Missouri Forest Management Guidelines

Voluntary Recommendations for Well-Managed Forests

Comment on this document at http://mdc.mo.gov/node/23883

Table of Contents

The Purpose of These Guidelines

The Missouri Forest Management Guidelines serve a number of purposes. Drawing on input from the diverse group of stakeholders who helped prepare them, these guidelines describe the forest practices that are most likely to achieve a sustainable forest resource for Missouri citizens to value and appreciate. A listing of involved organizations and individuals is provided in the Appendix.

This document has three sections. The first part, Chapters 1 thru 9 provide background information about the resource elements that are most important to sustainable forest management. Information addresses why these elements are important and the aspects of these elements that need attention when planning and implementing forest management. The second section, Chapters 10 thru 12 explain the foundations of forest management. This section outlines forest management planning and the generally accepted silvicultural and forest regeneration practices. The third section, Chapters 13 thru 18 offer standards, guidelines, and best management practices recommended for specific forest management activities. These recommendations are based on sound scientific input and common agreement as to what sustainable forest management means in Missouri.

The intended audience for these guidelines is, indeed, both landowners and resource managers. Although the information is technical, it is intended to be presented in a way that any interested person can understand. Resource managers may find some of the information too basic, but the best management practices listed throughout represent a comprehensive reference of specific recommendations that anyone should find useful.

Sustainability is not so much a scientific definition as it is an expression of what society values about forests. These guidelines express that:

- Missouri wishes to meet the forest-related needs of the present generation without compromising the ability of future generations to meet their own needs.
- In order to achieve this, forest resources as a whole should deliver a full range of outputs that include the generation of economic return, the protection of environmental values, and the provision of social benefits.
- This complete range of outputs is not achieved on every acre of forest in the same mix, but across the landscape and over time by a diverse group of forest landowners who are each enabled to pursue their own mix of objectives.
- These diverse outputs are not exclusive of one another but many times supportive of one another.

That is, generating economic return by such things as a timber sale provides landowners the income that can pay for measures to protect the environment, such as water bars on a road. By the same token, protecting environmental values such as soil, water, air, and biological diversity

protects the basic resources that underpin economic value. Creating values that society desires serves to create the social license and support for maintaining forest resources into the future.

The guidelines serve as a way to achieve those values using practices that represent the best available science. These guidelines have been developed in cooperation with Missouri's scientific and academic community. They are a reference that gives landowners and resource managers confidence that they are employing peer-reviewed, research-validated methods for achieving desired results.

Additionally, the guidelines have been constructed with an eye toward facilitating the use of third-party forest certification where a landowner may desire to do so. Background and further details about third-party forest certification are included in the Appendix. To the extent that landowners choose to follow the practices, procedures, and processes outlined here, they will be well positioned to achieve forest certification on their property.

Because social values and scientific information evolve over time, these guidelines have been constructed as a living document. Revisions will be considered at least every five years after examining trends in forest conditions, current issues, and new scientific data. As such, they serve as one resource for continuously improving upon efforts to achieve a sustainable forest resource in the state.

It is important to state what purposes the Missouri Forest Management Guidelines do not serve — they are not a law, a regulation, or a legal requirement in the state of Missouri. They are a strictly voluntary set of guidelines, subject to each landowner's decision as to whether he or she will use them or not.

Even though these guidelines are voluntary, there are laws that can influence forest management in Missouri, and landowners should be aware of these laws.

The requirements of the federal Clean Water Act (Title 33 USC, Chapter 26, Section 404) in Missouri are administered by the regional offices of the U.S. Army Corps of Engineers, Regulatory Section. The provisions of Section 404 deal with dredge and fill activities that may impact wetlands or other jurisdictional waters. Before engaging in such activities as placing a culvert for a stream crossing, landowners should contact the Corps to ascertain any permitting requirements.

If it is determined that a permit is necessary, the landowner will also need to secure a 401 Clean Water Certification from the Missouri Department of Natural Resources. Clean Water Act Section 401 permits are administered by the Department of Natural Resources (dnr.mo.gov) under Revised Missouri Statutes Chapter 644.

Best management practices to protect water quality during forest management activities are voluntary in Missouri. Nonetheless, landowners are obligated under the law to prevent sediment from entering water bodies at levels that would exceed state water quality standards as a result of such activities as timber harvesting and road construction. See Chapter 644, Section 051:

It is unlawful for any person:

To cause pollution of any waters of the state or to place or cause or permit to be placed any water contaminant in a location where it is reasonably certain to cause pollution of any waters of the state;

To discharge any water contaminants into any waters of the state which reduce the quality of such waters below the water quality standards established by the commission;

Where there is federal involvement on private land, when a 404 permit is required or federal grant dollars are received, for example, landowners must also comply with the National Historic Preservation Act. The state's suggested common format for stewardship and other plans contains a section where the potential existence of cultural resources is considered. Chapter 6, in this document, outlines potential steps if their existence is a possibility.

The use of pesticides in the state is regulated by the Department of Agriculture (mda.mo.gov) under Revised Missouri Statutes Chapter 281. Applicator licenses are required in order to purchase and use "Restricted Use Pesticides" as defined by the Federal Environmental Protection Agency. The Department of Agriculture's website allows you to query whether a particular chemical is restricted. Chemical use in Missouri forests is fairly limited and seldom involves a "Restricted Use Pesticide," but it is important to be aware of the legal requirements.

Missouri has a State Forestry Law (Revised Missouri Statutes Chapter 254) that is administered by the Department of Conservation. Most of this law pertains to an incentive program that is outdated and no longer widely used by landowners. It is worth noting, though, that Section 250 requires landowners to use any reasonable effort to control wildfire on their property and to allow Conservation Department employees access for the purpose of suppressing wildfire.

All of Missouri's statutes can be searched at moga.mo.gov/homestatsearch.asp.

One federal law that resource managers frequently encounter is the Endangered Species Act (Title 16 USC Chapter 35). The Endangered Species Act makes it illegal for anyone to "take" a species that is listed as federally endangered. This could involve the obvious, such as shooting an Indiana bat, or it could be a less direct method, such as cutting down a tree that contains a roosting Indiana bat.

An example of another species that is listed is the Ozark hellbender. Harvesting activity that might destroy their aquatic habitat (such as running equipment through a stream that represents an important breeding area) could again be considered a "take" of that species. Chapter 3 provides information on how to become aware of the potential for endangered species on any given piece of property and how to identify the management practices most suited to protecting that species.

Unit I: Background Resource Elements

Chapter 1: Missouri Forest Resources

Topics Covered

Forest Types and Extent
Environmental Forest Values
Economic Forest Values

Missouri has a unique and significant forest resource: unique because of where the state sits within the North American continent, and significant for the host of environmental, economic, and social values it continues to provide for Missouri's citizenry.

Forest Types and Extent

Geographically, the state is located at the juncture of four major land types — the prairies of the west, the glacially scoured landscapes of the north, the ancient Ozark Mountain range of the south, and the expansive Mississippi bottomlands in the far southeast. Prior to early settlement, roughly 30 million acres of forest were found in these four distinct regions encompassing a wide diversity of forest types.

Forests, Woodlands, and Savannas

The terms forest and woodland are often used interchangeably to describe land covered predominately by trees. In Missouri, a state which supports prairie, forest, and all points in between, there is a growing body of evidence that many natural communities combining features of both forests and prairies existed historically. The historical prevalence of these unique ecosystems and increased interest in their conservation has led to classification systems that recognize a variety of "woodlands" and "savannas" as parts of Missouri's natural heritage. Savannas have been recognized as a distinct community type in Missouri since at least the mid-80s. However, only since the early 2000s have woodlands been treated as a community type different from forests. Below are definitions for forest, savanna, and woodland that will help to distinguish among them.

Forest: an area dominated by trees forming a closed canopy, which is often composed of multiple overlapping layers (understory, midstory, and overstory). The midstory and understory of a forest is also dominated by trees and shrubs. Herbaceous vegetation is present in the understory, but rarely forms a continuous layer.

Woodland: an area supporting trees with 30-100% canopy closure, a sparse understory or midstory of woody plants, and a dense ground flora rich in forbs, grasses, and sedges. The near absence of a understory or midstory of woody plants enables more sunlight to reach the understory of a woodland, which, in turn, favors the development of a dense layer of ground flora.

Savanna: an area of grassland interspersed with open-grown trees with less than 30% canopy cover occurring as scattered individuals, groups of trees, and shrubs.

Historically, infrequent lightning-caused fires and more frequent Native American–caused fires had a profound influence over the character of forests in the different areas. In the prairie region, fire served to confine tree cover to riparian areas. In the north and as prairies transitioned to the east, sparsely treed upland savannas became parts of the forest landscape. In the Ozarks, riparian areas continued to support fairly dense stands while the ridges were more open woodlands. The bottomlands of the Missouri Bootheel saw significantly less fire activity and were heavily forested.

Today, forests in the north, west, and bottomland portions of Missouri have been mostly converted to agriculture. More than 15.5 million acres of forest cover remain in the state, with most of it found in the Ozarks.

The most prevalent forest type is a mixture of oak and hickory. Mixed forests of oak and pine can also be found, as can stands of elm, ash, black walnut, and cottonwood. Eastern red cedar is a common species on lands reverting from pasture back to forest and on historical glades where fire has been excluded. Sugar maple is frequently found in high numbers within the hilly landscape that abuts the state's largest rivers.

A large number of other species that are more typically associated with other parts of the country are also native to the state. These include more western species such as osage-orange, wetland species like bald cypress and water tupelo, eastern species such as tulip-poplar, black cherry and American beech and the more northerly prone aspen.

Although the Ozarks has retained most of its historical forest acreage, the land has been significantly influenced by human activity over the past 100 years. Intensive logging around the turn of the 20th century removed nearly all of the shortleaf pine and then the oak. Subsequently, lands were heavily burned and grazed well into the early 1960s, leaving few pine and a predominance of low-quality, defective oak. Eventually a law was passed banning open range, and over time uncontrolled burning has been substantially reduced.

Figure 1.1. Two photos shot from the same location. Cutover Ozark forest (north of Eminence) in 1934 and present (notice large rock in foreground).

Missouri's forests contain a large percentage of standing trees that show damage from past land use practices. High-grading, the practice of only harvesting the best trees from a stand and leaving everything else, has been an all-too-common practice. It leaves poor quality, defect-prone trees on the landscape, taking up scarce water and nutrients that could otherwise be used to grow more desirable trees.

Additionally, the exclusion of fire has served to increase more shade-tolerant species, such as sugar maple, in some areas. These shade-tolerant species can sometimes find a place in the

wood products market. Their more noted impact, however, is that they replace less tolerant oaks, a critical source of hard mast for Missouri wildlife.

The large majority of Missouri's forestland is privately owned by an estimated 339,000 families or individuals. Combined, these properties account for more than 80 percent of the forested acreage. Most private landholdings are less than 50 acres in size, but the majority of the state's 12.7 million privately owned acres are in holdings that are greater than 50 acres. The U.S. Forest Service and other federal agencies own roughly 2 million acres, while state and local governments own approximately 795,000 acres.

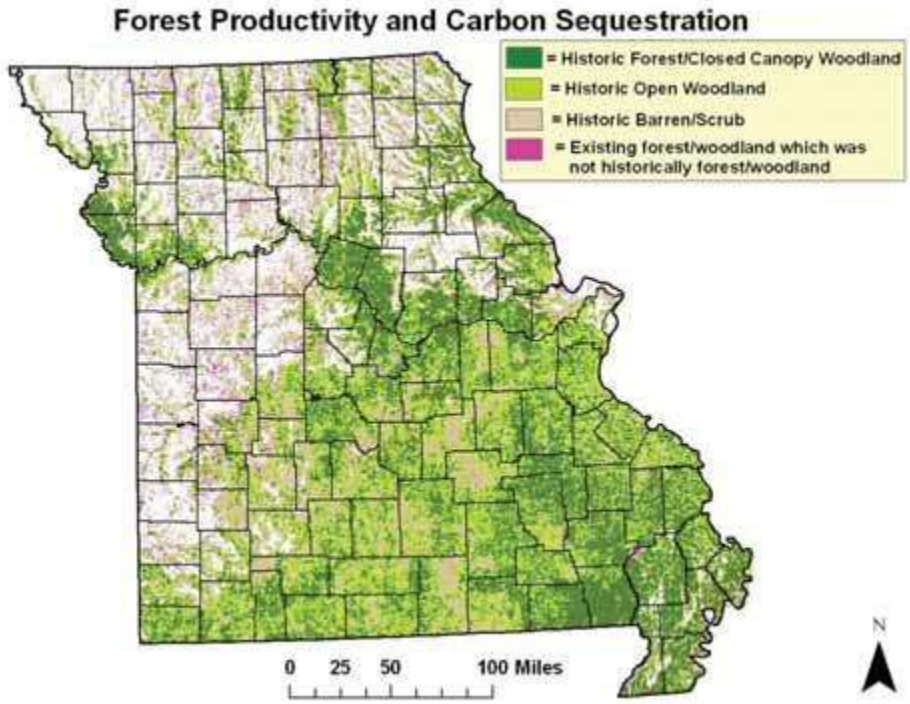


Figure 1.2. Historically, one-third of the state was in prairie vegetation primarily in the western and northern regions. The remainder of the state occurred as forests, woodlands, or savannas depending on the disturbance regime. Shortleaf pine, once prominent on 6 million acres in the eastern Ozarks, now occurs on only 600,000 acres. The Missouri Bootheel once supported productive bottomland forests that contained species typical of more southern floodplains but is a major crop producing area today.

Figure 1.3. Currently, forests occur on 34 percent of the land base in Missouri.

Environmental Forest Values

From an environmental perspective, Missouri's forests play a critical role in protecting water quality, supporting a rich biological diversity, maintaining soil productivity, and storing carbon.

Water from forested landscapes is cleaner than that from any other category of land use. The filtration and runoff control provided by a forest not only maintains water quality but also regulates the amount of flow in water bodies — keeping high water extremes to a lower level and low water flows to a higher level than what would be expected from a less protected watershed. The cost-effectiveness of forests as a provider of clean water is such that some municipalities view forest watershed investments as a critical component of their drinking water infrastructure.

An extensive list of plant and animal species depend on Missouri forests as their primary habitat. They are as varied as the types of forests found here. They include high-profile game species like deer and turkey, neo-tropical migratory birds, unique amphibians, and endangered bats. There are understory plants of economic note such as gingseng, pawpaw and golden seal, rare orchids, uncommon trees like butternut and yellow-wood and aesthetically important understory species like dogwood, chokecherry and sumac. Given their positive impact on water quality, forests are equally important to most of Missouri's fish species.

The forest functions that protect water quality also serve to maintain soil productivity by preventing erosion. With proper attention to leaving appropriate amounts of logging residue, forest management involving regular harvests can still build, or at least maintain, soil nutrient levels, organic matter, and micro-organisms. The appropriate harvest practices also minimize compaction and other physical changes to soil properties that might occur under other land uses.

It is estimated that forests in the state store upward of 840 million tons of carbon, the greenhouse gas whose release into the atmosphere is cited as a principal cause of man-induced global climate change. Not only do trees sequester carbon, they are also a potential renewable energy source. Nonrenewable energy sources such as coal, oil, and gas add to the overall carbon imbalance in the atmosphere, while the carbon released from burning wood can eventually be offset by the additional carbon stored from growing trees.

Economic Forest Values

In terms of economic benefits, Missouri's forest products industry contributes nearly $7.3 billion annually to the state. The industry supports almost 41,200 jobs and is responsible for more than $610 million in tax revenue. Railroad ties, pallet lumber, charcoal, wood chips for pulp and biofuel, hardwood lumber, and flooring are common products derived from the state's forested acreage. In addition, hunting leases are becoming a growing revenue source for Missouri forest landowners, and Missouri's tourism industry is closely connected to the attractiveness of the state's forested landscapes.

Social Forest Values

In terms of social benefits, forest-related recreation is a highly valued aspect of Missouri's quality of life. Camping, hiking, hunting, fishing, sightseeing, mushroom collecting, and nature viewing all depend on this resource for the best opportunities. These activities occur on both public and private lands. Although most private lands are not available to the public for on-site activities, scenic drives are enjoyed by all and are available regardless of ownership. Aesthetic values, no doubt, are the one forest benefit that directly impacts the greatest number of people.

Taken in their totality, all of these benefits combined have tremendous importance to the citizens of Missouri. Although not every single benefit is delivered equally on every single acre, the state's diverse set of owners and conditions ensures that a broad balance of values is offered across the broader landscape. By applying appropriate practices, our forest resource and its benefits can be sustained for many generations to come.

Chapter 2: Wildlife Habitat

Topics Covered

- Snags, Dens, and Super Canopy Trees
- Mast Production
- Water Sources
- Coarse Woody Debris and Slash
- Habitat Connectivity and Continuity / Forest Interior Bird Species
- Early Successional Habitat
- Edge
- Glades and Forest Openings
- Game Species Management
- Additional Resources

The term “habitat” refers to the various types of foods, cover, and other factors needed by a species in order to survive and reproduce. Approximately 191 native species of vertebrates (80 breeding birds, 42 mammals, 69 herptiles) utilize Missouri’s forests, woodlands, and savannas as key habitat for part or all of their life cycle. Climate, soils, topography, geology, and hydrology as well as land-use and natural disturbances determine the types of wildlife habitats found across the state.

Groups of plants and animals that occur repeatedly in time and space within specific locations are defined as natural communities. Land is classified by natural community type to help guide management decisions. In Missouri, 85 different terrestrial natural community types have been described. Since highly mobile wildlife species are not tied to one specific natural community, these species are usually described in association with the broad categories of community types.

The purpose of this chapter is to provide general site-level guidance on forest dependent terrestrial and amphibious wildlife. These habitat guidelines are written to give practical, scientifically based site-level guidance, but it is impractical to include all wildlife habitat improvement techniques, however. For further information, refer to the additional resources at the end of the chapter or contact a professional wildlife biologist.

Forest management practices impact various wildlife species differently. Some species respond favorably to a silvicultural practice such as even-aged regeneration harvests (clear-cuts) while others respond negatively. Still, forest and wildlife management can be complementary. What is required is an understanding of the habitat needs of desired species and the effect that forest practices can have on creating those conditions within different natural community types.

For example, species that depend on hard mast like acorns can benefit from forest management practices that encourage the continuation of oak species. This is most efficiently accomplished on lands where the natural community type features oak as a prominent tree in

the overstory. On a bottomland community where, for instance, cottonwood is the dominant species, managing for a hard mast producer may be difficult or even not infeasible.

Missouri's wildlife species generate important benefits. In and of themselves they are a key component of healthy ecosystems. Ensuring that populations remain at viable levels correspondingly generates economic and social benefits. In 2011, residents and nonresidents spent approximately $2.8 billion on wildlife recreation (fishing, hunting, and wildlife watching). From a social perspective, hunting and fishing are integral to Missouri's culture as an outdoor enjoying state. Knowing that unique species such as bald eagles, or even bats, are being protected is important to most people.

The management guidelines described in this chapter address site-level recommendations for the important habitat elements, but the contribution of an individual site should be considered in the context of the surrounding landscape. For example, many cavity-dependent species have home ranges that are larger than the typical harvest or management unit, so planning to meet the needs of these species requires a broader look, both spatially and temporally, at the forest community on a landscape scale. If adequate suitable habitat exists adjacent to a harvest site, then retention or promotion of those habitat elements within the management unit may not be as critical as if the elements are lacking on the impacted landscape. Land managers have opportunities to enhance wildlife habitat characteristics through careful planning and management at the site level, as well as through coordination with adjacent and surrounding landowners and managers.

Dens, Snags, and Super Canopy Trees

Den trees (live cavity trees) and snags (dead standing trees) with cavities provide wildlife with shelter and habitat for roosting, foraging, nesting, and hiding. A total of 89 vertebrate wildlife species in Missouri utilize cavity trees or snags for all or part of their life cycle. At least 54 species use the cavities in live or dead trees. About 59 percent of wildlife species will use cavities in either live trees or dead trees, but 13 percent prefer cavities in live trees, and 28 percent prefer cavities in snags. Cavity users are defined as primary excavators, those that make cavities such as woodpeckers and chickadees, or secondary users, which use cavities produced by others or by decay. Snags are about six times more likely to have cavities than live trees. Snags are also very important to invertebrate and fungi species. Twenty-two percent of Missouri's breeding bird species are cavity nesters. Screech and barred owls use snags and den trees for nesting and resting. They are also important to gray and fox squirrels, black bears, white-footed mice, Indiana bats, gray tree frogs, southern flying squirrels, raccoons, pileated woodpeckers, red-headed woodpeckers, and wood ducks. A number of songbirds including the eastern bluebird, nuthatches, chickadees, and wrens utilize snags and den trees for part of their life cycles as well.

"Wolf" trees are a particularly valuable type of live den (cavity) tree. They are large diameter, often open-grown, old-aged, hollow trees that provide cavities and are frequently a source of hard or soft mast. Oaks, hickories, and sycamore are all preferred den tree species. In regeneration harvests, it is important to reserve snags, den trees, and wolf trees either individually or in clumps. Large diameter snags and den trees — those greater than 18 inches

diameter at breast height — are particularly important wildlife habitat features to retain. Saving trees with holes located high in the tree is also an important consideration. Typically, holes located at least 20 feet above ground are the most beneficial. Where there is a shortage of snags it may be desirable to girdle some leave trees to accelerate their development into suitable habitat.

The fundamental idea is to retain some structure for snag- and cavity-dependent species on a site or maintain the potential to produce such structure as a stand grows and develops (see Chapter 15). If suitable habitat already exists next to a harvest site, then leave trees may not be as critical if the habitat values in those adjacent stands are to be maintained. Managers of larger landholdings may be able to plan for sufficient cavity-dependent wildlife habitat on portions of their property (such as riparian reserves) and reduce leave tree/snag requirements on other portions. From a temporal standpoint, consideration must be given to the time it takes for a regenerating stand to produce trees of a size and a degree of decay that represents suitable structure. Looking at adjacent stands, it is also important to think about how they may in fact change over time in relation to the changes expected within the stand being treated.

Super-emergent or super-canopy trees are large diameter trees with crowns that extend well above the plane of the forest canopy; ideally at least 50 to 75 percent of the crown or 20 to 25 feet. Such trees are of high importance in bottomland forests and riparian areas to provide nesting sites for bald eagles and other raptors, for heron rookeries, and as potential large cavity trees. On average, two to four super-emergent trees per acre, or those that have the potential to become such trees, should be retained to provide the needed structural diversity. Preferred tree species include oak, cottonwood, and sycamore.

Mast Production

Mast is the wildlife food provided by the seeds and nuts of trees. Fruit such as acorns, hickory nuts, and walnuts are considered hard mast and are valuable because of the length of time they remain available to wildlife. Soft mast include dogwood berries, maple seeds, or similar fruits that may not stay nutritional as long but are still important because of their availability at other times of the year.

The high levels of fat, protein, and carbohydrates in mast contribute to energy stores critical for migration or hibernation, as pre-breeding conditioning nutrients, and for survival of newly independent young. Some birds and mammals depend heavily on mast during peak production periods in late summer and early fall. During winter, some sources remain available on trees and shrubs, under snow, or stored in caches

Mast production is generally favored by increased mast species diversity, crown exposure to light, crown size, maturity of trees or shrubs, increased soil nutrients, tempered microclimates (especially during flowering), and adequate soil moisture. Riparian edges often contain a higher concentration and richness of mast-producing species. Production on a site and within various species of trees and shrubs tends to vary considerably from year to year. Most shrub species will regenerate well and produce mast after cutting, burning, or soil disturbance. Mast-producing species often depend on animals for their dispersal and reproduction.

Although certain dominant tree species such as oak are particularly important, other mast species also provide key benefits. Retention of all food-producing tree types should be prioritized in accordance with the local abundance of each tree species. In areas of least abundance, greatest attention should be applied to retention. Planning silvicultural treatments to increase mast-producing trees should be performed in accordance with silvicultural guidelines.

In Missouri, oaks are the foundation species for many wildlife species. Squirrels, white-tailed deer, black bears, eastern chipmunks, eastern wild turkeys, wood ducks, white-footed mice and red-headed woodpeckers are just some of the species heavily dependent on oak mast. The production of 100 pounds of oak mast per acre is needed to sustain reasonable wildlife densities. This is roughly equivalent to a basal area of 25 to 30 square feet per acre in oaks that are above 10 inches diameter. Most oak species begin mast production at around 20–25 years, but yields are not maximized before age 40 or 50. Thinning can enhance mast production by increasing diameter and canopy size on good mast producing trees.

Oak mast production is highly variable from year to year. There are also significant differences in flowering and acorn production among species in the red oak group (scarlet, cherrybark shumard, pin, black, and northern red oaks) versus those in the white oak group (post, chinkapin, burr, and white oaks). Species in the white oak group require one growing season to complete their reproductive cycle, and species in the red oak group flower every year but require two growing seasons for the acorns to mature. The white oak group can produce every year but may only have abundant crops sporadically. Year-to-year fluctuations in acorn production tend to be less extreme for the red oak group. In a year with a late spring hard freeze, acorn production may be comprised of only acorns produced by the red oaks the previous growing season. Therefore, managers should retain a diversity of both red and white oak species across the landscape to ensure overall adequate mast production for wildlife species.

There are important differences in nutritional and palatability values between red oaks and white oaks. Acorn-dependent wildlife select acorns low in tannin levels in autumn when energy requirements are low and food is relatively abundant. In contrast, in the winter when energy requirements are high, these same wildlife species select acorns with higher lipid levels even when they contain higher amounts of tannin. Since the red oak group species tend to have higher concentrations of tannins, these acorns tend to be most heavily utilized later in the winter when nutritional needs are highest. Due to these differences, it is important to manage for both white and red oak species in oak-dominated natural communities.

Soft mast producing shrubs and small trees are also important food sources for white-tailed deer, many songbirds, numerous small and medium-sized mammals, and some reptiles. Species include serviceberry, pawpaw, hackberry, sugarberry, dogwoods, hawthorns, persimmon, elm, ash, spicebush, red mulberry, black gum, black cherry, wild plums, sumacs, Carolina buckthorn, gooseberries, wild roses, blackberries, raspberries, dewberries, elderberry, sassafras, green briars, coral berry, blueberries, grapes, hollies, pokeweed, and poison ivy.

Soft mast production is enhanced by timber harvesting and/or thinning. Clear-cut and shelterwood harvests produce abundant soft mast the first few years after harvest. Group cuts made at more frequent intervals can provide moderate amounts of soft mast annually. Prescribed burning can also enhance production from shrub species if adequate light is available.

Land managers in regions with low mast availability have opportunities to enhance wildlife habitat characteristics by careful management of mast species on their land. Some wildlife species may forage significant distances. The black bear, for example, may travel 10 miles to obtain mast. Breeding birds will often relocate family groups to wetland edges or areas with increased levels of berries during late summer before migration.

Water Sources

Many wildlife species are dependent upon surface water. For example, one pond, stream, or other water source per 160 acres of land can enhance turkey habitat, and deer require a sufficient water source per square mile. Developing a fishless shallow pond for deer and wild turkey can also benefit amphibians, particularly in heavily wooded, upland karst topography where standing water is not a common occurrence.

In the Missouri Ozarks, 17 species of amphibians utilize fishless ponds: salamanders (ringed, spotted, marbled, eastern tiger, central newt, and four-toed), toads (eastern American, eastern narrow-mouthed, Fowler's), and frogs (Cope's gray tree frog, eastern gray tree frog, Blanchard's cricket, northern spring peeper, western chorus, pickerel, southern leopard, and wood). In addition, turtles and water snakes will benefit from these shallow ponds.

Guidelines on the construction and maintenance of shallow ponds for amphibians are available from the Missouri Department of Conservation. Note that many small wildlife ponds developed in the past may not be ideally suited for amphibians if they contain fish. Timbered buffers that are 50 feet in radius should be located near artificially created wildlife watering holes, and 200-feet-radius buffers should be used around other isolated wetlands such as sinkhole ponds, springs, fens, and seeps (see Chapter 15 for specific recommendations). All of these habitats can be important amphibian breeding sites.

Coarse Woody Debris and Slash

Standing dead trees, fallen trees, large decomposing roots, stumps, and treetops with limbs larger than 6 inches make up coarse woody debris. Coarse woody debris has many roles such as providing seed germination sites, acting as reservoirs of moisture during droughts, and serving as habitat for a number of forest organisms. Snags and down logs are important in cycling nutrients and energy, in providing habitat for invertebrates and fungi, and in soil development and watershed protection.

At least 66 vertebrate species in Missouri utilize down woody material such as rotting logs, dead limbs, and brush piles. Large fallen trees can provide important habitat for chipmunks, salamanders, and frogs for up to 50 years. They also provide drumming sites for ruffed grouse. Fallen logs located on steep north-facing slopes in the southern half of the state are especially

valuable to the western slimy salamander, Ozark zig-zag salamander, southern red-backed salamander, ringed salamander, marbled salamander, and spotted salamander. Many predators, ranging in size from shrews to black bears, rely on the food they find in coarse woody debris.

