



Cumulative Watershed Effects of Fuel Management in the Eastern United States

CHAPTER 8.

Fuels Management in the Subtropical Mountains Division

James M. Guldin

The Ouachita Highlands

The heterogeneity of the forests west of the Mississippi River in the Southern United States is strongly influenced by physiography and topography. The west Gulf Coastal Plain of southern Arkansas, northwestern Louisiana, and eastern Texas features highly productive pine-dominated forests (*Pinus* spp.) on gentle terrain that are interspersed by major and minor alluvial bottomland hardwood forests. The Ozark Mountains are an uplifted eroded dolomitic plateau in northern Arkansas, eastern Oklahoma, and southern Missouri; they feature primarily oak-hickory (*Quercus* spp.–*Carya* spp.) forests with a minor and varying pine component that was far more widely distributed 150 years ago than it is today. Both of these areas support forests similar in species composition and fire dependency as types farther to the east.

Between these two areas lie the Ouachita Mountains of western Arkansas and eastern Oklahoma, among the most ecologically unique ecoregions of the South. Three elements contribute to that uniqueness. First, the general orientation of Ouachita ridges runs from east to west, perpendicular to most other mountains and hills in the continental United States. This points to the second unique element; forest types are closely associated with aspect, with xerophytic pine-dominated forests on the south-facing slopes, and mesophytic oak-dominated forests on the north-facing slopes. The third element is unusually important—the dominance of shortleaf pine (*Pinus echinata*) in the Ouachitas. East of the 100th meridian, shortleaf is the most widely distributed of the southern pines (Guldin 2007), and is generally found in mixture with other pines or in pure stands of limited extent. But in the Ouachitas, shortleaf reaches its ecological maximum, where it is the only naturally occurring pine and the dominant tree species in many stands.

As a result of this unusual ecological association among tree species, forest types, and physiographic conditions, the area has a separate classification as the Ouachita Mountains Mixed Forest–Meadow Province within the Subtropical Division (Division 230). It is somewhat warmer, less wintry, and wetter than the Ozark Broadleaf Forest of the Hot Continental Division (Division 220) to the north. However, it is more prominently mountainous than the Southeastern Mixed Forest Province to the south or the Mississippi Alluvial Bottomland Forests to the east, both of which also lie within the Subtropical Division. And, it is more densely forested than the Prairie Parkland Province that lies to the west—although prairie elements do exist in the Ouachita forests. Finally,

the Ouachitas only cover roughly 29 000 km², making this ecoregion one of the smallest in the South.

Geologic Origin and Soils

Through most of the Paleozoic Era, up to about 320 million years ago, the area of the current Ouachita Mountains was under ocean water, and deposition of organic and inorganic materials occurred through marine sedimentary processes. But from 320 million to 286 million years ago, during the Pennsylvanian Period, a major tectonic event called the Ouachita Orogen resulted in the collision of what is now North America with a southern landmass. Essentially, the lateral compression from south to north shifted the marine sediments in ways that resulted in considerable folding, faulting, and subduction activity from western Texas to central Alabama (Viele and Thomas 1989). Geologic evidence of metamorphic rocks suggests some volcanic activity especially near Hot Springs, AR (Loomis and others 1994), which is not unusual in the context of prevailing theories of plate tectonics that continue to shape the Earth.

Over the past 280 million years, the major geologic event in the Ouachitas has been weathering and erosion, which have reduced the sandstones and shales that were exposed during the orogeny. The linear ridges of the Ouachita hills still show their folded and faulted history, with long ridges oriented from east to west. The terrain reaches maximum elevation of about 790 m, about 460 m above the adjoining valleys. The side slopes of the ridges are often steep and rugged in the upper slopes, but gradually flatten in the lower slopes. As a result, the hillsides grade into broad U-shaped valleys, whose breadth and gentle gradient are attributed to millennia of creek meanderings, especially along the larger streams and rivers that flow between the ridges.

Soils are highly weathered Ultisols (Buckman and Brady 1969). Pedogenesis is affected by the extremely rocky terrain, the resistance of the rocks to erosion, and the high level of soil stoniness. Phillips and Marion (2004) described the soils on the hillsides and ridges of the eastern Ouachitas as primarily medium-textured, well drained stony Hapludults; on steeper slopes or higher elevation, soils are shallow, whereas on more gentle slopes and benches, soils are moderately deep to deep. Liechty and others (2005) reported that soils in the western Ouachitas are typical Hapludults with loamy surface textures, and having unusually high rock content in surface and subsurface layers.

Site productivity closely follows slope position, with poor sites on ridgetops and upper slopes grading to better sites on lower slopes and floodplains. This common pattern is the result of colluvial activity carrying soils from ridgetops to floodplains over the years, leaving shallow thin soils on upper slopes and consequently deeper soils on lower slopes. Soil depth correlates with both soil moisture and soil fertility. In addition, south-facing slopes get considerably more sunlight than northern slopes. As a result, the south-facing ridgetops are the most xeric and least productive sites, whereas the lower north-facing slopes are the most mesic and feature highly productive sites.

Climate

Climatic conditions in North America have varied tremendously over the millennia, most recently seen in climatic variations associated with glaciation and interglacial ecosystem processes. However, over the past 4,000 years, pollen records show that the Ouachitas have supported relatively continuous vegetation under a relatively stable climate, but no doubt with annual variations in temperature and precipitation that can occasionally be ecologically important locally (Delcourt and Delcourt 1991, Smith 1984).

Current climatic conditions can be approximated by summaries of weather data over the past several decades. Comparisons using National Weather Service data—and the assumption that Little Rock represents statewide conditions—show that Ouachita Mountains are slightly cooler and slightly wetter than elsewhere in the State. Average monthly temperatures (fig. 1) vary from 3 °C in December (dropping to a negative 3 °C

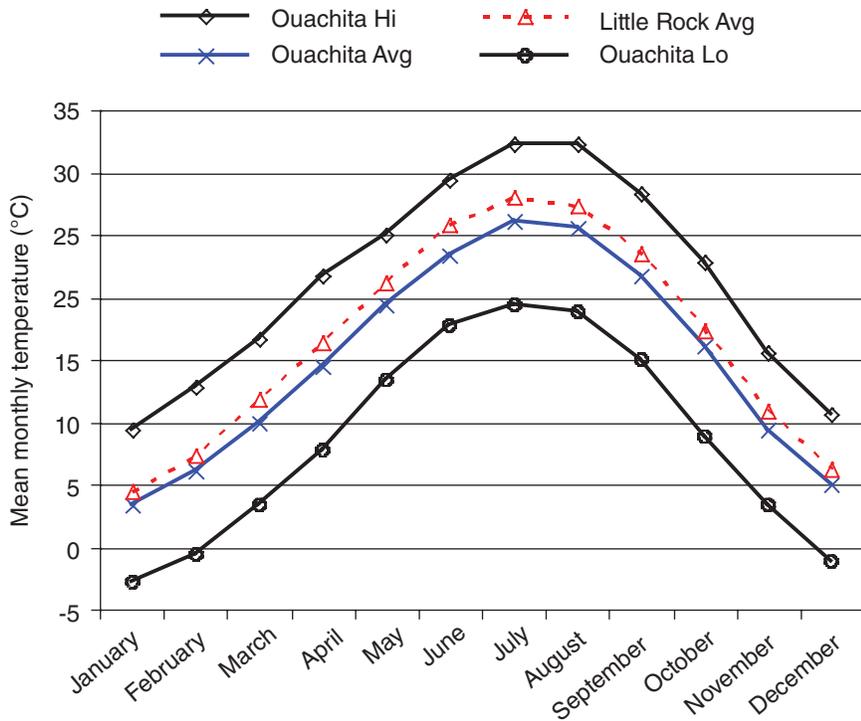


Figure 1. Mean monthly high, average, and low temperatures (in degrees Celsius) for the Ouachita region, compared with the mean monthly average temperature at Little Rock, AR. Source: National Weather Service, Little Rock, AR (Web access, active on 1/8/2008, <http://www.srh.noaa.gov/lzk/html/climain.htm>), Southern Regional Climate Center (Web access, active on 1/8/2008, <http://www.srcc.lsu.edu/southernClimate/arkclim/>)

average low) and January to 25 °C in July and August (rising to a 32 °C average high). Compared to the statewide average, the Ouachitas are about 1 °C cooler in winter and about 2 °C cooler in summer. Freezes are common, but continuous incidences of daytime highs remaining below 0 °C rarely last a week. Similarly, ice storms and snowstorms occur once or twice a year, but amounts of precipitation as snow are relatively low; 25 cm of snowfall in a single storm is an exceptional event, and snowpack rarely lasts >2 weeks, except on north-facing slopes. Conversely, summer daily high temperatures frequently exceed 40 °C, and the Ouachitas annually experience hot weather in July or August, with daily highs exceeding 38 °C for a week or longer.

