergo mortality. We are not fully certain of the impacts of tree mortality, but are more confident that stemflow volume will increase.

References

1. Clarke, S.R., Riggins, J.J., Stephen, F.M., 2016. Forest Management and Southern Pine Beetle Outbreaks: A Historical Perspective. Forest Science, 62(2): 166-180. DOI:10.5849/forsci.15-071
2. Coulson, R.N., 1979. Population dynamics of bark beetles. Annual review of entomology, 24(1): 417-447.
3. Fenn, M.E. et al., 2013. Atmospheric deposition of nitrogen and sulfur and preferential canopy consumption of nitrate in forests of the Pacific Northwest, USA. Forest Ecology and Management, 302: 240-253. DOI:http://dx.doi.org/10.1016/j.foreco.2013.03.042
4. Griffin, J.M., Turner, M.G., 2012. Changes to the N cycle following bark beetle outbreaks in two contrasting conifer forest types. Oecologia, 170(2): 551-565. DOI:10.1007/s00442-012-2323-y
5. Klepzig, K.D., Hofstetter, R.W., 2011. From attack to emergence: interactions between southern pine beetle, mites, microbes, and trees.
6. Levia, D.F., Germer, S., 2015. A review of stemflow generation dynamics and stemflow-environment interactions in forests and shrublands. Reviews of Geophysics, 53(3): 673-714. DOI:10.1002/2015RG000479
7. Levia, D.F. et al., 2011. Stemflow and dissolved organic carbon cycling: temporal variability in concentration, flux, and UV-Vis spectral metrics in a temperate broadleaved deciduous forest in the eastern United States. Canadian Journal of Forest Research, 42(1): 207-216. DOI:10.1139/x11-173
8. Martinez-Meza, E., Whitford, W.G., 1996. Stemflow, throughfall and channelization of stemflow by roots in three Chihuahuan desert shrubs. Journal of Arid Environments, 32(3): 271-287. DOI:http://dx.doi.org/10.1006/jare.1996.0023
9. Mikkelson, K.M. et al., 2013. Bark beetle infestation impacts on nutrient cycling, water quality and interdependent hydrological effects. Biogeochemistry, 115(1): 1-21. DOI:10.1007/s10533-013-9875-8
10. N.C.E.I., 2016. Annual Climatological Summary for station: STATE UNIVERSITY, MS US COOP:228374. In: Administration, N.O.A. (Ed.).
11. Paine, T.D., Raffa, K.F., Harrington, T.C., 1997. INTERACTIONS AMONG SCOLYTID BARK BEETLES, THEIR ASSOCIATED FUNGI, AND LIVE HOST CONIFERS. Annual Review of Entomology, 42(1): 179-206. DOI:doi:10.1146/annurev.ento.42.1.179
12. Reid, L.M., Lewis, J., 2009. Rates, timing, and mechanisms of rainfall interception loss in a coastal redwood forest. Journal of Hydrology, 375(3–4): 459-470. DOI:http://dx.doi.org/10.1016/j.jhydrol.2009.06.048
13. Reid, R.W., Whitney, H.S., Watson, J.A., 1967. REACTIONS OF LODGEPOLE PINE TO ATTACK BY DENDROCTONUS PONDEROSAE HOPKINS AND BLUE STAIN FUNGI. Canadian Journal of Botany, 45(7): 1115-1126. DOI:10.1139/b67-116
14. Soil Survey Staff, N.R.C.S., United States Department of Agriculture, 2013. Web Soil Survey.
15. Wood, D.L., 1982. The role of pheromones, kairomones, and allomones in the host selection and colonization behavior of bark beetles. Annual Review of Entomology, 27: 411-446. DOI:10.1146/annurev.en.27.010182.002211

Methods

Study Site: the study was located in a north-central Mississippi remnant pine plantation(F4a). Tree species in the stand consists of 60-year old loblolly pine in the overstory and a hardwood midstory of sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), winged elm (*Ulmus alata*), and red oak species (*Quercus* spp.). Overstory basal area is 28.1 $m^2\,ha^{-1}$ with 417 trees ha^{-1} (T1). The midstory basal area is 17.9 $m^2\,ha^{-1}$ with 713 trees ha^{-1}. The primary soil type on this site is Urbo silty clay loam[10, 14].