In Missouri and throughout the Midwest, old-growth forests (>175 years) typically contain larger amounts of coarse woody debris than mature second-growth forests (70–90 years.) Coarse woody debris is an important structural element for maintaining biodiversity in eastern deciduous forests. Managing for old-growth forests and woodlands on a variety of sites will ensure adequate coarse woody debris reservoirs across the landscape. Ensuring that adequate snags and reserve trees are left during regeneration harvests is also critical to maintaining coarse woody debris levels through time (see Chapter 15 for specific recommendations).

Habitat Connectivity and Continuity / Forest Interior Bird Species

Fragmentation results when forestland is interspersed with other land uses such as agricultural or residential development. It can also be caused by road building where rights of way are particularly wide.

The subsequent impact to natural communities can range from the increased introduction of exotic species to songbird nest parasitism. Forest tracts permanently isolated by fragmentation, particularly in north Missouri or the Bootheel, are frequently too small to prevent brown-headed cowbirds and nest predators from parasitizing and depredating the nests of interior bird species. As a result, forest interior songbird populations have poor reproduction in these regions. Similarly fragmented landscapes create more desirable conditions for the invasion of a variety of unwanted nonnative plants or animals into remaining woodlands.

Even-aged regeneration harvests (clear-cuts) within the context of large contiguous blocks of timber do not constitute fragmentation though they may result in a temporary change of habitat and of wildlife that use them. Smaller 2–20 acre clear-cuts in extensively forested landscapes like the southeast Missouri Ozarks have not been found to increase songbird nest predation or parasitism rates.

To encourage reproduction of forest interior songbird species such as ovenbird, wood thrush, worm-eating warbler, cerulean warbler, black-and-white warbler, Kentucky warbler, and others, forest landscapes should be at least 10,000 acres in size. A 12-mile-diameter landscape should be at least 70 percent forested in order to qualify for adequate forest interior conditions. The forested landscape should contain a variety of successional stages with core 2,000-acre mature or old-growth timbered tracts.

Bottomland forests in particular have been extensively converted to agricultural uses and are the most fragmented of forest types in the state. Efforts to reforest floodplains are very valuable for forest interior bird species. As an example, prothonotary warblers in an agriculture-dominated landscape require bottomland forest tracts that are at least 7,000 acres in size, in order to support a viable source population of 500 breeding pairs. Cerulean warblers require even larger bottomland forest tracts in order to support a viable source population.

Early Successional Habitat

Early successional habitat is dominated by shrubs and saplings less than 15 years old. It is an important habitat component for some species such as white-tailed deer, wild turkey, ruffed grouse, and eastern cottontail rabbit, as well as for songbirds like prairie warbler, blue-winged warbler, field sparrow, eastern towhee, white-eyed vireo, hooded warbler, indigo bunting, and yellow-breasted chat. It can be created with regeneration harvests on forest sites and is also present in old fields as well as glades and woodlands managed with thinning and prescribed fire.

As with old-growth, early successional stands are under-represented in most of Missouri's forested landscape. In large timbered blocks (>500 acres) it is desirable to have around 10 percent (5–15 percent) in some form of temporary structure such as regeneration areas or natural openings (e.g. glades) to provide early successional habitat. Managers should evaluate the abundance of habitat in the landscape and adjust treatments to enhance early successional habitat quantity and distribution.

Edge

Edge is the transition zone between habitat types. It can include "hard" edges between a forest and a crop field, or "soft" edges between a forest and the temporary regeneration opening created by a clear-cut. Edges can also be natural, such as those between a woodland and a glade or between a bottomland forest and a slough. They typically provide an abundance of grasses, forbs, shrubs, vines, and small trees that provide food and cover for many wildlife species (especially deer, rabbit, turkey, and quail). A seed-producing herbaceous layer of vegetation attracts a diversity of insect life, which can reduce the need for artificial food plots and reduce the wildlife population tie to cyclic mast production.

Edge feathering is a technique that can effectively create better edge habitat at the border between timbered lands and crop fields or old-fields by cutting trees in a 15–30 foot swath along these borders. Another wildlife practice that can be done in conjunction with edge feathering is the creation of brush piles. Brush piles offer good heavy cover and are utilized by rabbits and other small mammals, reptiles, salamanders, insects, and a host of bird species.

Large forested tracts often lack openings and therefore lack soft edge. Soft edge in these landscapes is not as critical to wildlife as is early successional habitat, though both are created through regeneration harvests. Glades and natural wind-throw openings also provide similar habitat.

Care must be taken when creating or enhancing edge habitat, or when conducting a harvest operation, to avoid introducing invasive exotic species such as sericea lespedeza or bush honeysuckle. These invasive exotics are extremely aggressive and can rapidly colonize disturbed areas. Where stand treatments will open the canopy, access the site and spot treat existing exotics prior to operation. Dense stands of honeysuckle can eliminate desired regeneration and can completely overtake the stand if left untreated. Roads and utility corridors may also provide edge habitat, but particular care should be taken in these situations with regards to exotics because these sites are common entry points for exotics across the

landscape and into opened stands. (Refer to Chapter 9 for more information on invasive species.)

Glades and Forest Openings

Openings in forested landscapes can be either natural openings, such as glades that exist due to shallow drought-prone soils, or openings created through intentional clearing. Where glades exist, they provide a distinct habitat type that many species utilize and benefit from. They are most often found on south and west-facing slopes or ridge tops.

The native species that occur on glades are very drought tolerant. It is recommended that glades be managed to promote these species by controlling cedar encroachment and using prescribed fire as needed. Nonnative species of grasses and forbs seldom survive the naturally dry conditions and are not recommended for these areas. Never attempt to grow a grain or green browse plot in a glade as any soil disturbance will likely lead to excessive soil erosion and unsuccessful plant growth.

Artificial clearings in the forest created to stimulate annual weeds, grasses, forbs, or grain can provide feeding sites for a variety of wildlife species and thus wildlife viewing opportunity. In most cases, these objectives can be achieved through normally planned forest management practices. Intentionally created openings, such as food plots that will be disked and planted each year, need to occur on a fairly level location to avoid excessive erosion. As woody growth begins to reinvade openings, a combination of mechanical, chemical, and/or prescribed burning practices may be used to maintain them.

Game Species Management

The term “game management” is reflective of a time in history when wildlife populations as a whole were taken for granted. Some species were driven to extinction and many others extirpated from the majority of their historic ranges as a result of habitat destruction and over-harvest. The concept of game management arose from a collective realization that natural resources (in general) and wildlife resources (more specifically) were not inexhaustible and that they had to be actively managed if they were to be retained. Much of the original concern was centered upon species that were hunted for recreation and consumption because declines among these were the most apparent. However, as the science of wildlife management has advanced, focus has shifted toward managing for diverse habitats that support the full range of native plants and animals.

Since the inception of game management, food plots have been popular with landowners. From a science-based perspective, they do little to increase wildlife numbers. However, from a social perspective they can create opportunities to spot game species like deer, turkey, or quail, and they can serve to create ideal hunting locations for increasing hunter satisfaction. Concentrating wildlife for easier viewing is a reasonable landowner objective, but it is a choice that should be made with full knowledge that broader scale management to improve overall habitat diversity is a more effective way to enhance the full spectrum of wildlife populations, including those considered game species.

Additional Resources

Wildlife Management for Missouri Landowners, Missouri Department of Conservation 2000. Available at mdc.mo.gov/node/5354

Forest Management for Missouri Landowners, Missouri Department of Conservation 2007. Available at mdc.mo.gov/node/5574

Chapter 3: Natural Heritage Resources

Topics Covered

- Species of Conservation Concern
- Natural Communities of Conservation Concern
- Major Natural Communities of Missouri
- Natural Heritage Resources — Protecting Fragile Ecosystems
- Heritage Reviews
- Special Considerations for Natural Areas and High Conservation Value Forest (HCVF)
- Significant Natural Heritage Resources
    - Isolated Wetlands
    - Karst Features
    - Old-Growth Habitat
- Threatened and Endangered Species (T&E species)
- Federally Listed Bat Species
- Potential Indicators of Species and Natural Communities of Conservation Concern
- Additional Resources

Missouri's natural landscape has changed greatly in the last 200 years. Agriculture, urban sprawl, dams and reservoirs, mining, stream channelization, land clearing, and other activities have had an impact on virtually all of the state's lands. High-quality intact natural areas are rare. However, many of Missouri's forests and woodlands currently retain significant natural quality and provide habitat for important natural communities and species.

Areas with high-quality significant natural features, communities, or species give us an appreciation for the diversity and strikingly rich and beautiful landscapes that were once prevalent. It is important to conserve these areas for their biodiversity. These elements of Missouri's natural heritage are valuable assets from cultural, aesthetic, and practical perspectives. Their status and management can add intrinsic worth to properties, and they should be carefully considered when managing lands.

Natural heritage resources include populations of native plants and animals and healthy natural communities and ecosystems. They are the result of thousands of years of selection and adaptation to the specific processes and conditions that characterize Missouri. Natural heritage resources include terrestrial, aquatic, and geologic features as well as habitats for species of conservation concern. Caves, sinkholes, limestone cliffs, sandstone canyons, springs, seeps, forested wetlands, glades, riparian areas, and old growth timber are some examples of natural heritage elements.

Forests, glades, springs, rivers and streams, savannas, wetlands, prairies, and caves each support a different combination of plants, animals, and microorganisms. Considering how

management impacts on these systems and lessening or mitigating degrading actions is important when conducting management in timbered lands.

Species of Conservation Concern

In the brief time since European settlement of Missouri, many plants and animals have declined to levels of concern, and some have disappeared entirely. One of the primary components of natural heritage resources is species of conservation concern. These are plants and animals whose rarity makes them vulnerable to extirpation from the state. Currently, 18 percent of native vascular plants, 14 percent of nonvascular plants, and 28 percent of the vertebrate animals in Missouri are considered species of conservation concern.

The Department of Conservation maintains two references relating to the status of listed plants and animals in Missouri; the Missouri Species and Communities of Conservation Concern Checklist and the Wildlife Code of Missouri. Native animal species, including invertebrates, have legal protection under the Wildlife Code. All animal species in the state of Missouri are protected as biological diversity elements unless a method of legal harvest or take is described in the Wildlife Code. Species listed in the *Wildlife Code* under 3CSR10-4.111 are protected by the State Endangered Species Law 252.240. Some of the plants and animals in the checklist also appear in the Wildlife Code and are afforded special legal protection. All federally endangered and threatened plants and animals are protected by the Endangered Species Act of 1973 (ESA) and by the Missouri State Endangered Species Law.

Best management practices for many species of conservation concern can be located by accessing the Missouri Department of Conservation's web page at mdc.mo.gov/node/4067.

Natural Communities of Conservation Concern

Natural communities are groups of native plants and animals and their associated physical environment that occur in repeatable patterns across the landscape and have been least impacted by modern society. In addition to species of conservation concern, terrestrial natural communities can be rare natural heritage resources in and of themselves. Terrestrial natural communities consist of interrelated assemblages of plants, animals, and other living organisms interacting with their physical environment and shaped by climate and other natural processes. High-quality terrestrial natural communities provide diverse assemblages of native species and represent the best remaining examples of ecosystems that existed prior to European settlement. These natural communities frequently provide habitats for Missouri species of conservation concern. On public land many of these areas have been designated Missouri natural areas.

A list of species and natural communities of conservation concern are found at mdc.mo.gov/node/4070.

Rankings are assigned to natural communities using established criteria. These include total number of occurrences, number of occurrences as related to overall quality (or grade), total acres, number of counties in which the community type occurs, number of protected occurrences, and threats.

Natural communities can be either terrestrial or aquatic. There are 85 different terrestrial natural community types and 35 different aquatic natural community types recognized in Missouri. These 120 different communities can be generally grouped under nine major terrestrial natural community types and seven major aquatic natural community types. These are described below.

Major Natural Communities of Missouri

Forests are dominated by trees that form a closed canopy reaching more than 70 feet high at maturity. Forests have multi-layered understories of shade-tolerant trees, shrubs, vines, ferns, and herbs.

Woodlands have a more open canopy than forests. Trees are often gnarled and reach less than 70 feet at maturity. Beneath the open understory the ground is covered with a dense growth of forbs, grasses, and sedges.

Savannas are transitional zones between woodlands and prairies. They have a scattering of trees interspersed with a thick ground cover of prairie grasses and forbs.

Prairies are native grasslands dominated by perennial warm-season grasses and forbs with scattered shrubs. The biodiversity of most prairies is staggering, with more than 200 native plant species often occurring on as little as 40 acres.

Glades form on shallow soils or open bedrock where drought-adapted grasses and herbs dominate. Few trees grow on glades. Many plants and animals found here occur nowhere else in Missouri.

Cliff and talus natural communities are characterized by exposed rock. Cliffs are vertical expanses of bedrock dotted with sparse vegetation. Talus defines areas of loose rocks, cobbles, and boulders that collect below cliffs.

Stream edges are riparian zones, such as gravel washes and stream banks that are affected by rushing water. Species that occur here are adapted to frequent flooding.

Wetlands are dominated by plants and animals adapted to periodic or constant soil saturation or flooding. Wetlands include fens, marshes, seeps, and swamps.

Caves are natural openings in the Earth's surface large enough for a person to explore beyond the reach of daylight. Caves include terrestrial and aquatic natural communities. On most natural areas, cave access is restricted to protect these fragile ecosystems.

Springs produce a continuous flow of water from the ground that follows a well-defined channel. Springs are fed by groundwater that is typically 58 degrees Fahrenheit year-round.

Headwater creeks are the smallest, uppermost segments of streams. They occur along the first six miles of a stream where surface runoff coalesces into a single channel. Here, stream gradients are fairly high and valleys are often shallow. Flow is often intermittent. Many natural areas contain headwater creeks.

Creeks occur from 7 to 31 miles downstream of where a stream begins. These natural communities have permanent pools, but riffles may dry out occasionally. The stream gradient is moderate with deeper valleys than those found in headwaters.

Small rivers flow from 32 to 96 miles downstream of where a stream begins. Water flows over riffles at all times. In the Ozarks, large springs contribute to the water flow of many small rivers.

Large rivers occur 97 or more miles downstream from where a stream begins. In the Ozarks, large rivers have relatively deep valleys. In other parts of the state, they have wide valleys.

Great rivers in Missouri are represented by the Missouri and Mississippi rivers.

Overflow waters are oxbow lakes, sloughs, blew holes, abandoned stream channels, and other standing waters that are connected to streams during floods.

Natural Heritage Resources — Protecting Fragile Ecosystems

As land managers it can be daunting to determine whether natural heritage resources may be affected by management activities. The Missouri Department of Conservation routinely requires heritage reviews for state land management initiatives and infrastructure development projects to ensure heritage resources are protected from unintentional harm. Heritage reviews are also provided when assisting private landowners with stewardship planning for their property. Heritage reviews ensure that endangered species, species of conservation concern, and rare natural elements are conserved to the fullest extent possible. Heritage reviews utilize the state's Natural Heritage Database to determine whether any known occurrences of priority natural communities or species are known from the site in question. Heritage reviews are informational in nature and result in a document informing a requestor of the presence (or absence) of known heritage resources in or near a proposed project site. In addition, potential concerns in the project area (e.g. we don't know that an endangered species is present, but the location seems to fit its habitat needs) are identified.

It is Missouri Department of Conservation policy not to reveal detailed locations of known heritage sites. Identifying sites with precision could expose them to damage from collectors or visitors. Moreover, with 93 percent of Missouri land in private ownership, many heritage records are on private property. Private landowners often are willing to share information only if they feel comfortable such cooperation will not direct unwanted visitors or trespassers to their land.

Heritage Reviews

Heritage reviews are normally sought by private or public entities for projects seeking federal funding or permits. Such projects are required to investigate and plan for potential impacts to rare or endangered species in accordance with the federal Endangered Species Act or other statutes. A heritage review is normally the first step in this investigation and planning process.

Missouri citizens have repeatedly shown their concern for conserving our natural resources. Anyone about to undertake a project and wanting to know if natural heritage database records indicate occurrences of species or natural communities of conservation concern may request a heritage review for his or her own lands.

To obtain a heritage review, send a project description, map, and township/range/section description to:

Missouri Department of Conservation
Attention: Resource Science Division
PO Box 180
Jefferson City, MO 65102-0180

Preliminary natural heritage reviews are available online through the Missouri Department of Conservation's public website. If no species of concern or sensitive communities are indicated by the database, the requestor receives a clearance letter. In the event the search results in a possible positive, given landowner permission, the project site will be evaluated internally by biologists to ascertain possible impacts and options.

For more information about the natural heritage database and heritage reviews, including how to request a review, visit mdc.mo.gov/node/16757

Special Considerations for Natural Areas and High Conservation Value Forest (HCVF)

In Missouri, some high-quality natural communities and geologic features have been designated as Missouri natural areas by the Missouri Natural Areas Committee (MoNAC), an interagency group consisting of the Department of Conservation, the Department of Natural Resources, the U.S. Forest Service, the U.S Fish and Wildlife Service, The Nature Conservancy, and the National Park Service. The Missouri natural areas system is composed of designated natural areas, throughout the state of Missouri; these areas are the highest quality natural communities, representative of the presettlement Missouri landscape.

Natural areas are protected and managed for the purpose of preserving their natural qualities. The goal of the natural areas system is to designate, manage, and restore high-quality examples of every extant natural community in each of Missouri's natural sections.

Natural areas are defined as natural communities or geologic features that represent the natural character, diversity, and ecological processes of Missouri's native landscapes. Natural communities are groups of plants and animals and the landscapes, such as forests or prairies, that they inhabit — and that occur repeatedly throughout the state. While most designated Missouri Natural Areas occur on state and federal land, some exemplary sites have been designated on private lands at the request of the landowner.

Natural areas are a type of natural resource containing relatively undisturbed native habitats. They are important reference areas for comparison with more modified habitats and provide places to study ecosystems, plants, animals, and their interrelationships. They are models for natural community management. They are also genetic reservoirs of living species of potential use to man. They can be home for rare, threatened, or endangered species. Natural areas can also serve as valuable outdoor classrooms, settings for nature interpretation activities, and places for individual nature study and appreciation.

In addition, natural areas are part of our cultural heritage. They represent the environment of the Native Americans — an environment that Spanish, French, and American explorers and

pioneers fought, overcame, and in many instances, destroyed. A region's history and culture are influenced by the surrounding natural environment.

Along with state designated Natural Areas, "high conservation value forests" (HCVF) is a term recognized by some certification bodies to indicate sites with especially high ecological and/or social value. They are intrinsically valuable for the number of different plant and animal species they support (biodiversity) and the ecological functions they provide. Maintaining these species and functions is generally recommended as the highest priority use for these areas, to the extent that other uses such as timber management may not be considered compatible. In Missouri, high-quality forested natural communities may be considered for natural areas status. Many high conservation value forests are present within the natural areas system. There are many examples of potential HCVF sites on private lands throughout the state.

As land managers and stewards it is important to sustain or enhance the quality of ecosystems. Conserving unique natural heritage resources often requires active management. Prescribed fire, selective cutting, and herbicide application are utilized to dynamically restore natural communities. Invasive species management, water level manipulation, and providing adequate buffer land are other management methods used in natural area and natural community maintenance and restoration.

For more information about natural communities, the natural areas system, or high conservation value forests, contact a professional forester, a Missouri Department of Conservation private land conservationist, or an Missouri Department of Conservation natural history biologist.

Significant Natural Heritage Resources

Isolated Wetlands

Wetland natural communities are particularly sensitive to disturbance and have been greatly impacted by human activity. Wetlands have been drained and destroyed in alarming numbers over the last 50 years. The most recent surveys indicate that more than half of the wetlands in the United States have been lost as a result of drainage and filling, and many of our remaining wetlands have deteriorated in quality because of siltation, pollution, and alterations. Wetland protection and restoration is certainly one of conservation's biggest challenges today.

When managing forested lands, isolated wetland features should be specially considered since these features can be limited in size and so easily adversely impacted. Wetlands such as springs, seeps, fens, shrub swamps, and swamps may be protected under the Federal Clean Water Act (CWA). Hydrologically isolated wetlands, like some sinkhole ponds and isolated fen natural communities, while not always protected by federal law are natural heritage resources that provide critical habit and watershed benefits.

Land managers should assess the wetland resources present on a property, looking for such features as springs, streams, oxbow lakes, fens, seeps, and sinkhole ponds. Wetlands are particularly fragile and careful consideration and planning of management projects must be

undertaken specifically if wetlands cannot be avoided by the work at hand. (See Chapter 15 for best management practices for protecting wetlands.)

In Missouri, wetlands data is readily available for land managers through the National Wetland Inventory (NWI); a U.S. Fish and Wildlife Service national mapping project of the wetland resources throughout the United States. A web-based utility known as Wetland Mapper (fws.gov/wetlands/Data/Mapper.html) integrates digital map data with other resource information to produce timely and relevant management and decision support tools. Wetland Mapper allows land managers to determine what mapped NWI wetlands are present within an area of interest.

Potential wetland resources assessment through Wetland Mapper coupled with a natural heritage review can provide a clear picture of the heritage resources present on a project. Wetlands often support species of conservation concern or may themselves be natural communities of conservation concern. Identifying wetlands and carefully considering management actions that may influence them can assist managers with regulatory permit processes or dictate what best management practices are pertinent to protect the wetland features present.

Karst Features

Karst features range from sinkholes, cave openings, losing streams, and springs to complex underground drainage systems and caves. It is of utmost importance that construction projects and forest management activities in known karst topography (including sinkhole plains) be extremely sensitive to the potential biological and environmental impacts that may occur, and that all possible precautions are taken to prevent or reduce those impacts.

Buffer zones should be maintained on all sides around cave openings, springs, and sinkholes. Refer to Chapter 15 for more information. Since karst features are frequently connected to groundwater sources, general applications of fertilizers, pesticides, or herbicides should be excluded from the buffer area. Spot application of wetland/aquatic approved herbicides in the buffer zone is acceptable. Appropriate erosion and sediment controls should be installed during any earth disturbing projects in karst areas. Where appropriate, a riparian corridor should be designated from caves with springs to water courses with permanent flow or intermittent flow with permanent pools.

These features can be home to unique species and communities, and Missouri species of conservation concern should be adequately accounted for during management planning and, specifically, as part of timber sale planning. The regional natural history biologist can be consulted in order for landowners to gain information on species of conservation concern and sensitive natural communities. Refer to Chapters 14–15 for guidance on how to protect karst features specifically.

Old-Growth Habitat

The term “old growth” has been applied variously in the context of forest resources and is typically exemplified by tree (or stand) age and/or size class. Old-growth management has often been assumed to require hands-off approach, with little or no human intervention, even if the systems evolved in a human context such as aboriginal fire regimes. From an ecological

perspective, old growth codified by these measures is not a particularly useful concept. A better approach would be to consider old growth in the context of site continuity and system sustainability that includes:

- Biological integrity and diversity,
- Continuity of site conditions and landscape character,
- Stability of process regimes that emulates the landscape of pre-European settlement (i.e. fire, hydrology, etc.),
- Ability to prevent adverse impacts such as invasive species, hydrological alterations, and human-caused site degradation.

Old growth is essentially a living linkage to what are often the most sensitive and rare phases of a forest system, providing continuity that facilitate the conservation of biological diversity and the interactions that characterize healthy ecological systems.

Under the concept, old-growth systems are more likely to be managed to sustain their rare characteristics, including providing habitat for viable populations of species with sensitive ecological requirements and serving as a reservoir for the eventual repopulation of nearby suitable areas.

This approach prevents management from being driven by a single-minded focus on old or large trees and instead focuses on sustaining a biological system that accommodates all of the elements of late successional communities.

Where some age reference point is helpful, forests that are at least 100–175 years old are generally considered potential old-growth candidates. They should also be structurally complex and contain large amounts of coarse woody debris. There should be trees with larger than average diameters for that particular species and site, cavities in live trees, standing snags, multi-layered vegetation structure, dead and down woody material, decadence evident in tops and boles of large trees, tree-fall gaps formed by windthrow, and characteristic herbaceous species for the community type.

Mesic old-growth forests support abundant and diverse populations of salamanders and land snails. In Missouri about 87 species of wildlife depend heavily on old-growth forest and woodland habitat. Characteristic old-growth forest birds include pileated woodpecker, hooded warbler, cerulean warbler, ovenbird, barred owl, and wood thrush.

Very few true old-growth forest stands occur across Missouri (perhaps less than 10,000 acres) but the potential is high for many stands currently at economic maturity (110± years) to pass into an old-growth stage within the next 50 years. Many stands dominated by long-lived trees such as oaks in the white oak group, shortleaf pine, sugar maple, sweet gum, hickories, sycamore, black gum, and bald cypress could be allowed to develop into old-growth stands. Providing for permanent old-growth forests and woodlands may best be accomplished by identifying larger units, primarily on public land, that can be managed as old growth. These could be in designated Missouri Natural Areas, natural community emphasis areas, research

areas, and sensitive sites (steep slopes, wetlands). Utilizing extended rotations of 200 years on appropriate sites could provide excellent old-growth attributes.

Threatened and Endangered Species (T&E species)

Threatened and endangered species are a group of species of conservation concern that are exceptionally imperiled. They are exceedingly rare in the state and have specific legal protection because of their rarity. Both federal and state laws may protect threatened and endangered species. All federally endangered and threatened plants and animals are protected by the Endangered Species Act of 1973 (ESA) and by the Missouri State Endangered Species Law. They may also be afforded further protection by one or more of the following laws: Lacey Act, Migratory Bird Treaty Act, or Bald Eagle Protection Act. Missouri status is determined by the Department of Conservation. Specific information may be obtained from your local Missouri Department of Conservation office (see Resource Directory) or online at mdc.mo.gov/node/4067.

Most forest management activities will not involve threatened and endangered species. Even when T&E species are located, the laws seldom totally prohibit activities. On public land, species of conservation concern and T&E species are considered when developing a management plan or conducting a timber sale.

Threatened and endangered species and most species of conservation concern tend to be found in specialized habitats. Many species are also localized in their distribution and may be found in only a few locations in the state. Species of conservation concern and T&E species should be considered during the management decision-making process, and those decisions should be made with the best information available. All species should be considered because of the following:

- Conservation of species of conservation concern is important because rare species have innate values and an important place in ecosystems.
- Rare species often play critical roles in ecosystem function and are important for ecosystem and natural community health.
- Organisms, including rare species, are important for nutrient recycling and soil building.
- Ecosystem health is important for maintaining natural disturbance regimes.
- Good ecosystem health deters invasion by aggressive, nonnative invasive species.
- Species of conservation concern and rare plants and animals are important to conserve because they often support genetic diversity that is adapted to local climate and site conditions.
- Healthy ecosystems have aesthetic and recreational values.
- Some species may produce economically valuable products or provide eco-tourism benefits.
- Species of conservation concern may have scientific and educational benefits.

Frequently Asked Questions

What happens if I find an endangered species on my land?

This depends on whether the species is a plant or an animal. An endangered plant on private property belongs to you as long as it continues to grow on your land. If you use federal funds or programs to help develop and improve your land, then the federal agency participating in the action must ensure that federal funds are not being used to destroy a federally listed plant. If you are using private money, there is no such requirement. Otherwise, endangered species law only applies unless/until the plant is moved from the land to be sold, traded, transported, etc. At that point the plant is no longer part of the land and may be further protected by endangered species law. An endangered animal on private land is a public resource. It cannot be "taken" except as allowed in the Wildlife Code. An endangered animal on private land is fully protected, and killing the animal is a violation of endangered species law. In general, a private landowner cannot be forced to manage private land for an endangered species. On the other hand, intentional habitat alteration by a private landowner does affect fish and wildlife habitat and the U.S. Fish and Wildlife Service could consider this "harassment" under the Endangered Species Act.

Is there anything positive about finding an endangered species on my land?

Yes!

There are hundreds of examples of people living successfully with endangered species on their land here in Missouri. Having an endangered species on a site indicates exceptional natural attributes and should be a point of pride in America's heritage and an admirable statement about the landowner's commitment to stewardship.

Who decides when a species is listed as endangered?

The U.S. Fish and Wildlife Service, Department of the Interior, develops the federal endangered species list. Federal listing is a rigorous process that includes peer review, a published notice in the Federal Register, and a period of public comment. In Missouri the state listing process is led by the Missouri Department of Conservation. Revised checklists are distributed to the interested public for comments, and these are utilized to address specific concerns prior to finalizing any changes to the state list.

Have any Missouri landowners lost their property because of the presence of an endangered species?

No private land in Missouri has ever been taken or experienced involuntary restrictions due to an endangered species being present.

Where can I find information about endangered species?

Public contact offices of the Missouri Department of Conservation, U.S. Fish and Wildlife Service offices, and National Wildlife Refuges. Information can easily be accessed by visiting U.S. Fish and Wildlife Service's Endangered Species Program in the Upper Midwest program by

accessing the following link: fws.gov/midwest/endangered/index.html. Information can also be obtained by visiting the Missouri Department of Conservation's website at mdc.mo.gov.

Federally Listed Bat Species

Habitats for imperiled bat species should be considered when conducting timber management activities. In Missouri, several species of bats are considered species of conservation concern. Two of those species, Indiana and gray bats, are federally endangered species and require special management considerations. Activities around potential hibernacula like caves need to consider smoke management, maintenance of habitat buffers, and disturbance during harvest. Protection of large trees in riparian forests and the maintenance of potential roost and nursery trees for adults and bat broods are also important practices.