Again, based on National Weather Service data, average precipitation in the Ouachita Mountains (150 cm) is about 15 percent higher than the statewide average of 130 cm (fig. 2). This shows the orographic effect of the Ouachitas: moisture-laden clouds that approach the mountains from the west must rise upward to clear the ridges, which condenses water vapor and increases rainfall. May is the only month when average monthly precipitation in the Ouachitas is >15 cm; whereas January, February, and August have average monthly precipitation <10 cm. In May, June, July, September, and October, the Ouachitas average 3 to 4 cm more precipitation than the State.

Scarcity of rainfall in August interacts with high temperatures to create conditions favorable for drought, which has the important ecological function of controlling which tree seedlings and other vegetation will have enough moisture from the soil to survive. Lightning is also common in the summer months, and the combination of dry vegetation and lightning strikes renders forests at risk from wildfire. Moreover, strong evidence suggests that Native Americans burned the landscape (Guyette and others 2006). This all suggests an ecological condition in which forest fires were an important agent of ecological disturbance before European settlement.

Physiographic Variations

The U.S. Department of Agriculture Forest Service developed an ecoregion framework for the Eastern United States (Keys and others 1995) based on a national map of ecoregions of the United States (Bailey 1995, Bailey and others 1994). A more

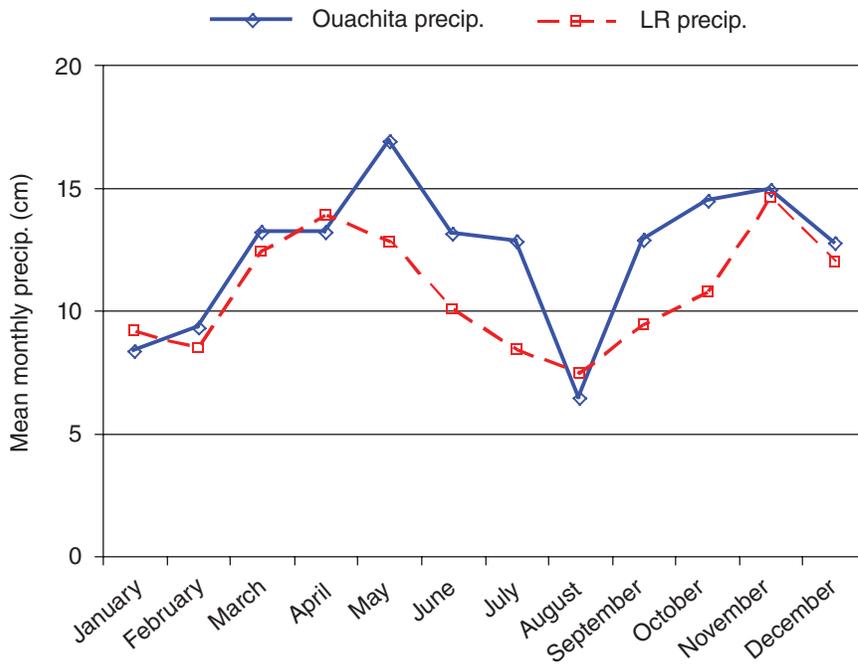


Figure 2. Mean monthly precipitation (cm) for the Ouachita region and for Little Rock, AR. Source: National Weather Service, Little Rock, AR (Web access, active on 1/8/2008, <http://www.srh.noaa.gov/lzk/html/climain.htm>), Southern Regional Climate Center (Web access, active on 1/8/2008, <http://www.srcc.lsu.edu/southernClimate/arkclim/>)

recentmap, which is based on slight movement of borders using local knowledge and experience, contains the best detail available with respect to coverage (Foti and Bukenhofer 1999).

The Ouachitas lie to the south of the Arkansas River Valley in west-central Arkansas and eastern Oklahoma (fig. 3). The area is classified in the Subtropical Division, Humid Temperate Domain (200), as the Ouachita Mixed Forest–Meadow Province (M231), also referred to as the Ouachita Mountains Section (M231A). Within the section are four prominent subsections—the Fourche Mountains (M231Aa) to the north, the Western Ouachita Mountains (M231Ab) to the west, the Central Ouachita Mountains

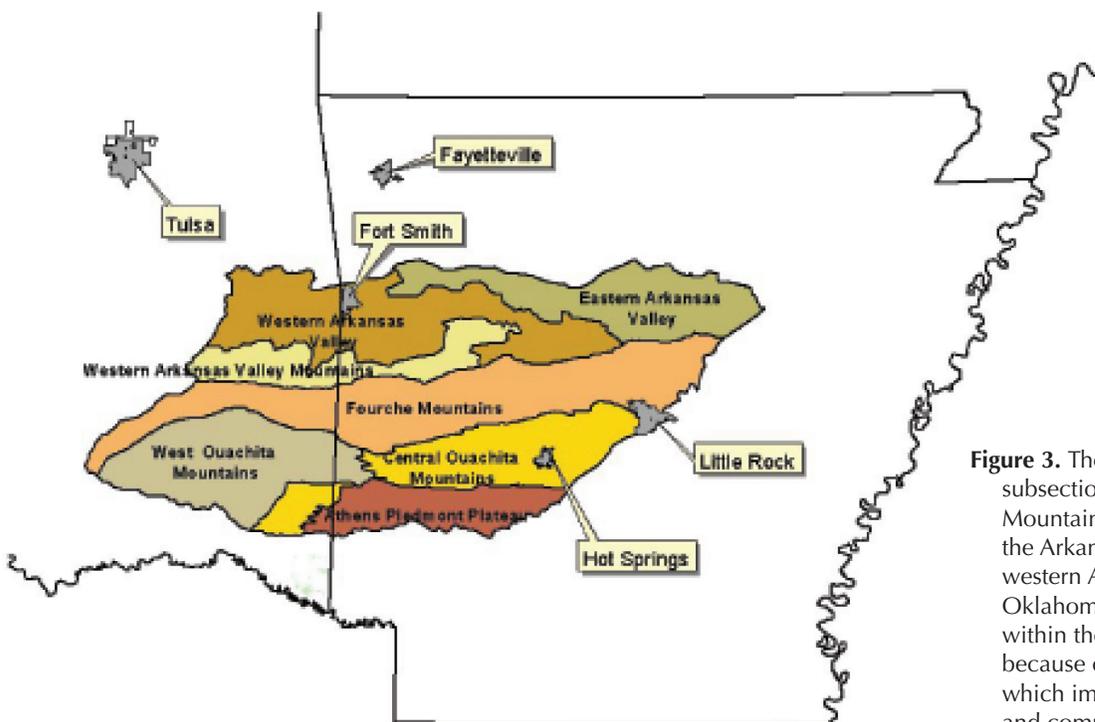


Figure 3. The ecological subsections in the Ouachita Mountains lie to the south of the Arkansas River Valley in western Arkansas and eastern Oklahoma. Cities are absent within the Ouachitas largely because of the rugged terrain, which impedes transportation and commerce.

(M231Ac) in the east-central area, and the Athens Piedmont Plateau (M231Ad) in the southeastern-most reaches (Foti and Bukenhofer 1999). Overall, these four sections encompass roughly 2.9 million ha.

The Fourche Mountains subsection occupies 1 180 414 ha. Ridges are moderate to high, containing some of the highest ridgetops in the area, and slope into broad valleys; elevation varies from 250 to 790 m. Ridges are underlain by Pennsylvanian and Mississippian sandstone and shale, and valleys consist of sandy residuum (Foti and Bukenhofer 1999). The area is 78 percent forested (Guldin and others 1999), the lowest percentage in the Ouachitas; stands are dominated by shortleaf pine (47 percent of forested area), oak-pine (29 percent), and oak-hickory (22 percent).

