SOIL AND WATER MANAGEMENT IN THE SHORTLEAF PINE ECOSYSTEM

Edwin L. Miller[1]

ABSTRACT

The opportunities for achieving watershed management goals in the process of timber management in the range of shortleaf pine are excellent. Water yield increases may occur with forest harvest but with little or no adverse watershed effects. Peak or flood flows for major storms are little affected by forest harvest. Serious erosion potentials exist when inappropriate silvicultural treatments are applied on erodible sites but prudent managers have many harvest and site preparation options which will not cause serious erosion problems when properly applied. Erosion from roads poses the greatest potential for water quality degration. Excellent opportunities exist for trapping road sediments on vegetated slopes when roads are properly located and drained. Stream crossings deserve special sediment control consideration. Streamside management zones (SMZ) are needed to stabilize stream beds and banks, protect flood zones and provide shade for stream temperature maintenance. SMZ's can meet watershed objectives and be managed for other timber - and non-timber outputs.

INTRODUCTION

Watershed management is defined as the use of natural resources of a drainage basin in a way that protects or enhances the water based resources. There is nothing particularly unique about shortleaf pine (Pinus enchinata Mill.) that either enhances or detracts from the foresters ability to practice good watershed management in the process of managing shortleaf for timber production. It is the physiographic variability of sites across the range of shortleaf pine and the nature of specific silvicultural practices used on those sites which must be examined and understood in terms of the regional water balance and the needs for water quality protection.

In this brief paper I have outlined what I believe are some of the more important forest watershed management considerations and generalized the direction of response to some broad forest management activities. Water yield, peakflows and water quality, including suspended solids and water temperature are considered in response to forest harvest and site preparation, forest roads and streamside management activities in the Ouachita Mountains.

[1]Assoc. Prof. Forest Hydrology, Oklahoma State University, Department of Forestry, Stillwater, OK Formerly Forest Hydrologist, Weyerhaeuser Co., Southern Forestry Research Dept., Hot Springs, AR.

Water Yield

A number of studies have been conducted to determine the streamflow response to forest stand removal in the southeastern United States. Generally, when the transpirational surface is reduced or removed from a watershed area by forest harvest, that portion of rainfall inputs not subject to evapotranspiration (Et) losses, including interception, evaporation and transpiration, are available for streamflow. In coniferous forests, Et reductions and subsequent streamflow increases can average about 1.5 inches per 10% reduction in forest cover (Hewlett 1982). Complete forest removal could therefore result in streamflow increases of from 7 to 20 inches the first year following harvest.

Lawson (1975) measured runoff before and following partial and complete forest stand removal on shortleaf pine-hardwood catchments in the Ouachita Mountains of Arkansas. First year runoff increases were 4.3 and 10.9 inches for the partial and complete harvest treatments respectively. No increases in stormflow were detected by Miller (1984) following clearcutting of shortleaf on three small watersheds in the Ouachita Mountains of Oklahoma. In this case, site preparation activities included a deep soil ripping treatment on the contour which may have affected the hydrologic response of the watersheds.

The nature and timing of streamflow increases is a function of watershed characteristics such as the depth of soils and geology as well as the vegetation. Most studies have shown that increases in flow following forest harvest occur during periods of normally low streamflow, and that the duration of response ranges from 7 to 10 years with prompt and full forest restocking (Douglass and Swank, 1972). Replacement of hardwood stands with pine at the Coweta hydrologic research watersheds, reduced streamflows below the original base levels (Swank and Douglass, 1974), a factor to consider when converting from mixed pine-hardwood to pure fully-stocked pine. Year-around interception losses by pine and a longer transpirational season are largely responsible for the increased water use by pine (Zahner, 1955).

Peakflow

The effect of forest harvest on flooding has and continues to be a topic of high interest and poor understanding by the general public. As with water yields, an excellent research record is available and forms the base of our understanding. Lull and Reinhart (1972), Stone et al. (1978) and Anderson et al. (1976) reviewed the results of numerous studies on forest harvest and flooding in the United States and concluded that extreme floods occur when soils are recharged (saturated) on harvested and uncut areas and floods resulting from rainfall are therefore little affected by normal forest operations. Watershed characteristics such as area, slope, soils and geology, which vary by physiographic province, are the key factors in determining the regional variation in peakflows. For smaller storms or for storms which occur during periods of high evapotranspiration, peaks on harvested areas may be larger than on forested areas as soil moisture levels will generally be greater on harvested areas and less soil water storage available when it rains. These smaller storms however are not the cause of flood damage.