For more information about Indiana bats, their habitats, and stressors visit the U.S. Fish and Wildlife website at fws.gov/midwest/endangered/mammals/inba/index.html.

For information about gray bats, visit fws.gov/midwest/endangered/mammals/grbat_fc.html.

Potential Indicators of Species and Natural Communities of Conservation Concern

Before conducting forest management activities conduct an on-site evaluation of the project area to see if there are any wetland features, geologic features, unique natural communities, imperiled wildlife and/or plant species (species of conservation concern), or important wildlife habitats that may need special care or protection during management actions.

During the on-site evaluation look for:

- Landforms or other features of significant geologic interest that may require special management, such as unusual karst or geologic features including sinkholes, sinkhole ponds, caves, cliffs and escarpments, talus slopes, shut-ins, natural bridges, rock formations, and outcrops.
- Natural communities of conservation concern, natural areas, or unique natural communities. Natural communities may include glades, woodlands, forests, cliff and talus, creeks and streams, caves and karst features, springs, and wetlands.
- Species of conservation concern and types of wildlife or plants rarely seen.
- Aggregations or colonies of wildlife, which may include heron rookeries (large nests in the tops of trees, especially near water), bat colonies or suitable snag tree habitats, bee trees, mussel beds, beaver dens or lodges, etc.
- Very large trees or very old trees uncharacteristic of the regional timber quality, often referred to as old-growth stands. Look for open grown characteristics, a gnarl and twisted appearance, large buttresses, and complicated or expansive crowns.
- Wetland features should be carefully scouted for during on-site evaluations, being specifically observant for isolated wetlands fens, seeps, springs, spring runs, and any

areas where hydric soils indicate subsurface flow. Wetlands may be very small in size and isolated from streams of other water bodies.

Additional Resources

The Species of Conservation Concern Checklist. Available at mdc.mo.gov/node/4067

The U.S. Fish and Wildlife Service's Endangered Species Program: fws.gov/endangered

NatureServe: natureserve.org/

The Missouri Breeding Bird Atlas: extra.mdc.mo.gov/nathis/birds/birdatlas/index.htm

Nelson, Paul W. 2010. *The Terrestrial Natural Communities of Missouri*. Revised edition, Second printing. The Missouri Natural Areas Committee, Jefferson City.

Pflieger, Bill L. 1989. *Aquatic Community Classification System for Missouri*. Aquatic Series No. 19. Missouri Department of Conservation, Jefferson City.

Chapter 4: Visual Quality

Topics Covered

Value of Visual Quality
Benefits of Visual Quality management
Visually Sensitive Areas
The Value of Recognizing Sensitive Areas
Additional Resources

Value of Visual Quality

Missourians value their forest lands as places to live and work and to spend their vacation and recreation time. Amenities such as scenic beauty, peace and quiet, observation of forest wildlife, clean air, and clean water rank high among the benefits that people desire from forests. These lands also provide economic benefits related to birding, fishing, harvesting, hiking, hunting, and a variety of emotional, spiritual, and sensory experiences that make living in or visiting forests deeply personal.

Missouri forests are vitally important to the health of two industries: tourism and forest products. While many of the demands from these two industries are compatible and complementary, concern about the specific impact of various forest management practices on visual quality warrant the use of guidelines that can help mitigate these issues. Generally the guidelines address roads; however, management activities near rivers, lakes, and hiking trails are also addressed and are important aspects of presenting a high-quality visual experience.

More than 80 percent (12.7 million) of Missouri's approximately 15.5 million forested acres are privately owned, mostly by individuals and farmers. Private forest owners are a key to providing visually appealing landscapes. A consistent theme foresters experience when working with landowners is a respect for the land and concern for its appearance during and following harvesting and other forestry practices. There are many techniques that can be applied to enhance visual quality.

Benefits of Visual Quality Management

Visual quality is one important aspect of the broad, multifaceted concept of integrated forest resource management. When visual quality management is implemented it can:

- Provide for a thriving tourism industry.
- Encourage public acceptance of forest management and timber harvesting for a healthy forest products industry.
- Provide for a better public understanding of forestry practices resulting in healthy forests.

- Minimize the visual and audible impacts of forest management activities on residents, tourists, and recreational users.
- Minimize visibility of harvested areas.
- Minimize the impact of logging slash.
- Minimize the impact of landing operations.
- Minimize visual contrast created by snags, broken, or leaning trees.
- Reduce the impacts associated with the construction and use of forest roads.
- Enhance the appearance of timber stand improvement activities.
- Reduce the impacts of dead or dying vegetation resulting from prescribed fire or herbicide use.

Visually Sensitive Areas

Visually sensitive areas range from large-scale vistas to a localized rural residence. Overlooks, scenic highways, residential areas, hiking trails, bluffs and hills facing rivers and lakes, roads to river accesses, lands designated as national and state parks, natural areas, and wilderness areas, all represent places where forest management activities should consider the visual impacts that may be created. On privately owned forests, the owners may designate visually sensitive areas that meet their objectives, for example, along the primary access to their property.

Sensitive areas are typically frequented by people having an expectation that the forest is healthy and an attractive place to visit. They may be in that locale solely to observe the color of spring or fall foliage or to view other amenities.

Visually sensitive areas may benefit from forest management practices such as prescribed fire, harvest, and tree planting to enhance native vegetation and animal communities. In these areas the visual quality guidelines can be followed to help provide a satisfying environment for people using the forest.

Some examples of recommended practices include:

- Using slashing techniques or firewood harvest to remove or reduce logging debris height.
- Retaining or planting trees or shrubs with showy flowers or good fall color (see below).
- Discussing proposed management activities with neighbors and other interest groups.
- Cutting stumps low during timber stand improvement activities to reduce the visual impact.
- Modifying timber stand improvement practices along ridge tops and valley floors, where hunters normally walk, by girdling or use of stem applied herbicide treatments.
- Retaining trees within regeneration areas.

Chapters 12–18 give specific guidelines for reducing the negative visual impacts related to each management activity.

When deciding how to modify a management activity in order to mitigate visual impacts, it is useful to consider the length of time that various activities remain visible. Table 4.1 below outlines how long it takes for a forest area to return to its pre-treatment visual condition following the implementation of different practices.

Table 4.1. Approximate Time Needed for Forest Management Practices to Return to Pre-management Visual Conditions

Practice		**Time in Years**			
	1 year	Up to 5 Years	6 to 10 Years	11 to 20 Years	21 + Years
Tops to decay — with treatment		X			
Tops to decay — no treatment			X		
TSI , intermediate harvest , or uneven-aged harvest			X		
Shelterwood harvest				X	
Regeneration harvest					X
Stumps <4” dia		X			
4–10”dia				X	
>10” dia					X
Herbicide treatment	X				

Colorful Native Flowering Trees and Shrubs

Aesculus glabra — Ohio buckeye

Amelanchier arborea — serviceberry

Catalpa speciosa — catalpa

Cercis canadensis — eastern redbud

Chionanthus virginicus — fringe tree

Cornus florida — flowering dogwood

Crataegus spp. hawthorn

Gleditsia triacanthos — honey locust

Gymnocladus dioica — Kentucky coffee tree

Liriodendron tulipifera – yellow poplar

Prunus americana — wild plum

Prunus serotina — black cherry

Prunus virginiana — chokecherry

Robinia pseudoacacia — black locust

Sassafras albidum — sassafras

Tilia americana – American basswood

Good Fall Color Native Trees and Shrubs

Acer rubrum — red maple

Acer saccharum — sugar maple

Carya glabra — pignut

Carya laciniosa — shellbark hickory

Carya ovata — shagbark hickory

Carya tomentosa — mockernut

Cornus florida — flowering dogwood

Fraxinus americana — white ash

Liquidambar styraciflua — sweet gum

Liriodendron tulipifera – yellow poplar

Nyssa sylvatica — black gum

Prunus serotina — black cherry

Quercus bicolor — swamp white oak

Quercus alba —white oak

Quercus coccinea — scarlet oak

Quercus ellipsoidalis — northern pin oak

Quercus imbricaria — shingle oak

Quercus lyrata — overcup oak

Quercus michauxii — swamp chestnut oak

Quercus palustris — pin oak

Quercus rubra — red oak

Quercus shumardii — shumard oak

Quercus stellata — post oak

Quercus velutina — black oak

Sassafras albidum — sassafras

Taxodium distichum — bald cypress

The Value of Recognizing Sensitive Areas

Recognizing visually sensitive areas helps the landowner, forest manager, and logger choose the visual quality guidelines that help meet the objectives and expectations of the owner, forest manager, or area user.

Timber sale contracts should reflect which visual quality guidelines will be used, their location, and how they will be implemented. It is important to understand that when implementing visual quality guidelines there will be associated costs that could be reflected in lower stumpage paid to the landowner and higher contracting costs to perform management activities, such as TSI or prescribed burning.

Some examples of increased costs for visual quality guidelines include:

- Time and labor to reduce the height of logging slash.
- Placing gravel on logging roads.

- Maintaining a scenic vista along a heavily traveled highway.
- Time spent explaining visual quality goals to logging crews.
- Signage and outreach to communicate forest health needs to area users.

Managing Missouri's forests for visual quality involves an integrated effort by forest owners, public land managers, leaders in the wood products and tourism industries, and forest users.

Figure 4.1. On the right side of the photo, a timber harvest recently occurred, several visual quality best management practices were applied to reduce the visual impact.

Additional Resources

Forest Management for Missouri Landowners. Missouri Department of Conservation 2007. Available at mdc.mo.gov/node/5574

Missouri Woody Biomass Harvesting Best Management Practices Manual. Missouri Department of Conservation 2009. Available at mdc.mo.gov/node/9806

A Guide to Logging Aesthetics: Practical Tips for Loggers, Foresters and Landowners. Jones, Geoffrey T. Northeast Forest Resources Council Series, 1993.

Chapter 5: Forested Watersheds

Topics Covered

- Watersheds
- Stream Channel Connectivity
- Stream Channel Identification
- Streamside Management Zones
- Floodplains
- Riparian Forest
- Wetlands
- Forested Wetlands
- Additional Resources

Missouri is a stream state. More than 110,000 miles of streams drain our diverse landscape. The characteristics of these streams are the product of the land surrounding them. Watersheds, which consist of uplands, floodplains, stream channels, springs, and wetlands, all interact to affect the quality of stream habitat and adjacent terrestrial communities. Natural characteristics of a watershed define the properties of a healthy stream. Unobstructed floodplains provide areas into which floodwaters may enter and reduce the erosive pressures on the rest of the stream system. Densely vegetated stream corridors contribute a multitude of direct benefits to the stream channel; they buffer surrounding lands from the effects of floods and provide wildlife habitat. Stable channels balance the force of flowing water with the surrounding physical and vegetative conditions. All these parts must be in balance for a healthy, stable hydrologic and biological system to operate.

Watersheds

For these guidelines, a “watershed” is defined as the total land area that contributes runoff to a body of water. This includes surface runoff and groundwater discharge. Watersheds can vary from a few acres to thousands of square miles.

Watershed conditions influence stream hydrology, groundwater recharge, and the quantity and quality of the water. Healthy watersheds trap pollutants, soil particles, and excess runoff. Excessive watershed runoff increases water quantity, reduces water quality, contributes to an increase in stream channel size, and delivers excess sediment to the stream, generally resulting in stream-bank erosion and filling of the stream channel. Intact watersheds also provide high-quality terrestrial habitat and foraging areas for migratory and resident wildlife and high plant diversity of both woody and herbaceous species.

Stream Channel Connectivity

Streams do not function in isolation from adjacent terrestrial landscapes; rather, the stream is connected to them and is determined by them. Stream channels are a product of the energy of flowing water (from the slope of the channel), sediment (from the watershed), and water quantity (from climate-watershed interactions). Altering these factors through upland, floodplain, streamside corridor, or channel activities can cause a stream to adjust to form a new balance between energy, sediment, and water quantity. For example, timber harvesting and forest road construction activities conducted without the use of Water Quality Best Management Practices (BMPs) can result in roads and skid trails that funnel water moving at a high rate of speed, which has energy to erode sediment from the landscape and deposit it directly into the stream. This can result in water quality problems as well as negative environmental and biological impacts.

Conversely, using BMPs ensures that barriers to water movement such as water bars, turnouts, and re-vegetation slow the movement of runoff water between streams and forest management activities, such as roads and skid trails, allowing sediment to be deposited before reaching the water so that streams will remain healthy and intact. Restoring historically forested communities can also benefit stream channels by decreasing erosion and sedimentation. As streams maintain a balance between the water and sediment coming into them, it is natural for them (as well as beneficial to fish and wildlife habitat) to meander and adjust in size and shape. Straightening or locking a stream in a fixed position by channelization or other means can cause a variety of problems, which can then extend well beyond the project site. These activities require permits from the U.S. Army Corps of Engineers.

Figure 5.1. Streams are connected to the adjacent landscape.

Stream Channel Identification

The active channel and adjacent high-flow channels convey all non-flood stream flows and a portion of flow during flood events. The stream channel consists of the area between both banks (Figure 5.2). Stream types are often classified by their flow, which is determined by their groundwater connection (Figure 5.3):

- **Perennial streams** flow year-round and have well-defined banks and natural channels; the water table is above the streambed.
- **Intermittent streams** only flow during wet seasons but still have well-defined banks and natural channels. They may contain seasonal pools during dry periods; the water table is above the streambed at certain times but not always.
- **Ephemeral streams**, or storm-water courses, only flow with runoff from rain or snowmelt. The water table never reaches the streambed of these streams. Because they are typically in the uplands, they can have steep slopes and therefore have the potential to carry high sediment loads during runoff events to the larger stream channels.

Identifying the type of stream is important to determine the level of protection needed. Specific information regarding how to protect different classifications of streams is located in Chapters 14 and 15. Forest owners will usually be familiar enough with a stream's flow patterns to identify the stream. If forest owners are uncertain as to which type of stream they have, they should consult a professional forester or other qualified natural resource professional. Always use the most protective measures when unsure.

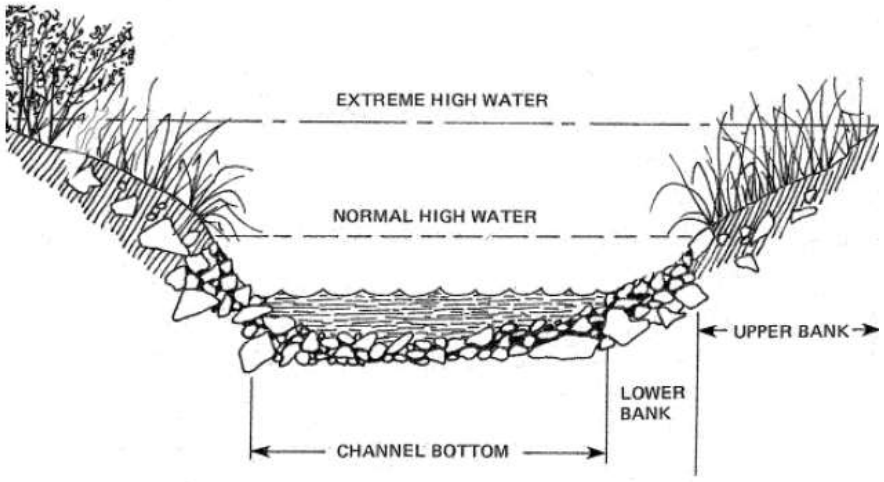


Figure 5.2. Stream channel diagram.

Figure 5.3. Stream type identification. Note: This does not necessarily represent typical forest management activities in Missouri. (Photo provided by South Carolina's *Best Management Practices* booklet.)

Streamside Management Zones

Streamside Management Zones (SMZs) or Riparian Management Zones (RMZs) are areas along streams and rivers that are important in maintaining water quality. Both the trees and other vegetation within the SMZ work together to benefit the stream and, in turn, the entire watershed. Trees in riparian areas that eventually become decadent and fall out of the canopy can also provide important in-stream habitat. Streamside Management Zones require special treatment when harvesting forest products and conducting other forest management activities to ensure that they continue to provide these important functions. Specific information on how and when to apply SMZs is found in Chapter 15.

SMZs have several major functions:

1. Slowing floodwater.
2. Filtering and trapping sediment.
3. Providing shade to cool stream temperature.
4. Helping to create rich bottomland soil.

Floodplains

A floodplain is the relatively flat land surface adjacent to a stream channel that is formed by erosion and sediment deposition during floods. Floodplains can be inundated annually or during large, less frequent flood events and comprise the above-bank area where floodwater enters

during high flows. Thus, floodplains are characterized by soils and vegetation that developed under the influence of flooding. They can be identified by characteristic soils, landforms, vegetation, and on topographic maps.

Floodplains have several major functions:

1. The floodplain allows for the transport and temporary storage of water during flood events. This reduces the velocity and erosive capability of floodwaters and reduces the impacts of flood events on downstream areas. Floodplain vegetation can also help reduce the velocity of floodwater.
2. Floodplain vegetation filters and traps sediments and nutrients during storm events that would otherwise reach the stream and cause deposition, streambed siltation and nonpoint source pollution problems.
3. Rainwater is retained in floodplains, and a portion of the water percolates into the ground. Depending on soils and local geology, this groundwater can augment base flows during drier periods.
4. Floodplains on large river systems are critical for some fish, for spawning and nursery habitat when inundated with floodwaters
5. Floodplains contain wetland habitats that are heavily used by a number of animals, including fish and other aquatic life, waterfowl, shorebirds, reptiles and amphibians, and aquatic mammals.
6. Floodplains provide terrestrial habitat for migratory and resident wildlife with native vegetation, high plant diversity including both woody and herbaceous species, and an abundance of snag and cavity trees. They also provide corridors for wildlife movement and dispersal of plant species and are critical habitat for many Missouri species of conservation concern.

Historically, floodplain wetland communities were dynamic. Floods and natural stream meanders created new wetlands that gradually converted to terrestrial communities. Many larger river systems have been highly altered. Some of these changes have been natural, although most of these changes have been man-made for improved drainage, flood control, and to provide for river navigation. Over time this has resulted in long-term changes in bottomland forests and vegetation. Today’s floodplain forests are much more fragmented or in some cases nonexistent due to clearing for agriculture and urbanization. Due to changes in the hydrology, the composition of many of these forests have also changed to more flood-tolerant species or have issues with regeneration of desirable species. Many of these floodplains have reduced

function, although they still provide some of the benefits of the large historic wetland.

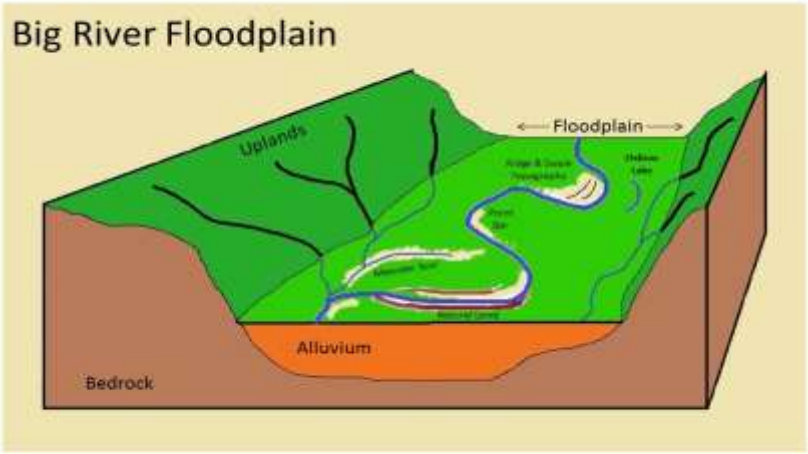


Figure 5.4. Diagram depicting big river floodplains.

Riparian Forest

Riparian forests are highly variable and can be located in large floodplains along major river systems or along narrow upland streams. The riparian forest significantly influences, and is significantly influenced by, the neighboring body of water. Of Missouri's 3.2 million acres of potential riparian forest buffer, approximately 1.8 million acres (55 percent) are currently forested. Reforesting much of these currently unforested riparian areas would significantly benefit soil and water resources.

Note: Although some Missouri streams were historically prairie streams and are best suited for prairie cover, a significant majority of stream riparian zones, including some in prairies, are best suited for forest or other woody vegetative cover.

Riparian forests have several major functions:

1. Riparian forests help armor stream banks with their root systems to keep them from eroding.
2. They provide roughness to the landscape, which slows down floodwaters from overland entering the stream and from the channel entering the floodplain; this allows them to capture sediment on the land and not in the stream channel and reduces water velocity helping to control stream erosion.
3. They increase the ability of infiltration of water into the ground, reducing runoff and increasing groundwater storage.
4. They filter pesticides, nutrients, and sediments before they can reach the stream.

5. They provide shade, which is important for maintaining water temperatures conducive to healthy aquatic ecosystem functioning.
6. Vegetation from riparian forests helps provide the food base and habitat needed by many aquatic organisms.
7. Riparian forests also provide important wildlife travel corridors and can be highly productive for forest products.

Wetlands

Wetlands can be found anywhere on the landscape, but generally in Missouri they are associated with floodplains or perennial streams. They are less frequently found in uplands in the form of fens or seeps or in depressions like sinkhole ponds. Depth, timing, and duration of water influences soil development and the type of plant and animal communities that inhabit wetlands.

Forested Wetlands

Forested wetlands in Missouri are dominated by deciduous trees and include swamps and wetland forest. Swamps are inundated for long durations and are rarely dry. Wetness duration in forested wetlands ranges from short duration flooding (lasting a few days) to long-term seasonal saturation (lasting as long as three months). Seasonally, wetlands that are forested may appear to be fairly dry.

Throughout the 19th and 20th centuries, most of Missouri's historically forested wetlands were drained and converted to agriculture. A prime example is Missouri's Bootheel, which was historically dominated by forested wetlands and is now dominated by agriculture. Although most of Missouri's forested wetlands have been lost, the state still has some quality representatives of this forest type as well as many areas that have good restoration potential.

Forest wetlands have several major functions:

1. Many animals live in or use wetlands for food, nest sites, and cover. Many plants, animals, and wetland communities themselves are listed in the Missouri Species and Communities of Conservation Concern Checklist.
2. Wetlands also help moderate stream flow and minimize flooding potential by storing runoff from heavy rains or snowmelt and reducing flood peaks.
3. Forested wetlands filter out sediments, nutrients, fertilizers, and pesticides from within the watershed.
4. Some wetlands use surface water to recharge groundwater supplies. Other wetlands discharge groundwater to the surface, an important wetland function that helps to stabilize stream flows, especially during dry months.

Forest management activities in a wetland can be challenging. Wetland soils generally have low weight-bearing capacity, making them more susceptible to rutting and compaction compared to upland soils. In addition, it is common for water to be moving through the soil near the surface.

The wetland BMPs are designed to prevent erosion, to minimize changes to the surface and below-surface water movement, and to strengthen or increase the weight-bearing capacity of the soil. Changes like rutting can interfere with water movement and result in vegetation changes and reduced wetland function, which can affect the health of the wetland ecosystem and the functions it performs. For specific information on best management practices for forest wetlands refer to Chapter 15.

Wetland Identification and Regulation

Jurisdictional Wetlands

The U.S. Army Corps of Engineers, in Section 404 of the Clean Water Act, defines jurisdictional wetlands as "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." A jurisdictional wetland must exhibit all three characteristics: hydrology, hydrophytes, and hydric soils (US ACOE 1987).

The U.S. Fish and Wildlife Service National Wetland Inventory uses the Cowardin classification system. Cowardin defines wetlands as "transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water." Cowardin requires the presence of only one or more of the three wetland attributes required by the regulatory definition. Areas that function as wetlands ecologically may perform valuable functions but are not regulated by the Clean Water Act.

Forested areas within Missouri's watersheds provide many valuable resources and support a variety of activities. Landowners, resource managers, loggers, and contractors attempt to balance a variety of objectives when planning and conducting forest management activities. These activities include the production of timber, the support of recreational uses, the enhancement of scenic beauty, the improvement of wildlife habitat, and the protection of forest ecosystems.

Missouri's BMPs provide recommendations designed to protect both the forest and the hydrologic systems in Missouri's watersheds. Careful planning for forest management activities will lead to harvest operations that use BMPs, remove forest products efficiently and profitably, and promote sustainable forest growth.

Additional Resources

Watershed and Stream Management Guidelines for Lands and Waters Managed by Missouri Department of Conservation. 2009

Missouri Watershed Protection Practices: Management Guidelines for Maintaining Forested Watersheds to Protect Streams. Missouri Department of Conservation, 2006. Available at mdc.mo.gov/node/9331

Chapter 6: Cultural Resources

Topics Covered

- What Are Cultural Resources?
- Examples of Cultural Resources
- The Value of Cultural Resources
- Cultural Resource Management (CRM) and the Law
- Potential Impacts to Cultural Resources
- Field Identification of Cultural Resources
- Identification as a Low-Sensitivity Site
- Identification as a High-Sensitivity Site
- Evaluation and Documentation
- When Accidental Discovery Occurs
- NHPA Glossary
- Additional Resources

What Are Cultural Resources?

Cultural resources provide records of history and are important evidence that tell the story of the past. In the following guidelines, “cultural resource” means any site, building, structure, object, or area that has value in American history, archaeology, architecture, engineering, or culture. A cultural resource may be the archaeological remains of a 2,000-year-old Native American village, a pioneer homestead, or an old family cemetery. It may be of value to the nation or the state as a whole or important only to the local community. In order to be considered important, generally a cultural resource has to be at least 50 years old.

The people of Missouri are heirs to a unique legacy of cultural resources, many of which occur within the state’s public and private forest lands. Generally, these cultural resources fall into five broad categories: historic structures, archaeological sites, cemeteries, traditional use areas, and historic areas.

Almost all Native American sites in Missouri pre-date 1800. While these sites are not common, tribes living in or passing through the state included the Osage, Iowa, Delaware, Shawnee, Kickapoo, Sac, Fox, and Cherokee.

Starting from the first European exploration of this territory in 1673 AD to the Civil War, Missouri's archaeological sites consist mostly of early trading centers, military occupations, river settlements, and rural farmsteads often associated with major rivers like the Mississippi. Mineral exploration by early prospectors looking to extract silver, lead, and gold also occurred in Missouri. Euro-American and African American sites primarily originated after 1800 and are

dated by coins, tombstone inscriptions, or maker marks on bottles. After the Civil War, historic sites reflect an increase in rural populations and farming activities.

In the forest-dominated portions of Missouri, primarily the Ozarks and the southeast lowlands, the timber industry significantly shaped the landscape leaving numerous potential cultural resource sites. These include logging camps, narrow gauge railroad beds, and large sawmill sites. Large blocks of standing virgin timber were exploited, and afterward lands were sold to settlers and speculators for farming.

Examples of Cultural Resources

Examples of cultural resources include but are not limited to historic structures, unique examples of architectural style, railroad beds associated with early logging, pottery shards or arrow heads, middens and cache pits from Native American villages, and cemeteries. Vegetation or plantings of historic significance as well as old foundations from early settlements can also be cultural resources. For a listing of common cultural resource types, see Appendix B.

The Value of Cultural Resources

As scarce and nonrenewable parts of the environment, cultural resources by their very nature provide physical links to the past, along with a sense of national community and personal identity. Historic structures, historic areas, traditional use areas, and other aboveground cultural resources provide environmental diversity, while some structures and artifacts have intrinsic value as works of art. Perhaps most important, the conservation of cultural resources contributes to an understanding of history, fosters an appreciation for heritage, and stimulates learning at all education levels. Resources that connect the present with the past fulfill important nostalgic and spiritual instincts shared by large segments of modern society.

The premise that cultural resources have value and should be wisely managed is the underlying reason for including cultural resource management (CRM) as part of forest management. Cultural resources represent parts of an inheritance shared by all people. This heritage is of fundamental value to modern-day societies and is truly a gift from the past. Cultural resources are valued in a variety of ways. They often possess spiritual, scientific, and other values that are weighed differently by different cultures. The benefits of CRM are both tangible and intangible.

Today, CRM is increasingly seen as a necessary component of land stewardship. Forest managers and landowners should use CRM as a tool to minimize conflict between stewardship and economics and should treat cultural resources as assets rather than liabilities. While the intangible benefits of cultural resource management cannot always be easily defined, they are nevertheless important.

Cultural Resource Management (CRM) and the Law

Although these guidelines are designed to be voluntary, forest managers need to have an awareness of the nonvoluntary, regulatory side of CRM. Cultural resource laws in general are intended to ensure that significant resources will be taken into consideration when activities are

planned that might damage their scientific or cultural values. Virtually all environmental legislation currently on the books includes protections for significant cultural resources as identified under the National Historic Preservation Act of 1966 (NHPA).

Administration and enforcement of environmental protection laws vary, but forest managers would do well to assume that whenever a government permit or license is required, some kind of CRM review and compliance may also be required. Federal and state laws, for example, require public land forest managers to consider the effects of their projects on cultural resources.