The Western Ouachita Mountains cover 679 100 ha primarily in Oklahoma, where the ridges are high and relatively steep, again with broad valleys, varying from 250 to 760 m. The area is composed of Mississippian sandstone and shale with clayey colluvium in the valleys (Foti and Bukenhofer 1999). Nearly 88 percent of this area is forested; of that, 55 percent is in pine-dominated stands, 29 percent is in oak-pine stands, and 15 percent is in oak-hickory stands (Guldin and others 1999).

The Central Ouachita Mountains encompass 663 000 ha in two separate areas—a small part in Oklahoma and the larger part in Arkansas. Elevation varies from 250 to 760 m in open wide hills, low mountains, and wide valleys; the underlying geology is Mississippian sandstone and shale with clayey colluvium in the broad valleys (Foti and Bukenhofer 1999). About 82 percent of this area is forested. It has the highest proportion of oak-hickory stands (48 percent) in the Ouachita Mountains; pine stands account for 39 percent of the forested area, and oak-pine stands only 10 percent (Guldin and others 1999).

The Athens Piedmont Plateau is the smallest subsection of the Ouachita Mountains, covering 367 500 ha in the southeast. Geologically, this area is the first uplift from the upper west Gulf Coastal Plain immediately to the south. Elevation varies from 250 to 750 m, and includes open high hills underlain by Mississippian and Pennsylvanian sandstone, with valleys built on sand and clay-loam colluvium (Foti and Bukenhofer 1999). This area has the largest percentage of forest area (91 percent) as well as a concentration of forest industry ownership. Pine-dominated stands make up 73 percent of the forested area, oak-pine stands only 6 percent, and oak-hickory stands 19 percent of the area (Guldin and others 1999). In this subsection more than the others, forest industry is converting oak-pine stands to plantations of loblolly pine (*Pinus taeda*).

Ownership

Ownership of timberland in the Ouachitas is roughly divided equally among three major classes. The public owns 29 percent of the timberland, with 85 percent of that managed by the Ouachita National Forest. Forest industry holds 37 percent, with nearly two-thirds in the Western Ouachita Mountains and Athens Piedmont Plateau. Other private (nonindustrial) forest landowners hold the remaining 34 percent (Guldin and others 1999). The recent divestiture of forest industry land to other individuals and organizations represented by timberland investment management organizations (TIMOs) or real estate investment trusts (REITs), which is nearly complete elsewhere in the South, has just commenced in the Ouachitas.

Forest Stands in the Ouachitas

The native forest types in the Ouachita Mountains vary from stands that are heavily dominated by shortleaf pine and pine-hardwood mixtures to oak-hickory stands that are dominated by hardwoods with only a minor pine component, if any. Closed-canopy forests are typical. However, open woodlands were probably more common 200 years ago, because of the changing midstory and understory forest conditions that resulted from effective fire control over the past 80 years. In addition, under forest industry

ownership, large areas of native shortleaf pine-dominated stands have been converted from to plantations of loblolly pine.

Pine Dominated Stands

Natural pine forests

In these native stands, naturally regenerated shortleaf pine is the dominant tree. Where fire has been excluded, the result is a prominent hardwood midstory and understory (fig. 4), potentially complicating silvicultural practices intended to maintain the pine component or regenerate pines after harvesting old stands. As an alternative to fire exclusion national forest lands, specialized silvicultural systems for ecological restoration have been developed that reduce the overstory density of shortleaf pines, remove midstory hardwoods, and reintroduce a cyclical prescribed burning program (fig. 5). The goal is to maintain the production of high-quality pine sawtimber while concurrently restoring understory grasses, sensitive plant species such as the purple coneflower (*Echinacea purpurea*), and endangered animal and insect species such as the red-cockaded woodpecker (*Picoides borealis*) and the Diana fritillary butterfly (*Speyeria diana*). The value of robust local timber markets has been a critical factor in the success of this restoration (Guldin and others 2004b).

Average conditions were quantified for a “typical” Ouachita stand in a study of mature unrestored second-growth stands of shortleaf pine and pine-hardwoods on south-facing slopes on national forest land (Guldin and others 1994). This “typical” stand has a stem density of approximately 800 trees/ha, of which about half are pines and the other half are hardwoods. Basal area is roughly 30 m²/ha in trees >10 cm d.b.h. (diameter at breast height); about 75 percent is pine and 25 percent is hardwood, half of which is in midstory trees 10 to 24 cm d.b.h. The average conifer is larger than the average hardwood, with the quadratic mean diameter (the diameter of the tree of average



Figure 4. Mature second-growth shortleaf pine-dominated stand in the Ouachita Mountains, with typical development of midstory and understory in the absence of prescribed fire. (Photo by James M. Guldin)



Figure 5. Mature second-growth shortleaf pine-dominated stand in the Ouachita Mountains after overstory thinning, midstory reduction, and reintroduction of cyclic prescribed burning. (Photo by James M. Guldin)

basal area) for conifers at 26 cm, compared to 16 cm for hardwoods. Pines age classes are bimodally distributed, with peaks in the 10- to 15-cm class (suppressed trees that still persist) and the 25- to 30-cm class, and with only 30 trees per ha ≥ 40 cm d.b.h. The dominant conifer is shortleaf pine, and the only two common overstory hardwoods in the typical stand are post oak (*Q. stellata*) and white oak (*Q. alba*). In the midstory, shortleaf pine also dominates with the most common associates being post oak, white oak, mockernut hickory (*Carya tomentosa*), and black or Texas hickory (*Carya texana*). In the understory, however, 13 tree species are prominent, including post oak, white oak, mockernut hickory, black hickory, winged elm (*Ulmus alata*), black oak (*Q. velutina*), and blackjack oak (*Q. marilandica*).

Loblolly pine plantations

The second pine-dominated forest stand in the Ouachitas is a local exotic, the loblolly pine plantation. Forest industry and some private landowners use intensive silvicultural prescriptions to harvest shortleaf pine and oak-pine stands, and to replace that native vegetation with artificially regenerated plantations established using seedlings of genetically improved loblolly pine from Arkansas, Oklahoma, or North Carolina. These loblolly pine plantations are managed primarily for timber products over rotation lengths of 27 to 35 years. The silvicultural systems used to manage them typically include ripping to promote seedling establishment and development, broadcast herbicide application and fertilization to enhance the growth of the pines and decrease the competition, thinning to maintain adequate growth, and pruning to ensure development of clear wood in the butt log of the crop trees (fig. 6). Compared to naturally regenerating shortleaf pine, these practices are much more effective in meeting the goal of rapidly growing wood fiber, with conservative estimates of 20 to 30 percent gain in volume production (Lambeth and others 1984).

The ecological concern is that loblolly pine is native only to the southeastern-most part of the Ouachita Mountains. Throughout most of their natural southern range—and



Figure 6. Loblolly pine plantation after prescribed burning and first thinning near Waldron, AR. (Photo by James M. Guldin)

notably immediately to the south of the Ouachitas in the upper west Gulf Coastal Plain—loblolly and shortleaf pines can be found in mixture, with loblolly usually the dominant pine. But research and photographic evidence from 70 years ago refer to second-growth “shortleaf-loblolly” pine-hardwood type stands (Reynolds 1947), which may refer to a more robust shortleaf-pine presence in mixture with loblolly pine and hardwoods compared to domination by loblolly pine today. The difference may be due to the different regeneration dynamics of these two species. As discussed above, shortleaf is a less prolific seed producer, but resprouts if topkilled by fire; compared to loblolly, which will not recover if topkilled by fire. The tactic for loblolly seems to be in producing prolific annual seed crop, dropping adequate or better seedfall four years in five (Cain and Shelton 2001).

As one crosses the ecotone northward from the Coastal Plain into the Ouachitas, loblolly drops out of the native forest completely and abruptly, within a span of 20 to 30 miles. This unusually rapid change in species composition suggests a major ecological influence at work. But the nature of that influence is unclear and is further clouded by the generally successful development of loblolly pine plantations in the Ouachitas. These plantations grow and reach reproductive maturity rapidly, and observation shows successful loblolly pine regeneration beneath planted parents. This is not the developmental dynamic one would expect from a species that was essentially absent from the mountains during presettlement times.

