Effect of climate change and forest management on wood mass loss in southeastern US loblolly pine forests

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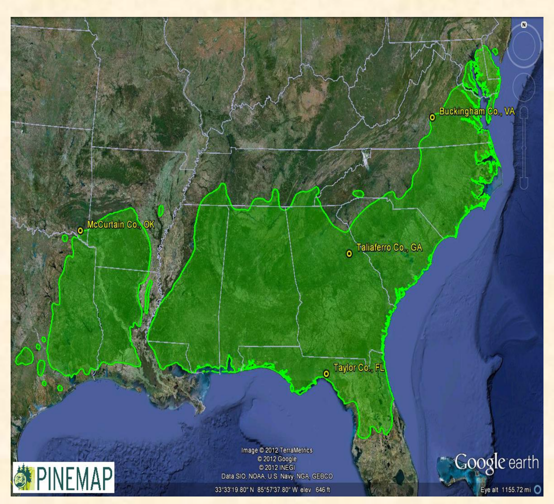
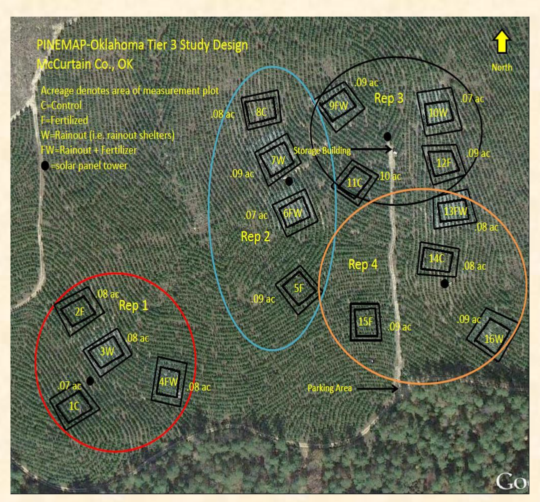
Abstract

Wood debris is an important C pool in forest ecosystems. Understanding the response of wood decomposition to climate change is necessary for studying forest soil carbon cycling. The productivity of managed pine forests in the southeastern US has been improved in part through nutrient management over the past 50 years. Although significant uncertainty exists, climate change may drive a reduction of rainfall of 10%-30% by 2080 for the region. In managed forests that undergo periodic harvesting, the forest can become a source of C when decomposer activity increases C loss from residual wood. We analyzed wood decomposition in response to fertilization, reduced precipitation, location, time, and sites. Our results showed that fertilization stimulated wood decomposition in OK site but tended to inhibited wood decomposition at the FL site with the positive effect on mass loss of woods with termites tunnels. In FL and OK, wood mass by Macro-invertebrates was much higher compared to GA and VA. Interestingly, we found fertilization reduced mass loss of woods with macro-invertebrates' tunnels in FL but increased mass loss of woods with macro-invertebrates' tunnels in OK. Our data indicated that in OK future drought would cause slower substrate decomposition but higher substrate mass loss by fertilization. In FL, fertilization may cause lower substrate. Higher woody mass loss and percentage of tunneled wood in FL compared to OK, GA and VA may be explained by higher temperature and precipitation. The temperature response of the relationship of sticks attacked by macro-invertebrates had a greater intercept than microbial-only decomposed sticks , suggesting that response of macro-invertebrates to climate and fertilization needs to be included in ecosystem carbon models.

Figure 1: Experimental site and wood substrates


Distribution of *P. taeda* and locations of four Tier 3 sites


OK's experimental design layout


Southern pine wood used as common substrate


Southern pine wood (back)

