CARBON SEQUESTRATION AND NATURAL LONGLEAF PINE ECOSYSTEM

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Abstract—The Southeastern United States was once dominated by a longleaf pine ecosystem which ranged from Virginia to Texas and covered approximately 22 to 36 million ha. The unique fire tolerant species provided the necessary habitat for numerous plant and animal species. Different seasons of prescribed fire have various results on the ecosystem and the carbon which is stored in the trees and different vegetation classes. After analysis of the various hardwood treatments and seasons of burn, the basal area of the longleaf pine and the soil carbon amounts differ. These results show that certain seasons of prescribed fire can yield more basal area (winter) and soil carbon (winter). Vegetation classes and the amount of stored carbon are also affected by the season of burn.

INTRODUCTION

Atmospheric carbon dioxide (CO_2) levels have been increasing over the past several decades. As a greenhouse gas, there are concerns that the increased CO_2 levels will cause potentially damaging changes to global climate. Worldwide, there has been increasing attention given to reducing atmospheric CO_2 levels by increasing carbon sequestration and storage, in forested ecosystems. Birdsey and Heath (1997) estimated United States forests have sequestered enough carbon over the past 40 years to offset approximately 25 percent of CO_2 emissions in the United States. According to this report, managed southern forests played a large role in this offset.

Kush and others (2004) presented reasons for longleaf pine (*Pinus palustris* Mill.) being the major southern pine species to consider growing for sequestering carbon. The southeastern United States was once dominated by natural communities of longleaf pine. This longleaf pine ecosystem, which currently covers 1.2 million ha, was historically estimated to have covered 22 to 36 million ha ranging from Virginia to Texas. The ecosystem formed by the fire tolerant longleaf pine is unique because it supports a number of endangered species of plants and animals, such as the pitcher plant and red-cockaded woodpecker. It is also the second most endangered ecosystem in the United States.

Fire is critical to longleaf pine management. What is not known is what role fire will play in sequestering carbon? Preliminary research was begun by using a long-term study conducted by the U.S. Forest Service on the effects of season of burn and hardwood control treatments on understory plant succession and overstory development of longleaf pine. Boyer (1995) reported on response of understory vegetation before, and then seven, and nine years after the treatments. Kush and others (1999, 2000) examined the effects of 23 years of these treatments on the long-term response of understory vegetations.

OBJECTIVES

The experiment was conducted in order to determine the relationship between the different prescribed burn treatments and the above ground biomass and carbon sequestration. The subsurface carbon sequestration of the soil in the longleaf pine ecosystem was also sampled.

METHODOLOGY

The Escambia Experimental Forest (EEF) was used as the site of study. Located in Escambia County, AL, it is managed by the U.S. Forest Service in cooperation with the T.R. Miller Mill Company. The design of the experiment consisted of three treatments using a Randomized Complete Block Design (RCBD) to limit hardwood competition. The first treatment was the use of prescribed fire in a biennial burn. The different seasons for the prescribed burns were winter (December to February), spring (April to May), and summer (July to August). A control treatment of a no burn check was included. The second type of treatment was a chemical treatment using undiluted 2, 4-D with an application rate of 1 mL per 2.54 cm of diameter at breast height (d.b.h.). This herbicide was applied to hardwood species in the late spring of 1973 as the initial and only treatment. The third type of treatment was a mechanical treatment. Mechanical treatments were initially used in 1973 on any stem greater than 1.3 m in height. Future use of the mechanical hand clearing method was used when it was necessary to do so. An untreated check was used as a control for the experiment.

Plot Sampling

The overstory, consisting of longleaf pine, was sampled by measuring d.b.h., crown height, and total height in early September 2003. All hardwood trees having a d.b.h. greater than 1 cm were measured for d.b.h. and total height. All living materials having a d.b.h. less than 1 cm were destructively sampled in nine plots per treatment plot in late September and early October in 2003. The destructively sampled plot size was 0.90 square meters. The various vegetation classes include grasses, vines, herbaceous plants, and woody plants. The litter layer was sampled with a single 30.5 square cm subplot contained in each sample plot.

Soil Sampling

The soil was sampled in each of the nine sample plots at three different depths with a stainless steel probe in early May 2006. Sample depths of 0-10 cm, 10-20 cm, and 20 cm

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Citation for proceedings: Stanturf, John A., ed. 2010. Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-121. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

and below were used. The slope on the plots was minimal; therefore its influence was small.

Carbon Analyses Protocol

A Thermo Finnigan Flash 1112 Series N/C Analyzer was used to perform the carbon analyses in the different vegetation classes, the litter layer, and the soil.

Statistical Analysis

A two-way analysis of variance (ANOVA) was used in order to determine the statistical significance of the treatments on understory biomass and overstory longleaf pine basal area. The soil carbon was also analyzed by using a two-way ANOVA with the various soil depths as the block variables. The SAS program was utilized to perform the two-way ANOVA (SAS Institute Inc. 2003). All tests were conducted using an alpha of 0.05.

RESULTS AND DISCUSSION

The basal area was the highest in the no burn sample plot (table 1). The summer prescribed fire resulted in the lowest amount of basal area, and the winter fire had the highest amount of basal area. The spring prescribed fire resulted in a basal area which was between the winter and summer fires.

There were no statistically significant differences in the percent of carbon between the hardwood treatments or the season of burn (table 2). However, there was a significant difference in the percent of carbon in the vegetation classes.