Moreover, industry experience with loblolly pine plantations began in the early 1970s; in the past 40 years, only two ecological events have adversely affected these plantations to any important degree. The first—a prolonged drought in 1980—resulted in some mortality, especially of seedlings from North Carolina families that had been planted on some of the driest Ouachita hillsides (Lambeth and others 1984). The second was an ice storm in December of 2000, which only caused mortality in late-teen stands that had been recently thinned (Bragg and others 2003). So although some planted loblolly pine stands have been adversely affected by natural events, none has been sufficiently large or long lasting to fully explain loblolly pine’s natural absence from the Ouachitas.

Shortleaf pine plantations

The final and least widespread pine-dominated forest stands in the Ouachitas are shortleaf pine plantations, which are typically established on national forest lands and occasionally established on private lands after clearcutting or in response to rehabilitation of cutover or understocked stands. The use of shortleaf pine rather than loblolly on national forests relates to the general Forest Service mission of managing native ecosystems for native flora and fauna. The oldest shortleaf pine plantations on the Ouachita National Forest are ≥ 70 years, dating to the 1930s when Civilian Conservation Corps workers were assigned to reforestation work. Today, one would not recognize the older stands as plantations, because the easily detected rows in which seedlings were planted have generally become less obvious as stands have matured (Rosson 1995).

Establishment of shortleaf plantations generally follows the intensive treatments prescribed for loblolly plantations on private land with two differences: substitution of individual-stem applications of herbicide rather than broadcast treatment, and absence of pruning. The genetically improved seed source for shortleaf pine used in these plantations comes from Ouachita families maintained in a seed orchard in Montgomery County, Arkansas, in the eastern portion of the Central Ouachita Mountains. However, clearcutting is required when using artificial regeneration such as planting; with the decline of clearcutting on national forests from the mid-1980s to the mid-1990s, the establishment of new plantations has also declined dramatically (Guldin and Loewenstein 1999). Since 2000, clearcutting followed by planting shortleaf pine has been used on slightly >500 ha annually on the Ouachita National Forest; in all instances, the goal has been to reforest understocked stands or to convert cutover loblolly pine plantations acquired from forest industry back to shortleaf pine.

Oak-Hickory Stands

Oak-hickory stands represent the opposite end of the silvicultural spectrum from pine-dominated stands in the Ouachita Mountains with respect to species composition, topography, and intensity of management. These stands are most commonly found at two topographic extremes in the Ouachitas. In the highest elevations, stands dominated by post oak, blackjack oak, some white oak and black oak, and black hickory occupy the steep south- and north-facing thin-soiled slopes and the ridgetops that are too exposed or too xeric for pines. Some of the most interesting stands are the stunted oak-hickory stands on the ridges at the Rich Mountain and Black Fork Mountain summits, where dominant oaks can be >100 years in age and yet be ≤ 3 to 10 m tall, in part caused by wind and ice (Johnson 1986). Stands such as these support old-growth remnants, and are important sources of dendrochronological records for analyses of disturbance and changing climate (Stahle and Hehr 1984).

Conversely, stands that feature white oak, southern red oak (*Q. falcata*), black oak, red maple (*Acer rubrum*), and sweetgum (*Liquidambar styraciflua*) can be found in mesic conditions on flat or gentle terrain along ephemeral and perennial streams on low north-facing and south-facing slopes; in many respects, these are the most productive sites anywhere within the Ouachitas. On the more mesic sites of lower slopes, white oak can become especially important, and the species could probably be commercially managed for timber under reasonable rotation lengths. The mesic Ouachita oak-hickory stands will be dominated by white oaks, especially on more mesic sites, on more xeric sites, the tendency will be toward post oak. The red oaks—such as southern red oak, black oak, and blackjack oak—are also found, though slightly less commonly than the white oaks. Other common species include winged elm, sweetgum, red maple, and flowering dogwood (*Cornus florida*).

Ouachita oak-hickory stands are rarely managed specifically for timber products, primarily because the demand for hardwood sawtimber and pulpwood is low. Most of the sawmills in the Ouachitas are dedicated to pine; the few hardwoods that loggers are willing to take for firewood or other merchandising opportunities are easily found in harvested pine stands. Moreover, recent forest plans for the Ouachita National Forest

have not emphasized hardwood management for timber production, although the plans' standards and guides allow for silvicultural activities as needed in hardwood stands to improve or restore ecosystems, manage or restore key species of flora and fauna, and promote hard and soft mast production for wildlife. In landscapes that are being aggressively restored with prescribed fire, the area burned in a single fire has in some situations been >1000 ha at a time. No effort has been made to deliberately exclude hardwood stands from these large burn units, largely because periodic fires undoubtedly have a role in maintaining healthy and sustainable ecological conditions in these stands. Allowing large-scale fires to spread as they will also places an appropriate degree of natural variation within the burn unit, as the fires will burn with less intensity and even die out on the most mesic sites.

Oak-Pine Stands

The delineation between pine-dominated stands and oak-hickory stands in the Ouachita Mountains is rarely discrete. A transect northward over an Ouachita ridge shows a mesic oak-hickory stand next to a creek, a pine-dominated hillside midway up the southern slope, a pine or oak-hickory stand on the ridgetop, a pine-oak or oak-pine stand on the upper northern slope, and a white oak-dominated oak-hickory stand on the lower northern slope. Almost all of these stands contain both hardwoods and pines; but hardwoods are more likely than pines to occupy the midstory and understory unless subjected to surface fires. The varying proportion of oaks and pines is as much a product of past stand development and disturbance patterns as it is a stable representation of the intermediate stand condition.

Historical accounts (Smith 1986) outline a systematic harvesting of virgin shortleaf pine stands through the Ouachitas from 1880 to 1920. This activity spread from south to north; railroads were constructed through the mountain passes in the rugged terrain, and then branched out from east to west through the valleys to the ridges. Merchantable pines were cut to a 12-inch diameter limit, and horselogged through the network of creek drainages to the railroads in the valleys below. Smaller pines were not cut, and these responded to the suddenly open conditions with continued growth. Larger pines that were rotten, hollow, and otherwise not useful for lumber were also left behind, but they were capable of producing seed to reforest the site. Harvested stands may also have had some shortleaf seedlings and saplings as advance growth; if they were present, many would resprout after logging. Thus, varying amounts of pine of various size and vigor were probably left uncut after the harvesting of the virgin stands. Hardwoods, too, were left on the site, especially smaller diameter hardwoods that would not even have valued for local use as lumber, fuelwood, or railroad ties.

The next influence would be an uncontrolled surface fire. One might speculate that with frequent or intense fire, seedbeds would be created for pine seed to germinate, advance growth seedlings and saplings would resprout, hardwoods would be killed, and the subsequent stand would likely be colonized by pines. If surface fires were infrequent or if fires were controlled, the hardwood residual trees and sprouts would be favored; the pines that successfully competed in the stand would also persist, but at lower densities. The influence of the Civilian Conservation Corps in fire suppression during the 1930s may thus have been important in the development of oak-pine stands.

Across the South, the acreage in naturally regenerated pine and oak-pine stands has decreased and pine plantations have increased (Conner and Hartsell 2002), a trend that is prominent in the Ouachita Mountains as well. Certainly some of the loblolly pine plantations being established by forest industry were planted on sites that had previously supported oak-pine stands with the goal of increasing the volume of pine.

Throughout this chapter, the focus is on deciding what to manage and with what tools. The Ouachitas have such a variety of conditions, soils, and species that foresters working within different ownership sectors can easily develop whatever spectrum of pine, oak-pine, or oak-hickory stands that they think is appropriate to meet the prevailing objectives of the landowner.

Fire as an Element of Ouachita Ecosystems

Fire has been important in the ecosystems of the Ouachita Mountains for thousands of years. The evidence for this is found in the analysis of fire scars from old pines, from historical observations of explorers and surveyors, and from an understanding of the life cycles, requirements, and vulnerabilities and of the plants that are found in these forests. Fire scar analysis reveals changing patterns in fire occurrence over time. Presettlement fires generally occurred on the order of every 7 to 20 years (Foti and Glenn 1991). However, in the two centuries since, the fire-return interval has become much longer, with some estimates as low as one occurrence every 1,200 years (Johnson and Schnell 1985). Thus, for some unknown presettlement period, fires occurred frequently, but have since occurred much less frequently. This has important implications for the dynamics and development of forest ecosystems, and for their management.