The legal basis for CRM is rooted in federal and state legislation concerned with natural resource conservation and environmental protection. The NHPA is the centerpiece of the national historic preservation program and has become an important component of state and local CRM programs in Missouri. NHPA establishes the National Register of Historic Places and provides for state and tribal historic preservation officers to implement the national preservation program.

Section 106 of NHPA requires that federal agencies consider the effects of their activities on cultural resources. NHPA Section 106 applies anytime there is an “undertaking” with federal involvement and an action that affects historic properties. How the statutory protection of cultural resources laws apply is determined by three factors: landownership, the source of funding being used for the activity, and any licensing or permitting authority that might be involved. Federal law applies whenever activity will take place on federal land, will use federal funds, or will require a permit or license issued pursuant to federal authority (an “undertaking”).

When a cultural resource eligible for inclusion on the National Register is present, it should not be destroyed or damaged by forest management activities. On public land, public funds may be used to recover important historical, archaeological, or cultural data that would otherwise be lost.

Activities on private land may not be mandated by the NHPA if there is no federal undertaking, however state law/regulations may still apply. Human burial sites are given special consideration under both federal and state law, requiring that all human burial sites in the state be protected from disturbance, regardless of age, ethnic affiliation, or landownership. Burial sites are a special category of cultural resources. Under sections of the Missouri Revised Statutes 194 and 214, all human burial sites are afforded the same legal protection as platted cemeteries, regardless of landownership. Similar protection applies to burial sites on lands under federal control. Many graves in pioneer cemeteries do not have markers, making identification and protection more difficult.

Potential Impacts to Cultural Resources

In general, cultural resources are fragile. Threats range from natural forces (erosion, flooding, weathering, and fire) to human action (logging, agriculture, mining, land development, and

vandalism). Unlike wetlands and forest habitats, once lost, cultural resources cannot be mitigated or restored. Lack of awareness of the existence of a cultural resource is the main cause of damage. Use of these guidelines will encourage implementation of practices that will minimize unintentional damage to cultural resources.

Field Identification of Cultural Resources

It is important to assess project sites for cultural resource potential. Identification of cultural resources is fundamental for protection of those resources. The first step in cultural resource management (CRM) planning is to check existing cultural resource inventories to determine whether any important cultural resources are known to be present within a given area. Follow the check of existing inventories with a walkover examination. (See Appendix B: Best Management Practices for Common Cultural Resources.) In particular, landowners and forest managers are encouraged to check for recorded burial sites in management areas.

Identify resources, features, and site conditions that may require special attention, such as family cemeteries, Native American campsites, sawmill sites, and pioneer cabin sites. While other inventories exist (such as those maintained by local units of government and county historical societies), the cultural resources inventories available through the State Historic Preservation Office (SHPO) are the most comprehensive databases, and professional staff can provide assistance. Most of the statewide cultural resource inventories maintain “hard copy” site maps that show specific cultural resource locations, as well as areas that have been surveyed for cultural resources. A formal written request is not necessary. Requests may be made by phone, and requested information is most often available within a few days.

A visual examination during a walk-over inspection of the management area may reveal unrecorded cultural resources. If possible, a visit during winter or fall when leaves are off trees enables a better evaluation. Forest managers, landowners, and others following these guidelines can undertake a preliminary assessment of a site’s cultural resource potential. A walk-over inspection can be done at the same time as other field activities, such as timber inventory or timber sale preparation. Background information gathered during the cultural resource assessment process may provide some clues as to what kinds of cultural resources might be present and where to look for them. Consider doing additional research on the history of the project area, especially if existing cultural resource inventories contain no information about the area. Such research efforts may include checking existing maps, aerial photos, and printed historical information as well as contacting individuals who are knowledgeable about local history or archaeology.

Certain landforms were naturally attractive to Native Americans and early European settlers. Elevated, well-drained sites with easy access to water sources such as a springs or perennial streams were historically used by Native Americans and early settlers as dwelling sites. Good places to camp for Native Americans and early settlers included islands and river overlooks. Landforms such as elevated natural levees adjacent to major streams that rarely flood were

attractive to early inhabitants. Caves or rock overhangs were preferred shelters and are good sites for potential cultural resources.

Other potential cultural sites include abandoned river channels (oxbows and sloughs) and sites at the mouths of stream, stream inlets, and any elevated solid dry land around large wetlands like marshes or swamps. Good fishing spots like traditional fish spawning beds, rock riffles where walleye spawn, deep pools where paddlefish congregate during spawn, or other fish gathering pools attracted Native Americans and early settlers alike.

Good indicators of potential cultural resources can be landscape anomalies such as clearings in the woods, objects in or attached to trees, and blazed trees. Areas near community centers such as towns and villages, especially in combination with old transportation routes like old trails, roads, and railroad beds, may have cultural significance or may harbor artifacts. (Many modern roads follow old trails and wagon roads.)

The presence of old farmsteads often are indicated by isolated stands of trees in an otherwise open landscape. The presence of domesticated plant species such as silver poplar or lilacs, fruit trees, irises, or daffodils often indicate homesteads or cemeteries. Trash dumps containing antique items or fence materials (wood posts, metal posts, wire) and tin cans may indicate a potentially significant cultural resources site.

The presence of any “surface” artifacts (anything man-made) such as arrowheads, broken clay pottery, and stone tools, as well as manufactured items, are good indicators of cultural resources significance. Look for relics like foundation stones, rock- or brick-lined cisterns, depressions that may have been icehouse pits, wells, or storm shelters.

For standing structures and buildings, ask yourself: How old is it? Who owned it? Who designed it? What condition is it in? Is it associated with an important person or event? Is it an unusual architectural style? How much has it been altered from the original?

Identification as a Low-Sensitivity Site

More often than not, significant cultural resources will not be present on a work site. If no cultural resources have been recorded and the pre-field review and walk-over inspection yielded no indications of important cultural resources, the site likely has low sensitivity, which means there are no important cultural resources located there. You may proceed with the management activity without further review.

Identification as a High-Sensitivity Site

If cultural resources are known to exist, or if the pre-field review and walk-over inspection indicate their presence, the site has high sensitivity. In this case, the forest manager has several alternatives to consider, of which the following are recommended in order of preference. Private land compliance is voluntary unless a federal undertaking exists.

- Safeguard the condition of the cultural resource by preventing further damage, loss, or deterioration.
- Investigate and document the cultural resource in order to determine its significance and conservation potential.
- Adjust work schedules to allow time for data recovery or other mitigation measures (including following the appropriate cultural resource guidelines).
- Avoid the highly sensitive areas identified within the project area.
- Fill over the area either temporarily or permanently to avoid disturbance.
- Conduct a more extensive archaeological examination of the area, enlisting the services of a trained professional archaeologist to determine if the site is significant. (This may incur considerable expense).

Evaluation and Documentation

Evaluation uses the information generated during cultural resource identification to determine whether a particular cultural resource is eligible for inclusion on the National Register of Historic Places (NRHP). All cultural resources are not equal. Only cultural resources qualifying for listing under the NHPA are protected. See Appendix B: National Register Criteria for Evaluation of Cultural Resources.

Even though documentation of cultural resources discovered during forest management activities is not required under the National Historic Preservation Act (NHPA, sharing a record of cultural resources discoveries is valuable to future generations. Information shared with the State Historic Preservation Office (SHPO) is private and confidential and is not available to the general public.

When Accidental Discovery Occurs

If a human burial site is accidentally discovered during operations, cease operations immediately in the vicinity of the discovery. This is mandatory whether it be on private or public land. Halt operations and contact the State Historic Preservation Office and your local law enforcement agency for sources of information and assistance.

For accidental discovery of other types of cultural resources (such as archaeological artifacts), temporary suspension is not required on private land, but it is recommended, and if a federal undertaking exists, it is mandatory. Suspending operations in the immediate vicinity of the cultural resource will allow time to contact a cultural resource professional or develop plans to initiate procedures to avoid or reduce damage to the cultural resource. When cultural resources are discovered during forest management activities, the following procedures are recommended:

- Safeguard the condition of the cultural resource by preventing further damage, loss, or deterioration.

- Investigate and document the cultural resource in order to determine its significance and conservation potential.
- Adjust work schedules to allow time for data recovery or other mitigation measures.

NHPA Glossary

Undertaking as defined in Section 106 of the NHPA (1966) means a project, activity, or program funded in whole or in part under the direct or indirect jurisdiction of a federal agency, including those carried out by or on behalf of a federal agency, those carried out with federal assistance, and those requiring a federal permit, license, or approval. If an activity is an undertaking, the agency then determines whether it is "a type of activity that has the potential to cause effects on historic properties." (36 CFR § 800.3[a])

Effect means alteration to the characteristics of a historic property qualifying it for inclusion in or eligibility for the National Register. (36 CFR § 800.16[i])

Additional Resources

Missouri State Historic Preservation Office website: dnr.mo.gov/shpo/index.html

State Historic Preservation Office, PO Box 176, Jefferson City, MO 65102. 800-361-4827, 573-751-7858. Email moshpo@dnr.mo.gov

Chapter 7: Soil and Sustainable Forestry

Topics Covered

- Obtaining Soil Information
- Sustaining Soil Productivity and Quality
- Soil Quality Indicators
- Physical Properties and Forest Management Impacts
- Soil Compaction
- Rutting
- Soil Erosion and Sedimentation
- Chemical Properties and Forest Management Impacts
- Biological Properties and Forest Management Impacts
- Additional Resources

Soil is defined as a natural, three-dimensional body at the Earth's surface. It is capable of supporting plants and has properties that are the result of climate, topography, and living organisms acting on parent material over time (Figure 7.1).

Soil is a fundamental resource in the pursuit of sustainable forestry. Along with other environmental factors it provides a foundation and a medium for growth and productivity. Forest growth is largely governed by the availability of water and nutrients provided by the soil. A minimum understanding of how soil nutrient and water availability is characterized, how soils function, and how soil can be impacted is essential to understanding what forest practices are most sustainable.

A soil's health as measured by physical, chemical, and biological properties can be influenced by forest management. Alterations to these soil properties will impact plant growth and the ability to manage for the long term. Implementation of practices that protect the physical, chemical, and biological soil properties will improve the potential for long-term sustainability of the forest.

Because soils are quite variable, it is important for forest managers to evaluate each management unit separately. This information is used to develop prescriptions that ensure productive capacity is not reduced as a result of forest management activities.

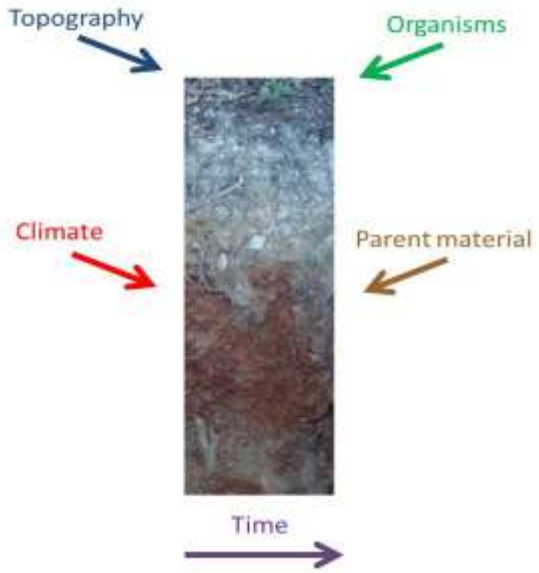


Figure 7.1. Soil is a function of climate, topography, and organisms acting on parent material over time.

Obtaining Soil Information

Soil information and technical assistance are available from the USDA Natural Resources Conservation Service (NRCS), the Missouri Department of Natural Resources (MDNR), or the University of Missouri Extension Service.

Maps of the soils for specific properties are available online from the NRCS Web Soil Survey, at websoilsurvey.nrcs.usda.gov/app/HomePage.htm

General information concerning the soils of Missouri is described by physiographic regions known as Major Land Resource Areas (MLRA). Missouri has twelve (12) MLRAs: These are also the regional layers for the Missouri's Ecological Classification System (ECS) and are called ecological sections. (Refer to Chapter 11 for more information.)

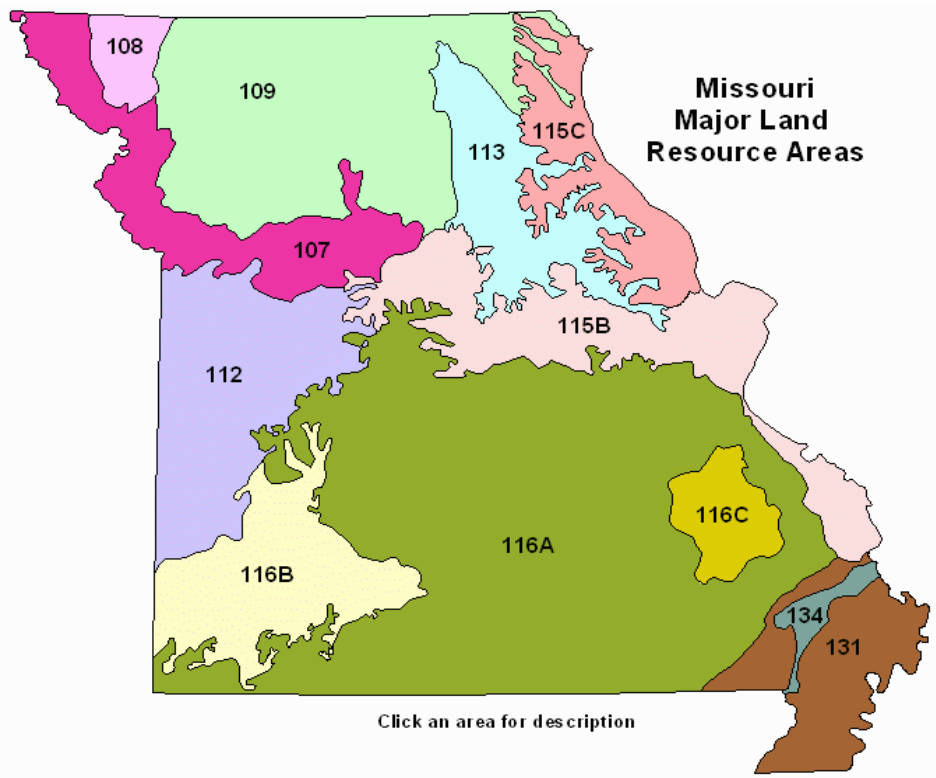


Figure 7.2. This map can be found at mo.nrcs.usda.gov/technical/nat_res_data/mo_ecoregion/mlra.html

107	Iowa and Missouri Deep Loess Hills
108	Illinois and Iowa Deep Loess and Drift, Western Part
109	Iowa and Missouri Heavy Till Plain
112	Cherokee Prairies
113	Central Claypan Areas
115B	Central Mississippi Valley Wooded Slopes, Western Part
115C	Central Mississippi Valley Wooded Slopes, Northern Part
116A	Ozark Highlands
116B	Springfield Plains
116C	St. Francois Knobs and Basins
131	Southern Mississippi River Alluvium
134	Southern Mississippi Valley Loess

The extent and description of these areas are found in the NRCS publication *Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin*, U.S. Department of Agriculture Handbook 296. At soils.usda.gov/survey/geography/mlra/index.html

Soils are also a fundamental data layer in most forest ecological site classification systems. Site classification systems generally integrate key soil information with other information about the climate, geology, geomorphology, and native vegetation from stand to ecoregional scales. Site

classification systems, along with a soil survey, are another important tool for sustainably managing forest ecosystems because they integrate a number of factors related to site nutrient capital, water supply, and site productivity (see Chapter 11).

Managers that desire to have more detailed on-site soils information to prepare a forest management plan can contact private consultants. Site-specific information will help the manager develop prescriptions to maintain the productive capacity.

Sustaining Soil Productivity and Quality

Soil productivity is defined as the capacity of soil, in its normal environment, to support plant growth. Soil productivity is reflected in the growth of forest vegetation or the volume of organic matter produced on a site. In forest management, soil productivity is most often measured in volume of trees produced. However, other methods of determining productivity exist, including forest community assessments.

Soil quality is defined as a soil's capacity to function for its intended use. In forest ecosystems, this not only includes sustaining forest productivity but also includes sustaining the soil's ability to support a diversity of native plants and animals, to store carbon and cycle nutrients, and to regulate the storage, flow, and quality of water. Another important function of forest soils is protecting the environment by filtering and detoxifying contaminants.

There are forest management activities that impact soil productivity and quality. Identifying and reducing impacts to the soil are an essential strategy in sustainable management. A certain amount of soil impact is inevitable, but many of the recommended practices are aimed at keeping this impact to a minimum level.

Soil Quality Indicators

The ability of a soil to function is evaluated with specific properties called soil quality indicators (Table 7.1). Some indicator soil properties are "inherent," meaning that they are not readily altered by management but can be changed relatively slowly. Examples include the texture class of individual soil horizons, the types of minerals found in the soil, soil depth, water-holding capacity, and the drainage class. Other soil properties are much more "dynamic," meaning that they can be altered rapidly by management or natural disturbances during a single growing season or year. Examples include bulk density, porosity, and water infiltration.

Forest management activities can affect both inherent and dynamic soil properties. Consequently, BMPs are designed to mitigate the negative impacts of both inherent and dynamic soil properties in order to maintain soil quality.

Soil quality indicators are allocated into the categories physical, chemical, and biological properties. Physical properties include texture, structure, porosity, density, water infiltration, and water-holding capacity. Chemical properties include nutrient concentrations or quantities, pH, soil organic matter content, and cation exchange capacity (see glossary). Biological properties include the number and kinds of fungi, bacteria, invertebrates, and vertebrates that live in the

soil. Soil properties and functions are highly interdependent. A change in one soil property can affect other soil properties within or among these three categories as well as affect a number of different soil functions.

Table 7.1. Examples of Soil Quality Indicators and Their Potential Influence on Soil Functions for Forested Ecosystems

	Soil Function				
Soil Quality Indicator	Sustaining plant diversity	Sustaining production of forest fuel and fiber	Regulating water movement and solute flow	Storing and cycling nutrients and carbon	Filtering, buffering, and detoxifying water
Texture	+	++	++	+++	+++
Structure	++	+++	+++	++	+++
Bulk Density/Porosity	++	+++	+++	+++	+++
Infiltration	++	++	+++	+++	+++
Water-Holding Capacity	+++	+++	++	++	+++
Nutrient Concentrations or Quantities	+	+++	+	+	+
pH	+++	++	+	+	+
Cation Exchange Capacity	+++	+++	+	+++	++
Soil Invertebrate and Vertebrate Populations	+++	+++	+++	+++	+++

+ Means there is a relatively weak relationship between this particular indicator of soil quality and a soil's ability to provide that specific function
++ Moderate indicator relationship
+++ Strong indicator relationship

Physical Properties and Forest Management Impacts

Soil physical properties are important determinants of productivity, erodibility, the kinds of fauna inhabiting the soil, water infiltration (water moving into the soil) and percolation (water moving through the soil), and nutrient cycling rates. "Texture" refers to the percentage of sand, silt, and clay in the soil. Soils are grouped into soil texture classes by the relative amounts of sand, silt, and clay (Figure 7.3). "Structure" refers to the arrangement of the sand, silt, or clay particles into aggregates (called peds). Together, texture and structure greatly affect many other soil properties and functions.

Texture greatly affects the soil's ability to hold and supply water. Clayey soils hold more water than silty or sandy soils. However, clays hold some of the water so tightly that the roots of trees and other forest plants are unable to absorb it. Texture classes having a mixture of sand, silt,

and clay, such as silt loams, loams, and silty clay loams, provide the most water to plants and tend to be the most productive.

Soils that contain particles that are strongly aggregated, especially those with strong granular structure, are less vulnerable to erosion. Texture also influences a soil's susceptibility to erosion. For example, soils with high silt content tend to be more vulnerable to erosion. This is because, unlike clay-sized particles, silt-sized particles do not form strong aggregates and because silts are much smaller and lighter than sand-sized particles. This allows the silt-sized particles to be readily detached and transported during rainfall compared to clay-sized or sand-sized particles.

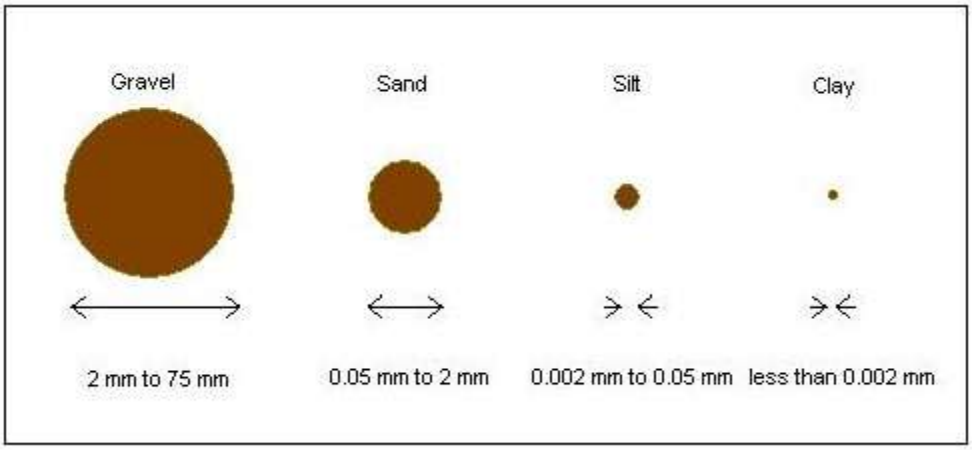


Figure 7.3. Soil particle sizes and texture classes. (From usda.gov)

The space around the soil particles and the soil aggregates (peds) is referred to as the pore space, and the relative volume of the pore space is the porosity. Pores are very important for the movement of water and air into and through the soil. Decreasing the volume of the pores reduces the amount of air and water that can move into and through the soil. Water and air move through large pores much more readily than through small pores. These large pores are called macropores and are defined as pores greater than 0.002 inches in diameter; smaller pores are called micropores. A small reduction in the number of macropores greatly reduces infiltration and percolation, aeration, and drainage.

Soil porosity is also directly and inversely related to soil density (referred to as bulk density). In addition to the porosity, the soil bulk density affects the extent of rooting by trees and other plants. For a given texture class, increasing the bulk density decreases root penetration. Decreasing root penetration reduces the amount of water and nutrients that can be taken up by trees and other forest plants, ultimately decreasing productivity.

The drainage class of a soil — a measure of the frequency and duration of soil saturation — is also related to total porosity and pore size distribution. Poorly aggregated soils or soils with a high proportion of micropores generally have poorer drainage than well-aggregated soils and soils with a high proportion of macropores.

Abrupt changes in the pore sizes among different horizons or layers within the soil, due to differences in texture or structure, also affect soil drainage. The presence of a fragipan (dense and compact subsurface layer) or a claypan (a dense, slowly permeable soil layer of high clay content) can impede soil drainage.

Soil drainage also affects species composition and productivity. In forest ecosystems, plant species naturally align themselves along soil drainage gradients by their ability to tolerate wetness or dryness. Although some tree species are well adapted to poorly drained soils, tree productivity generally decreases with increasing (prolonged) soil saturation. Saturated soils are also much more vulnerable to damage caused by the heavy weight of skidders and other harvesting equipment.

In forests, most of the alterations to soil physical properties occur during harvesting operations. Felling, forwarding, and skidding operations with heavy equipment can cause decreases in porosity by compacting and rutting the soil surface, leaving the soil vulnerable to ponding and erosion. The susceptibility of soil to compaction is primarily dependent on soil texture and moisture content. Soils are most susceptible to compaction, ponding, and rutting when they are saturated. Such conditions occur during spring and early summer months, immediately following heavy rains, and in the fall after transpiration has ceased. Soils that have a high content of gravels, cobbles, and other coarse fragments tend to be less vulnerable to compaction than soils without coarse fragments. Limiting equipment traffic to drier seasons of the year is one way to reduce compaction and other types of physical damage to the soil. Soils that are solidly frozen are relatively resistant to compaction, so winter operations are an option for wetter sites.

Soil Compaction

Soil compaction is the decrease in soil volume and associated increase in bulk density caused by heavy weight or high pressure applied to the soil surface. Increasing the bulk density decreases the total porosity of the soil. The macropores are the most vulnerable to compaction, and they can be readily eliminated where traffic from forest harvesting is heavy. Because macropores largely govern the exchange of gases through the soil, reducing the number or volume of macropores greatly decreases soil aeration. Where soil aeration is diminished, oxygen is less available for respiration in tree roots. Concentrations of carbon dioxide and other toxic gasses can build up, injuring roots. Soil micro-organisms that play a role in making nutrients available to plants are also negatively affected by the lack of oxygen and high levels of injurious gasses. Where soils are compacted, root penetration is reduced. This limits the amount of water and nutrients that can be absorbed by trees and other plants. This reduces tree growth and overall site productivity.

Because compaction reduces the number and volume of macropores, it reduces water infiltration and movement in soils. This ultimately leads to increased runoff on slopes and to increased ponding on level sites. Increased runoff causes less rainfall to enter and be stored in the soil for plant use. Instead, rainfall flows rapidly into nearby streams, causing stream water levels to fluctuate. The rapid water flow across the landscape surface increases the risk of erosion and sedimentation. On level slopes, ponding causes unfavorable conditions for plant growth. Seedlings and many herbaceous plants grow poorly in standing water. When the surface layer of soil is saturated, the strength of the soil is reduced and becomes more vulnerable to rutting by heavy equipment. In addition, soil particles become dispersed in water, and after they have dried and settled, the smaller particles form a crust on the surface. This further limits the productivity of the site.

In Missouri, soils that are most susceptible to compaction contain few coarse fragments and are fine- to medium-textured. This includes soils with silt, silt loam, clay loam, silty clay loam, silty clay, and clay textures. These soils are extensive in northern and western Missouri and in the Bootheel region and occur to a lesser degree throughout the remaining portions of the state. Soils with saturated zones or with perched water tables are particularly vulnerable, particularly on level sites or in depressions where water cannot drain laterally. However, nearly all soils in Missouri are vulnerable to compaction when saturated such as after heavy rainfall. Care must be taken before beginning any harvesting operation.

Rutting

Rutting is the creation of depressions made by the tires of vehicles such as skidders, log trucks, and other equipment, usually under wet conditions. It occurs when soil strength is not sufficient to support the applied load from vehicle traffic. Rutting directly affects the rooting environment by physically wounding or severing roots, compacting and displacing the soil, and reducing aeration and infiltration. Also, rutting disrupts natural surface water hydrology. Ruts occurring perpendicular to the slope obstruct surface water flow increasing soil wetness. Ruts that run parallel to a slope gradient can divert water flow away from a site, drying or draining it, but may also increase erosion and sedimentation. Rutting typically occurs under the same circumstances that create other physical soil impacts, including compaction and ponding.

Much like with compaction, soils susceptible to rutting contain few coarse fragments and generally are the fine- and medium-textured soils such as silts, silt loams, clay loams, silty clays, and clays. Soils with poor drainage are particularly vulnerable, such as those that have a claypan and those on level sites or in depressions. Soils that are well drained to excessively well drained and are very gravelly or cobbly such as those occurring throughout the Ozarks and outer Ozark border are less vulnerable to rutting. However, nearly all soils in Missouri are vulnerable to rutting when saturated, and care must be taken before beginning any harvesting operation.

Soil Erosion and Sedimentation

Soil erosion is not usually a major impact associated with forest management in most parts of Missouri, except when associated with roads and skid trails (see Chapter 14). Minimizing the number of haul roads and primary skid trails will reduce the chance for erosion and sedimentation to occur. Erosion seldom occurs on areas with established vegetative cover. Harvesting that temporarily removes all forest cover on steeper slopes can occasionally result in accelerated erosion. However, harvesting used in conjunction with a silvicultural regeneration method (see Chapter 11) and BMPs will ensure that vegetative cover is reestablished quickly and the impact of skidding and hauling is minimized so that the soil is protected.

The application of prescribed fire temporarily removes leaf litter and ground vegetation, leaving soils vulnerable to erosion until new litter is deposited or the ground vegetation grows back. On steep slopes, avoid using intense fires because they remove most of the forest floor, which protects the mineral soil from erosion. Also avoid intense burns during the late fall or early winter because of the risk that the soil will remain without litter or other vegetative cover until spring.

Soil erosion in livestock grazed forests can be many times greater than erosion in ungrazed forests. Large roots and hair-like feeder roots are easily damaged by trampling hooves as the soil erodes from around the base of a tree. Livestock also compact the soil, which has many negative impacts on trees. Pores in the soil that allow tree roots to get air and water are sealed off. Rainwater that should infiltrate into the ground simply runs off the surface, thereby contributing to erosion. The weakened trees are less drought tolerant and are more vulnerable to insects and disease.

In Missouri, soils with silt and silt loam textures are the most vulnerable to erosion. This is because silt-sized particles do not aggregate very strongly and thus are easily detached from each other and transported by wind or water. The silty textures are commonly associated with the parent material named “loess,” which covers a portion of the land surface in the uplands near the Missouri and Mississippi Rivers and on gently to moderately sloping landforms throughout much of northern Missouri and on broad ridges throughout the Ozark Highlands. Extra care should be taken on silt and silt loam soils, as these tend to erode more easily when disturbed or exposed, especially on long or steep slopes.