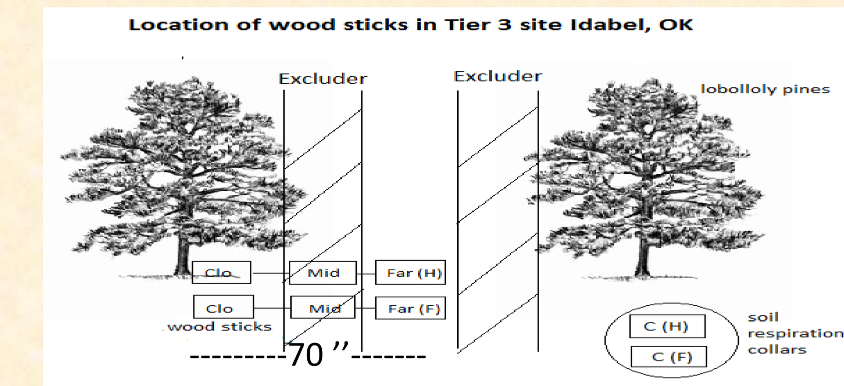

Wood substrate associated with termites

Study Design & Methods

The experimental design is factorial combination of soil moisture reduction and fertilization. 'Fertilization' (urea, DAP and potash) was conducted on April 2012 to achieve 'optimum' nutrient. The 'throughfall excluders' were installed in under the canopy on June 2012 to divert 30% of rain off of the plot. No rainfall manipulation or fertilization was the control (C), paired with a 1/3 throughfull reduction (TR) exclusion, an optimum fertilization (F), and an F+TR treatment with four blocks. Prior to placement, sticks (6.3cm x 1.8 cm x 0.6 cm) were dried (105 °C) and weighed. Sticks were placed in all tier 3 sites (OK, FL, VA, and GA) on Aug 2013. To assess the response of decomposition to treatments and spatial variation, a common substrate (southern pine wood sticks) was placed as shown in Figure 2.

The treatment effects within each site were analyzed using 4 way (F, RO, location, time) mixed model. Treatment effects across sites were analyzed by adding temperature as co-variable. Decomposition constant K was calculated ($k = -\frac{\ln\left(\frac{M_t}{M_0}\right)}{t}$, M_t: Remaining mass after time t, M_0: Initial mass) and the linear regression between k of control plots in 4 sites and mean temperature was analyzed. All statistical analyses were conducted in R version 3.1.0 (Team 2010).

Figure 2: Location of wood sticks



Location
Clo Close to tree
Mid Under excluder/middle distance
Far Between excluders/furthest from tree

Incubation time
H Half year
F Full year

Cross Site Results

Figure 5. Percent of tunneled wood for 4 sites.

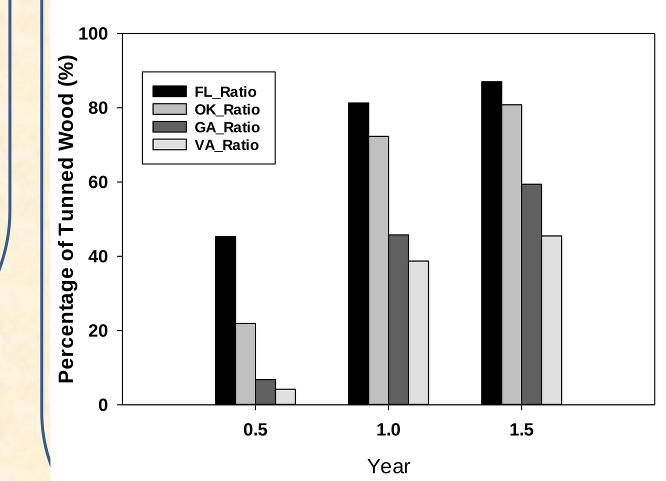
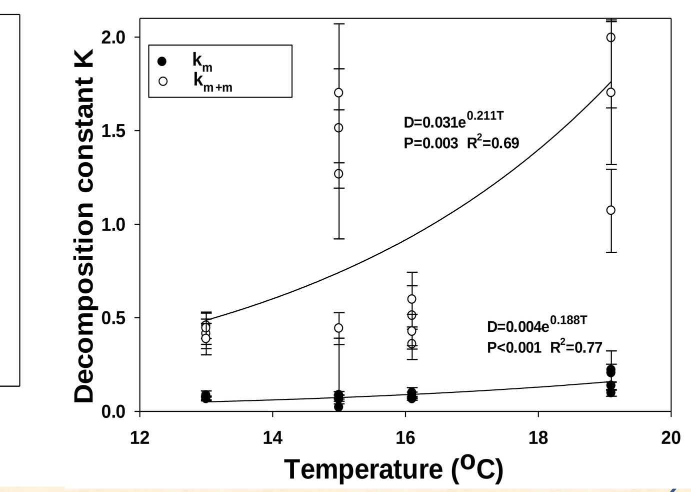


Figure 6. Summary of decomposition constant k for microbial and microbial+macroinvertebrates over annual average temperature across 4 sites.



Results: Climate trends & Treatment effects within each site

Figure 3. Monthly mean air temperature (°C), Vaper Pressure Deficit (VPD) and monthly summed precipitation (cm) for FL, OK, GA and VA.