Presettlement fire occurrence was a combination of natural and deliberate ignitions. Guyette and others (2006) compared fire occurrence to historical Native Americans populations, and showed a close correlation between population and fire scars—strong evidence that Native Americans used fire as part of their daily lives. Benefits from the use of fire were probably related to the open understory conditions that burning creates. One might speculate that those benefits would include controlling ticks and chiggers, promoting grasses and browse for wildlife, and clearing openings for agricultural use. In addition, projectiles such as arrows will fly longer and more accurately in the open rather than through brush, which would have value both in hunting and perhaps also in community defense from attacks by wildlife or aggressive neighbors.

In the 1930s, the need for fire control arose from wildfire in cutover stands that had become a threat to resource management and conservation. The first field survey of Arkansas, conducted in 1929, reported that of the 22 million total acres of land remaining in forest at that time (about two-thirds of the area of the State), 20 million had been cutover—70 percent of which had been severely damaged by wildfires, with millions of acres burned annually (Beltz and others 1992, Roberts and others 1942). The need for fire suppression and control was an important element in the expansion of the forestry profession especially in State agencies such as the Oklahoma Forestry Commission (now Oklahoma Forestry Services) established in 1925, and the Arkansas Forestry Commission, established in 1931. Firefighting was a primary reason for their establishment, but staffing in Federal and State agencies was inadequate to control wildfires effectively until the end of World War II when the GI Bill for war veterans provided an educational boost to the forestry profession.

The combination of harvesting the virgin forest, rampant wildfires, and effective fire suppression over a 70-year period (1930 to 2000) profoundly altered forest ecosystems in the Ouachita Mountains. The change was especially pronounced in reproduction dynamics and stand development. Ecologically, a vigorous midstory woody vegetation component thrived in the absence of fire. Excluding fire over these seven decades led to a change in habitat conditions from open forests and woodlands to closed canopy forests with a prominent midstory, causing a decline in species that thrived in open forest and woodland conditions such as wood bison (*Bison bison athabasca*) and North American elk (*Cervus elaphus canadensis*), both extirpated from the area in the 19th century. Also greatly reduced in extent were prairie flora such as purple coneflower, bluestem (*Andropogon* spp.), flowering plants such as birdfoot violet (*Viola pedata*), pollinators such as the Diana fritillary butterfly, and birds such as the cavity-nesting red-cockaded woodpecker, which is currently a federally listed endangered species.

The regeneration ecology of shortleaf pine and the oaks closely follow this natural dynamic. Fires benefit the establishment and development of shortleaf pine for a number of reasons. Most pines germinate best on exposed mineral soil; fires promote a patchy distribution of mineral soil for optimum seed germination and seedling establishment. Shortleaf pines up to about 8 years also have a unique trait not shared by the other southern pines; the ability to resprout if topkilled. The significance of this was

appreciated early on when Mattoon (1915) described it as an adaptive advantage in response to frequent fires. The importance of this trait is that if fire burns a cutover or understocked stand, subsequent regeneration of the pines can occur either through seed-fall or resprouting of the existing advance-growth seedlings and saplings.

Similarly, the oaks are adapted to advance-growth regeneration dynamics (Johnson and others 2002) in which resprouting and dieback of seedling and sapling shoots continue over time, enabling the development of a robust rootstock and eventual establishment of a sapling to grow into the midstory and overstory. In the absence of fire, the oak shoot will persist in the understory until overstory shading causes it to die back to the root collar. This shade-induced mortality is a slow process. Conversely, with frequent surface fires, the process of growth and dieback of the shoot is faster, the rootstock grows faster, and the development of the sapling into the midstory and overstory is more expeditious.

With fragmentation of the Ouachita by different ownerships and varying degrees of agricultural development, forest managers are unlikely to see widespread fires restored across the entire area, but restoration of large fires in some areas is feasible. An example of is found in the Shortleaf Pine–Bluestem Management Area on national forest land to the west. Here, managers have developed prescriptions for ecosystem restoration that use commercial timber sales to reduce overstory density and mechanical treatments to remove the midstory hardwoods that have developed under seven decades of fire exclusion, and afterward have reestablished a program of cyclic prescribed burning (Guldin and others 2004b, Hedrick and others 2007). When restoration has been fully completed, about 100 000 hectares of the Ouachita forest land will have a structure and function similar to presettlement conditions.

However, management activities on the remaining 97 percent of the Ouachita landscape will likely not support sustained cyclic prescribed burning, but nevertheless must reduce fuel levels so as to minimize risk of loss to wildfire, an increasingly important consideration for the expanding wildland-urban interface.

Fuel Management in the Context of Silviculture

From a forest management perspective, the vegetation that has developed in the Ouachita ecosystems—as overstocked overstory trees, excessive numbers of midstory trees, and standing or downed dead trees and branches—is considered biomass that has accumulated as a result of fire exclusion. It is also flammable material that can maintain, support, increase fire intensity and otherwise exacerbate conditions associated with wildfires. Fuels treatments represent a subset of intermediate silvicultural treatments, and so are specifically designed to reduce that material in the short term (ch. 2) thereby altering the behavior of wildfires should they occur. But a more profound impact on forest management is made, not through short-term stopgap solutions to fuels, but in long-term programmatic management practices that integrate fuels treatments with the larger long-term objectives of the landowner. Fuels treatments are therefore more robust if they are examined as part of a larger and integrated program of silvicultural treatments called a silvicultural system (Smith and others 1997).

Individual silvicultural treatments can target several categories of biomass: the forest site, the forest floor, the woody vegetation in the main canopy, the woody and nonwoody vegetation in subordinate canopy positions, and the residues of vegetation. While these treatments are designed to achieve specific goals in forest stand dynamics and development, all have ancillary effects on the accumulation or reduction of biomass residues when viewed from the perspective of wildfire hazard and risk.

Identification of Fuels in a Silvicultural Context

A silvicultural system is little more than a long-term plan for the stand being managed. It is implemented using a silvicultural prescription containing a planned set of

treatments—each applied at a given point in time—that guide the stand to its desired future condition. But in some situations, events conspire to interrupt the long-term plan. Often, that event is triggered when enough plant material exists in the forest stand to pose a threat to the continued life of the stand if it is subjected to an uncontrolled fire.

Fuels are the living vegetation and detritus from dead vegetation that accumulates in the forest through natural or managed events. They are found as logging slash, pruned branches, and vegetation in the various strata of the forest. The term can include living trees and nonwoody vegetation, and also dead material that is still attached to live standing trees—dead snags—or dead material that has fallen to the forest floor but has not yet decomposed.

The biomass of material that can be called fuels changes during the course of a rotation. It follows that different periods of stand development differ in the amount or kind of fuels that are produced. It also follows that the main canopy of the stand is more susceptible to loss from fire at some periods than others, independent of biomass amount.

The absolute level of biomass is of less concern for fuels treatment than is the effective implementation of treatments placed in the right stands at the right time. Without timely or effective fuels treatments, fires can ignite a given level of biomass that is distributed in certain ways at highly sensitive times of year, resulting in the loss of the entire stand. In uncontrolled fire conditions, the resulting conflagration will jump from stand to stand, and losses will accumulate unacceptably across the landscape before the fire can be contained.

Questions about what constitutes fuels and when and how fuels should be treated are complicated by the fact that wood and wood fiber have monetary value. In the ideal world, fuels would be treated as an element of broader silvicultural treatments that involve identifying a desired complement of trees to retain, harvesting and selling trees that are surplus to the desired complement, and then using some of the proceeds from the commercial sale to reduce any residual fuels to an acceptable level. The situation is made less than ideal if there are no local markets for the commercial sale, if harvesting is precluded in a stand for some reason, or if natural disturbance events adversely affect the commercial value that a stand might have.