Chemical Properties and Forest Management Impacts

Forest growth depends on the supply of soil nutrients. Nutrient supply is the balance between nutrient accumulations and nutrient losses. In forested ecosystems, soil nutrients accumulate through a variety of mechanisms. Nutrients such as calcium, magnesium, potassium, and phosphorus are released through the weathering of primary or secondary minerals in the soil and become available in soil solution. Nitrogen is captured or “fixed” from the atmosphere by plants or soil microorganisms. Some of these nutrients occur in dust or in rainwater that falls on the forest.

Nutrients are also released through the decomposition of plant residues, and thus an important process operating in a forest is nutrient cycling, the nutrient exchange between the soil and the plants. This exchange of nutrients between soil and plants is particularly important for forest growth. Annually, more nutrients are cycled through the ecosystem than are released by mineral weathering or by atmospheric deposition.

Nutrients are lost from an ecosystem in a number of ways. Some are lost by leaching from the soil. Others are lost as gases during the decomposition of plant residues. Nutrients in biomass are removed from the forest during harvesting, and shortly after harvest they can be lost from the root zone through the leaching of nutrients released during the decomposition of large quantities of residues left behind. Elevated temperatures and moisture in soil following harvest can also enhance decomposition of the soil organic matter, thus further enhancing nutrient release and potential loss from the root zone.

Prescribed fires that are applied to reduce fuel loading or to favor desirable forest structures and species compositions can also cause nutrient losses. Burning leaf litter and organic matter on the soil surface causes nitrogen losses through vaporization. The ash left behind on the soil surface immediately following a prescribed fire is rich in calcium, magnesium, and potassium but also highly vulnerable to leaching and runoff.

Nutrient depletion is greater with shorter rotations, shorter fire-return intervals, and greater harvest intensities. In forests managed with short rotations, the removal rate of nutrients in the harvested material can exceed inputs from the atmosphere and from mineral weathering in the soil. Similarly, a shorter fire-return interval may cause nitrogen losses to exceed nitrogen inputs. Increasing the harvest intensity by removing foliage and branches in addition to bole wood also increases nutrient removals. Where whole trees are harvested either for biofuel production or for limbing operations performed at log landings, greater nutrient removals occur compared to where branches and leaves remain well distributed in the forest. Nutrient concentrations also differ among tree species. For example, oaks have greater calcium concentrations in their boles and branches than do red maples or many species of pines. Consequently, greater calcium depletion occurs where more oaks are harvested relative to these other species.

Soils containing small quantities of available nutrients, and with a limited capacity to store nutrients or to resupply nutrients through mineral weathering, are the most vulnerable to accelerated nutrient depletion. Soils formed in highly weathered parent materials or in parent materials derived from sandstone or rhyolite generally have a low cation exchange capacity, which limits their ability to store nutrients and to provide them to plants.

These kinds of parent materials also contain few primary minerals capable of resupplying nutrients such as calcium, magnesium, or potassium when they weather. Soils containing large quantities of rocks comprised of chert or quartzite have a diminished supply of nutrients because these kinds of rocks reduce the volume of soil material capable of storing and supplying nutrients and because few nutrients are released from these rocks during the

weathering process. Phosphorus supply is also limited in highly weathered soil because it becomes adsorbed to the surfaces of iron oxides or because it is converted into a mineral with either iron or aluminum that is resistant to release by weathering. Coarse-textured soils contain less organic matter and generally have a lower capacity to hold or supply nutrients.

In contrast, soils formed in parent materials such as glacial till, loess, residuum from limestone or shale, or in alluvium derived from these parent materials generally are rich in nutrients and have a large capacity to supply nutrients through mineral weathering.

In Missouri, oaks are the most abundant and commonly harvested species. Because oaks contain high concentrations of calcium, care should always be taken when planning and conducting harvesting operations to minimize unnecessary depletion of this nutrient. Depletion of calcium (and of other base cations) can decrease the soil pH, which in turn can lead to high levels of aluminum in the soil solution. Aluminum is toxic to many plants, and high levels of aluminum in the soil solution limits rooting depth, injures roots, and decreases the uptake of cations, increasing drought susceptibility and lowering plant productivity. Nitrogen losses can be minimized by increasing the rotation length or by decreasing fire-return intervals.

Soils most vulnerable to nutrient depletion are those that are highly weathered and contain high concentrations of cherty coarse fragments. These occur throughout the Ozark Highlands, particularly where the soils are formed in rocky colluvium (soil material moved by gravity) or residuum (soil material developed in place) derived from sandstone, rhyolite, cherty limestones or dolomites, or acidic shale. Not all soils of the Ozark Highlands are equally vulnerable to nutrient depletion as some are formed in clayey residuum derived from limestone, dolomite, or calcareous shale or alluvium (soil material transported and deposited by water) and are rich in calcium and magnesium. The soils in much of central, northern, and western Missouri are derived from glacial till, loess, residuum from limestone or dolomite, or alluvium derived from the these parent materials and are much less vulnerable to nutrient depletion.

A soil survey is useful for identifying the soils that are most vulnerable to nutrient depletion. Soils that are classified in the Soil Order Ultisols are the most vulnerable. Those that are least vulnerable are classified as Alfisols, Mollisols, Entisols, or Inceptisols.

Biological Properties and Forest Management Impacts

Biological characteristics of soil include the populations of plants and animals, including macrofauna (including small animals, worms, termites, ants, and other arthropods), microfauna (including nematodes, rotifers, protozoa), and microflora (including fungi, bacteria, algae, oomycetes). Macrofauna aid in the creation of macropores and also mix the soil, incorporating organic matter. Microfauna play an important role in regulating microbial populations and mineralizing the organic matter. Microflora mineralize organic substances or transform inorganic compounds, making nutrients more readily available to plants.

Fungi are particularly important microflora in forest soils. They decompose cellulose and lignin, which otherwise are very resistant to breakdown by other organisms. Some fungi — called mycorrhizae — have a beneficial relationship with plants. Mycorrhizae infection in the plant's roots helps the plant take up water and nutrients. Infection by mycorrhizae occurs most frequently in soils that are infertile. Other fungi are pathogenic, feeding on the roots of living plants and causing injury or death.

The number of organisms is generally greatest in the forest floor and in the volume of mineral soil directly associated with plant roots. The population of soil organisms (both density and composition) and how well that population thrives is dependent on many soil factors including moisture, aeration, temperature, organic matter, acidity, and nutrient supply.

Poor harvesting practices can favor soil organisms that cause disease or damage to standing timber. The reduced aeration and increased ponding and soil wetness associated with compaction and rutting favors the growth of Phytophthora. These thrive under saturated soil conditions where they feed on the fine roots of trees and other plants causing growth reductions or death.

The wounding of tree roots and stems by skidders and other harvesting equipment or by prescribed fires increases susceptibility to Armillaria fungi. Some species of Armillaria are pathogenic, eventually killing trees that have been initially wounded during harvesting, prescribed burning, or other management activity.

Generally, protecting the soil from compaction, rutting, erosion, organic matter loss, and excessive nutrient depletion favors soil organisms that are the most beneficial for maintaining healthy forests. Implementing practices that protect the physical and chemical properties of the soil also protects the habitat of the soil organisms and sustains their populations.

Additional Resources

NRCS Web Soil Survey. Available at websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Chapter 8: Forest Products

Topics Covered

- Common Forest Products and Species in Missouri
- Woody Biomass
- Carbon Sequestration and Biomass
- Encouraging Landowners to Produce Forest Products
- Encouraging Trust among Landowners, Foresters, and Industry
- When to Harvest
- Maximizing Utilization and Product Values
- Additional Resources

Missouri's forest products industry is an important contributor to Missouri's economy and supports a number of economic, social, and environmental values. Ensuring that these values are maintained in the future means carefully balancing harvest and consumption rates with available growth and making sure that harvest practices account for long-term productivity and sustainability of all forest benefits and services.

Missouri's forests are an important supplier of numerous wood products that are used in our state and worldwide. Some of the many products originating from Missouri's forests are railroad ties, furniture and cabinets, flooring, barrels, tool handles, charcoal, pallets, shavings, paper, and firewood. Through the production of these and other wood products, Missouri's forest products industry contributes approximately $7.3 billion to Missouri's economy annually; it supports 41,200 jobs and generates $77 million each year in state sales tax.

Besides the social and economic benefits of Missouri's forest products industry, there are some less obvious benefits as well. When properly conducted, the harvest of forest products can provide an economical means of improving forest health and wildlife habitat. Harvesting can be used to mimic historic disturbances that maintained diverse forest structure and composition, important to both forest health and wildlife. Forest products can have several environmental advantages over alternative resources:

- Trees and forests are renewable resources. As trees are harvested, new trees quickly emerge and fill in the gaps left behind.
- Harvesting trees is generally much easier and leaves less of a human footprint compared to the extraction of other resources such as metals, coal, and oil.
- Forest products are generally biodegradable and/or recyclable.
- Forest products and biofuels help reduce greenhouse gases through carbon storage in forest products and through avoided use and extraction of fossil fuels. Carbon released from tree harvesting is quickly taken back up by new forest growth.

Despite all of the benefits and opportunities associated with forest products, they have their limitations too. First, there is a limit to how much timber can be harvested without reducing opportunities for future generations. Second, the harvest of forest products is only beneficial if it is done using management practices that ensure the long-term health, sustainability, and productivity of the forest. Forest management decisions need to ensure that all of the benefits forests provide can be sustained into the future.

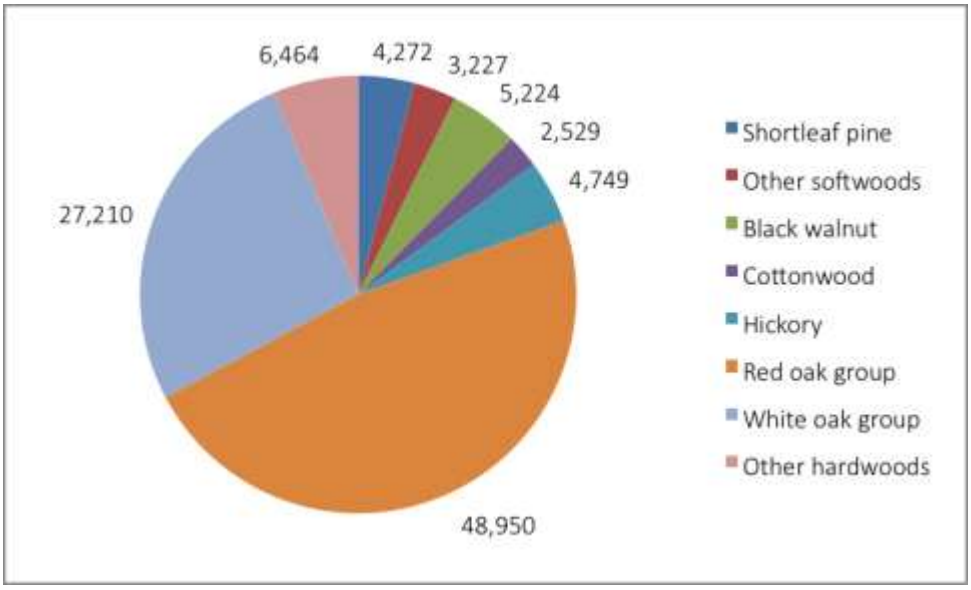


Figure 8.1. Industrial roundwood production, in thousand cubic feet, by species group and state of mill, Missouri, 2009.

Common Forest Products and Species in Missouri

Saw logs will be made into pallets, flooring, railroad ties, grade lumber, and various other products. Typically the lowest quality logs are converted to pallet lumber and railroad ties. Modern technology has allowed flooring manufacturers also to use fairly small and/or lower quality logs. Grade lumber must meet specifications for size and lack of defect and requires better quality logs.

Veneer logs are very high-quality saw logs that are either sliced or peeled into very thin layers, which are used to cover less expensive wood in furniture making or for hardwood plywood. Logs must be nearly free of defect and of a sufficient size to produce useable slices or have enough veneer to be peeled economically.

Cooperage is white oak logs that are used to create barrels. Barrel staves must have zero defect. Seldom will a single timber sale yield more than a few stave-quality logs. Their value makes it worthwhile for most loggers and sawmills to sort out these logs until they have a truckload ready to be delivered to a cooperage facility.

Pulp is wood fiber used to create paper products. These are pieces of harvested wood that are too small or defective for even the lowest quality product. Unless a logger has an economical way to consolidate and transport pulpwood it may never leave the woods. Unfortunately these defective trees may not even be cut down even though doing so would serve to improve the long-term health and quality of the stand. Viable pulpwood markets can enhance the forest manager's ability to conduct the necessary management work in a more cost effective manner.

Posts are typically small pine but can be oak or cedar. Posts are typically treated with a wood preservative to extend their useful life.

Sawtimber shortleaf pine can produce construction-grade lumber. Missouri shortleaf pine is desirable due to both its slower growth and greater strength compared to other southern yellow pines. Unfortunately, Missouri markets that capitalize on this resource are limited. The highest quality shortleaf pine can be used for telephone poles. Pole-quality pine represents a small percentage of trees. Their high value makes marketing pole-quality pine a good financial decision. Pine shavings are another growing market for shortleaf pine. Shavings are utilized for animal bedding material for livestock and poultry.

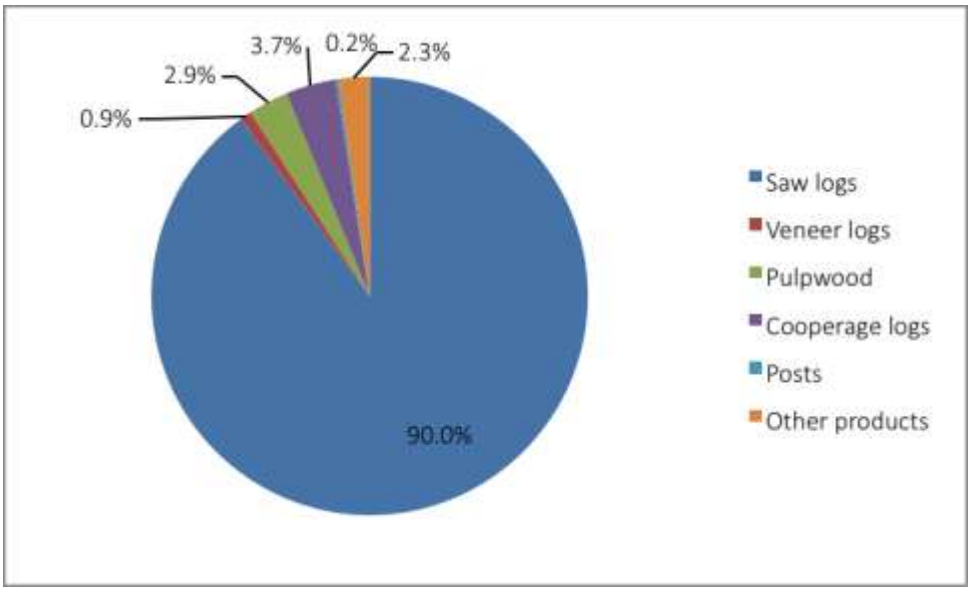


Figure 8.2. Industrial roundwood production by product type, hardwoods, and softwoods.

Woody Biomass

Dramatic increases in petroleum prices have resulted in greater emphasis on the need to develop alternative energy sources, including woody biomass. Woody biomass can be utilized to create many different products such as firewood, charcoal, and various biofuels. For more information on how to properly harvest woody biomass, refer to *Missouri Woody Biomass Harvesting Best Management Practices Manual*.

Carbon Sequestration and Biomass

When trees grow, they accumulate and store carbon. When they die and decompose, they gradually release carbon. When trees are used for products, carbon remains stored in the wood and paper products until they decompose and release carbon back to the atmosphere. For paper this may be a few months or a few years. For wood products it may not be for decades or even centuries.

Although there are instances around the country where landowners have sold the carbon sequestered by their forest, a dependable and price-attractive market for carbon sequestration has yet to develop. At some point in the future, a viable market for this ecological service may yet emerge. Regardless, landowners and managers can benefit from a better understanding of the role that forests play both as a carbon sink and as an energy source that is more carbon-emitting neutral than nonrenewable fuels.

Landowners selling the carbon sequestered by their forests enter into a contract with the purchaser that guarantees a volume of carbon to be stored over a specified period of time. This stored carbon serves to offset a carbon emission elsewhere, by a coal-fired power plant perhaps, thus mitigating that emission's impact on the global balance of greenhouse gases. Formulas are applied that estimate carbon storage based on the composition, age, condition, and extent of the forested acreage.

When a forest is sustainably managed to produce woody biomass there is an off-setting effect between the carbon that is accumulated in the growing forest and the carbon that is emitted when the wood is used for energy. Comparatively, nonrenewable fuels such as petroleum products emit carbon when consumed with no counter-balancing absorption of carbon from the atmosphere. Although studies suggest that the use of woody biomass is not perfectly carbon neutral, as an alternative energy source it can have a positive impact on greenhouse gas accumulation when used in place of nonrenewables.

Encouraging Landowners to Produce Forest Products

The 359,000 private forest owners in Missouri own forest land for a great variety of reasons. The vast majority of these (95 percent) are family forest owners who rank timber production as a relatively low priority. The forest management practices that interest these owners may be those designed to improve wildlife habitat, increase herbaceous vegetation diversity, improve aesthetics, provide firewood, or provide recreation opportunities rather than grow marketable timber. Timber sales can provide a source of income to help implement silvicultural treatments designed to meet non-timber objectives. Timber sales are the primary source of income from Missouri forests. Commercial forest harvest operations may be the most economical means of altering forest structure and composition, which may be necessary for achieving other goals such as habitat restoration, hazardous fuel reduction, or invasive species mitigation. Landowners can benefit from working with foresters to combine timber sales with treatments to meet other conservation objectives and thereby reduce or eliminate out-of-pocket costs associated with non-timber management objectives.

Encouraging Trust among Landowners, Foresters, and Industry

Another issue that significantly influences the process of buying and selling timber is trust or the lack thereof between landowners, foresters, and industry. Reassuring all partners of the integrity of a transaction is essential to improving the viability of the forest products industry. A timber harvesting contract with a forester serving as a sale administrator can help to ensure that all parties are protected. An example of a timber harvesting contract is located in the Appendix D.

When to Harvest

Timber harvesting can be used to accomplish numerous landowner objectives: generating revenue, improving individual tree growth, improving conditions for regeneration, and maintaining or enhancing habitat for wildlife. Without a forest management plan (see Chapter 10), it can be difficult to know the best time to conduct a timber sale. An important first step in knowing when to harvest is the development of a forest management plan that identifies landowner objectives and articulates the harvest methods and timing of activities to achieve these goals.

Timber resources experience financial ingrowth, or increasing product value as a tree's diameter increases over the course of its life. An example of financial ingrowth is when a tree grows from a pulpwood size class into a sawtimber class. (Figure 8.3).

Harvesting too early can yield substantially lower revenue to the landowner. A properly conducted thinning, however, may produce short-term income while allowing the stand to grow into the next size class sooner. Based on the concept of financial ingrowth, a landowner should delay final harvest until the estimated revenue of a timber sale is maximized. Delaying a timber harvest is not totally without risk. The likelihood that a natural disturbance will damage or kill a tree increases the longer it is left to grow. The decision on when to harvest should be based on a forest inventory. An inventory can reveal whether the landowner should delay harvesting until financial ingrowth leads to an increase in timber sale revenue.

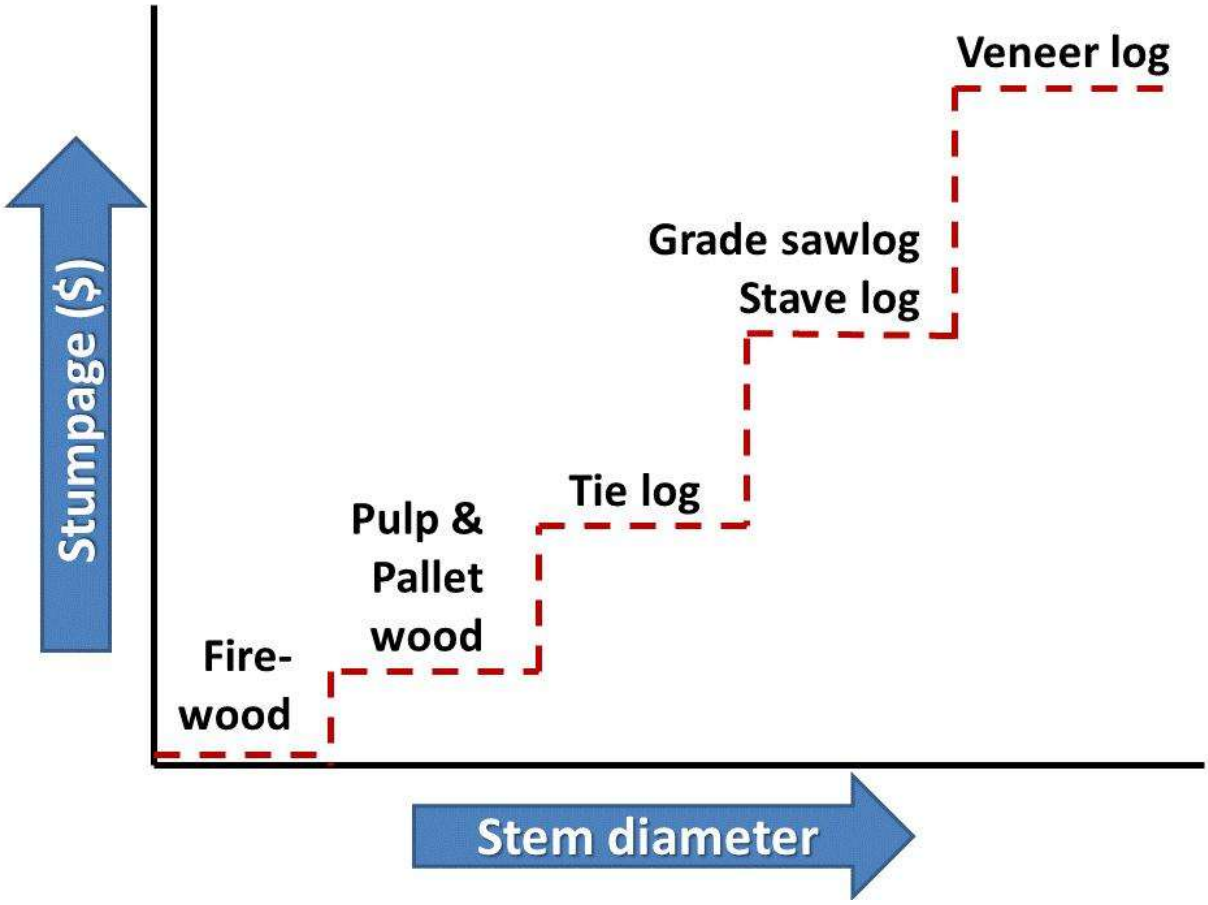


Figure 8.3. Timber resources experience financial ingrowth, which is the jump in product value associated with increasing tree size. This phenomenon can create a financial incentive for landowners to delay harvesting until the ingrowth of their timber to a higher-valued product class has occurred.

Maximizing Utilization and Product Values

The types and availability of wood product markets is highly variable throughout Missouri. For example, in portions of the Missouri Ozarks, markets are available for pulpwood, pallet lumber, tie logs, as well as stave logs and veneer. In this area, there is potential for marketing products of a variety of sizes and levels of quality. Markets in northern Missouri limit utilization of timber resources due to lack of small diameter wood markets. Landowners, foresters, and loggers should work together to ensure that products removed during harvest operations reflect the highest and best use of each tree removed. This will help maximize the profit for both the landowner and the logger and can help create a more visually appealing timber sale with lower fuel loadings. It is also socially responsible to use the forest resource wisely. Although trees are a renewable resource it may take decades for a stand to mature enough to provide higher valued products. If low value product markets are not available in your area, consider using

firewood cutters to meet these objectives. Refer to Chapter 15 for guidelines on how to maximize product utilization during harvesting operations.

Additional Resources

Forest Management for Missouri Landowners, Missouri Department of Conservation 2007. Available at mdc.mo.gov/node/5574

Missouri Woody Biomass Harvesting Best Management Practices Manual. Missouri Department of Conservation 2009. Available at mdc.mo.gov/node/9806

Call before You Cut Program: callb4ucut.com

Chapter 9: Forest Health

Topics Covered

- Threats to the Health of Missouri's Forests
- Integrated Pest Management
- Potential Health Threats to Missouri's Forests — Native Forest Health Threats
  - Red Oak Decline
  - Oak Wilt
- Potential Health Threats to Missouri's Forests — Nonnative (Exotic) Forest Health Threats
  - Bush Honeysuckle
  - Garlic Mustard
  - Emerald Ash Borer
  - Asian Longhorned Beetle
  - Gypsy Moth
  - Thousand Cankers Disease
  - Feral Hogs
- Other Forest Health Threats
  - Extreme Weather Events and Climate Change
  - Large Animal Impacts
- Additional Resources

Thousands of species of bacteria, fungi, and insects occur naturally in a forest and have developed along with trees, other plants, vertebrates, and other organisms as essential components of healthy ecosystems. Natural and human-caused disturbances occasionally cause changes in the interactions of these many elements leading to declines in forest health.

Disturbances can be caused by changing weather patterns, weather events (e.g., tornados), human actions directly affecting the forest, human-assisted introduction of invasive species, and many other events.

Threats to the Health of Missouri's Forests

One good example of human actions directly affecting the forest is oak decline. Back at the turn of the 20th century, the forests of the Missouri Ozarks were clear-cut. Two to three sprouts occurred on almost every black and scarlet oak stump resulting in too many trees growing on too little land. To make matters worse, these sites had historically been dominated by pine and had soil that was rocky, infertile, and susceptible to drought. This was further complicated by the fact that the normal life expectancy of these tree species is only 70–90 years. When the severe droughts of 1980 and 2000 took place, a major component of Missouri's forests came under major stress. Various insects and pathogenic fungi whose normal role in the forest is to attack and decompose weak and dying trees had an overabundant food supply, and their populations exploded, leading to even more decline. The cycle was broken when the most vulnerable black and scarlet oaks died, weather conditions moderated, and insect and fungal populations declined. Oak decline is expected to be a continuing problem in the future as trees increase in age and additional drought and other stress events occur.

At times humans have knowingly introduced "exotic" or "non-native" plants and animals for a specific use, as in the case of autumn-olive for erosion control or Serecia lespedeza for livestock feed. In other instances, introduction has occurred accidentally via incoming international cargo, as in the case of chestnut blight, Dutch elm disease, or the emerald ash borer. In these or similar instances, when an organism is taken out of its original environment and placed in another the ecological balance shifts. Other species that help keep the introduced organism in check may not be a part of the new environment. In the case of an introduced insect or disease, the host plant species has not coevolved with the introduced species and has few natural defenses to resist the attack. These "invasive" species are then able to modify native ecosystems resulting in adverse economic and ecological impacts.

One of the most difficult aspects of managing a harmful pest species is that it is usually widespread before it is detected. And it usually takes multiple detections before public awareness reaches the point where action is taken to combat the threat. The Nature Conservancy developed the following graph (Figure 9.1) to depict how one forest health threat, an invasive plant, increases over time and the relative potential for controlling it. Insects and disease-causing pathogens follow the same pattern.

A note of caution is appropriate here regarding the concept of "eradication" of an invasive species. The chances for eradication or containment (control) of a pest or an invasive species are greatest immediately after their introduction. However, due to a lack of adequate detection technology and lack of public awareness of the problem, detection of many invasive species occurs after the pest is well established over a broad area. As a result, eradication is not possible in most cases. Even if eradication is feasible, it is often very expensive. For example,

local, state, and federal agencies spent millions of dollars trying to eradicate the emerald ash borer in what was perceived then as isolated infestations outside the initial introduction area of southeast Michigan. In all instances the eradication efforts failed. The emerald ash borer had spread to larger areas than could be easily detected. Slowing the spread of a newly established pest is typically the primary objective of invasive species management. As such, early detection and rapid response are both key to managing the threat of invasive species.