The different seasons of prescribed fire resulted in different amounts of stored carbon. For the burn treatments, the winter fire had the highest amount of stored carbon, followed closely by the spring burn (table 3). The summer burn had the least amount of stored carbon. The no burn check treatment contained the highest amount of stored carbon of all the treatments.

The amount of carbon in the vegetation classes and the litter layer varied with the season of burn. The grass had the most carbon with the winter burn and the least carbon in the absence of a burn (table 4). The herbaceous layer had the most carbon in the spring burn and the least carbon in the absence of a burn. The vine layer had the most carbon in the absence of a burn and the least carbon with the summer burn. The woody layer had the most carbon with the spring burn and the least carbon with the winter burn. The litter layer had the most carbon in the absence of fire and the least carbon with the summer burn.

Table 1—Relation of season of burn to basal area

Season of Burn	Basal Area (m^2/ha)
Winter	26.6
Spring	26.1
Summer	25.7
No Burn	27.1

Table 2—Statistical significance for the hardwood treatment, season of burn and vegetation classes

% Carbon	p-value
Hardwood Treatment	0.1985
Season of Burn	0.8604
Vegetation Classes	0.0004

Soil Carbon

The interaction between the hardwood treatments and the seasons of burn was not significant (p-value of 0.733). The supplemental hardwood treatments had no effect on the soil carbon content (p-value of 0.649). However, the season of burn did have a significant effect on the soil carbon content (p-value of 0.0408). A pair-wise comparison of soil carbon and different seasons of burn was performed by using Tukey's Studentized Range (HSD) test, with an alpha value of 0.05. Overall, the mean carbon contents are significantly different among the summer burn and the plot without a burn.

A comparison between the control treatment and the three seasons of burn was performed with Dunnett's t-test. The summer burn and the no burn had significantly different results in the means of the soil carbon content. The plot without a burn had the highest soil carbon percentage. Among the plots with prescribed fire, the spring burn resulted in the highest soil carbon percentage and the summer burn resulted in the lowest soil carbon percentage.

Table 3—Total aboveground biomass for the different seasons of prescribed fire

Season of Burn	Total Biomass (kg/ha)
Winter	359740.0
Spring	353954.3
Summer	339791.3
No Burn	385967.7

Table 4—Amount of carbon present in non-longleaf pine vegetation

Season of Burn	Grass	Herbaceous	Vine	Woody	Litter	Total
	------------------- Vegetation Classes ------------------					
	Kilograms per Hectare					
Winter	54.7	18.1	50.9	113.6	8237.1	8474.4
Spring	36.1	41.4	18.0	570.7	9508.4	10174.6
Summer	28.8	34.7	3.1	141.1	8037.4	8245.1
No Burn	0.9	2.1	187.3	259.9	20761.8	21212.0

CONCLUSION

The sample plot without a burn had the highest amount of basal area and the greatest amount of carbon storage. The winter burn resulted in the greatest basal area and carbon storage of all the plots treated with prescribed fire. There was very little significant interaction between the hardwood treatments and the season of burn.

The season of burn had a significant effect on the amount of soil carbon storage, with the spring burn having the highest amount and the summer burn having the least amount. However, the only truly significant results occurred in relation to soil carbon when the summer burn and the no burn were compared. The no burn plot had the highest amount of soil carbon.

ACKNOWLEDGMENTS

The authors wish to acknowledge the U.S. Geological Survey for funding this project through the Alabama Cooperative Fish and Wildlife Research Unit. The T.R. Miller Mill Company and the USDA Forest Service were very cooperative in their endeavors to assist the study on the Escambia Experimental Forest in Brewton, Alabama. John Gilbert, Anshu Shrestha, and Arpi Shrestha were invaluable for their help in the field and the lab. Thanks goes out to Ben Whitaker for helping to put this manuscript together.

LITERATURE CITED

Birdsey, R.A.; Heath, L.S. 1997. The forest carbon budget of the United States. In: Birdsey, R.; Mickler, R.; Sandberg, D.; Tinus, R.; Zerbe, J.; O'Brian, K., eds. U.S. Department of Agriculture Forest Service Global Change Research program highlights: 1991-1995. Gen. Tech. Rep. NE-237. Washington, DC: U.S. Department of Agriculture, Forest Service: 81-85.

Boyer, W.D. 1995. Responses of groundcover under longleaf pine to biennial seasonal burning and hardwood control. In: Edwards, M.B. (ed.) Proceedings of the eight biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-1. Asheville, NC: U.S. Department of Agriculture, Forest Service: 521-516.

Kush, J.S.; Meldahl R.S.; Boyer, W.D. 1999. Understory plant community response after 23 years of hardwood control treatments in natural longleaf pine (*Pinus palustris*) forests. Canadian Journal of Forest Research. 29: 1047-1054.

Kush, J.S.; Meldahl R.S.; Boyer, W.D. 2000. Understory plant community response to season of burn in natural longleaf pine forests. Fire and forest ecology: innovative silviculture and vegetation management. Tall Timbers Fire Ecology Conference Proceedings, No. 21. Tall Timbers Research Station, Tallahassee, FL: 32-39.

Kush, J.S.; Meldahl, R.S.; McMahon, C.K.; Boyer, W.D. 2004. Longleaf pine: a sustainable approach for increasing terrestrial carbon in the southern United States. Environmental Management. 33: S139-S147.

SAS Institute Inc. 2003. Version 9.1. Cary, NC: SAS Institute Inc. [Number of pages unknown].