Impacts of Resource Manipulation Upon Soil Carbon and Nitrogen Processes

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Abstract

Longleaf pine (*Pinus palustris* Miller) wiregrass (*Aristida stricta* Michx.) savannas are regulated by fire and soil resources. Preliminary data point to landscape controls on soil moisture as a major regulator of productivity, but understanding how soil water and nitrogen availability regulate temporal, spatial, and species-specific differences in water and nutrient relations is needed to more fully understand how those controls are manifested throughout the landscape.

We propose that predicting the consequences of management on productivity requires a more general understanding of how interactions among resources and disturbances regulate productivity differentially above- and belowground.

We designed a study to examine the extent that fire, nitrogen (N), and water control plant community composition, productivity, and nutrient cycling in a longleaf pine-wiregrass ecosystem. Here we report the results of the aboveground resource manipulation (water and N) portion of the experiment.

Questions

1) Will water and N amendments increase productivity (Figure 2 & 3), litterfall (Figure 4 & 5) and N mineralization (Figure 6)?

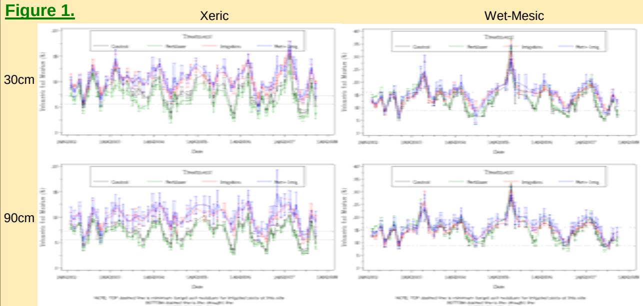
2) Will responses in carbon (C) and N cycling processes on xeric sites be greater than wet-mesic sites (Table 1)?

3) Will the indirect effects of N and water addition be greater on xeric or wet-mesic sites? This hypothesis to be mediated over time through shifts in species composition and their resulting influences (results not reported here).

Materials & Methods

- These forests are second-growth stands with the average tree ages ranging from 70-90 years.
- Soils at the xeric site are Typic Quartzipsamments and are characterized by coarse sand that exceeds 2.5 m in depth. Wet-mesic soils are Aquic Arenic Paleudults and are characterized by a heavy textured subsurface horizon.
- This study is a multi-factorial experimental design with 4 combinations/4 replications of irrigation and N addition as experimental treatments.
- 50 kg/ha/yr of ammonium nitrate is applied every 4 months in the fertilized plots to coarsely mimic the natural distribution of net N mineralization throughout the year.
- Irrigated plots are maintained at or above 40% field moisture capacity, which is approximately 75% additional mean annual precipitation (131 cm). (Figure 1)
- 32 study plots 2500 m^2 (50 m x 50 m) in size were randomly established in 2000 at each of the two sites (16 at each of the xeric and wet-mesic sites).
- Five subplots were randomly established across the gradient of pine overstory basal area in the xeric site; seven subplots were established at the wet-mesic site.
- The estimate of aboveground productivity (ANPP) will be based on allometric equations developed for pines and oaks (Mitchell et. al 1999).
- Understory biomass in proximity to each subplot will be collected in October of each year.
- Measurements and estimates of soil net N mineralization will follow a closed core in-situ incubation technique (Wilson et. al 1999).
- Volumetric soil moisture values at 30 cm and 90 cm depths will be followed monthly in all treatment plots using time domain reflectometry (TDR). (Figure 1)
- Soil temperature measurements will be made every 10 minutes at 10 cm using data loggers.
- Overstory litterfall will be collected monthly from circular, 0.25 m^2 traps and separated into categories: pine needles, oak leaves, and other.

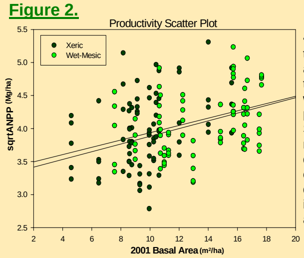
Figure 1.



•Figure 1 represents volumetric soil moisture over time and our ability to maintain proper soil moisture as measured by TDR for each site at 30 and 90 cm. Only during times of extreme drought have we not been able to maintain >40% field capacity.