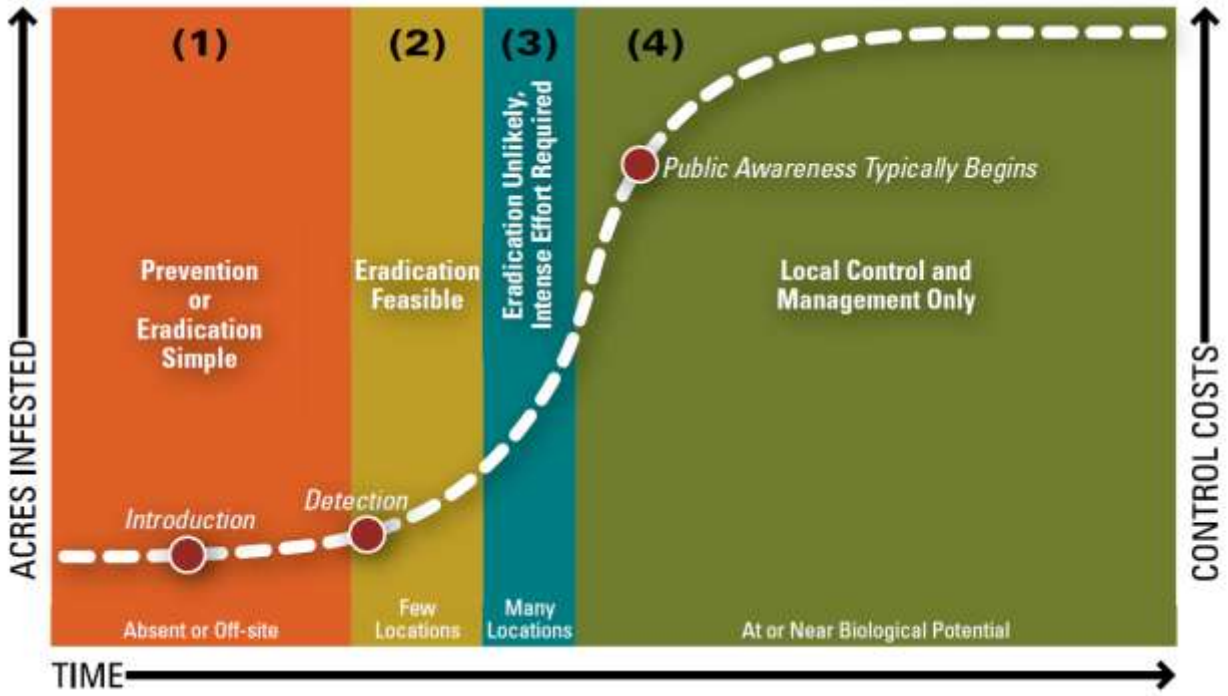


Figure 9.1. Invasive plant increase over time and control potential. The process of invasion is characterized in four phases. The first phase (1) is the introduction phase, where prevention or eradication is simple. Typically an introduced species must survive at low population densities before it becomes invasive in a new location; some species are present for many years before they exhibit invasive characteristics. The second phase (2) has a few populations, and eradication is still feasible. If an invasive species is detected early, when it is found in a few locations before the population has entered the exponential growth phase, it may be possible to eradicate it. The third phase (3) has many more populations, and eradication is unlikely and requires intense effort. The fourth phase (4) is where the population is at or near its biological potential, and local control and management is the only option. The goal is to keep a species in phases 1 through 3 and have the public awareness point on the curve drop. (Figure credit: The Nature Conservancy, John Randall.)

Integrated Pest Management

Given the unpredictability of pest invasions and their impacts, the most effective preventative measure is to manage forests to be resilient to a wide range of disturbances.

The best strategy for maintaining this resiliency and managing a pest if action is warranted is through integrated pest management (IPM). IPM is a concept that recognizes ecological, social, and economic values in resource planning and management. IPM in a forest ecosystem is the

process of managing a forest with all available tools so that potentially destructive organisms are maintained at a level that is below an economic or damage threshold.

Each invasive plant, insect, or disease-causing organism will have a life cycle that makes it unique. IPM requires an understanding of the forest pest life cycle or method of infection, reproduction, and spread. Interrupting the life cycle is key to managing these species. There is no one source of information on all forest pests, yet technical information on the biology and management of the most destructive species is available through a variety of resources.

The following IPM practices can help minimize pest damage:

- Establish or maintain a diverse mixture of tree species, along with a mixture of ages and sizes of trees.
- Match tree species to the sites where they grow best.
- Use only native planting stock:
    - Avoid planting nonnative trees for most field applications, such as wind breaks, soil stabilization and erosion control, fiber production, and wildlife habitat
- Maintain individual tree vigor by regularly thinning the forest:
    - Remove low vigor trees, infested trees, and those that are especially susceptible to local pest problems.
- Leave snags for cavity-nesting birds.
- Avoid pruning or thinning during the growing season.
- Avoid wounding trees when operating heavy equipment or logging.
- Periodically monitor the forest to identify pests before they cause too much damage:
    - Monitoring can be integrated with other forest activities.
    - Monitoring may be targeted to specific areas:
        - Where introductions of invasive species are likely, such as access points and travel corridors (along roadways or near parking lots for feral hogs)
        - With high ecological value, where impacts are likely to be significant
        - That are vulnerable habitats or recently disturbed areas
- Minimize disturbance if invasive species are known to be present on–site; openings in forest canopy and/or ground cover could allow invasive plants to gain a foothold; wounding, creation of slash and stumps, and increased stress on trees could allow invasive wood borers or pathogens to build up.
- Avoid transporting insects and diseases:
    - Do not move firewood

    - Examine recreational vehicles
    - Brush debris off of equipment before leaving the site
    - Be aware of quarantines

- Maintain awareness of conditions that may result in opportunities for invasive plant or animal establishment (i.e., proximity to disturbance, pockets of source species, etc.).
- Salvage damaged trees after a weather event (e.g., ice/wind storm or flood) to reduce the opportunity for introduction of invasives.
- Before taking action to manage the pest consider:

    - All available control methods.
    - Any local, state, and federal regulations that apply.
    - The benefits and risks of each available treatment method or combination of methods.
    - Whether there are any threatened or endangered species in the area to be treated.

- Choose the methods that are effective yet will cause the least harm to you, others, and the environment.
- Correctly carry out the control practices and keep accurate records.

Native Forest Health Threats

This is a list of some examples of forest health threats in Missouri. For more information about other forest health threats refer to the additional resources at the end of the chapter.

Red Oak Decline

There is no single cause responsible for oak decline. Periodic episodes of decline and death of oaks occur over widespread areas and are caused by a complex interaction of environmental stresses and pests. Scarlet oak, black oak, and northern red oak are the species primarily affected.

First, red and black oak trees are predisposed to decline because of their age (many live only 70–90 years), where they grow (shallow rocky soils, often on ridge tops and upper slopes) which originally dominated by pine, and historical land use (excessive harvesting, burning, and grazing in early 1900s). Declines are then triggered by inciting factors such as short-term drought, repeated insect defoliation, and late-season frosts. Contributing factors such as Armillaria root rot, Hypoxylon canker, red oak borer, two-lined chestnut borer, and leaf-eating insects combine with the previously mentioned factors to cause greater stress and damage to the oaks.

Identification

The first symptoms often include progressive dieback in the upper crown of the tree. Dieback symptoms can result from the effects of stress alone. Indeed, stress, if sufficiently severe or prolonged, can result in tree mortality. However, the continued decline and death of stressed

oaks usually results from lethal attacks by Armillaria root rot, Hypoxylon canker, two-lined chestnut borers, and other insects. Final symptoms of oak decline primarily reflect the root killing and stem-girdling effects of these organisms. In attacked trees, leaves sometimes fail to develop in the spring or wilt shortly after budbreak; sometimes they wilt or brown suddenly in the latter part of the growing season.

A characteristic of oak decline is that it may develop suddenly on many trees in the area affected by the initiating stress factor. Within the affected areas, however, decline and mortality occur in patterns, which may reflect the intensity and severity of the stress, the distribution of the hosts, the aggressiveness of Armillaria root rot, and the abundance of two-lined chestnut borers, coupled with site features such as poor or excessive soil drainage and frost pockets. Oak decline may become more apparent 2–5 years after the initiating stress factors occur.

Prevention

Oak decline is initiated by tree stress, which can disappear before effects are manifested. Practices to promote good tree health such as thinning to reduce stand density, regenerating stands as trees mature and maintaining tree diversity appropriate to the site can reduce the potential impacts of damage by oak decline.

Management

While it may be possible to improve the health and vigor of some declining trees, many of them are past the point of no return. The resulting spike in mortality and decline has and will continue to have a significant impact on the forest products industry.

Missouri's maturing red oaks need to be harvested in a short period of time to help reduce the threat of widespread oak decline. However there will always be some trees that do not get harvested before they die, these trees will still serve other useful purposes such as wildlife habitat.

Additional Information

USFS Oak decline Forest Insect and Disease Leaflet:
na.fs.fed.us/spfo/pubs/fidls/oakdecline/oakdecline.htm
Managing Oak Decline. pub by University of Tennessee (at University of Kentucky):
uky.edu/Ag/Forestry/extension/pub/pdf/for99.pdf

Oak Wilt

Identification

Symptoms of oak wilt can look similar to other tree health issues, such as oak decline. Consider contacting a forester for assistance with identification or contact a plant diagnostic lab (npdn.org) for information on sample testing to confirm oak wilt.

Red Oak Group: The first symptom of oak wilt in red oaks is usually browning and wilting of leaves in the crown in early summer. Wilted leaves show olive drab or light tan to bronze

tissue starting at the margins and progressing toward the leaf base. Brown or black streaking may be seen under the bark of wilted branches. Rapid defoliation and death of red oaks can occur within two to six weeks of initial infection.

White Oak Group: White oaks often exhibit scattered patches of wilt and leaf drop in the crown. Brown or black streaking may be seen under the bark of wilted branches. White oaks may take years to die from the infection.

Prevention

In areas where oak wilt occurs, avoid pruning or damaging oaks from mid-March through June. Use tree paint on wounds or storm-damaged areas during the spring infection period. Don't move untreated wood from infected trees to areas where oak wilt is not present.

Management

Overland Spread

In areas where oak wilt occurs, if healthy trees are wounded during the high risk period of mid-March through June, the wounds should be treated with a tree-wound paint to prevent sap-feeding beetles from feeding on them. Trees that have died from oak wilt can harbor mats of the oak wilt fungus. If this wood is moved, the fungal mats are moved and the disease may spread into unaffected areas. Small trees are less likely to produce fungal mats.

Trees that have died from oak wilt and have bark that is tightly attached to the wood could harbor fungal mats. This wood must receive special treatment before moving. In Missouri, trees are most likely to produce fungal mats the spring following tree death. Fungal mat production is unlikely beyond the year after tree death. In that case, no special treatment is necessary and movement of the wood is no longer a concern.

Underground Spread

This method of spread is less likely in Missouri. Disrupting root grafts can stop the underground spread of the fungus. Options include physically severing roots with a vibratory plow, cable plow, or trencher. Not all sites are suitable for this option; steep slopes prohibit the use of root barrier equipment, and sites with large rocks inhibit barrier placement. Locating barriers correctly is crucial to success. Guidance on barrier placement is available in Oak Wilt Management: What Are the Options? (University of Wisconsin–Extension Bulletin G3590) or consult an oak wilt management specialist.

Firewood

Two methods of wood treatment are effective in preventing overland spread via firewood:

1. Debarking the wood (removing the bark from the wood) will prevent the fungal mats from forming. Debarking must be conducted before fungal mats form, thus it should occur in the late summer, fall, or winter following tree death.
2. Cutting, splitting, stacking, and covering the wood with 4 mil or thicker plastic will prevent overland spread. All sharp edges or stubs should be cut to eliminate the possibility of puncturing the plastic. The entire pile must be sealed all around. Seal the bottom by

covering it with dirt, stones, or other heavy objects. If the wood is not burned over the winter following tree death, leave the tarp on through the next growing season (until October 1) or until the bark is loose. Once the bark is loose, the wood is no longer infectious.

Additional Information

na.fs.fed.us/pubs/howtos/ht_oakwilt/identify_prevent_and_control_oak_wilt_print.pdf

Nonnative (Exotic) Forest Health Threats

Bush Honeysuckle

Amur and Bella honeysuckle are exotic shrubs that thrive in shaded forest understory. They form a thick understory that limits sunlight to native plants and inhibits forest regeneration. They may produce a chemical that inhibits native plant growth. The fruit is not as nutritious for wildlife as the native plants it replaces.

Identificaton

Bush honeysuckles are easily separated from native honeysuckles by their stout, erect shrub growth. All native species are vine-like in nature.

Leaves are opposite, elliptical, and have a green surface with a pale green, slightly fuzzy underside. The leaves emerge early in spring and remain late in the fall.

In the spring, flowers are fragrant, paired, tubular, and 1 inch long with narrow petals. They may be white or pink but become yellowish as the plant matures.

The fruit matures in September to October. Red berries are produced in pairs near the origin of the leaves.

Prevention

Do not plant nonnative honeysuckles. Use native plants in landscaping. For suggestions of native substitutes visit the Grow Native website at grownative.org.

Educate and coordinate with your neighbors to prevent spread as the seeds are primarily carried by birds and small mammals.

Management

Hand pulling can be used when the plant is small and the soil is moist. Don’t use this method in sensitive areas because it disturbs the soil and aids in the spread of other invasive species.

The cut-stump method involves cutting the bush off at the stump and applying a 20 percent glyphosate solution to completely cover the cut area.

The foliar spray method involves spraying the leaves with a 2 percent solution of glyphosate and water plus a nonionic surfactant. Use this method in early spring or late fall when leaves of native plants are not present.

The basal-bark method consists of spraying a mix of 25 percent triclopyr and 75 percent horticultural or crop oil to the bush's stems. Thoroughly wet the bottom 12–15 inches of the plant.

Fire can be used when done safely and as part of a plan. Burn every spring, or every other spring, for several years in order to control re-sprouting.

Additional Information

Missouri Department of Conservation, Identification and Control: mdc.mo.gov/8243
Plant Conservation Alliance Bush honeysuckle page: nps.gov/plants/alien/fact/loni1.htm

Garlic Mustard

Garlic mustard is extremely invasive due to its prolific seed production. It out-competes native vegetation by spreading quickly and producing a chemical that inhibits other plants. The plant is unpalatable to wildlife.

Identification

First year: A rosette of green, roundish leaves about 4 inches off the ground that stay green throughout the winter.

Second year: A 2–3.5 foot tall flowering stem that has a distinctive "S" crook at the base. The leaves are alternate and triangular with the largest near the base. They have large teeth around the margins and are 2–3 inches wide.

Flowers begin to form in April, are clustered near the top of the stem, and have four white petals.

Fruit is a narrow, linear 1–2.5 inch green pod, produced from early summer through early fall.

Dead garlic mustard appears as long, slender seed stalks, with the seed pod turned upward

Prevention

Minimize disturbance of soil

Clean vehicles and equipment before moving from a known infestation site

Management

New infestations and small populations: Hand pulling is effective if done before seed dispersal.

Other methods: Cut the plant just above the ground after the flower stalks have elongated but before the flowers have opened. Bag plants and deposit in a landfill (compost piles do not produce enough heat to kill the seed).

Chemical control: A foliar spray of 2 percent glyphosate can be applied to individual plants in the fall or early spring when native plants are dormant. Or, when non-target vegetation is dormant, apply 2,4-D or 2,4-D plus Dicamba.

Control with prescribed fire: Annual burns in spring or fall could help control or reduce medium-to-large infestations. However, the effectiveness of fire differs based on site characteristics and burning conditions. Mis-timed burns could actually encourage germination of seed.

No matter the method, control must be continued annually until the seed bank is exhausted. Seeds can remain viable in the soil for five or more years.

Additional Information

Missouri Department of Conservation: mdc.mo.gov/node/4946

Emerald Ash Borer

Emerald ash borer (EAB) is a wood boring insect that attacks all types of ash trees. It is a threat to native forests as well as urban trees. It has killed many millions of ash trees in Michigan, where the infestation was first discovered, and across the northeastern United States and eastern Canada. Ash makes up 3 percent of Missouri's forests but a much higher percentage in riparian and bottomland forests. The emerald ash borer has been detected in several locations in Missouri.

Identification

Look for signs of stressed ash trees: Canopy dieback beginning at the top of the tree and progressing until the tree is bare, new sprouts on the roots, lower trunk, or lower branches (known as epicormic sprouting) and vertical splits in the bark about 3–5 inches long.

Increased woodpecker activity.

S-shaped galleries under the bark indicate larval feeding. Adults emerge from D-shaped exit holes one-eighth inch in diameter.

The adult EAB is bright, metallic green, and is a half inch long with a flattened back.

There are several native borers that feed on both healthy and stressed ash trees. Become familiar with EAB look-alikes (emeraldashborer.info/identifyeab.cfm).

If you find EAB contact your local MDC forester or call 1-866-716-9974.

Prevention

Do not move ash material (firewood, nursery stock, logs) onto property. Buy only local firewood and burn it all.

Use appropriate forest management strategies to reduce your risk: Consult a forester, inventory the trees on your property to identify your ash resource, and develop a plan of action.

Management

Until EAB is found in the local area, continue current management practices. Practice sustainable forestry.

When selecting ash trees to remove, first select those that have low vigor and quality. You should maintain dominant and co-dominant ash trees with good health and form.

Know the risks of moving logs and firewood from and to your land. Become familiar with state quarantines and the associated regulations.

Landowners in quarantined areas should consult with a forester to determine whether their management practices should change due to a known EAB infestation.

Insecticide treatments are only recommended for high value trees in areas with known infestations. Be aware that these treatments may provide only limited control.

Additional Information

Missouri Department of Conservation: mdc.mo.gov/node/5326
University of Missouri: eab.missouri.edu
US Forest Service Pest Alert: na.fs.fed.us/spfo/pubs/pest_al/eab/eab.pdf
National EAB website: emeraldashborer.info

Asian Longhorned Beetle

The Asian Longhorned Beetle (ALB) is a wood boring insect that attacks a wide variety of hardwood trees. It will attack live, healthy trees. The first infestation was discovered in Brooklyn, New York, in 1996 after it arrived in wood crates and shipping material from China. ALB could have damaging impacts to forest ecosystems because of its wide host range, which includes maple, willow, birch, poplar, and elm.

Note: ALB is a potential threat. As of May 2013, established populations have not been found in Missouri.

Early Detection/Identification

The adults are shiny black with irregular white spots and are from three-quarters of an inch to an inch and a half in length, with antennae that are 1–2 times their body length. The antennae have alternating black and white bands.

Adults emerge from round exit holes three-eighths of an inch in diameter or larger.

Adult females chew bowl-shaped holes in the bark to deposit eggs. These egg niches are roughly the size of a dime and often are orange in color.

Larva can be up to 2.4 inches long, fleshy, off-white in color, with many segmented body parts and brown mouth parts.

Infested trees may have “frass” or sawdust on the upper sides of branches or at the base of the tree.

There are native borers that can look similar to ALB, especially the cottonwood borer. Become familiar with look-alikes (na.fs.fed.us/fhp/alb/ident_reporting/identifying.shtm).

If you find Asian Longhorned Beetle contact your local Missouri Department of Conservation forester or email: forest.health@mdc.mo.gov.

Prevention

While most of the infestations to date have been from wood crates and pallets entering the United States, the movement of wood (firewood, nursery stock, logs) is still a potential spread method. Don’t move firewood. Buy only local firewood and burn it all.

Use appropriate forest management strategies to reduce your risk: maintain a healthy forest.

Control and Management

Until Asian Longhorned Beetle is found in the local area, continue current management practices. Practice sustainable forestry.

Because the majority of the beetle’s life is spent inside the tree, pesticides are rarely effective.

The best method of control is cutting, then chipping or burning of infested trees.

If an ALB infestation is discovered, expect that a quarantine will be issued. Become familiar with the quarantine and associated regulations.

Additional Information

Missouri Department of Conservation: mdc.mo.gov/node/6134
USDA: beetlebusters.info
U.S. Forest Service Pest Alert: na.fs.fed.us/pubs/palerts/alb/alb_pa.pdf

Gypsy Moth

Gypsy moth is a highly destructive, leaf-eating insect. It feeds on a wide variety of hardwood trees but oak is one of its preferred hosts. When populations are high, the caterpillars can defoliate entire neighborhoods or forests of leaves. Repeated defoliations can stress trees causing widespread mortality.

Note: Gypsy moth is a potential threat. As of May 2013, established populations have not been found in Missouri.

Identification

Look for tan-colored egg masses the size of a nickel or quarter and covered with tiny, fuzzy hair. Egg masses can be found on tree trunks and the underside of branches, as well as buildings, firewood, vehicles, boats, play sets, and other outdoor objects.

Caterpillars, or larvae, change appearance as they grow. Young caterpillars are black or brown and are about one-quarter inch in length. Mature caterpillars are as long as 2.5 inches and have pairs of blue and red dots along their back.

Adults are seen in midsummer. Males are gray-brown and can fly; females are white and cannot fly.

Egg masses are 1–2 inches in diameter, flattened, velvety brown masses (shown in photo).

Prevention

Inspect vehicles, trailers, and belongings for egg masses, larvae, and adult moths after visiting an infested state.

Use appropriate forest management strategies to improve forest health and tree vigor so trees are more likely to survive if defoliation occurs.

Management

Early detection is the key to combating this pest. Should you find a suspect insect, collect a sample by trapping the insect in a zippered plastic bag. Place the bag in the freezer for several days to kill the insect. Contact your local MDC forester.

Management of gypsy moth requires an integrated approach that depends on the size of the infestation and the type of site where it is found (landscape vs. forested environment). Strategies may include the use of insecticides, mechanical control, and/or biological control organisms.

Additional Information

Missouri Department of Conservation: mdc.mo.gov/node/6146
US Forest Service leaflet: na.fs.fed.us/spfo/pubs/fidls/gypsymoth/gypsy.htm
Missouri Department of Agriculture: mda.mo.gov/plants/pests/gypsymoth.php

Thousand Cankers Disease of Black Walnut

Thousand cankers disease of walnut (TCD) is a recently recognized insect/disease complex affecting eastern black walnut, butternut, and other walnut species. Black walnut appears to be the most susceptible species, with eventual tree mortality. The disease is the result of the activity of the walnut twig beetle, which transports spores of a canker producing fungus,

Geosmithia morbida. As cankers expand and coalesce, the tree becomes unable to store and move nutrients, causing tree decline and mortality after several years.

As of March 2013, TCD has been found in four eastern states (NC, PA, TN and VA) within the native range of black walnut, as well as nine western states (AZ, CA, CO, ID, OR, NM, NV, UT, and WA). Evidence suggests the disease has been present in these locations for several years prior to detection, with the potential for the disease to have been transported to other locations on TCD infected walnut materials. Walnut is the most valuable timber species in Missouri, and the economic impact to the state from a loss of walnut is estimated at $851 million dollars over 20 years.

Note: TCD is a potential threat. As of May 2013, established populations have not been found in Missouri.

Identification

In midsummer yellowing, wilting, and browning of foliage can be seen high in the crown. Leaves that wilt in midsummer often remain attached to twigs. Limbs die back, usually from the top downward.

New sprouts may grow from roots or trunk leading to a “bushy” appearance below dead branches.

Removing outer bark from dying limbs exposes shallow dark brown cankers underneath. Tiny insect tunnels may also be present. Cutting too deeply removes cankers. TCD cankers occur only in the thin phloem layer immediately under bark in branches greater than one inch in diameter.

Signs of walnut twig beetles: The beetles are tiny, about the size of the letter “i” in the word “liberty” on a dime. It may be easier to find cankers and beetle tunnels under the bark than to find the beetles themselves.

Prevention

Don’t bring walnut trees or untreated walnut wood into Missouri. While the rate of natural spread of this disease is expected to be slow, TCD spreads quickly when walnut wood containing the walnut twig beetles is moved to new locations.

Be aware of state quarantines. The current Missouri quarantine can be found at mda.mo.gov/plants/pests/TCDEmergencyRule.pdf.

All walnut plants and plant parts as well as all hardwood firewood from TCD-infected states are now prohibited from entering Missouri. This includes nursery stock, budwood, scionwood, green lumber, and other material living, dead, cut, or fallen including stumps, roots, branches, and composted and uncomposted chips. Exceptions are nuts, nutmeats, hulls, and processed lumber (100 percent bark-free, kiln-dried with squared edges).

Don’t move firewood. Buy only local wood and burn it all.

Avoid stressing trees. Trees that are on suitable sites and are growing vigorously may resist some of the effects of TCD.

Management

Currently, no effective methods have been identified to control TCD successfully once it is established. The priority in Missouri is to delay the establishment of TCD and slow the spread of TCD in any areas where it is detected.

If you believe your walnut tree is infested with TCD, take photographs of the entire tree, close-ups of the leaves, and any other symptoms. Contact your local MDC forester or e-mail forest.health@mdc.mo.gov.

Additional Information

Missouri Department of Conservation: mdc.mo.gov/thousand-cankers

A collaborative website between the Northeastern Area State and Private Forestry, the USDA Forest Service Northern Research Station, the Purdue University Department of Forestry and Natural Resources, the Hardwood Tree Improvement and Regeneration Center, the American Walnut Manufacturers Association, and the Walnut Council: thousandcankers.com

US Forest Service TCD Pest Alert: na.fs.fed.us/pubs/palerts/cankers_disease/thousand_cankers_disease_screen_res.pdf

Feral Hogs

Feral or wild hogs are any swine that have escaped or have been released into the wild. Because of their feeding habits and their potential to spread disease, they cause significant damage to landscape, agriculture, and forestry lands as well as to native wildlife. Feral hogs compete directly with native wildlife for food.

Identification

Feral hogs can include an assortment of hybrids of domestic breeds as well as Russian and European wild boars. Any hog roaming freely on public or private land that is not conspicuously identified is considered feral.

They can be 3 feet in height and 5 feet in length, weighing up to 400 pounds. However, average size for a sow is 110 pounds and 130 pounds for boars.

Tracks are similar to deer but are more rounded.

Feral hogs can plow the soil to depths of 2–8 inches. The ground looks as if it has been plowed and they can cover many acres in one evening.

Prevention

Report feral hog releases, sightings, or kills to your local conservation agent, the nearest MDC regional office, the state veterinarian's office (573-751-3377), or USDA Wildlife Services (573-449-3033).

Management

Hunters afield for other game are encouraged to shoot feral hogs on sight.

Feral hogs may be killed in any number throughout the year. Special restrictions apply during the spring turkey and fall firearms deer and turkey seasons.

Resident landowners and lessees on land on which they reside may kill feral hogs without a permit.

Trapping can be done using corral-type traps. Assistance with trapping can be obtained from MDC.

Additional Information

Missouri Department of Conservation, Feral Hog Control: mdc.mo.gov/node/17158
University of Missouri Extension: extension.missouri.edu/p/G9457

Other Forest Health Threats

Extreme Weather Events and Climate Change

Weather can also have a significant impact on forest health. With advancing changes in global climate, variability in climatic conditions and frequency of extreme weather events are predicted to increase. Floods, droughts, wind events (i.e., tornadoes), late frosts and freezes, and ice storms impact tree health directly and indirectly. Direct impacts include tree mortality and damage, but increasing the stress on trees and forests can cause indirect impacts such as increased vulnerability to insects and diseases and changes in the structure of forests and the sites they grow on.

Large Animal Impacts

Large animals, both native and nonnative, can impact tree and forest health. Overgrazing by domestic livestock or high populations of white-tailed deer can be destructive to forests. They can compact forest soils and reduce herbaceous vegetation that wildlife rely on.

Additional Resources

mdc.mo.gov/sites/default/files/resources/2010/05/5398_3326.pdf — contains links to Missouri Vegetation Management Manual and Missouri Conservationist articles on exotic species topics. On the link to the management manual, use the navigation bar to access species' info by common name.

nps.gov/plants/alien/ — Go to "Entire List of Completed Fact Sheets" and pick species that are presented in alphabetical order by Latin name. Clear, concise documents with photos, U.S. range maps, and control recommendations.

Bugwood.org — Extensive resource on forest insects and related topics.

Unit II: Foundations of Forest Management

Chapter 10: Forest Management Planning

Topics Covered

Forest Management Plans
Planning
Doing
Checking

Forest Management Plans

No one has unlimited amounts of time to spend caring for their forest land. It goes without saying that the dollars and energy dedicated to managing a forest should be expended as efficiently and effectively as possible.

A time-tested “system” for continuously improving efficiency and effectiveness in just about any situation is the Plan-Do-Check operating model. Simply put, you plan what you want to accomplish, you set about trying to accomplish it, you check how you did, and then you use the knowledge gained to modify the plan and continue the cycle of doing and checking.

It’s called a system because each step connects to the other two steps, constantly influencing and ultimately improving overall performance. Most of us just want to go “get stuff done” rather than spend time planning first or documenting the results. But a system that includes all three steps — each step informing the next — will yield better, more cost-conscious results.

Planning

Missouri has an outstanding common plan format that is the result of collaboration and formal agreements between a number of agencies and organizations. As a result, following this common plan format means that you’ve met the requirements for having a forest management plan that apply to federal cost share programs, state assistance programs, and the three third-party certification programs — (1) Forest Stewardship Council, (2) Sustainable Forestry Initiative, and (3) American Tree Farm. (See Appendix A.)

It follows this specific outline:

- Introduction
- Table of Contents
- Property Information
- Landowner Objectives
- Plan/Stand Map
- Record of Decisions Summary/Activity Schedule
- Existing Conditions/Field Examination Findings

- Appendices
- Location Map/Plat Map
- Soil Information
- Topographic Map
- Endangered and Threatened Species
- Archaeological, Cultural, & Historical Sites
- Environmental Evaluations
- Glossary/Helpful Internet Sites
- Supporting Documents/Stand Information

The common plan format can be accessed at efotg.sc.egov.usda.gov/treemenuFS.aspx. Although the format uses a standard outline of information to be included, the amount of information and the level of detail are expected to be appropriate for the size and complexity of the forest property. The plan serves several purposes.