Federal forest managers have two sources of funds for fuels treatment: timber sale proceeds that can be reinvested to manage fuels in the harvested area, or funds appropriated through Congress. A program of fuels treatment that relies on sale proceeds is more effective in the long term, because it allows larger areas to be treated more rapidly, making a faster and more durable ecological change on the landscape—essentially, a sustainable stand structure in a fuels context. That then allows the scarcer appropriated funds to be applied strategically in stands that are not in a condition, or a location, conducive for the timber sale process. Private forest landowners have far fewer opportunities to tap Federal funds for fuels treatment, except through landowner assistance funds, which are both scarce and competitively distributed. Thus, fuels treatments are unlikely on private lands unless they can be supported by proceeds from harvesting in the stand that requires treatment.

This also explains the interest in biomass as an energy source. Wood fiber that has previously been too small for commercial use might become commercially operable if markets for biomass and biofuels can be developed. That potential could lower the size threshold for commercial value, allowing smaller material (perhaps including branches and twigs) to be sold. This might have ecological implications if carried to extremes, but it would be useful if smaller standards for merchantability could allow more stands to be self-sustaining in fuel treatment costs.

Regeneration Treatments

Both natural and artificial regeneration is used to regenerate shortleaf-dominated forests in the Ouachitas, whereas loblolly pine plantations are by definition established with artificial methods. Planting either loblolly or shortleaf pine after clearcutting is not a trivial matter, because of the extreme stoniness of the soils and the late summer droughts common in the area. Two approaches have enhanced plantation survival. The

first is to plant a seedling with a big root collar (Brissette and Carlson 1992), which promotes root development during the growing season and enhances the chances of survival. The second is to prepare a suitable planting spot through an intensive site preparation technique called ripping or subsoiling—using a bulldozer to plow a furrow into which the seedling is subsequently planted. In combination, these practices improved plantation survival in the Ouachitas by 10 to 30 percent (Walker 1992).

Natural regeneration of shortleaf pine and hardwoods in the Ouachitas can be accomplished using either even-aged or uneven-aged methods, but some methods are more effective than others (Guldin and others 2004a). Studies show that shortleaf pine produces only three to five adequate or better seed crops per decade (Shelton and Wittwer 1996, Wittwer and others 2003); moreover, seedfall varies geographically with higher amounts in the eastern Ouachitas and lower amounts in the west. Research scientists have more work to do to better quantify regeneration dynamics and development in shortleaf pine stands, because there are some yet-to-be-answered questions about stocking and distribution of regeneration resulting from their application.

Practicing silviculturists in the area see administrative advantages in using group selection rather than single-tree selection in uneven-aged stands. Logging is less damaging because the group openings serve as logging decks, the groups can be drawn on a map to assist contractors site preparation and release treatments, and the matrix of groups can be developed to retain hardwoods for wildlife and aesthetics. However, these are attributes of convenience in application more than an indication that one method works better than the other.

The sprouting habit of shortleaf pine might be useful in silvicultural applications that are applied to increase pine regeneration by supporting both new seedlings and sprouts from established sapling rootstocks to regenerate a stand (Guldin 2007). A properly timed surface fire in a stand with some existing shortleaf pine saplings will result in top-killed seedlings that subsequently resprout, and will also create exposed seedbed conditions favorable to germination of new seedlings. Repeated fires of proper intensity thus serve the dual advantage of both controlling fuels and developing a cohort of pine saplings and sprouts to naturally regenerate the site after disturbance or reproduction cutting.

Although no studies have been dedicated to oak regeneration in the Ouachitas, many studies in upland forests (including the Ozark Highlands of Arkansas and Missouri) suggest that the principles of oak regeneration established elsewhere would most likely be successful in the Ouachitas. The commonalities are twofold: first, successful oak regeneration depends on the presence of competitive regeneration sources before substantial overstory is removed; and second, in the absence of regeneration sources, treatments to develop competitive oak regeneration sources should be applied a decade or two before harvesting (Johnson and others 2002, Loftis 2004). As with the pines, the objective is to accumulate enough sources of oak regeneration (such as seedlings, saplings, and stump sprouts), so that the probability of successful establishment is high.

The first step is to evaluate the existing oak regeneration potential in the stand using established guidelines (Sander and others 1984), and decide if supplemental regeneration sources are needed before reproduction cutting. If so, one should wait for an abundant acorn crop, underplant oak seedlings, or both. Controlling competing vegetation in the understory and midstory is important to promote the development of the oak seedlings and seedling sprouts.

The role of prescribed fire as part of a regeneration prescription for oaks is not fully understood, but one might expect fire to contribute to maintaining or increasing the vigor of seedlings and saplings through top-killing and resprouting, as well as controlling fire-intolerant competing species in the understory. Numerous studies are underway to investigate fire effects on oak regeneration and to better define how it might be used.

Intermediate Treatments

Three practices form the bulk of intermediate silvicultural treatments for the Ouachita Mountains—release, thinning, and pruning. All have effects to be considered

for fuels management, because the wood produced during intermediate treatments is often of marginal commercial use.

In the Ouachitas, release treatments typically remove small hardwoods or herbaceous plants that compete with young pines (<10 years). Release methods can be chemical, mechanical, or ecological. Herbicides offer the most permanent approach to competing vegetation because both shoots and roots are killed and resprouting is minimized. If topkilling the hardwoods allows the pines to prosper, mechanical treatments and prescribed burning treatments would be appropriate. However, prescribed burning in young stands requires an experienced crew and a cool fire; an effective combination is to ignite backing fires using hand tools in the coldest months of the dormant season. But winter burning may not be as effective in controlling the resprouting of hardwoods as a late spring or summer burn.

Thinning in immature and mature stands reduces stem density of trees primarily by removing trees of poor quality, form, and vigor, thereby promoting health and vigor in the trees that remain (Helms 1998). In the Ouachita Mountains, thinning is used in both pine and hardwood stands, but treatment acreage of pines is far higher—not surprising, given the emphasis that Federal land managers and forest industry foresters place on the management of pine-dominated forest stands.

Almost by definition, thinning is primary tool that foresters have to reduce the volume of fuels in forest stands. At the stand level, thinning reduces biomass in rough proportion to basal area; retaining 75 percent of basal area after thinning will result in about the same proportion of retained biomass. The pattern of thinning might affect the size class and distribution of the biomass being removed, possibly resulting in some treatments being more effective than others. A key consideration is whether the thinning can be conducted using a commercial timber sale. Payments made to the landowner from timber sales can be reinvested into treatments that further reduce fuels, especially fine fuels such as branches and tops that might otherwise have to be hauled from the stand during logging.

Precommercial thinning, or thinning in stands too small to sell commercially, is the biggest single challenge in fuels treatment for those stands. Stands that are candidates for precommercial thinning in the Ouachita Mountains are usually overstocked with small trees of marginal to no commercial value, with a high number of stems, dead trees standing or down, and dead needles draped over the lower branches of the trees. Such stands are at a high hazard of loss from fire. The two available treatment options are both costly. The first is to conduct the precommercial thinning using either appropriated dollars on public lands or out-of-pocket dollars on private nonindustrial lands. The second has high risk cost: wait until the stand grows to commercial size, hoping that it does not burn in the meantime, and then prescribe a commercial thinning.

Pruning is a relatively unusual intermediate treatment in many forests, but it is a common treatment in the Ouachitas for loblolly pine plantations that are managed by forest industry for wood production. This treatment removes living and dead branches from the stems of trees up to a certain height (3 to 6 m), so that the wood that is produced afterward is free of knots. The byproduct of the treatment is a mat of dead branches and needles around the base of the tree. Because all these branches and needles are close to the ground, natural decomposition reduces this threat after a year or so. However, should wildfire occur during that short period of time, the hazard and risk of widespread mortality is high.

Reproduction Cutting Methods

The first indicator of forest sustainability is found at the stand level—when a reproduction cutting is made, whether a new cohort of the desired species is successfully established in conditions that will allow it to grow and develop in an acceptable manner. Even-aged and uneven-aged methods are both used for sustainable forest management in the Ouachitas.

Even-aged pine regeneration

Clearcutting is common in the Ouachita Mountains, especially in pine-dominated stands on forest industry lands. The typical silvicultural prescription for regenerating loblolly pine is to clearcut the stand, utilizing as much biomass as can be removed; conduct supplemental site preparation treatments to dispose of logging slash and competing vegetation as needed; use ripping to prepare the site for planting; and then to plant with genetically improved stock selected for rapid growth and some degree of drought tolerance. On public lands, improved shortleaf pine planting stock is substituted. Clearcutting has been a controversial practice in the Ouachitas because of the unsightly appearance of harvested stands. But there is no question that, silviculturally, clearcutting is an effective method that quickly results in the establishment of a new fast-growing stand of desired species.