- Treatments applied
  - 10 trees girdled with a chainsaw in July 2015
  - 5 girdled trees inoculated with blue stain fungus in November 2015
  - 5 girdled trees inoculated with nutrient agar in November 2015
- Measuring hydrologic fluxes
  - Stemflow collectors placed on 15 study trees, three 1L throughfall Nalgene collection bottles placed near trees(F 4b, 4c).
  - 6 Onset Data Logging Rain Gauges (Onset HOBO, #RG3-M)
- Measuring water qualities
  - Stemflow and throughfall collections taken, filtered, and stored within 24hours of storms, and assessed using fluorescence spectroscopy to find a_{254}, HIX, and FI(F5) Emission, Excitation, and Raman corrections were performed to ensure accuracy.
- To Measure Soil CO_2 flux
  - A Li-Cor 8100A and a 20cm survey chamber were used to measure CO_2 respiration chambers(F6,7)

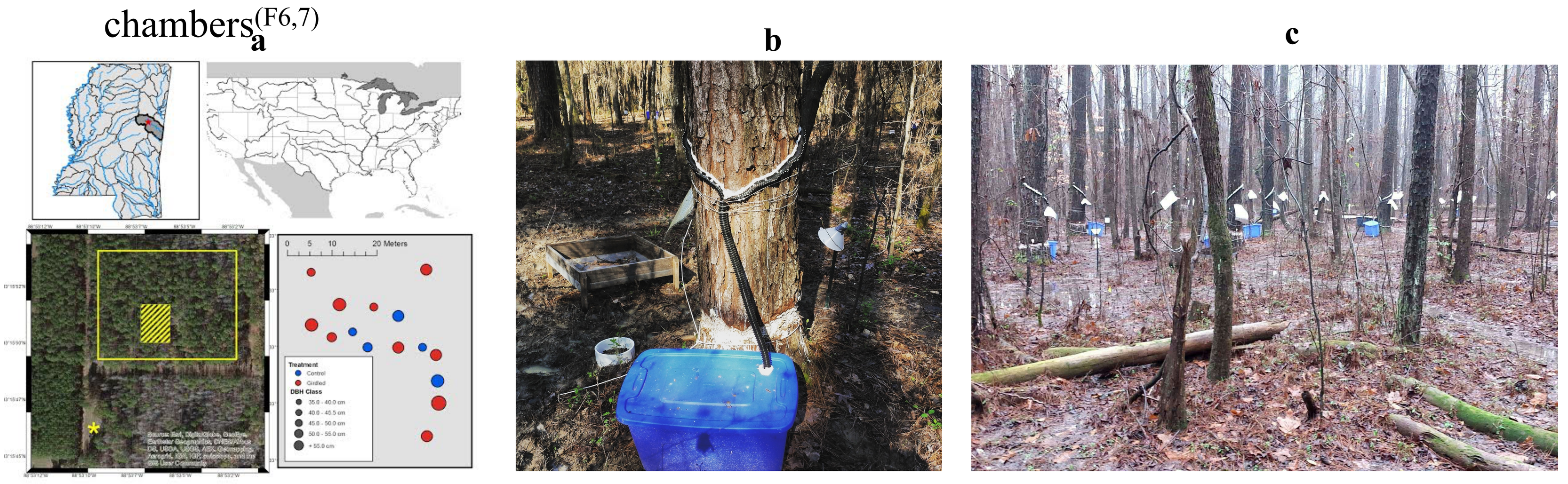

Figure 4. (a) the study plot is part of the Noxubee watershed, which drains into the middle Tombigbee-Lubbub watershed. The open area near the asterisk is used for precipitation measurements and collections. The DBH class and stem map are given.
(b) Cottonhouse study installations include a polyethylene collection bin connected to a polyethylene stemflow collection collar, and a stake for mounting 1L Nalgene throughfall collectors. CO_2 respiration chambers are also installed near the base of the tree.
(c) shows the lateral view of the study site after a winter rainfall

