# Shortleaf Pine Ecosystem Restoration: Impacts on Soils and Woody Debris in the Ouachita Mountains of the Southern United States

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## ABSTRACT

**A number of organizations and government agencies have been involved with restoration of overstocked shortleaf pine-hardwood stands to shortleaf pine-bluestem ecosystems in the Ouachita Mountains of the southern United States. These restoration efforts entail the reduction of stand density by harvesting and midstory competition control as well as the reintroduction of repeated fires. Application of these restoration practices has been shown to successfully develop communities and habitats that were abundant at the time of European settlement of this region. Currently, the U.S. Forest Service is in the process of restoring 62,730 ha of the Ouachita National Forest to a shortleaf pine-bluestem ecosystem. Although there is considerable information concerning the effects of restoration on animal and plant communities, little is known about the impacts of restoration on soils or to what degree important habitat components such as downed wood debris (DWD) changes during restoration activities. We found that initial harvesting and competition control treatments added significant amounts and changed the species composition of DWD within areas being restored. Almost 30% of the woody debris was lost and significant amounts of nutrients were displaced from DWD during initial restoration fires. However, following approximately 20 years of restoration activities, soil nutrient availability in restored stands appears to be greater or similar to that in unrestored stands. We found no evidence indicating that shortleaf pine-bluestem ecosystem restoration reduces inherent soil or forest productivity.**

## Introduction

The current forest and vegetative communities of the Ouachita Mountains in the southern United States reflects fire suppression that followed removal of the virgin forests during the late 19th and early 20th century (Bukenhofer and Hedrick 1997). Shortleaf pine (*Pinus enchinata* Mill) still dominates the overstory of these second growth forests but the current forests contain a much higher density of hardwoods than did the frequently burned, virgin shortleaf pine forests (Foti and Glenn 1991). Woody, rather than herbaceous plants such as bluestem grasses (*Andropogen* spp.), dominate the understories of these second growth forests. In an effort to provide habitat for red-cockaded woodpeckers (*Picoides borealis*) and other biota associated with pine-grassland communities, the Ouachita National Forest is currently restoring shortleaf pine-bluestem grass ecosystems to a portion of this region (Bukenhofer and Hedrick 1997). Restoration includes harvesting and midstory tree control to reduce pine and hardwood basal areas to approximately 13-14 and 2-3 $m^2$/ha respectively. In addition prescribe fires are applied on a 3-5 year interval to reduce understory woody vegetation (Masters et al. 1996) and promote the reestablishment of forb and grass communities. Although it is obvious that shortleaf pine-bluestem restoration can improve the habitats and diversity of biota in this region, the short and long-term impacts of these restoration activities on soils and woody debris have frequently not been quantified. We were interested in how restoration affects various inputs, losses, and pools of nutrients in these stands as well as the amounts of DWD following restoration efforts. We measured changes in the amounts of DWD and nutrients contained in DWD following initial harvesting and midstory control activities as well as the application of prescribed fire to a watershed undergoing pine-bluestem restoration. In addition we compared levels of nutrients in soils in stands that had 20 years of restoration activities to those that in unmanaged stands that had no restoration activities.

## Methods/Study Design

### Initial Harvesting/Midstory Control and Prescribed Fire

Impact of initial harvesting and applications of prescribed fire was determined in two adjacent sub-watersheds in the Upper Lake Winona watershed which is located in the western portion of Arkansas, USA (34° 48-51' N Latitude and 93° 0-4' W Longitude). One sub-watershed (pine-bluestem) is being restored to a shortleaf pine-bluestem ecosystem while the other sub-watershed (control) had no restoration or other management activities. Seventy-nine 0.08 ha circular plots were established on a 200 m grid in the two sub-watersheds prior to any restoration activities. Downed woody debris (DWD) inventories (diameter≥10.2 cm) were performed on all plots prior to harvesting in fall of 1999. DWD (diameter<10.2 cm) was inventoried on a subset of these plots following initial harvesting and midstory control (6 plots pine-bluestem, 5 plots control) in the fall of 2000. The subset of plots selected for this inventory was located outside of any riparian areas. In addition plots in the restored area received both harvesting and midstory control throughout the entire plot. DWD was again inventoried on these 11 plots following application of a prescribed fire during the spring of 2001. Species class (Hardwood or Pine), decomposition class, and size class was recorded. Wood and bark samples were also collected at the time of the inventories to calculate specific gravity and nutrient (C, N, P, K, Ca, and Mg) concentrations. Volumes, mass, and nutrient contents were computed and compared between the pine-bluestem and control sub-watersheds as well as prior to and after the initial prescribed fire in the pine-bluestem sub-watershed. Average standing basal area in the pine-bluestem sub-watershed was reduced from 20.9 $m^2$/ha prior to 8.7 $m^2$/ha by harvesting and midstory control.