Studies in Oklahoma and Arkansas confirm the general relationship between forest harvest and large peakflows. In the Ouachita Mountains of Oklahoma, Miller (1984) found no significant difference in peakflows between forested and clearcut harvested watersheds for the eight largest runoff events recorded in a three year period following harvest. In Arkansas, Miller et al. (1986) measured no significant difference in peakflow between clearcut, selection cut and uncut watersheds for a storm which exceeded the 100 year return period. In these cases, storms occurred when soils were fully recharged on all watersheds regardless of vegetative cover and very little storage available for rainfall.

The nature of streamflow and peakflow responses to forest management are not unique for shortleaf pine. That a lower intensity of harvest and site preparation practices, which may be more common with shortleaf pine, will be uniformily favorable in the case of flood flows does not hold true and sound intensive evenage management of shortleaf has not been shown to necessarily increase peakflows from extreme rainfall events.

Erosion

The physiographic variability across the range of shortleaf pine, the nature of the soil erosion processes and the variability in the application of harvest and site preparation practices, limit our ability to generalize about the absolute levels of erosion and sedimentation which may occur due to silvicultural practices. It is accepted that small and temporary increases in erosion and suspended sediment transport will normally occur as a result of carefully conducted harvest and site preparation activities (Patric, 1978). It is also accepted that the form of harvest and regeneration activities evenaged or unevenaged has little direct influence on erosion and sedimentation in the long term (Stone et al. 1978). Increases in erosion due to silvicultural activities are largely a function of the site, appropriateness of the treatment and the operator.

Baseline rates of erosion from forest lands in the United States are low. Soil losses from 812 erosion measurements were summarized by Patric et al. (1978). Erosion rates ranged from 0.01 to 1.09 tons/ac/yr and three-fourths of the observations did not exceed 0.25 tons/ac/yr. Sediment yields from undisturbed forest lands in the eastern U.S. were reported to range from 0.05 to 0.10 tons/ac/yr (Patric 1976). In one respect these low base levels present a dilemma in that environmentally acceptable rates of erosion due to forest management activities may appear large in comparison to baseline erosion rates.

Focusing on the Ouachita Mountains of Oklahoma and Arkansas, Miller (1984) and Miller et al. (1985) reported the results of two studies in which soil losses were measured following various methods of forest harvest and regeneration and compared to losses from forested areas. In the Oklahoma study soil losses averaged 0.126, 0.016 and 0.007 tons/ac the first three years following clearcutting and intensive site preparation while soil losses from control areas averaged 0.02, 0.004 and 0.002 tons/ac in respective years. In Arkansas soil losses averaged 0.105, 0.040 and 0.080 tons/ac from clearcut and site prepared watersheds, 0.015, 0.017 and 0.035 tons/ac from selection cut watersheds and 0.005, 0.075 and 0.031 tons/ac from control watersheds, the first three years following harvest treatments. Obviously the erosion rates measured in these studies were very low regardless of treatment and presented no threat to the long term productivity of the watersheds.

In contrast to the low rates of erosion measured in the Ouachita Mountains, Beasley (1976) measured much higher rates following harvest and site preparation treatments on highly erodible soils on steep slopes in north Mississippi. First and second year sediment losses with mechanical site preparation, which included shear and pile and contour bedding, averaged about 6 and 2.5 tons/ac in comparison to undisturbed rates of 0.28 and 0.05 tons/ac respectively. When inappropriate treatments are applied on erodible soils unacceptable rates of erosion will occur.

A few general principles concerning silvicultural practices and erosion which apply across a range of physiographic and vegetative types can be summarized. One key to preventing erosion is to maintain soil cover and high infiltration rates which precludes overland flow. Erosion cannot occur when sediment transport mechanisms are not provided. Ephemeral channels should not be disturbed. Stream channels are normally a ready source of sediment and their stability should be maintained. A large percentage of the annual sediment load produced from a watershed is normally the result of a few and occasionally only a single intense rainstorm. Protecting sites from large storm events may be possible if they occur seasonally. Finally there is great variability in the application of given silvicultural treatments. Good operators are therefore a key element in effective and efficient operations.