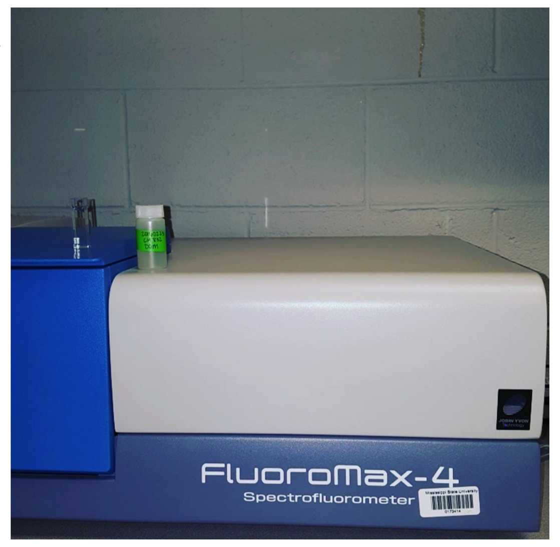

Figure 5. A FluoroMax-4 was used to produce 3D spectra assessing DOM.

Figure 6. Li 8100A fitted to a 20 cm survey chamber (Li-Cor model 8100A-103), in the background, and a soil moisture probe and thermocouple. The LI-8100 A uses the rate of increase of CO_2 in the measurement chamber to estimate CO_2 diffusion into the free air around the chamber.

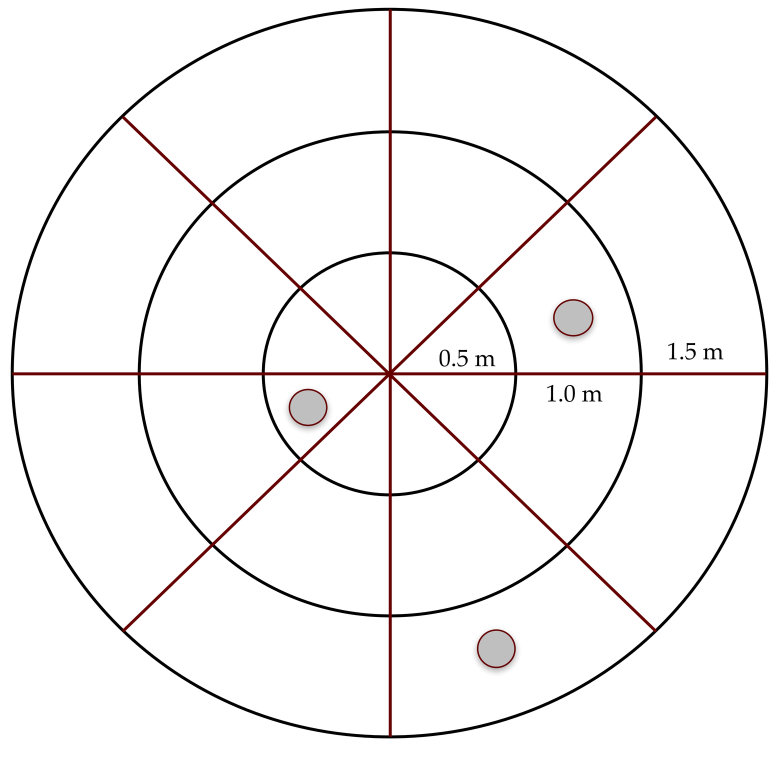

Figure 7. Three 20-cm diameter soil collars were installed at distances of 0.5m, 1.0m, and 1.5m from the tree at randomly selected points.