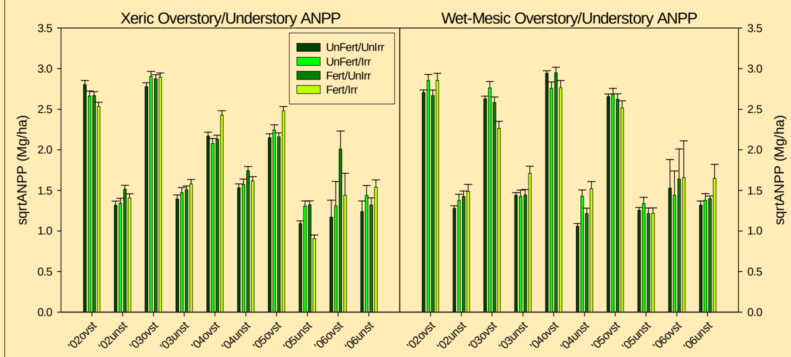
Results

Figure 2.



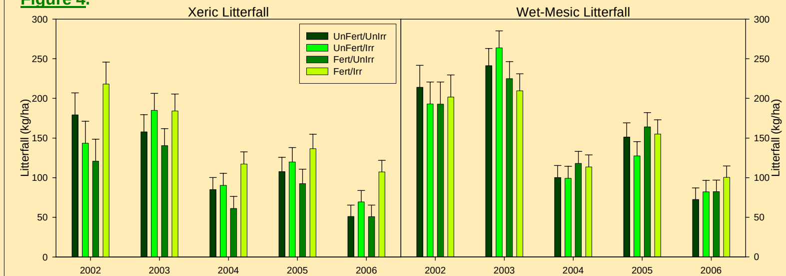
•Figure 2 is a scatter plot of the square root of the total ANPP (Mg/ha) and pre-treatment basal area (m^2/ha). The square root of ANNP transformation helped to normalize the data and was positively correlated (.68) with and easily predicted by the pre-treatment basal area. Slopes of the Xeric (.07) and Mesic (.06) regression equations where not significantly different. 2001 basal area was not used a covariate however due to the large basal area difference by site. Current analysis will us incremental growth from tree cores as basal area. Not reported here.

Figure 3.



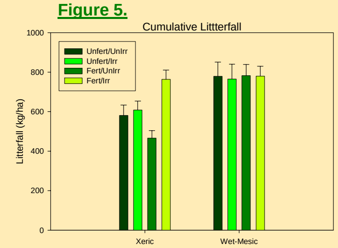
•Figure 2 depicts the square root of the total ANPP (Mg/ha) on the overstory and understory by year. Square root transformation normalized the ANPP data. Variability with in the sites has made it difficult to arrive at a confident inference about treatment differences. Only subtle increases in productivity where seen between the two site types. Irrigation and fertilization influences may be more evident with analysis of the overstory (pine and oak) and understory (wiregrass and forbs) components separately. Decreases in ANNP over time may be attributed to drought conditions and treatment influences may hinge on our ability to maintain adequate moisture levels through irrigation. Decreased productivity for the overstory and understory through time is consistent with other variables and may be attributed to climatic variability. The inherent property of these ecosystems to resist change may prove difficult to overcome and require modification of sampling techniques to capture change in overstory productivity.

Figure 4.



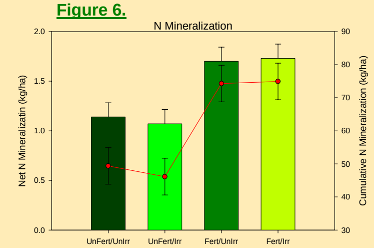
•Figure 4 is a graph of litterfall (kg/ha) for each site and treatment by year. Wet-mesic litterfall rates were not as susceptible to increases in N and water as xeric sites. The combined fertilizer and irrigation treatments increased litterfall at the xeric site. Decreased litterfall with time is consistent with other variables and may be attributed to climatic variability. Future test will include a covariate to control site variability.

Figure 5.



•Figure 5 graphs the cumulative litterfall for the first 5 years of the study and also confirms the significant impact that the N and water combination have on litterfall production for the xeric site. Decreased litterfall for fertilization treatments may be a factor of loss of leaf area due to plant stresses from drought coupled with increased N availability.

Figure 6.



•Figure 6 graphs net (bar) and cumulative (line) N mineralization for each treatment. Mineralization did not differ by site. N mineralization increased with fertilizer addition. Net mineralization for the N addition was 1.7 ±.10 kg/ha and for the reference net mineralization for the N addition was 1.1 ±.10 kg/ha. Like wise for cumulative mineralization N addition was 75 ±5.5 kg/ha and the reference 49 ±5.5 kg/ha.