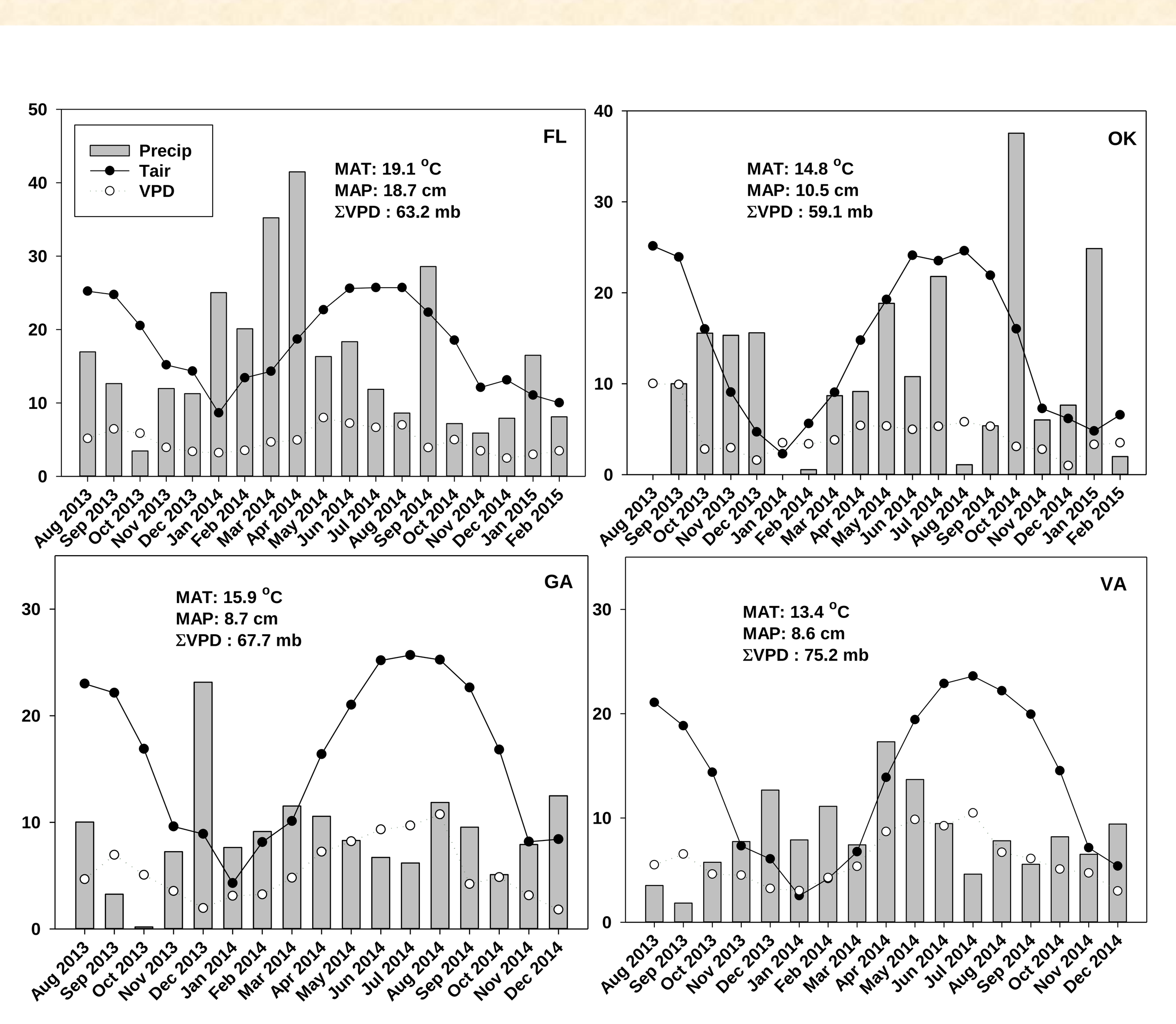


Figure 4. Treatment effects over time on mass loss of the individual wood sticks for all decomposers, microbial-only decomposed wood and wood decomposed by both microbes and macro-invertebrates across 4 sites.