Suspended Sediment

As with erosion both the baseline levels of water quality and the potentials for water quality degradation vary greatly across the physiographic divisions of the southern U.S. and water quality maintenance is not directly a function of the species under management. Even as the potential for sediment to reach a stream course varies greatly, acceptable levels of instream sediment loading necessary for the maintenance of aquatic communities varies. Nutter and Douglass (1978) observed that lower levels of erosion are generally required to maintain good water quality, as measured by low levels of total suspended sediment, than are required to maintain site productivity. Other factors such as non-forest land uses and stream channel and bank sediment sources further complicate the link between forest management practices and the sediment loads of larger streams and rivers.

Nevertheless, the direct sediment loads which result from forest management have been summarized and reported for a number of specific silvicultural practices over a broad range of soils and topography (Yoho. 1980). These data do give a relative measure of the impact of forest management on water quality. Normally, average sediment concentrations are calculated for individual storms or for streamflow on an annual basis as a measure of water quality impact. Erosion and sediment loading varies within storms and therefore the suspended sediment concentration in streamflow changes with stage (discharge) and through time. We have all casually observed these phenomia in streams and rivers.

For the Arkansas and Oklahoma studies reported above we examined the concentration of sediment at discrete points through time during stormflow runoff. Analysis of individual samples allowed an examination of the percent of time total suspended sediment (TSS) levels exceeded some predetermined levels (Miller, 1984). A summary of the Oklahoma, Ouachita Mountain results showed that only small differences in the time of elevation of TSS occurred between treatments at the 10, 20, 50, and 100 mg/l levels for the four years following clearcutting and intensive site preparation treatments (figure 1). Similar results were obtained in the Arkansas, Ouachita Mountain study (Miller et al. 1986). This method of summarizing suspended sediment data may be more useful than average annual or storm TSS concentration calculations, to those evaluating the impact of suspended sediment on aquatic organisms.

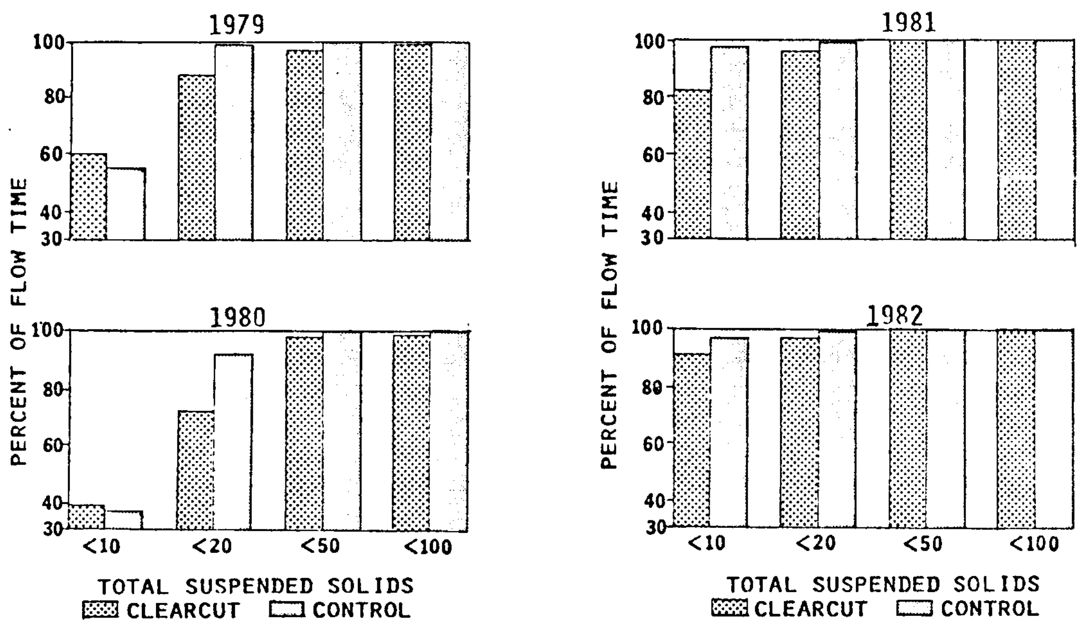

Figure 1. Percent of stormflow time that total suspended solids (TSS) in stormflow were less than 10, 20, 50 and 100 mg/l.

Road Sediments

Unfortunately a thorough review of forest road erosion studies in the southern U.S. is not available and research has been conducted in only a few southern physiographic regions. However, it is generally accepted that among forest management activities, the construction and maintenance of a road system presents the greatest single potential source of sediment (Patric, 1978 and Ursic and Douglas, 1979). Roads are a necessary part of any forest management scheme and since forest road erosion is largely a function of physiographic conditions, general principles apply in forest road erosion control (Trimble and Sartz, 1957, Kochenderfer, 1970, Groves et al. 1979 and Swift, 1984).