Table1.

	Wet Mesic							
	2002				2006			
	UF/UI	UF/I	F/UI	F/I	UF/UI	UF/I	F/UI	F/I
Total C	**16.34(1.21)**	**14.26(1.21)**	**17.00(1.21)**	**14.02(1.21)**	**12.52(1.21)**	**13.15(1.21)**	**15.83(1.21)**	**12.08(1.21)**
^{13}C	-25.08(.29)	-25.13(.29)	-25.32(.29)	-25.65(.29)	-24.57(.29)	-25.37(.29)	-24.94(.29)	-25.18(.29)
C:N	27.39(1.04)	27.72(1.04)	30.53(1.04)	26.91(1.04)	28.23(1.04)	28.43(1.04)	27.01(1.04)	26.35(1.04)
^{15}N	**2.38(.25)**	**2.38(.25)**	**2.47(.25)**	**2.24(.25)**	**2.99(.25)**	**2.41(.25)**	**2.41(.25)**	**2.29(.25)**
Total N	0.59(.04)	0.51(.04)	0.55(.04)	0.52(.04)	0.44(.04)	0.46(.03)	.59(.04)	.46(.04)
	Xeric							
	2002				2006			
	UF/UI	UF/I	F/UI	F/I	UF/UI	UF/I	F/UI	F/I
Total C	11.58(2.03)	11.17(2.03)	11.44(2.03)	12.84(2.03)	9.36(2.03)	12.97(2.03)	9.85(2.03)	13.94(2.03)
^{13}C	-25.15(.27)	-24.45(.27)	-25.05(.27)	-24.75(.27)	-24.47(.27)	-24.68(.27)	-24.82(.27)	-24.75(.27)
C:N	23.94(1.15)	23.76(1.15)	25.10(1.15)	22.77(1.15)	22.99(1.15)	25.09(1.15)	22.31(1.15)	24.55(1.15)
^{15}N	1.71(.43)	1.64(.27)	1.25(.27)	1.82(.27)	2.11(.27)	1.87(.27)	1.40(.27)	2.21(.27)
Total N	0.48(.07)	0.46(.07)	0.45(.07)	0.56(.07)	0.41(.07)	0.51(.07)	0.44(.07)	0.54(.07)

•Table 1 summarizes soil C and N 10 cm soil variables, Total C (g/kg), ^{13}C isotope signature, C to N ratio, ^{15}N isotope signature and Total N (g/kg) from 2002 and 2006. Treatments are designated by Unfertilized/Unirrigated (UF/UI), Unfertilized/Irrigated (UF/I), Fertilized/Unirrigated (F/UI), Fertilized/Irrigated (F/I). Numbers in parentheses indicate ±1se.

•Significant treatment effects between the two periods were only seen for Total C and ^{15}N at the wet-mesic site and ^{15}N for xeric. Total C decreased significantly from 2002 to 2006. Most notably decreased C from the reference plots indicate possible climatic controls on carbon turnover in more aerobic conditions. ^{15}N tended to follow these C decreases by becoming more enriched as total carbon decreased through time.

Conclusions & Future Considerations

•N fertilization and irrigation treatments increased ANPP, in certain situations depending on year and site. More in depth analysis and statistical inference involving overstory and understory components along with species richness and below-ground data is need to fully understand interaction of water, N and fire on total productivity.

•N fertilization and irrigation treatments influenced litterfall more on xeric than wet-mesic sites and was higher with water and N combination. Increased xeric litterfall may be due to the opportunistic nature of the species inhabiting the site and their response to the increased resources.

•N fertilization and irrigation treatments increased N mineralization. However, irrigation alone decreased N mineralization, possibly due to leaching on xeric site and denitrification on wet-mesic sites or changes in soil temperature.

• Site was the biggest influences on soil C and N processes. Decreases in total carbon for wet-mesic site may be linked to climate. The relationship between decreasing C and enriching ^{15}N is consistent with Nadelhoffer and Fry (1988) and Hendricks et. al (2002). Analysis of C and N for vegetation, litter and deep soil sampling is need to better understand C and N cycles.

•More refined analysis of irrigation application is needed to understand soil moisture changes through time and adequately adjust irrigation to overcome seasonal variation.

•Future considerations include fire coupled with N, species richness and wildlife impact as areas of interest to help evaluate controls on productivity and management implications.

References.

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