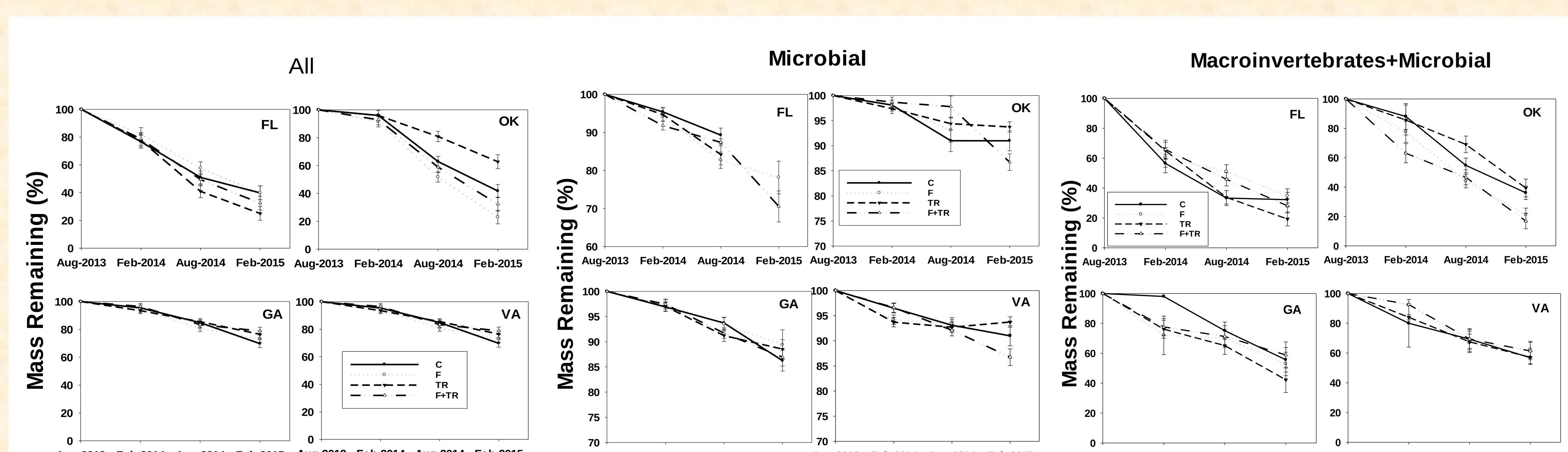


Table 1. FL's summary of degrees of freedom and p values for all decomposers, microbial and microbial plus Macro-invertebrates decomposition with individual stick as a carbon pool.

Treatment[a]	df N[b]	df D[b]	All	df D[b]	Microbes	df D[b]	Microbes & Macro-invertebrates
F	1	158	0.121	156	**<0.001**	95	**0.006**
TR	1	164	**0.007**	155	**<0.001**	93	*0.085*
L	2	513	**<0.001**	155	**0.005**	360	*0.086*
T	2	513	**<0.001**	156	**<0.001**	369	**<0.001**

Table 2. OK's summary of degrees of freedom and p values for all decomposers, microbial and microbial plus Macro-invertebrates decomposition with individual stick as a carbon pool.

Treatment[a]	df N[b]	df D[b]	All	df D[b]	Microbes	df D[b]	Microbes & Macro-invertebrates
F	1	57	**<0.001**	129	**0.002**	87	**<0.001**
TR	1	57	**0.001**	118	**<0.001**	92	0.648
L	2	462	**<0.001**	184	**<0.001**	269	**0.020**
T	2	468	**<0.001**	199	**<0.001**	265	**<0.001**

Results & Conclusions

(1) Higher air temperature and precipitation in FL compared to OK, GA and VA (Fig. 3).

(2) Fertilization stimulated wood decomposition in OK site for all, microbial, macroinvertebrates + microbial. Fertilization reduced mass loss of wood with macro-invertebrates' tunnels but increased microbial wood mass loss in FL (Fig.4; Table 1,2).

(3) TR increased wood decomposition for all and microbial decomposers in FL; In contrast, TR reduced wood decompositon for all and microbial decomposers in OK (Fig. 4; Table 1,2).

(4) FL and OK had higher ratio of tunneled wood compared to GA and VA (Fig. 5). Fertilization increased the ratio of tunneled wood in OK but had no effect in FL; throughfull reduction decreased the ratio of tunneled wood in OK but had no effect in FL.

(5) Significant exponential relationships were found between annual average temperature and decomposition constant k. The temperature response of the relationship of sticks attacked by macro-invertebrates had a greater intercept than microbial-only decomposed sticks (Fig. 6).

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