Two studies of erosion from forest roads in the Ouachita Mountains are reported by Beasley et al. 1984, Miller et al. 1985 and Vowell, 1985. The primary objectives of these studies were to evaluate the sediment production rates from two contrasting road types, a 15 year old USFS primary access road and a recently constructed state of the art industrial primary access road, and to determine the nature and extent of sediment routing and delivery to stream courses. In the Arkansas study on the older established road erosion rates averaged about 60 T/mi/yr from monitored road sections, about 10% of the 692 T/mi/yr estimated in the Arkansas statewide nonpoint source assessment (Arkansas Department of Pollution Control and Ecology, 1980). Sediment delivery to streams was projected to be 7.9 T/mi/yr, about 10% of total production and only 1% of the Arkansas assessment estimate. A large portion (90%) of the total sediment production was entrapped before entering a stream course. The delivered sediment equated to about 0.038T/ac/yr over the entire basin, roads and forested acres combined, a relatively low level of sediment loading. erosion from roads was related to soils, slopes, area of exposed backslopes, and the timing and intensity of rainfall. Sediment delivery to streams was more a function of road location and/or the direct discharge of road runoff into ephemeral and flowing streams. Single poorly constructed and designed stream crossings where road ditch sediments were delivered directly to the stream had an overriding influence on suspended sediment levels in streams. When roads are properly located and drainage structures are well designed and maintained, excellent opportunities exist to trap sediments on vegetated slopes before they reach streams. Results of the Oklahoma study showed similar results indicating sediment yields and delivery can be controlled on newly constructed roads, as well as older established systems.

Streamside Management

The idea that management near the stream should be different in order to protect the stream environment is not new. However, the concept of the streamside management zone (SMZ) was developed during the formulation of Best Management Practices (BMP's) for forestry and to many it is in contrast to the older concept embodied in the terms buffer, leave or filter strip. There are two basic differences in the old and newer concepts. First, under the old concept, the streamside zone was expected to mitigate the effects of activities or practices outside and upslope of the streamside zone. For example, erosion on the hillslope might be acceptable so long as a "filter strip" (usually the wider the better) was provided to stop all sediment from entering the stream. Unfortunately, due to the physical processes involved, SMZ's do not usually act to filter out sediments from upland erosion. And second, that all forestry practices should be restricted from the streamside zone and that only in this way could the value of the streamside zone be maintained. For example the removal of any trees from the streamside zone would reduce it's ability to function as a wildlife corridor or in erosion control.

In contrast the SMZ concept involved identifying specific objectives to be met in the riparian area and subsequently devising a management scheme to meet those objectives. Forestry or other management activities could be allowed within the zone if the objectives were met and in some cases forestry activities within the SMZ might enhance the opportunity to meet SMZ objectives.

Given this concept what are some key objectives to be met through wise use of the SMZ? The primary watershed oriented objectives of streamside management are, 1. Stability of the stream bed and bank, 2. protection of the floodway from erosion and scour and 3. maintenance of stream temperature. Other non-watershed objectives may be appropriate and compatible with these watershed objectives.

Stability of the stream bed and bank means prevention of the short or long term destabilization of the bed and bank by mechanical equipment or the removal of streambank vegetation. The SMZ may be used as a barrier for stream crossing except at designated areas. The width of the SMZ and acceptable mechanical and harvest guidelines must be determined on a site specific basis and will be a function of factors such as stream size, bed and bank soils (natural), bed and bank configuration (steepness and stability), timber type and size, and the importance of vegetation in maintaining stream bank and bed stability.

Where overbank flooding occurs forest vegetation can provide important erosion protection for the alluvial soils of the flood plain. The soil materials and the nature and timing of flood events largely determining the erosion risk and would be a key in determining a reasonable level of harvest from the SMZ. Flood plain vegetation can be both a source of and a trap for large and small organic debris. Large debris can form substantial check dams within the SMZ or in stream channels during floods and can consequently cause serious flood plain erosion and in some cases stream rechannelization. Large debris must therefore be carefully managed. The stability of overflow channels should also be given special attention if rechannilization is to be avoided.