Results

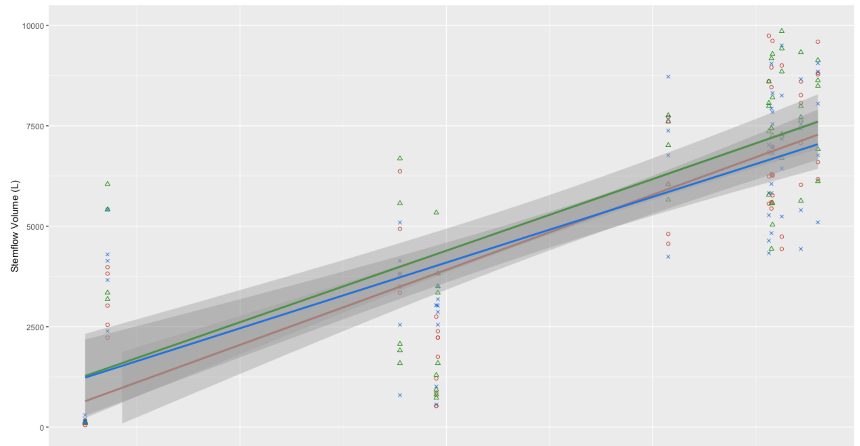

Figure 7. As precipitation increases, stemflow did for each treatment class as well. There does not appear to be an effect of treatment type on the volume of stemflow produced per storm event at this time.

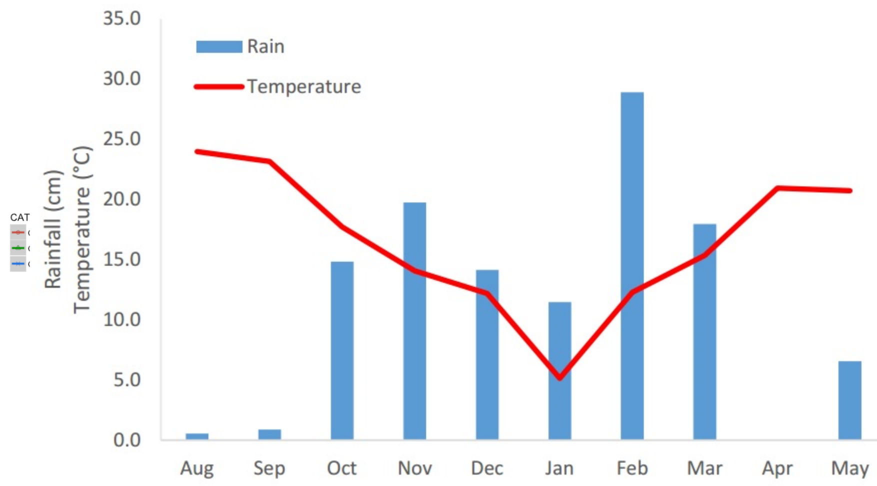

Figure 8. Climatic data for the study area. April is omitted due to an incomplete dataset.

Table 1. Stand attributes and treatments applied (BSF = Blue Stain Fungus).

TREE#	TREATMENT	DBH (cm)	CANOPY AREA (m^2)	TREE#	TREATMENT	DBH (cm)	CANOPY AREA (m^2)
828	Girdled + BSF	49.53	17.69	836	Girdled + Agar	38.10	5.75
829	Control	38.35	12.49	837	Girdled + Agar	48.51	16.08
830	Girdled + Agar	49.40	9.76	838	Control	38.10	11.22
831	Girdled + Agar	52.32	9.80	839	Girdled + BSF	51.05	14.26
832	Girdled + BSF	37.59	10.00	840	Control	48.01	10.38
833	Control	51.31	8.99	841	Girdled + BSF	42.93	14.27
834	Control	36.07	6.73	842	Girdled + BSF	45.97	11.60
835	Girdled + Agar	60.71	18.20				