It is an archive of basic information. Included are maps and references that support legal tenure around property lines, access, rights-of-way, approval signatures, etc. There are also maps and descriptions of the property's natural resources such as soils, topography, water, special sites, vegetative cover, and unique species. Ultimately, the archive is there to assist landowners in reaching objectives they have set with their woods that are consistent with sound management outlined in this document.

Ecological Site Classification (ECS) is an informational resource for describing the kinds of vegetation a specific location would be expected to support based on soils, topography, region of the state, and other criteria. This is a useful tool for determining the area's potential for meeting the landowner's forest and wildlife habitat objectives. (Detailed information on Ecological Site Classification is located in Chapter 11.)

Focusing on the forest resources, the common plan describes current conditions, based on a stand-level forest inventory and field evaluations. These conditions include such things as tree species present, forest health concerns, tree densities, growth rates, wildlife populations, recreational developments, and interior access.

Based on the quality of the growing site, tree ages, densities, and species, each forest has a "sustained yield" of wood fiber. In essence, based on these conditions, each forest grows a calculated amount of new wood each year. Theoretically, if annual growth stays constant and over a period of years, the average wood removal per year equals growth per year, then you should be able to maintain this practice indefinitely.

In reality, annual growth fluctuates as forest conditions such as age, density, and species fluctuate — either naturally or because of management. The smaller the acreage of forest the more growth rates will fluctuate. At any given time a landowner may harvest more or less than the sustained yield. Still, the three forest certification programs and this document's overall goal

to promote forest sustainability would expect a landowner to have some sense of the sustained yield for a property and to include it in the plan's basic information as an aid in guiding the harvest of wood over time.

Once the property is adequately described, the plan should document the landowner's objectives. Objectives state the desired future conditions of the forest and the benefits the landowner wants to produce, whether they be economic (e.g., timber sales income, hunting lease revenue, home heating fuel), environmental (e.g., wildlife habitat, watershed protection, endangered species recovery) or social (e.g., recreational opportunity, attractive scenery, protecting a historic cemetery). Objectives should be as specific as possible. For instance, if deer and turkey are the wildlife objective, then a statement of "management for wildlife habitat" would be inadequate. Objectives must also be consistent with the potential of the property. Growing high-quality walnut would not be an appropriate objective if the site cannot support walnut.

Once objectives are established, management prescriptions for achieving those objectives are outlined. The prescriptions answer such questions as when a specific stand of trees will be harvested, where and how specific habitats will be created, or what kind of buffer will be left around a cemetery. It's also important to address such things as how wildland fire protection will be handled, how forest health issues will be managed, or where roads and trails will be located.

Another issue that deserves treatment in each plan is the management of invasive species. Chapter 9 provides extensive detail on species to be concerned about and methods to prevent their spread. Regardless of what objectives a landowner desires, virtually all are served by specific attention to preventing the introduction of and controlling the spread of unwanted, nonnative plants and animals.

Considering the plan's importance to the future of the forest and the technical nature of the information that plans need to include, it is imperative that a resource professional assists with its development.

Doing

With a clearly written, well-researched plan the landowner seeks to achieve desired results by executing the strategies according to the time frame laid out.

It is as important to use qualified professionals during the implementation of a plan as it is to prepare a plan. Among other things, a resource professional can make sure you get a fair market value for the trees that are sold, that the prescribed treatment has the best chance of meeting a landowner's objective, or that harvesting occurs according to the state's best management practices. The right professional can ensure a new interior road will be easier to maintain, more useful for its intended purposes, and suitably protecting soil and water. The right professional can even provide tax saving advice for income earned from timber sales. Harvesting should be done by a professionally trained logger. They have added training to know

how to work safely, recover the best value from a harvested tree, protect any trees left behind, and minimize soil impacts.

Whenever such services are secured, make sure the work is completed under the structure of an acceptable contract between the landowner and the service provider. A copy of a sample timber sale contract included in the Appendix D. Contracts can ensure that all applicable laws are being followed, that best management practices are utilized, that work is completed under the desired time frame. They can include any other special considerations a landowner feels are important. For example, do you want roads restored if they are damaged by hauling activities, broken fences repaired, litter removed?

State and federal technical assistance specialists working in the vicinity of the property can connect landowners to the appropriate pool of potential contractors and cost share funding as available.

As a standard best business practice all contracts should be archived.

Checking

In order to improve how efficiently and effectively landowner objectives are being met, it's necessary to have a commitment to continuous learning. Conditions on the property (average tree age, tree species, wildlife populations, or road and trail systems) change over time. Change can be brought about by implementing a strategy, through some catastrophic disturbance, through more subtle natural processes, or even through some change taking place on an adjoining ownership.

Depending on the nature of the changes occurring, field evaluations should be re-conducted frequently enough to update the plan's description of present conditions every five to ten years. Based on the changes that have taken place, including any changes on the part of the landowner's desires, objectives should be revisited to make sure they're still valid.

Management prescriptions should be updated based on any revisions to objectives but also based on a close look at the results of implemented practices to this point. First, were they implemented as described? If not, what can be changed so that they are implemented? If practices are not implemented, needless to say objectives will not be met. Perhaps the objectives were unrealistic for the time and abilities of the landowner or were not appropriate for the site conditions.

For example, did a shelterwood harvest lead to an amount of advanced regeneration sufficient to conduct a final harvest during the year that was planned? If not, what's the next set of practices that will lead to an objective to realize income by a certain date? Or, should that objective be revised?

Second, what was learned from implementing each practice? Did it help to achieve the related objective? Were problems encountered, costs higher than expected, or dollar returns lower than

expected? For example, should the shelterwood harvest have removed more overstory? Pre- and post-operational checklists help you gather and retain this important information.

Examples are included in Appendix C. Typically, it is important to maintain pre- and post-operation checklists for timber harvests, chemical treatments, tree planting, other vegetative management activities, road and trail construction, prescribed burns, and other key practices that are carried out.

On these checklists, information is gathered about what is being implemented, when, how, where, and by whom. What objective is the activity addressing? What are the special considerations that need attention, such as protecting a water body or bat cave? Afterward, the checklist asks if things went according to plan. If not, what action was taken to correct things or prevent the same thing from happening in the future? What was the outcome? Was it what was expected? Why, or why not?

Evaluating what was implemented and documenting what conditions have changed serve to drive the revision of the plan. This closes the loop of interconnected planning — followed by doing — followed by checking — followed by plan revision and a new cycle of doing and checking. With each new cycle, landowners use what was learned in order to improve efficiency and effectiveness and creates a higher likelihood that they will achieve their desired objectives.

When a landowner desires to become third-party certified, documentation of actions, results, and corrective responses become very important. These records help a third-party auditor to select a sample to field check for compliance with the certification standard. If he or she were not able to pull samples from documentation, then field checks would have to be much more extensive and costly.

Chapter 11: Generally Accepted Principles for Silviculture

Topics Covered

- Silviculture
- Sustainable Forestry
- Ecological Site Classification
- Ecological Classification System Project in Missouri
- Terrestrial Natural Communities of Missouri
- Planning: Identifying Your Goals and Objectives
- Silvicultural Treatments
- Silvicultural Systems
- Regeneration Methods
- Even-Aged Regeneration Methods
- Artificial Regeneration and Even-Aged Methods
- Two Aged Methods
- Uneven-Aged Regeneration Methods
- Fire and Silviculture
- Woodlands
- Woodlands and Silviculture
- Regeneration and Tending Methods Applicable to Woodlands
- Effect of Burning and Thinning on Diameter Distributions of Woodlands
- Salvage Harvest
- Low-Intensity Management for Non-timber Values
- Passive Management or Nonmanagement
- Discouraged Harvest Practices
- Additional Resources

Silviculture

Silviculture is the art and science of tending and regenerating forests to meet human objectives. Often these objectives include growth and extraction of timber or biomass, but other common (and often concurrent) objectives are to improve wildlife habitat, enhance aesthetics, increase diversity and resilience, or protect soil and water resources. Silviculture uses controlled disturbances such as combinations of cutting, planting, burning, and herbicide (or their exclusion) to achieve these human objectives. Ideally, silvicultural prescriptions are based on practices that improve a forest's ecological function, are compatible with natural stand dynamics, conserve forest resources, promote wise use, and ensure long-term forest sustainability.

Silviculture links knowledge across many disciplines — ecology, plant physiology, soil science, hydrology, economics, recreation, and wildlife biology, among others. Consequently silviculture is an integrated discipline that merges the socioeconomic, biological, and physical sciences associated with forest change. When landowner objectives require changes to the forest vegetation, a silvicultural prescription identifies the type and sequence of actions necessary to implement those changes on the ground. Although timber production historically was the primary emphasis of silviculture, this is no longer the case.

Silviculture is the path to achieving a great variety of owner objectives associated with forest restoration, recreation, wildlife habitat improvement, carbon sequestration, soil conservation, and diversity. Although timber production may be low on the list of management objectives for many owners, revenue from timber production — when it is compatible with other owner objectives — can provide a way to finance non-timber objectives that are costly to implement but that generate no source of revenue.

Sustainable Forestry

Sustainable forestry is an evolving concept that has multiple definitions, including:

"The practice of meeting the forest resource needs and values of the present without compromising the similar capability of future generations; note that sustainable forest management involves practicing a land stewardship ethic that integrates the reforestation, managing, growing, nurturing, and harvesting of trees for useful products with the conservation of soil, air and water quality, wildlife and fish habitat, and aesthetics." (Helms 1998)

"The stewardship and use of forests and forest lands in a way, and a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality, and potential to fulfill, now and in the future, relevant ecological, economic, and social functions at local, national, and global levels, and that does not cause damage to other ecosystems; note that criteria for sustainable forestry include (1) conservation of biological diversity, (2) maintenance of productive capacity of forest ecosystems, (3) maintenance of forest ecosystem health and vitality, (4) conservation and maintenance of soil and water resources, (5) maintenance of forest contributions to global carbon cycles, (6) maintenance and enhancement of long-term multiple socioeconomic benefits to meet the needs of societies, and (7) a legal, institutional, and economic framework for forest conservation and sustainable management." (Helms 1998)

The above definitions are broad and inclusive of all forest commodities, amenities, and services. To be fully sustainable, natural resource decisions must account for environmental, social, and economic considerations. For example, forest resource practices that are unacceptable to society or that are economically intractable are considered unsustainable even if they are expected to result in ecologically desirable outcomes. The needs of society and economic considerations change over time, and the above definitions of sustainable forestry are broad enough to accommodate such changes. However, these definitions are difficult to quantify and monitor. Specific targets or thresholds to evaluate sustainability often are defined vaguely, and

most are relevant at the scale of a forest landscape or a large forest ownership rather than for an individual stand receiving a silvicultural prescription.

Sustained yield, however, is one readily quantifiable indicator of sustainable forestry that has been advocated by foresters for centuries. Sustained yield is “the achievement and maintenance in perpetuity of a high-level of annual or regular periodic output of the various renewable resources without impairment of the productivity of the land” (Helms 1998).

Sustained yield is most often used to identify maximum rates of timber harvesting. Simply stated, the periodic timber or biomass harvest should not exceed the periodic growth. However, the sustained yield concept is applicable to other resources including wildlife populations, recreation opportunities, and water yield. Success or failure in achieving sustained yield is usually measured at the landscape scale as determined by the cumulative effects of silvicultural treatments applied to dozens, hundreds, or thousands of forest stands that comprise a forest landscape or a forest ownership but can also apply to individual stands managed with uneven-aged methods. Some management objectives such as savanna or woodland restoration, insect or disease mitigation, or salvage of weather-damaged timber can result in special situations where short-term timber harvest volume must exceed the periodic timber growth in order to meet those specific management objectives.

Other quantifiable indicators of sustainable forestry that can be measured for forest landscapes or large ownerships include:

- Maintaining a stable forest land base
- Maintaining or increasing forest biodiversity
- Maintaining or enhancing diverse vertical and horizontal forest structure
- Maintaining or increasing desired wildlife habitat
- Maintaining or increasing the quality and quantity of water yield from forest ecosystems
- Maintaining or increasing forest-based employment and community stability
- Maintaining or increasing the quantity and quality of forest recreation opportunities
- Maintaining soil productivity
- Minimizing soil erosion and contamination

Silvicultural prescriptions for individual stands should be designed to support these objectives, but (with the exception of the last two) these are measured for forest landscapes or large ownerships rather than for individual stands. Tradeoffs and compromises among these objectives are inevitable, and favoring some will limit the degree to which others can be achieved.

Ecological Site Classification

Ecosystems such as forests and woodlands are strongly shaped by the biotic and abiotic factors associated with the sites in which they occur. Generally, combinations of site characteristics such as climate, geomorphology, and soils result in specific environmental conditions that can

be predictably associated with vegetation communities. The response of the plant community following management activities such as grazing, burning, or silvicultural manipulations is strongly related to the combination of environmental conditions at a given site. A deeper understanding of the relationships between site characteristics and vegetation communities can assist land managers in (1) identifying the “natural” ecological community that likely occurred on a site prior to European settlement, and (2) predicting the response of the existing plant community to specific management treatments.

Ecosystem classification is an attempt to organize and characterize ecological systems based on similar physical and environmental characteristics. However, classification systems may differ based on the scale of classification and the abiotic and biotic criteria included in the classification. Two common classification systems used in Missouri include the Ecological Classification System Project and the Terrestrial Natural Communities of Missouri (Nelson 2005).

Ecological Classification System Project in Missouri

An ongoing collaborative effort by the Missouri Department of Conservation, Natural Resource Conservation Service, USDA Forest Service, Missouri Department of Natural Resources, University of Missouri, and Southern Illinois University at Carbondale is underway to provide a robust ecological classification system (ECS) throughout the state of Missouri. The current detailed classification is based on the NRCS soils database. Regions are broadly defined using the NRCS Major Land Resource Areas (MLRAs) and are called Ecological Sections (Figure 11.1). These ecological sections are subdivided to ecological subsections (Figure 11.2).

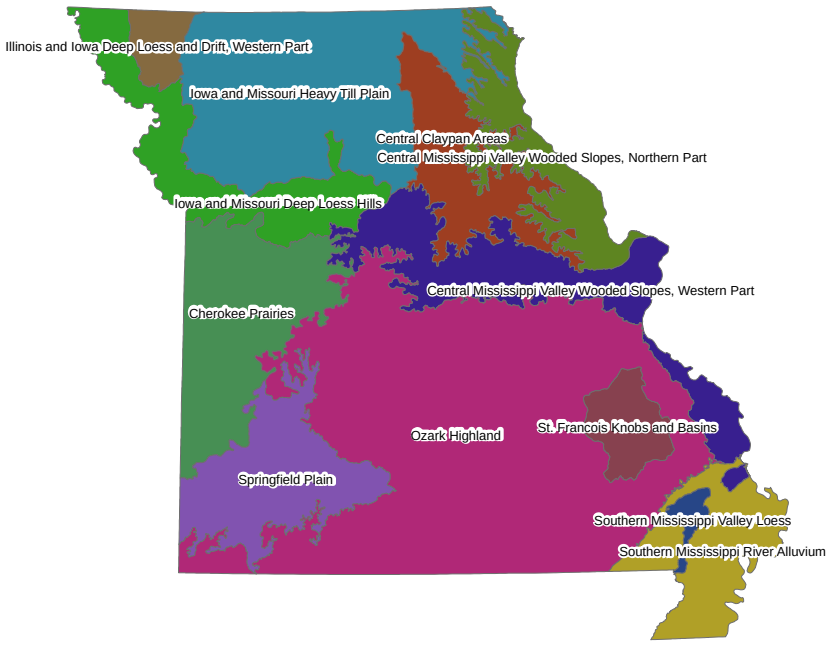


Figure 11.1. Ecological sections (major land resources areas) in Missouri.

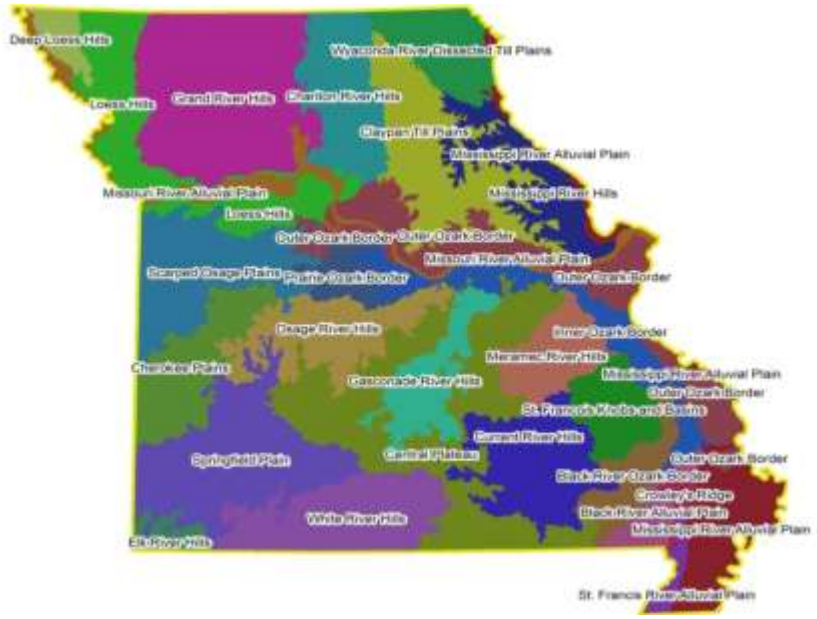


Figure 11.2. Ecological subsections for Missouri.

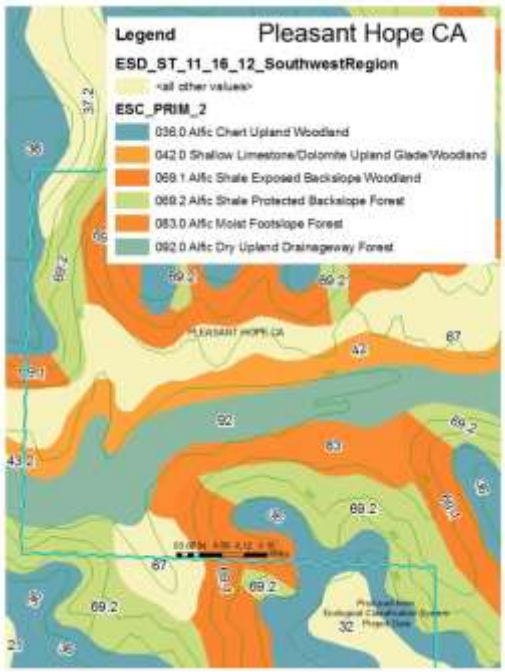


Figure 11.3. Example of an ecological sites map on Pleasant Hope Conservation Area.

The ecological subsections are subdivided into what are known as ecological sites (Figure 11.3). An ecological site is a distinctive land area capable of producing certain ecological communities. This unit of land is characterized by specific soil and physical characteristics that differ from other land areas in their ability to produce distinctive vegetative communities that display certain stand structure, composition, production, and ability to respond similarly to management actions and natural disturbances. Unlike vegetation classification, ecological site classification uses climate, soil, geomorphology, hydrology, and vegetation information to describe the ecological potential of land areas.

The ecological site level is where forest management in Missouri will primarily be applied, which is essentially the stand level or smaller.

For each ecological site there is an ecological site description which describes the ecological site and its potential pre-settlement vegetation community. Also included in the ecological site descriptions are state and transition models, which will allow managers to determine what vegetative state a certain land area may fall in and will aid in management decisions to transition one vegetative state to another.

More info on the ecological classification system is available from the Web Soil Survey, websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx.

Please note this project is ongoing and still in the early stages of development. For more information on ECS contact the Columbia regional office at 573-815-7900.

Terrestrial Natural Communities of Missouri

Using many of the same conceptual relationships among climate, soils, and geomorphology, *The Terrestrial Natural Communities of Missouri* (Nelson 2005) provides another system of classification for the plant communities in the state. In this system, Nelson (2005) provides descriptions of vegetation and community structure to first identify the major natural community type as forest, woodland, savanna, prairie, glade, cliff/talus, stream edge, wetland, or cave.

Within each of those broad categories of natural community type, characteristics of the hydrology, landform, soils, parent material, and vegetation structure are used to further refine the natural community type. The resulting classification includes the natural community type that is then generally modified by a soil moisture description and a description of the substrate (e.g., Mesic Sand Forest). For each natural community, Nelson (2005) provides a description of the vegetation, including dominant plants, characteristic plants, restricted plants, and associated natural communities. He provides additional information on the physical characterization where each community is expected to be found, as well as natural processes, threats, and management considerations for the natural communities.

Planning: Identifying Your Goals and Objectives

A forest management plan considers the entire forest estate, which may range from tens to millions of acres. It identifies the broad goals and objectives of the landowner and guides management activities done at finer spatial and temporal scales. In practice, forest operations occur at the stand-scale (i.e., usually < 100 acres); this is where silviculture is practiced. A recent exception is in the restoration of fire-dependent communities such as woodlands and savannas where prescribed burning may be applied across landscapes of thousands of acres. But even in large-scale restoration projects there are smaller areas that require silvicultural treatments such as thinning and mid-story reduction to complete the restoration of glades and fens.

Also, smaller areas within the greater restoration area may need to be treated differently in order to create a diverse mosaic of stand composition and density represented as hardwood or conifer savannas, woodlands, and forests.

Regardless of landowner objectives, good resource management requires that good silviculture be practiced; the details of which should be articulated in a forest management plan (see Chapter 10).

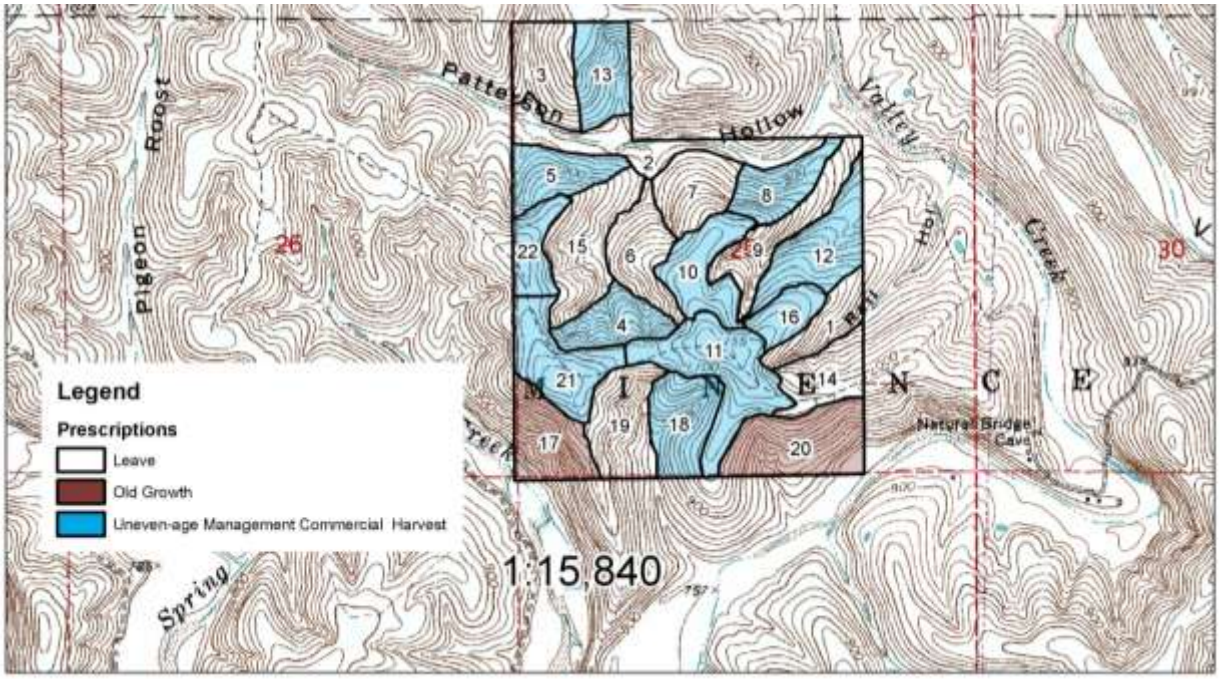


Figure 11.4. This forest management plan prescription map depicts the location and type of treatment.

Silvicultural Treatments

Silvicultural treatments are used to regenerate forests or manage stand development in both structure and composition within existing stands. Treatments are traditionally applied to a stand,

which is a contiguous area of forest sufficiently uniform in species composition and structure to be a distinguishable unit.

Single-tree and group selection regeneration methods produce uneven-aged stands. This is accomplished through periodic entries that harvest some of the trees within the stand. The objective is to create at least three distinct age classes, or cohorts, of trees intermingled throughout the stand.

The clear-cutting, shelterwood, and seed-tree regeneration methods are used to create even-aged stands, in which trees are of a single age class, or cohort, and the range in age does not exceed 20 percent of the rotation. The rotation is the period of time an even-aged stand is allowed to grow until it is regenerated again.

Tending treatments (see Chapter 13 for more details) may be done in conjunction with the regeneration harvest, as in the uneven-aged system, or at various times between regeneration events in the even-aged system. In tending a forest stand, some trees are deliberately removed to achieve specific responses from remaining trees, resulting in planned changed to stand character.

Tending treatments are named according to the intended purpose or stage of stand development. For example, (1) thinning is done to reduce stand density and increase growth (e.g., bole diameter or crown size) of residual trees; (2) release cuttings are applied to young cohorts to release seedlings from competing vegetation (weeding), to free saplings from overtopping undesirable competing trees of the same age (cleaning) or to release them from overtopping older trees (liberation); (3) pruning removes branches to improve future tree grade and log quality; (4) sanitation cutting reduces the threat of insect and disease pests by improving tree health and vigor; and (5) salvage harvesting recovers dead or dying trees after insect or disease outbreaks, or wildfire.

Silvicultural Systems

A silvicultural system is a comprehensive program of planned treatments including regeneration and tending that are designed to manage a forest stand through its life. The name is derived from the number of age classes (e.g., even- or uneven-aged) or the regeneration method (e.g., clear-cutting, shelterwood, selection, etc.)

A silvicultural prescription outlines for each stand the timing and sequence of all treatments in the silvicultural system, including the specific regeneration method and tending treatments needed to carry the stand from its existing condition to the desired future condition that meets the needs of the landowner.

Development of the silvicultural prescription for a stand is based on the assessment of the current stand and site conditions, and consideration of any expected problems from insect and disease pests, damaging wildlife (i.e., white-tailed deer browsing), invasive species, and other

factors. The prescription is the final result of a thorough evaluation of how well each of a set of alternative silvicultural systems achieves the management objectives, and it identifies the preferred system in light of social, economic, and ecological constraints and opportunities. The prescription also identifies the type and timing of activities needed to meet other resource objectives listed in the management plan, for example, reduce fire risk, retain trees and coarse woody debris for wildlife habitat, sustain native biodiversity, protect culturally sensitive sites, mitigate soil erosion, or maintain an ecological legacy from the previous stand.

Normally, there are multiple objectives that are achieved through implementation of each silvicultural treatment. The stand prescription provides quantitative benchmarks at various key stages in stand development, benchmarks that must exist for the outcomes of silvicultural treatments to be desirable and sustainable. Stands should be examined after treatment using appropriate sampling methods to determine if benchmarks have been met.

Regeneration Methods

A brief review of the common regeneration methods used in Missouri will provide an understanding for the discussions of specific silvicultural systems and their relationship to achieving other resource objectives.

Even-Aged Regeneration Methods

The following methods regenerate even-aged stands.

Clear-cutting removes the entire stand in one operation. Some trees may be left in the clear-cut to achieve goals other than regeneration, but their density is not enough to inhibit the development of reproduction; generally, less than 10 square feet per acre of basal area would be retained. Natural reproduction is by seeding from adjacent stands and harvested trees, advance reproduction (seedlings or saplings in the understory before harvesting), stump sprouts (shoots arising from stumps of harvested trees), and root suckers (shoots arising from tree roots).

Generally, species require rapid early growth to be able to successfully compete when establishing from seed in clear-cut conditions, because they are likely to be competing with individuals that originate as sprouts or advance regeneration. Artificial regeneration can also be used by direct seeding or planting before — or more commonly after — clear-cutting.

Forest Certification Note

When working on forest land that is enrolled in a forest certification system, it is important to know and understand the standards that apply to that program and how to implement them. Some forest certification systems have very specific guidelines concerning clear-cutting, while other systems have no specific policy concerning clear-cuts.

Seed-tree harvesting is similar to clear-cutting except that a small number of mature trees are left singly or in groups throughout the harvested area to supply seed for natural regeneration.

The residual crown cover of seed trees does not modify the physical environment significantly from that which occurs in clear-cuts. This system can be applied for species where natural regeneration may be limited by the availability of seed. In Missouri, this method can be used to regenerate shortleaf pine, provided that conditions of the seedbed are suitable for germination and the regeneration grows quickly after establishment.

Shelterwood harvest removes the overstory in a series of harvests that are conducted over a relatively short portion of the rotation with the goal of retaining a good number of seed producers to naturally regenerate the stand and enough residual overstory to shelter both newly established seedlings and existing advance reproduction from environmental extremes. The shelterwood is generally retained for less than 20 percent of the rotation; for example, less than 20 years for a 100-year rotation.