The seed-tree (fig. 7) and shelterwood methods (fig. 8) are more commonly applied on national forest lands, where management plans call for retention of some residual seed trees through the life of the new age cohort to provide structural diversity in the new stand. On private lands, the landowner may choose to remove the seed trees after the new age class is adequately established.

Uneven-aged pine regeneration

Uneven-aged silviculture has been used in the Ouachitas since the 1950s by family lumber companies and forest industry landowners. The single-tree selection method is used occasionally to grow large high-quality shortleaf pine sawtimber (fig. 9).



Figure 7. Shortleaf pine and hardwood regeneration 12 years after seed cutting under the seed tree method in a shortleaf pine stand near Mount Ida, AR. (Photo by James M. Guldin)



Figure 8. Shortleaf pine and hardwood regeneration 12 years after seed cutting under the shelterwood method in a shortleaf pine stand near Waldron, AR. (USFS photograph by James M. Guldin)



Figure 9. Shortleaf pine and hardwood regeneration 12 years after the first cutting cycle harvest under the single-tree selection method in a shortleaf pine stand near Pencil Bluff, AR. Several cutting cycles will be required to develop the typical structure of an uneven-aged stand. (Photo by James M. Guldin)

Uneven-aged structure can be sustained with 10-year cutting cycle harvests that retain about 5,000 board feet of volume in 60 square feet of basal area of the best trees across all size classes. These stands have annual growth rates (in English units) of approximately 200 board feet per acre and 2 square feet of basal area, which give operable cutting cycle harvest volumes of about 2,000 board feet every 10 years. Herbicide control of competing hardwoods roughly once every 10 years is generally needed to maintain pine sapling development.

Since the early 1990s, managers on national forest lands have committed to expanding the use of uneven-aged silviculture in their pine and oak-pine stands. The single-tree and group selection (fig. 10) prescriptions that are being applied are somewhat less intensive than forest industry's single-tree selection method in that they retain some hardwood component. Most national forest sites to date are still in the early stages of the transition from mature second-growth even-aged pine and oak-pine stands to an uneven-aged structure.

As is true throughout the United States, there has been virtually no long-term experience in the Ouachita Mountains with multiple entries using the group selection method. Questions remain as to whether the group identity can be retained in the long run, and whether doing so is even important. In all likelihood, the group selection methods will gravitate more toward a single-tree selection method as multiple-age cohorts are established and stand structure becomes more balanced.

By definition, uneven-aged reproduction cutting methods in southern pine stands create discontinuous stand conditions. They provide a temporally and spatially transient distribution of logging slash and debris within the stand, resulting in a heterogeneous distribution of volatile fine fuels. This reduces the need to treat fuels, because the entire stand is unlikely to have fine fuels throughout, but it also complicates fuel treatments. Pine regeneration is being recruited in a discontinuous spatial pattern as well, and recruitment is repeated following every 10-year cutting cycle. As a result, stand-wide



Figure 10. Shortleaf pine and hardwood regeneration 12 years after the first cutting cycle harvest under the group selection method in a shortleaf pine stand near Mount Ida, AR. (Photo by James M. Guldin)

treatments such as prescribed burning are difficult to implement. On one hand, fuels are sufficiently heterogeneous to confound uniform fire effects and fuels treatment. On the other, the logging debris is concentrated in the openings where the desired regeneration is found, and the saplings will not survive the fire. More research is needed to better understand the degree to which uneven-aged stands can be managed with fewer age cohorts on 20-year cutting cycles—this might provide a window during the second decade when prescribed burning would not kill the youngest age cohort.

Hardwood regeneration

Compared to pines, few stands in the Ouachita Mountains are actively managed for hardwood species because of their lower growth and yield and the far less vigorous market for hardwood products. But for landowners interested in white oak, the dominant commercially valuable hardwood species in the area, both clearcutting and shelterwood method both can be applied successfully. As discussed previously, this requires sufficient oak regeneration potential in the stand before harvesting and appropriate followup site-preparation treatments to encourage the development of all oak regeneration sources.

The nearest successful example of successful uneven-aged silviculture in oak-hickory stands is found on the Pioneer Forest in the Missouri Ozarks (Flader 2004, Iffrig and others 2008, Loewenstein and Guldin 2004). To date, the silvicultural approach used on the Pioneer Forest has not been translated to oak-hickory stands in the Ouachita Mountains—partly because of the low demand for hardwood products, the generally higher quality of oak sites (especially white oak-dominated lower northern slope sites) in the Ouachitas, and perhaps also the absence of efficacy testing beyond the Pioneer.

Unique Silvicultural Systems

Two unique silvicultural systems merit some special consideration in the context of fuels treatments in the Ouachita Mountains. One is the work done on shortleaf pine-bluestem restoration on the Ouachita National Forest, which has a management goal of roughly 100 000 ha over time (Guldin and others 2004a, Hedrick and others 2007). The other is the intensive forest management practiced on roughly 800 000 ha by forest industry. Both practices have been successful in achieving their respective goals; and for both, the scale of application for is large enough to have considerable ecological and silvicultural effects.

Common Fuels Treatments in the Ouachitas

Fuels treatment is in large measure a popular name for a classically established subset of silvicultural practices that contribute to a reduction in standing and down woody biomass. In that context, a number of practices that have been discussed merit specific mention.

Timber Harvesting Treatments

Harvesting activity such as reproduction cutting and thinning removes large piece sizes from the stand being harvested, but adds a considerable amount of fine fuels. Although decomposition rates are rapid, as would be expected in the humid Subtropical Division, the volume of material and the hazard it presents can be a threat during the time between harvesting and decomposition. Supplemental standards in harvesting such as lopping and scattering the slash will accelerate decomposition, but this comes at a cost of extra work. The current interest in biomass utilization may result in more complete utilization of biomass during harvesting. Otherwise, supplemental site preparation treatments such as mechanical reduction of excess biomass or prescribed burning 2 or 3 years after harvest may be appropriate.

The greatest potential watershed impact from harvesting is associated with logging activities such as skid roads that can damage forest soils and log transport on permanent roads that can result in sediment delivery directly to creeks. The application of best management practices is voluntary in Arkansas and Oklahoma, but attention to the rules set forth in the voluntary guidelines for both States will help minimize adverse effects from skidding and hauling. A more indepth discussion of these effects is found in chapters 12 and 13.

Prescribed Fire Treatments

Prescribed fire in the Ouachita Mountains is generally applied as either a site-preparation or intermediate treatment with a goal of cleaning and release in pine plantations and in even-aged, naturally regenerated shortleaf pine, pine-hardwood, and hardwood stands. The prescription is usually applied on Federal lands, where burns in the dormant season through the early part of the growing season typically extend from January through April. Forest industry avoids using prescribed fire in their loblolly pine plantations because of concerns about unwanted reductions in growth and yield. Private nonindustrial landowners typically do not have access to the personnel required to efficiently burn large areas. Liability issues also limit a broader application of prescribed burning on private lands.

The choice of an ignition source depends on the condition of the landscape being burned, whether there are young stands within the landscape that need special attention to withstand burning, and the proximity to private land. Drip torch ignition early in the burning season is common for burn units near or interspersed with private land, so as to better control fire intensity and the area covered by the fire. Young stands are often burned very early in the growing season, again with drip torches, so as to consume fine flashy fuels that might create too hot a fire if burned later. Aerial ignition is preferred in large well burned landscapes where sensitive stands have been preburned because of the cost and labor efficiencies that result from burning large areas.

The watershed effects of prescribed fire are usually minimal. Vegetation recovers quickly in the Ouachita Mountains, and the risk of direct erosion through overland flow is minimal. Smaller fires ignited directly with drip torches are often imposed at a stand level; in these circumstances, permanent and intermittent stream channels usually form one of the boundaries of the burn unit. The intensity of larger fires ignited by aerial ignition can be adjusted by spacing the incendiary spheres that are dropped from the helicopter, and streamside zones are likely to burn with lower intensity if not directly hit by incendiary spheres or if soil conditions are wet, as they usually are in the spring. The greatest likelihood of unwanted watershed effects is if fire lines directly cross perennial or intermittent streams—a situation that can be avoided as conditions warrant.