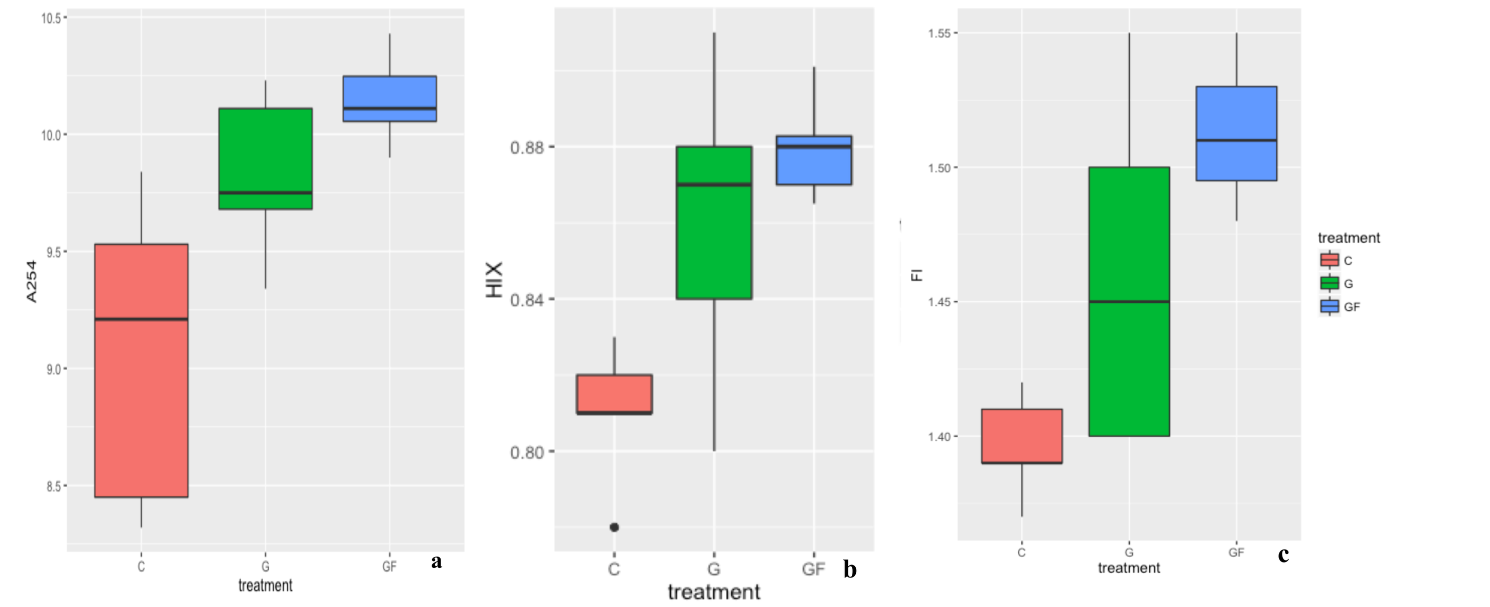

Figure 9. DOM qualities of stemflow by treatment, (n=15, 1 storm event). These are preliminary data, but they show potential trends which may become clear with further study.
(a): A_{254} is a measure of the aromaticity of DOM in stemflow, but without normalization to carbon. Higher A_{254} is positively associated with DOC and DON concentrations.
(b): Humification index(HIX) measurements characterize DOM humification status, and correlates with DON concentrations.
(c): Fluorescence index (FI) distinguishes between terrestrial and microbial sources of DOM. Values from 1.2-1.5 denote terrestrial sources, while values from 1.7-2.0 are indicative of microbial sources.

Discussion

These preliminary results are based on a relatively short time frame, but they show a distinct difference in DOM constituents(F7,8). These differences in DOM qualities could impact forest soils, and further study to assess those impacts should be completed(F9). Eventually, as the trees begin to decompose there result in greater inputs of highly aromatic organic carbon and nitrogen at the base of the trunk. As the amount of time after tree death increases, the carbon being released will become more recalcitrant, which could lead to nitrogen immobilization in the soils. This input of organic carbon and nitrogen could result in a decomposition hotspot, and it is unknown how long that impact would persist in remnant forests.

Acknowledgements

I would like to thank the faculty and students at the Mississippi State University College of Forest Resources and The Department of Biochemistry, Molecular Biology, Entomology, & Plant Pathology also working on this study site. This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, McIntire Stennis capacity grant #MISZ-069390. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

FT. LAUDERDALE esa 2016