### Long-term Restoration Impact on Soils and Nutrient Availability

Six shortleaf pine-hardwood stands located within 5 km of $34^{o}$ 47” N Latitude and $94^{o}$ 10’ W Longitude in the Ouachita Mountains were used for this study. Three stands had not received any restoration or silvicultural activities for a period of 40 years prior to the study and were typical closed canopy shortleaf pine-hardwood stands (control). The other three stands were restored to a shortleaf pine-bluestem ecosystem (pine-bluestem). Initial overstory and midstory harvesting or control activities occurred from 1978-1980 in the restored stands. Midstory and overstory hardwoods that were felled were typically left on the ground due to the lack of suitable hardwood markets. Prescribed fires were generally applied on a 2-4 year interval following harvesting and competition control. The last prescribed fire at all three pine-bluestem stands occurred during March of 1997 prior the initiation of the study. All stands occurred on Carnasaw or Sherless soils series (NRCS 1998) and have loamy surface textures. These soils have similar surface soil (35-50 percent) and subsurface soil (35-40 percent) rock contents. Stands chosen for the study were located on 10-20 percent slopes, on southern to southwestern aspects at elevations between 237 and 317 m above MSL

## Results and Discussion

Initial harvesting added large amounts of DWD (Figure 1) to the forest floor. Volume and mass of DWD was approximately 250 to 350% greater in the pine-bluestem sub-watershed (122.9 $m^3$/ha and 67. 3 Mg/ha) than in the undisturbed control sub-watershed (34.9 $m^3$/ha and 15.5 Mg/ha) following initial harvesting and control activities. The composition of the DWD was also altered. Since pine but not the hardwoods could be sold and removed from the restored watershed, harvesting activities primarily added fresh, undecomposed, large hardwood debris (Figure 2) to the forest floor. Pine DWD only

Figure 1. Study plots in control sub-watershed (top) and in the pine-bluestem sub-watershed (bottom) following harvesting and midstorycontrol.

only represented 36% of the total DWD in the pine-bluestem sub-watershed but comprised 65% of the DWD in the control sub-watershed following these initial restoration activities. It seems likely that at least for a short period of time, the addition and change in DWD composition could alter populations of biota that use DWD for food or habitat. We are not aware of any studies that have evaluated the impacts of DWD inputs on biota during or in transitional periods of shortleaf pine

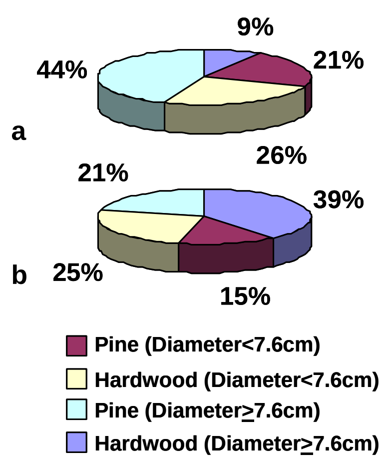


Figure 2. Proportion of DWD by species and size class in the control sub-watershed (a) and the pine bluestem sub-watershed (b).

bluestem ecosystem restoration. DWD levels are extremely low in stands that have been fully restored to pine-bluestem ecosystem conditions (Figure 3). Biota dependent on DWD are likely to be at low population levels during this stage of restoration.

Figure 3. A restored shortleaf pine-bluestem ecosystem typically contains little or no DWD.

DWD added to the forest floor by harvesting and midstory control also added nutrients (Table 1). The increase in the amounts of N, P, and Mg in the pine-bluestem sub-watershed generally reflected the increase of DWD mass following the initial restoration activities. However the increases in amounts of Ca and K exceeded that attributed to increases in DWD mass. Ca and K within the pine-bluestem sub-watershed was respectively 760 and 622% greater than that in the control sub-watershed plots while DWD mass was only 334% greater. The increases in Ca and K reflected the higher concentrations of these nutrients (Table 1) in the hardwood DWD that dominated the inputs of DWD from harvesting and tree felling. Generally levels of nutrients in woody debris in the pine-bluestem sub-watershed were similar or slightly greater than those generated by clearcutting or partial harvests in shortleaf pine-hardwood stands reported by Liechty and Shelton (1998).