The shade provided by streamside vegetation is often critical for maintaining favorable stream temperatures necessary for aquatic organisms. Studies have shown that maximum stream temperatures increase and minimums may decrease when stream shade is removed (Greene, 1950, Swift and Messer, 1971, Lynch et al. 1975 and Kochenderfer and Aubertin, 1975). Temperatures may return to normal upon reentry to shaded stream segments depending largely on the amount of shade and groundwater flux or other cool water inflow. Even when stream temperatures are increased, thermal refuges or zones where stream water remains cool may exist which provide relief for aquatic organisms during stressfull periods.

Specific temperature requirements depend on the species present. Temperature sensitive streams and stream segments are normally designated in state water quality standards. The effectiveness of streamside shade in moderating stream temperatures is a function of season, the height, and type and density of vegetation, stream orientation, topography, stream size and groundwater flux among others. Reviews of the literature and principles involved in determining stream temperatures are readily available (Brown, 1974, Woolridge and Stern, 1979 and USFS 1980). Some of this information is applicable in the southeastern U.S. or can be modified as the general principles apply.

Summary

In this paper some key watershed management concerns within the shortleaf pine ecosystem have been briefly discussed. For most concerns the principles are well understood and forest management alternatives for the protection of watershed values are available and attractive. We have good opportunities to sustain the quality of our soil and water resources in the process of managing for timber.

There is nothing particular about shortleaf pine that enhances or detracts from our ability to practice good watershed management. There is a wide physiographic diversity across the range of shortleaf and the watershed management objectives and requirements will vary accordingly. Even within a narrow range of silvicultural practices applied on a particular site there is room for error or success as the abilities of individual managers and operators to apply watershed management principles in the field will vary.

References

Anderson, H.W., M.D. Hoover and K.G. Reinhart. 1976. Forests and water: effects of forest management on floods, sedimentation, and water supply. USDA Forest Serv. Gen. Tech. Rep. PSW-18. 115 p.

Arkansas Department of Pollution Contol and Ecology. 1980. Water quality management plan: 208 continuing planning process for non-point sources for FY 1980. 1294 Lakeshore Dr., Little Rock, Arkansas. 29 p.

Beasley, R.S. 1979. Intensive site preparation and sediment loss on steep watersheds in the gulf coastal plain. Soil Sci. Soc. Am. Proc., 43:412-417.

Beasley, R.S., E.L. Miller, and S.C. Gough. 1984. Forest road erosion in the Ouachita Moutains. Peters, P.A. and John Luchok, eds. Mountain logging Symposium Proceedings; 1984 June 5-7; West Virginia University, Blacksburg, West Virginia. p. 202-213.

Douglas, J.E. and W.T. Swank. 1972. Streamflow modification through management of eastern forests. U.S.D.A. Forest Serv. Res. Pap. SE-94. 15 p.

Greene, G.E. 1950. Land use and trout streams. J.Soil and Water Cons. 5(3): 125-126.

Groves, F.D., R.K. Baughman, M.E. Hundley and R.L. Sherman. 1979 Timber haul road construction in southern mountains. Southern J. of Applied For. 3 (3): 68-76.

Hewlett, J.D. 1982. Principles of forest hydrology. University of Georgia Press, Athens, GA 30602. 183 p.

Kochenderfer, J.N. 1970. Erosion control on logging roads in the Appalacians. N.E. Forest Exp. Sta.

Kochenderfer, J.N. and G.M. Aubertin. 1975. Effects of management practices in water quality and quantity: Fernow Experimental Forest, W.Virginia. p. 14-24. In Municipal Watershed Management Symp. Proc., USDA Forest Serv. Gen. Tech. Rep. NE-13.

Lawson, E.R. 1975. Effects of partial and complete vegetation removal on soil water, runoff and tree growth in the Ouachita Mountains of Arkansas. Ph.D. diss. Colorado State Univ. Fort Collins (Diss. Abstr. V.36, n.4, p.1528B).

Lull, H.W., and K.G. Reinhart. 1972. Forests and floods in the eastern United States. USDA Forest Serv. Res. Pap. NE-226, 94 p.

Lynch, J.A., W.E. Sopper, E.S. Corbett, and D.W. Aurand. 1975. Effects of management practices on water quality and quantity: The Penn State experimental watersheds. p. 32-46. In Municipal Watershed Management Symp. Proc., USDA Forest Serv. Gen. Tech. Rep. NE-13.

Miller, E.L. 1984. Sediment yield and stormflow response to clearcut harvest and site preparation in the Ouachita Mountains. Water Resour. Res. 20(4):471-475.