Mechanical Treatments

Mechanical treatments associated with site preparation and intermediate prescriptions are widely applied in lieu of prescribed fire on all ownerships in the Ouachita Mountains regardless of species composition. The silvicultural objective generally depends on the ownership, the origin of regeneration (whether natural or planted), the silvicultural system being applied, and the resources of the landowner.

The goals of site preparation treatments are to reduce logging slash and competing vegetation and to prepare the seedbed. Usually, the intensity of treatments prescribed depends on whether natural regeneration or planting is to ensue, with more intensive site preparation activities usual for plantation establishment. In even-aged reproduction cutting followed by plantation establishment, all of the commercial timber is removed by harvesting and the noncommercial residual biomass is removed by mechanical felling (shearing, chopping, or chainsaw felling), which is sometimes concentrated by piling followed by either broadcast burning or burning of piles to eliminate slash. Ripping usually occurs again in late summer, with planting feasible in the following spring.

Bedding is not typically used in the Ouachita Mountains because of the extreme rockiness of the soils.

Soil displacement as a result of site preparation is a concern for cumulative watershed effects of silvicultural activity. Prescriptions that require logging debris to be raked, pushed, or dragged into rows or piles cannot be accomplished without some degree of soil movement; the less of this activity that is prescribed, the less the soil movement. Ripping deliberately moves soil so that rainfall can wash particles from the sides of the rip into the furrow, thereby creating an ideal planting medium and increasing the survival of seedlings. Cumulative watershed effects can be minimized by ripping along the contour, creating periodic discontinuities of the rip so that flow is interrupted, and stopping the rip before it reaches sensitive watershed areas such as streamside zones. However, in essence, ripping along the contour at 10-foot spacing creates a hillside of small fire lines, which impede site-preparation burning and other prescribed fires. The most effective approach for site preparation burns on ripped sites is to use drip torches and drop fire in the spaces that separate the rips. Once the rips are grassed over, though, the prescribed fire is usually able to carry across the rips without restrictions.

Intermediate mechanical treatments include activities, such as chipping or mulching, that reduce fuels. This activity is expensive, however, and thus is typically reserved for situations in which an uncontrolled fire might escape across property boundaries. Several recent disturbance events—windstorm and ice storm—in the Ouachitas over the past decade have resulted in down woody debris across landlines; these are a high priority for reduction by chipping and mulching, which produce a rather thick layer of chips and residues that usually remain in place within the stand and that do not burn easily. Cumulative watershed effects would be minimized by the simple expedient of not operating the mulchers or chippers within streamside zones.

Of course, the problem with mechanical treatments is that only the tops of trees are removed; rootstocks remain. Hardwood rootstocks without hardwood tops quickly become hardwood sprouts, and sprouting hardwoods have unwanted ecological influences on developing pine seedlings and saplings. This is not because of any inherent superiority or inferiority of hardwoods over pines ecologically, but rather because a sprout that is supported by a large preexisting root system can grow faster than a seedling supported by its own small developing root system. This imbalance threatens the seedling with suppression.

Herbicide Treatments

A more permanent approach to sprout control—either through cleaning, weeding, or release treatments—is an herbicide applied in a manner that kills both the tops and the roots of the sprouts. Aerial application of herbicides is effective when the goal is to control hardwoods competing with pines; a number of chemicals and application methods are available that target hardwoods with a minimal effect on pines. For example, in late summer, hardwoods are still photosynthetically active but pines are dormant. This difference in characteristics suggests a tactic of late-summer herbicide application over large areas, using helicopters, that will affect the actively-growing hardwoods but will have little or no effect on the dormant pines. Individual-stem treatment methods are more labor intensive, but have several advantages in specificity of target application and minimization of effects on nontarget vegetation. They can be applied to cut stumps or to the foliage of the targeted tree using a backpack sprayer. Although these methods are labor intensive, they minimize the volume of herbicide applied across a stand, and they are specific to a target tree rather than a target species, meaning that they can be used in pine-hardwood or hardwood-pine stands, or in hardwood stands to release desired hardwoods from competing hardwoods. These differences in application often reflect ownership differences as well; the broadcast methods are more common on private lands, and the individual-stem applications are more common on public lands.

The cumulative effects of herbicide applications have become considerably lower over recent decades. Modern herbicides are developed to act specifically on plant metabolism—by inhibiting photosynthesis or synthesis of amino acids that are only

found in plants. As a result, they have reduced adverse effects on other organisms than herbicides that were used in the past, and also have a short half life in the environment. Watershed effects are generally limited to the movement of the soil solution that contains the herbicide before being degraded in the environment, and also by the general chemistry of the inactive ingredients in carriers, surfactants, and other herbicide formulations. Following common safety precautions—such as applying setbacks from sensitive areas, avoiding direct application to streams, and employing environmentally safe loading and cleanup procedures—will also limit cumulative watershed effects.

Cumulative watershed effects are a function of the proportion of forest land in ownerships with varying of ability to engage in rigorous monitoring. In many respects, the Ouachita Mountains have an advantage because two-thirds of the forest land is managed by either forest industry or Federal agencies, more than elsewhere in the Eastern United States. These landowners and managers have a highly capable infrastructure in place to control wildfire, efficiently process unwanted forest residues (usually as part of commercial timber sale or harvesting activity), and otherwise integrate specific attention to fuels, treatment of fuels, and minimization of cumulative effects as part of their larger forest management program.

Forest lands owned by forest industry in the Ouachitas are primarily under an intensive program of even-aged forest management that emphasizes clearcutting and planting for commercial timber and fiber production. On these lands, management activities are carried out with keen attention to prompt reforestation, effective site preparation and release, timely thinning and pruning, and efficient reproduction cutting. Industry foresters have taken steps to execute this intensive program of silviculture with a minimum of adverse cumulative watershed effects, and in doing so have agreed to be bound by independently-verified standards.

Similarly, public forest management is dominated by the Ouachita National Forest. Again, these lands are managed under a comprehensive land and resource management plan that incorporates a diversity of both even-aged and uneven-aged silvicultural systems and includes comprehensive standards for ensuring that forest operations conducted under the timber, water, recreation, lands, and engineering programs are carried out in compliance with best management practices, all of which are detailed in public records.

The nonindustrial private forestry sector is more variable in this regard. Owners of these forest lands are less likely to be under a management plan, less likely to understand the hazard of fuels buildup, somewhat less likely to have sufficient resources to respond to wildfire risk (which is a responsibility of State agencies in Arkansas and Oklahoma), and less likely to be proactive in integrating fuels treatments into an overall program of silvicultural activities specified by management plans for their forested property. Finally, cumulative watershed effects on nonindustrial private lands are addressed by State-issued best management practices that are voluntary. The greater the degree to which owners can develop management plans, seek advice from professional foresters when making harvesting decisions, or get involved in public or private management assistance programs, the better will be scientific basis of the silviculture that is applied on their lands, and the fewer will be the cumulative watershed effects from improper attention to fuels and fuels treatments.

Conclusions

Fuels are a subset of the living and dead vegetation found within every stand in the forest. They are important insofar as their size, biomass, and distribution contribute to the risk of loss to forest resources in the event of an uncontrolled wildfire. Similarly, tools such as prescribed fire, fire surrogate treatments, and fuels treatments are a subset of a broader array of general silvicultural practices that are typically applied within forest stands and landscapes as a part of general forest management activities. These tools for fuels are most effectively implemented if they fall within the context of the larger silvicultural systems being imposed within stands and landscapes, rather than as stand-alone treatments applied at a given point in time. According to this perspective, the

cumulative watershed effects of fire, fire surrogate, and fuels treatments are best characterized as similar to those that result from all forest management activities. Unlike other areas in the South, two-thirds of the Ouachita Mountains forest landscape is under management, either by Federal agencies or forest industry. Active management under the guidance of professional foresters is the most effective way to integrate fuels treatments, and to minimize their cumulative watershed effects, as elements of a larger program of active forest management.

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