Table 1. Mean nutrient contents and concentrations of the DWD in the control and pine-bluestem sub-watersheds.

| *Nutrient* | | *Control* | *Pine -bluestem* | *p-value* |
|---|---|---|---|---|
| N | (kg/ha) | 29.7 | 139.4 | 0.001 |
| | (g/kg) | 2.1 | 2.4 | 0.662 |
| P | (kg/ha) | 1.8 | 8.6 | 0.003 |
| | (g/kg) | 0.12 | 0.13 | 0.475 |
| K | (kg/ha) | 10.8 | 78.0 | 0.016 |
| | (g/kg) | 0.7 | 1.1 | 0.045 |
| Ca | (kg/ha) | 61.3 | 446.6 | 0.006 |
| | (g/kg) | 4.1 | 6.6 | 0.071 |
| Mg | (kg/ha) | 4.5 | 25.0 | 0.005 |
| | (g/kg) | 0.30 | 0.37 | 0.287 |

The prescribed fire set during the spring of 2001 significantly reduced the amount of DWD in the pine-bluestem sub-watershed. DWD volume on the inventoried plots within this sub-watershed was reduced from 122.9 to 88.5 $m^3$/ha and mass was reduced from 67.3 to 48.9 Mg/ha. Approximately 60% of this reduction was in size classes less than 7.6 cm in diameter. The fire also significantly reduced the amount of nutrients in DWD (Table 2). Reductions in nutrient content ranged between 32 and 47%. Reductions, as a proportion of initial amounts, were greatest for P and Ca, nutrients that have much higher concentrations in small DWD (twigs and branches) than larger DWD (boles). It is not known if these nutrients were retained on site within the soils or remaining forest floor because additional work that collected soils or forest floor have not been completed.

Table 2. Mean nutrient contents in DWD in the pine-bluestem sub-watershed before and following a prescribed fire.

| *Nutrient* | | *Before Fire* | *After Fire* | *p-value* |
|---|---|---|---|---|
| N | (kg/ha) | 139.4 | 95.2 | 0.018 |
| P | (kg/ha) | 8.6 | 4.8 | 0.020 |
| K | (kg/ha) | 48.6 | 78.0 | 0.020 |
| Ca | (kg/ha) | 446.6 | 241.1 | 0.010 |
| Mg | (kg/ha) | 25.0 | 15.9 | 0.021 |

N and K can be volatized or leached from soils following prescribed fires in the southern US. Comparisons of nutrient losses from DWD to nutrient pools reported by Johnson et al. (1988) or Beasley et al. (1988) suggest that these losses represent 0.2 to 6.0% of the total amounts of these individual nutrients in the biomass, forest floor, and soils of mature shortleaf pine-hardwood stands. If these nutrients are truly removed by offsite transport, replenishment of these losses by wet deposition would be slow. Comparisons of losses to annual wet deposition inputs measured at a nearby National Atmospheric Deposition Program station indicated that annual inputs of N were 11% of N losses while inputs of Ca, Mg, and P were only 1-3% of losses. Continued use of fire could reduce nutrient levels further unless soil weathering or dry atmospheric deposition offset the differences between wet deposition inputs and potential losses from fire.

However, nutrient levels in surface soils after a number of years of restoration do not appear to be reduced.

Nutrient availability observed within the restored stands was generally similar or generally greater than in the unmanaged shortleaf pine-hardwood stands sampled in the long-term study (Table 3). Increases of pH and Ca are frequently found following prescribed fires in southern pine stands. The large increase in Ca and pH observed in these stands most likely reflects the combined effects of fire and harvesting. These increases were not transient and were observed in each of the three years following the spring prescribed fire in the three pine-bluestem stands. Mineralizable N was also consistently higher in the pine-bluestem stands than the unmanaged stands. This may potentially be related to the increase in forbs, herbaceous plants, and legumes. The higher levels of C in the soils of the pine-bluestem stands may also be related to an increase in legumes. Johnson (1992) reported after reviewing a number of studies that soil C and N increased by 20-100% when N-fixing plants were present following harvesting. Cation exchange capacity although not shown in Table 3, was also higher in the pine bluestem stands. No nutrient or soil parameter measured within the surface soils was significantly reduced as a result of restoration. Thus nutrient availability and soil productivity within the restored ecosystems appeared to be maintained or increased following shortleaf pine-bluestem restoration.