Miller, E.L., R.S. Beasley and J.C. Covert. 1985. Forest Road sediments: Production and delivery to streams. Blackmon, B.G., ed. Proceedings: Forestry and Water Quality: A Mid-South Symposium: 1985 May 8-9: Little Rock, Arkansas. Dept. of Forest Resources, University of Arkansas at Monticello, Arkansas.

Miller, E.L., R.S. Beasley and E.R. Lawson. 1985. Stormflow, sedimentation and water quality responses following silvicultural treatments in the Ouachita Mountains. Blackmon, B.G., ed. Proceedings; Forestry and Water Quality: A Mid-South Symposium; 1085 May 8-9; Little Rock, Arkansas. Dept. of Forest Resources, University of Arkansas at Monticello, Arkansas, p. 117-129.

Miller, E.L., R.S. Beasley and E.R. Lawson. 1986. Forest harvest and regeneration in the Ouachita Mountains: I. Effects on stormflows and peakflows. J. Environ. Qual. (In press).

Nutter, W.L., and J.E. Douglass. 1978. Consequences of harvesting and site preparation in the piedmont. Tippin, T., ed. Proceedings; A symposium on principles of maintaining productivity on prepared sites; 1978 March 21-22; Mississippi State Univ., So. For. Exp. Sta., USDA Forest Service, New Orleans, LA p. 65-72.

Patric, J.A. 1976. Soil erosion in the eastern forest. J.For. 74:671-677.

Patric, J.H., J.O. Evans and J.D. Helvey. 1984. Summary of sediment yield data from forested land in the United States. J. of For. 82(2):101-104.

Patric, J.A. 1978. Harvesting effects on soil and water in the eastern hardwood forest. So. J. of App. For. 2(2): 66-73

Stone, E.L., W.T. Swank and J.W. Hornbeck. 1978. Impacts of timber harvest and regeneration systems on streamflow and soils in the eastern deciduous region. In: Proc. Fifth North Am. For Soils Conf.; Aug 1978. Colo State Univ., p. 516-535.

Swank, W.T. and J.E. Douglass. 1974. Streamflow greatly reduced by converting hardwood stands to pine. Science 185:857-859.

Swift, T. W. 1984 Soil losses from roadbeds and cut and fill slopes in the southern Appalachain Mountains. Southern J. of Applied For. 8(4) 209-216.

Swift, L.W. Jr. and J.B. Messer. 1971. Forest Cuttings raise temperatures of small streams in the southern Appalacians. J. Soil and Water Cons. 26 (3):111-115.

Trimble, R.G. Jr. and R. S. Sartz. 1957. How far from a stream should a logging road be located? J. of Forestry 55:339-341.

Vowell, J.L. 1985. Erosion rates and water quality impacts from a recently established forest road in Oklahoma's Ouachita Mountains. Blackmon, B.G., ed Proceedings; Forestry and water Quality; A Mid-South Symposium; 1985 May 8-9; Little Rock, Arkansas. Dept. of Forest Resources, University of Arkansas at Monticello, Arkansas.

Yoho, N.S. 1980. Forest Management and sediment production in the south - a review. Southern J. of Applied For. 4(1):27-36.

Zahner, R. 1955. Soil water depletion by pine and hardwood stands during a dry season. Forest Sci. 1:264-284.

PROCEEDINGS

of

Symposium on the Shortleaf

Pine Ecosystem

LITTLE ROCK, ARKANSAS

MARCH 31 - APRIL 2, 1986

Edited by

Paul A. Murphy
Southern Forest Experiment Station
U.S. Department of Agriculture, Forest Service
Monticello, Arkansas

Symposium Coordinator

R. Larry Willett
Extension Forester
Arkansas Cooperative Extension Service
Monticello, Arkansas

Symposium on the Shortleaf
Pine Ecosystem

Sponsored by

University of Arkansas
Department of Forest Resources
Agricultural Experiment Station
Cooperative Extension Service

Arkansas Forestry Association

Arkansas Forestry Commission

Arkansas Kraft Corporation

Deltic Farm and Timber Company

Department of Forestry
Oklahoma State University

Society of American Foresters

Texas Forest Service

USDA Forest Service
Southern Forest Experiment Station
Region 8
Ouachita National Forest
Ozark-St. Francis National Forest

Weyerhaeuser Company

Proceedings available from:
Arkansas Cooperative Extension Service
P. O. Box 3468, UAM
Monticello, AR 71655