Table 3. Mean surface soil (0-15 cm) characteristics collected during the fall of 1997-1999 within three shortleaf pine stands following 17-21 years of restoration (pine-bluestem) and three unmanaged stands (control).

| | *Control* | *Pine -bluestem* |
|---|---|---|
| pH | 4.9 | 5.3 |
| C (g/kg)[1] | 19.8 | 25.6 |
| C:N[1] | 17.9 | 20.9 |
| Total N (g/kg)[1] | 1.1 | 1.2 |
| Mineralizable N (mg/kg) | 50.4 | 59.8 |
| P (mg/kg) | 7.0 | 6.2 |
| K (mg/kg) | 66.1 | 76.0 |
| Ca (mg/kg) | 332.2 | 533.1 |
| Mg (mg/kg) | 134.7 | 117.2 |

[1]Measurements only from the fall 1999 sample collection

## SUMMARY

Initiation of harvesting and midstory control during shortleaf pine-bluestem restoration introduces large amounts of DWD to the forest floor. The introduction of woody debris, at least during the beginning stages of restoration, produces resource and environmental conditions that are much different than those prior to initiation of restoration or after shortleaf pine-bluestem ecosystem restoration has been completed. This transitional period can likely support a much different biotic community than is found prior to restoration or after shortleaf pine-bluestem grass ecosystem restoration has been completed. Recognition of this aspect of restoration as well as the impact of this restoration period on biotic communities could be an important consideration for land managers.

Addition of woody debris also transfers large amounts of nutrients from the living biomass to the soil. Although, this transfer of nutrients is significant and potentially could result in a reduction of nutrient levels by offsite movement, it does not appear that these restoration practices reduce inherent soil nutrient availability. Availability of many nutrients in the surface soils was in fact higher in restored stands than in stands without restoration activities. This research indicates that restoration does not negatively impact inherent soil or stand productivity attributed to reductions in soil nutrient availability.

## LITERATURE CITED

Beasley RS, Miller EL, Lawson ER, Stogsdill WR. 1988. Contrasting acidic deposition and nutrient pools in an undisturbed forest and a young pine plantation in the Ouachita Mountains. Arkansas Science and Technology Authority Project Report. Proposal #86-A-0008. 41p.

Bukenhofer, G.A. and Hedrick, L.D. 1997. Shortleaf pine/bluestem grass ecosystem renewal in the Ouachita Mountains. In: Wadsworth, K.G. (Ed.) Transaction of the Sixty-second North American Wildlife and Natural Resources Conference. March 14-18, 1997. Wash. D.C. pp. 509-515

Foti, T.L. and Glenn, S.M. 1991. The Ouachita Mountain landscape at the time of settlement. In: Hendeson, D. and Hedrick, L.D. (Eds.) Proceedings of the conference on Restoration of Old Growth Forests in the Interior Highlands of Arkansas and Oklahoma. Ouachita Nat. For. Winrock Intern. Inst., 19-20 Sept. 1990. Morrilton, Ar. pp. 49-65.

Johnson DW, Henderson GS, Todd DE. 1988. Changes in nutrient distribution in forests and soils of Walker Branch Watershed over an eleven-year period. Biogeochemistry. 5:275-293.

Johnson, D.W. 1992. Effects of forest management on soil carbon storage. Water, Air, Soil Poll. 64: 83-120.

Liechty HO, Shelton MG. 1998. Evaluation of the effects of phase II ecosystem management reproductive cutting methods on litter/ soil nutrients. USDA Forest Service Final Report: Coop Agreement. SO-19-92-009. 25p.

Masters, R.E., Wilson, C.W., Bukenhofer, G.A., and Payton, M.E. 1996. Effects of pine-grassland restoration for red-cockaded woodpeckers on whitetailed deer forage production. Wildife Soc. Bull. 24: 77-84.

NRCS. 1998. Soil survey of Scott County. United States Department of Agriculture, Natural Resource Conversation Service.