Harvesting is usually done from below (i.e., trees in the smaller diameter classes and lower crown classes are removed first), leaving the prescribed stocking of co-dominant and dominant trees of desirable species. The shelterwood is removed in a final harvest once sufficient numbers of competitive stems of reproduction are established. The shelterwood system can be applied uniformly across the stand (uniform shelterwood) or in patterns such as groups (group shelterwood) or strips (strip shelterwood). The shelterwood method may consist of three harvests:

(1) Preparatory cut removes the seed source of undesirable species and the low-quality individuals and promotes the crown expansion of seed trees. It is not necessary if the existing stand has adequate seed production potential or advance reproduction is present.

(2) Seed or establishment cut further reduces canopy closure in — or just before — a seed year, provides opportunities for site preparation before seed fall, and creates environmental conditions that favor germination, seedling establishment, and enhanced growth of advance reproduction.

(3) Removal cut harvests the residual overstory to release well-established reproduction.

Artificial Regeneration and Even-Aged Methods

The common silvicultural systems described above were designed to address the requirements for natural regeneration but can also be used in conjunction with artificial regeneration. For example, planting oak seedlings in shelterwood stands can be a good approach for introducing oak regeneration to a site on which it is absent.

However, because artificial regeneration initiates the establishment of individuals, the aspects of a silvicultural system that affect seed production or dispersal are not necessary for the target species. For this reason, artificial regeneration is most often used following clear-cutting, but it can also be used with other silvicultural systems that retain the canopy and moderate the

growing conditions for the regeneration. It is important to consider the effects of the other trees in the stand on the regeneration of competing or undesirable vegetation.

Two-Aged Methods

A portion of the shelterwood may be retained for longer than 20 percent of the rotation for purposes other than regeneration, such as sustaining mast production, aesthetics, and structure for wildlife habitat. This silvicultural approach is sometimes referred to as a shelterwood with reserves, which is often used to create a two-aged stand.

Another noted benefit of retaining an older age class is that it may allow for the development of large sawtimber or veneer trees. If the older age class attains higher product value by the time the younger age class is ready for tending, a timber sale to harvest all or a portion of the older cohort can help financially justify an operation to tend the younger age class. In addition, a single harvest entry may yield a wide range of wood products from pulpwood to sawtimber or veneer. Drawbacks to managing two-aged stands are slower development of the younger age class and potential for damage to the younger age class during harvest of the older class.

Uneven-Aged Regeneration Methods

The following methods regenerate uneven-aged stands.

Single-tree selection is when individual trees are harvested indefinitely on a periodic cutting cycle that may be 5–25 years long (Figures 11.5–6). Both regeneration and tending take place simultaneously in each harvest. Trees are considered for removal from all diameter classes in the stand to establish reproduction and to allow existing trees in all size classes to recruit into larger size classes. Selection of individual trees for removal is also influenced by the quality, vigor, and growing space requirements of the tree and by considerations for wildlife habitat.

Regeneration is largely from natural seedfall, existing advance reproduction, or stump sprouts and root suckers that develop after harvesting. Single-tree selection is generally most appropriate for shade-tolerant species such as sugar maple that can become established beneath an existing canopy, although it has been used successfully for regenerating oak species in the Ozarks where oak is more successionally stable. With single-tree selection, regeneration is a continuous process, and the individuals that accumulate as advance regeneration are gradually recruited to the canopy following the removal of individual canopy trees.

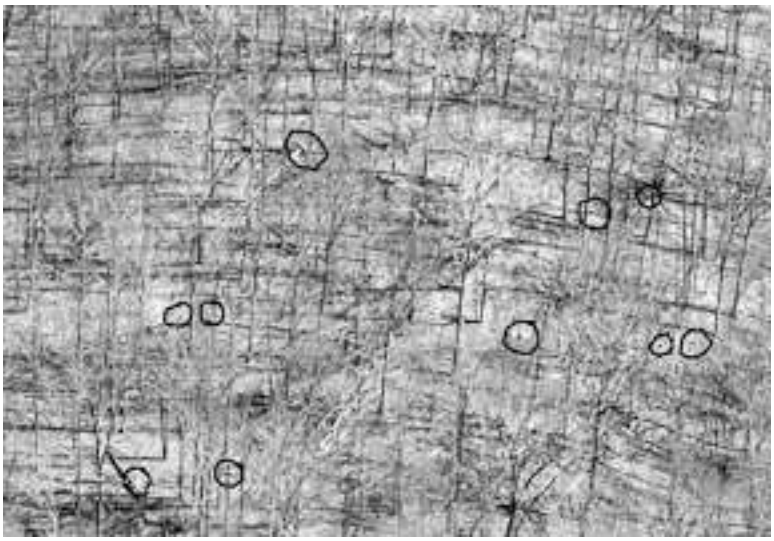


Figure 11.5. View of an approximate one-acre area of Pioneer Forest, Shannon County, where stumps from individually selected and harvested trees have been circled. (Photo by Dale Dufer; taken from Guldin et al. 2008.)

Figure 11.6a. Before harvest from a single-tree selection harvest on Pioneer Forest. (Photo courtesy Pioneer Forest.)

Figure 11.6b. After harvest from a single-tree selection harvest on Pioneer Forest. (Photo courtesy Pioneer Forest.)

Group selection is used to regenerate trees in small patches in which all trees are cut, creating openings that are larger than single-tree gaps but smaller than clear-cuts (Figure 11.7). Group openings vary in size depending on the requirements of the desired species for regeneration, but commonly their opening diameter is twice the height (e.g., about 125–250 feet) of adjacent mature trees (about 0.2–1.1 acres). The abundance and size of advance reproduction largely determines what reproduction will dominate forest openings, but when it is small, sparse, or absent, then regeneration is from seed. Group openings are often located where abundant advance reproduction occurs in patches within the stand.

Stand prescriptions for either single-tree or group selection are guided by the goal of uneven-aged management to maintain a specified stand structure that sustainably yields a flow of products. In single-tree selection, the intensity and frequency of harvesting and the selection of trees for removal is determined by growth rate, target basal area, maximum tree diameter, and diameter distribution. In a stand or management unit, the area harvested by group selection is often regulated by area control and the length of the rotation. Practically, single-tree and group selections are applied together in a stand, with group openings being opportunistically used to increase forest diversity by favoring species that are intermediately tolerant to intolerant of shade.

Figure 11.7. Aerial view of group selection harvest. (MOFEP Randy Jensen.)

Fire and Silviculture

The silviculture required for regenerating and tending forests has been studied extensively for decades in North America and for centuries in parts of Europe. In the United States, the concept of sustained yield (defined earlier in this chapter) was an important factor influencing the development of silvicultural practices. Consequently, the optimization of biomass or timber production was usually the most important forest management objective during much of the 20th century. During this time, wildfire was identified by federal and state agencies as one of the most damaging agents to timber quality. Consequently, campaigns were waged by forestry agencies to prevent forest fires.

During the latter part of the 20th century, the importance of prescribed fire as a silvicultural tool was increasingly being recognized. In the western United States, prescribed fire was used to reduce fuel loading and stand density to ultimately protect against catastrophic wildfires. In the South , fire was increasingly used after timber harvesting as a tool for preparing the site for planting. In the East, fire was applied to mesic hardwood forests during the regeneration process to favor oaks. In the oak forests of the central United States, fire was increasingly being used to restore the structure and diversity of woodlands and savannas.

Woodlands

Woodlands are natural communities that are typically distinguished from forest communities by their site, vegetation, structure, and composition. Generally, woodlands are characterized by open to nearly closed canopies of overstory trees, relatively sparse mid-story and understory layers, and dense, species-rich ground layer plant communities dominated by forbs, sedges, and grasses. In contrast to forest natural communities, the dominant and co-dominant trees in the canopy of woodlands often have large spreading crowns. Shrubs, saplings, and small trees may be present but generally are much less abundant than in a mature forest. The relatively

open canopy and mid-story of woodlands allows sunlight to reach the ground to support a species-rich layer of light-demanding plants that may be present but seldom are abundant in closed-canopy forests.

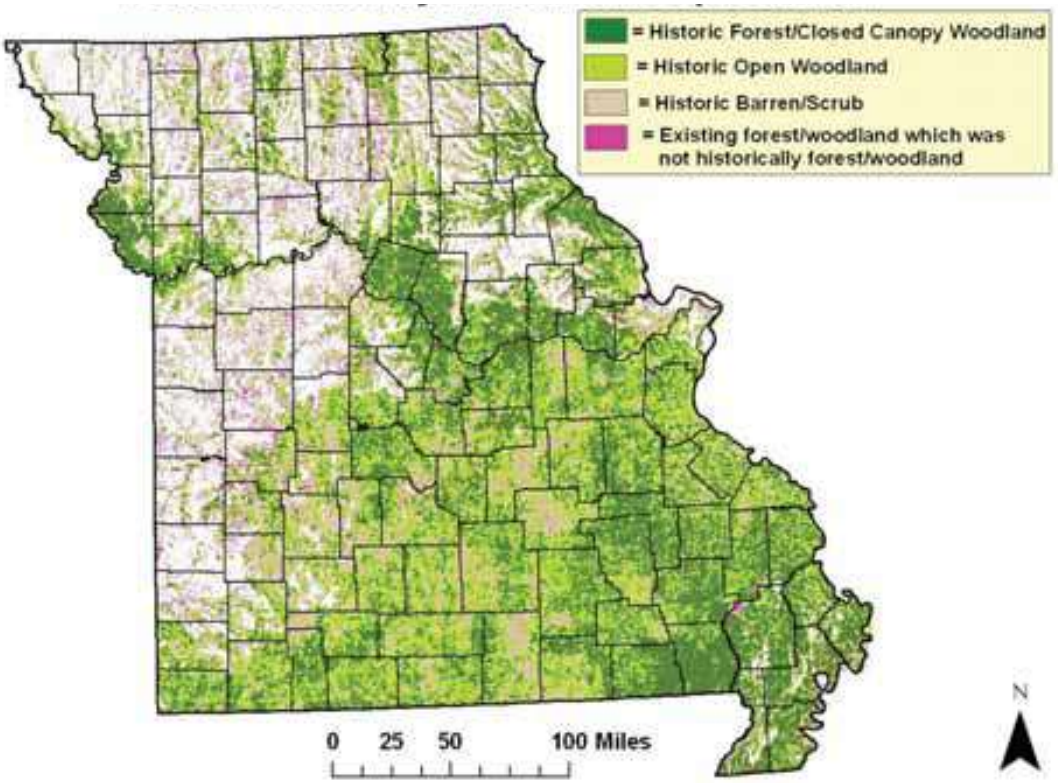


Figure 11.8 Historic forest and woodland cover map. (National Land Cover Database — 2001; Historic Vegetation Map — Geographic Resources Center, Department of Geography, University of Missouri.)

Oaks and hickories are the dominant hardwood tree species of many woodlands and often occur in association with pines. Numerous ground flora species are considered woodland indicators (see Table 11.1), particularly graminoids, sedges, and bush clovers (*Lespedeza*), goldenrods (*Solidago*), and asters (*Symphyotrichum*). Most of the woodland indicator species are herbaceous plants that produce flowers and seeds during the summer months and are adapted to ecosystems where light penetration is relatively high. These species, often associated with prairie and savanna ecosystems, suggest that stand density has remained sufficiently low to allow sunlight to reach the ground vegetation.

Table 11.1 List of Characteristic Woodland Plant Species

Latin name	Common name	Latin name	Common name
Amorpha canescens	Lead Plant	*Listris squarrosa*	Scaly Blazing Star

Andropogon gerardii	Big Bluestem	*Lithospermum cansecens*	Hoary Puccoon
Asclepias purpurascens	Purple Milkweed	*Monarda bradburiana*	Bradbury Bee Balm
Asclepias quadrifolia	Four-Leaved Milkweed	*Orbexilum pedunculatum*	Sampson's Snakeroot
Aureolaria grandiflora	Yellow False Foxglove	*Oxalis violacea*	Violet Wood Sorrel
Baptisia bracteata	Cream Wild Indigo	*Parthenium integrifolium*	Wild Quinine
Blephilia ciliata	Ohio Horse Mint	*Phlox pilosa*	Prairie Phlox
Carex muhlenbergii	Sand Sedge	*Pycnanthemum albescens*	White mountain mint
Ceanothus americanus	New Jersey Tea	*Pycnanthemum tenuifolium*	Slender Mountain Mint
Clitoria mariana	Butterfly Pea	*Schizachyrium scoparium*	Little Bluestem
Comandra umbellata	False Toadflax	*Silene regia*	Royal Catchfly
Coreopsis palmata	Prairie Coreopsis	*Silene stellata*	Starry Campion
Cunila origanoides	Dittany	*Silphium integrifolium*	Rosinweed
Dalea purpurea	Purple Prairie Clover	*Solidago hispida*	White Goldenrod
Desmodium rotundifolium	Round-Leaved Tick Trefoil	*Solidago petiolaris*	Downy Goldenrod
Dichanthelium laxiflorum	Lax-Flowered Panic Grass	*Solidago radula*	Rough Goldenrod
Echinacea pallida	Pale Purple Coneflower	*Solidago speciosa*	Showy Goldenrod
Eryngium yuccifolium	Rattlesnake Master	*Solidago ulmifolia*	Elm-Leaved Goldenrod
Eupatorium purpureum	Purple Joe Pye Weed	*Sorghastrum nutans*	Indian Grass
Euphorbia corollata	Flowering Spurge	*Symphiotrichum anomalum*	Blue Aster
Gentiana puberulenta	Downy Gentian	*Symphiotrichum oolentangiense*	Azure Aster
Gillenia stipulata	American Ipecac	*Symphiotrichum patens*	Spreading Aster
Helianthus hirsutus	Oblong Sunflower	*Symphiotrichum turbinellum*	Prairie Aster

Ionactis linearriifolia	Flax-Leaved Aster	*Taenidia integerrima*	Yellow Pimpernel
Lespedeza hirta	Hairy Bush Clover	*Tephrosia virginiana*	Goat's Rue
Lespedeza procumbens	Trailing Bush Clover	*Verbesina helianthoides*	Wing-Stem
Lespedeza virginica	Slender Bush Clover	*Veronicastrum virginicum*	Culver's Root
Liatris aspera	Rough Blazing Star	*Viola pedata*	Bird's Foot Violet

Frequent, low-intensity surface fire is thought to have played an important role in shaping the composition of woodlands. Oaks and hickories can persist in association with low-intensity fires because the cotyledons of oak and hickory seedlings remain belowground; if top-killed by fire, the cotyledons remain protected and provide some of the nourishment needed to resprout and remain in the stand. Oak seedlings also establish a large root system at the expense of early shoot growth. This larger root system enables oak seedlings to resprout readily after being top-killed.

In contrast, maples are disfavored by fire; their cotyledons emerge aboveground and will perish if the seedling is top-killed by a surface fire. Maples also allocate more energy into shoot growth at the expense of root growth and have thinner bark, leaving them more vulnerable to mortality following top-kill.

Grasses, sedges, forbs, and other herbaceous vegetation are also favored by fire compared to vines, shrubs, and other woody vegetation that lose a considerable proportion of their energy reserves if their aboveground tissue is consumed.

Fire was also thought to have played an important role in reducing stand density and altering forest structure. Shrubs and other small-diameter trees are particularly susceptible to top-kill by fire, and frequent low-intensity fire is thought to have maintained the density of the mid-story and understory layers. Surface fire also removes some or all of the leaf litter that can inhibit the germination of many species of grasses, sedges, and forbs. Fire history studies have documented the wide variation in the fire-return interval during the past few hundred years. This wide variation in fire-return interval is thought to have greatly influenced woodland dynamics. Tree regeneration and recruitment most likely occurred during fire-free periods.

In addition to fire, disturbances such as wind, drought, ice storms, insects, and disease also periodically affected woodlands by reducing their density or by altering their species composition. As in forests, these disturbances historically contributed to regeneration and stand development patterns. Also, herbivore grazing undoubtedly historically affected woodland structure and composition. However, there presently is very little information about how these disturbances shaped woodland character in the past.

Site quality also affects woodland composition and structure and influences the contemporary distribution of woodlands on Missouri landscapes. Dry and nutrient-deficient sites support fewer plant species and a lower shrub and understory density than rich sites. The tree and shrub species that are adapted to these site conditions also produce litter that dries rapidly and decomposes slowly, allowing them to burn readily. The lower site quality causes trees and shrubs to grow more slowly so that their canopies remain open for longer time periods following disturbance.

Even in the absence of disturbances, the lower shrub and understory densities allow many of the light-demanding woodland ground flora to persist in the understory. Because of this effect of site quality on natural succession, communities with structural and compositional elements of woodlands are often found on low-quality sites, which also happen to be poor timber producing sites. Therefore, site classification systems are essential for identifying where site conditions favor the management of woodlands and for predicting how they will respond to management.

Woodlands and Silviculture

Much like forests, woodlands must be managed to sustain their structure and biodiversity and to ensure desirable distribution of woody and herbaceous vegetation in the future. Where woodlands are left unmanaged, a dense mid- and understory eventually develops and the overall tree density and canopy cover increases. In addition to the increasing shade caused by the increased density and canopy closure, the absence of fire allows a thick layer of leaves to accumulate. Succession to a more shade-tolerant mix of vegetation may occur, particularly in woodlands of moderate to high site quality.

Generally, the amount of management required to maintain woodland conditions increases with site quality. If left unmanaged for long time periods, these successional changes may become irreversible due to losses of woodland sedges and grasses and to the additions of shrubs and woody plants that change the nature of the fuels and the response to fire.

Many silvicultural concepts, principles, and methods used for managing forests can also be used for managing woodlands. However, the application and timing of treatments may differ to meet the objectives of woodland management. Woodland management objectives emphasize conserving the native biodiversity and providing a habitat rather than maximizing the production of the highest quality wood products.

Two important silvicultural treatments for tending woodlands include thinning and prescribed fire. Each is applied at the appropriate frequency in order to retain a smaller number of large trees in the overstory, to reduce the number of trees and shrubs in the mid- and understory, to consume some of the seedlings and leaf litter, and to promote the diversity of forbs, sedges, and grasses in the ground layer.

Thinning and prescribed fires may be applied differently in woodlands managed for biodiversity than in forests managed for timber production. In forests, thinning operations are done to

improve the quality of the timber and to accelerate the growth of the remaining trees. Although thinning also accelerates the growth of the residual trees in woodlands, it is done primarily to alter stand structure and increase the amount of sunlight reaching the ground to favor light-demanding plant species. In forests, prescribed fire is also used but primarily as a regeneration tool to favor the accumulation of fire-adapted tree seedlings. Where timber quality is a concern, the application of prescribed fire is generally limited to a short time period prior to or after a regeneration harvest in order to favor the desirable species. Fire is excluded from the stand during later tending operations to prevent damage to future timber trees.

In woodlands, prescribed fire is used as a tending tool to periodically reduce seedling and sapling density, remove leaf litter, and alter species composition. When using a combination of thinning and prescribed fire for managing woodlands, an important consideration is the increase in fuel loading from harvest residues following a thinning, which can increase fire intensity and potentially kill larger trees that are necessary for woodland structure. However, a high intensity burn may also cause greater mortality of competitive understory woody vegetation.

Many of the state's woodlands have not been managed for many years. Consequently, a management priority is to restore woodland structure, composition, and function. Once the structure, composition, and function have been restored, it is necessary to plan for regenerating some of the trees in the woodland community. This need arises because some of the trees will succumb to competition-induced mortality as they mature, and others will die of old age or indirectly of injuries suffered through woodland management. In addition, many woodlands are also capable of producing low- to moderate-grade sawlogs, ties, and blocking material, and the periodic harvest and sale of timber can be used to offset woodland management costs. Therefore, a comprehensive management system for woodlands requires a plan for restoring, tending, and regenerating trees.

A silvicultural system is a comprehensive plan tending and regenerating a stand of trees. Presently, there are no well-defined silvicultural systems that include a planned series of treatments for regenerating and tending woodlands. Nonetheless, important silvicultural principles and tools for managing woodlands are discussed below.

Regeneration and Tending Methods Applicable to Woodlands

Although specific research on regenerating and tending woodlands is limited, most of the regeneration and tending methods used in forest management can be applied to woodlands. For example, trees in woodlands can be regenerated with the clear-cut, seed-tree, or shelterwood method and can be tended with thinning and prescribed burning in even-aged systems or regenerated with the group selection methods and tended with thinning in uneven-aged systems. However, these regeneration and tending methods may be applied differently in woodlands than in forests. For example, retaining residual stocking with reserve trees may be more preferable for regenerating woodlands than forests. This residual overstory provides habitat and provides partial shade to reduce the density of regeneration that develops after harvesting. Applying two-aged methods — where reserves comprise more than 20 percent of

the pre-harvest basal area in dominant or co-dominant trees — will reduce the intense shading of the ground flora layer by woody vegetation developing in the regeneration layer.

During the regeneration phase in woodlands, prescribed fire should be excluded until a portion of the reproduction cohort is sufficiently large to escape being top-killed by fire's reintroduction. The fire-free interval should be at least 10 years to allow some trees to recruit into the overstory, so as to ensure that the stand will maintain a woodland character in the future. If producing marketable timber is also an objective, the fire-free interval may need to be 30 years or longer to allow a small number of trees (about 20–30 trees per acre) to become large enough to not be severely damaged by prescribed fire. These 20–30 trees can be treated as the future timber crop and eventually harvested to offset some of the costs of implementing woodland management treatments. After the regeneration phase, care must be practiced when reintroducing prescribed burning in order to prevent the mortality of the desired trees or to minimize damage to the future timber crop.

Because of uncertainty in fire behavior, the concept of area regulation is useful for managing woodlands. With area regulation, specific stands or land units of the woodland are selected for regeneration or tending. For those selected for regeneration, prescribed fire can be excluded from stands or land units with fire lines, roads, or natural fire breaks to protect the seedlings and to allow for recruitment. After a sufficient number of trees have been recruited and are no longer in danger of being top-killed or severely damaged, fire can be reintroduced along with other tending methods. Area regulation can be applied with even-aged regeneration methods and with the uneven-aged group selection method. In contrast, it may be exceptionally difficult to ensure adequate recruitment in woodlands using single-tree selection because this method creates a mix of tree sizes all within a small area, making it nearly impossible to protect seedlings and small trees from being top-killed by fire.

Most of the tending activities are to reduce stand density and increase the amount of sunlight reaching the ground. For tending activities in woodlands, stocking charts and diameter distributions provide quantitative benchmarks for managing woodland structure. Woodland stocking is generally managed to be lower than that of most forests (Figures 11.9-10). For managing open woodlands, stocking levels lower than B level are preferred; and for managing closed woodlands, stocking levels at or slightly above B level are preferred. Thinning from below until the stocking goal is met is more likely to create the diameter distribution characterized by frequent, low-intensity fire (Figure 11.11).

Longer rotations may be used in woodlands than in forests. Rotations of 100 years are commonly used in hardwood forest management for optimizing the sustained production of timber. However, a longer rotation can be used for managing long-lived species where timber production is not a primary objective. Extending the rotation means that woodlands can be maintained in a mature state and tended with prescribed fire for a longer proportion of the rotation. It also means that at any point in time, the land area in the regeneration phase can be smaller.

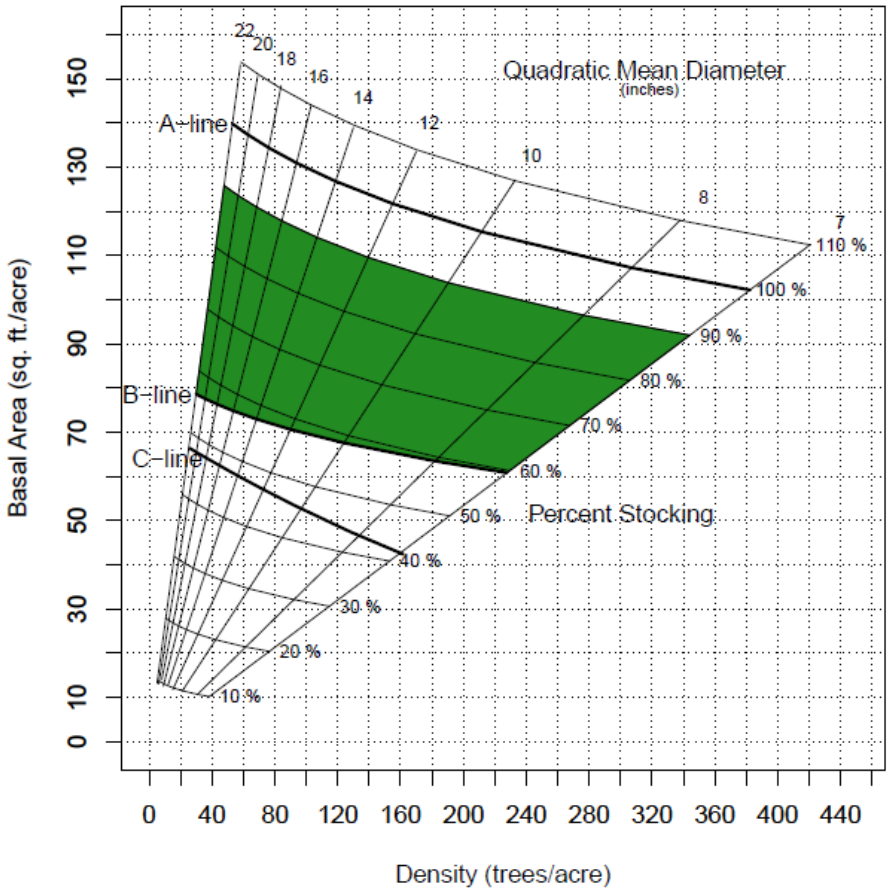
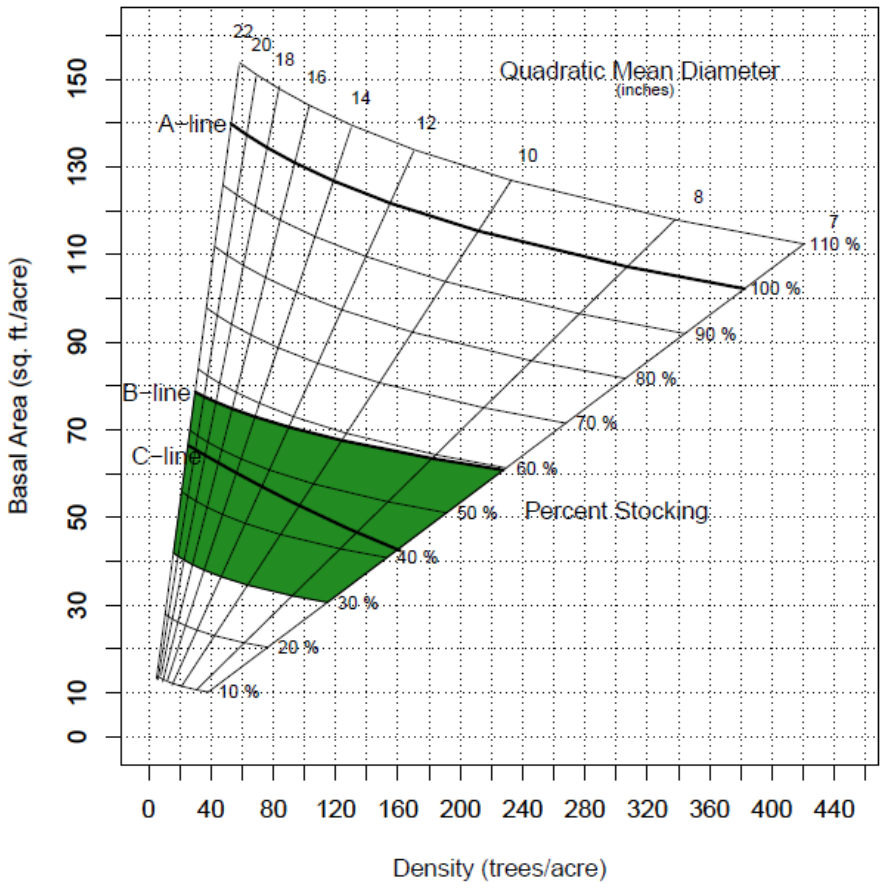


Figure 11.9. Gingrich (1967) stocking chart for oaks and hickories where the quadratic mean diameter at breast height is > 7 inches. Stocking at the A line (100 percent stocking) represents the average maximum density that occurs in the absence of management treatments. The B line (56 to 58 percent) is the stocking at which all of the growing space is being occupied by trees, below which the stand will have large gaps in the canopy. On average, it takes 10 years for a stand of trees to increase in stocking from the C line to the B line. The stocking chart provides biologically meaningful density thresholds for managing forests and woodlands. Forests are typically tended between the A and the B line unless they are being regenerated. Closed woodlands are tended between the B line and to greater stocking levels below the A line (shaded area).



3734

3735 **Figure 11.10. Gingrich (1967) stocking chart for oaks and hickories where the quadratic mean diameter at**
3736 **breast height is > 7 inches. Open woodlands are tended below the B line but at greater than 30 percent**
3737 **stocking (shaded area), the point at which the structure and composition begins to resemble that of a**
3738 **savanna. For regenerating forests and woodlands, stocking is reduced below the B line.**

Effect of Burning and Thinning on Diameter Distributions of Woodlands

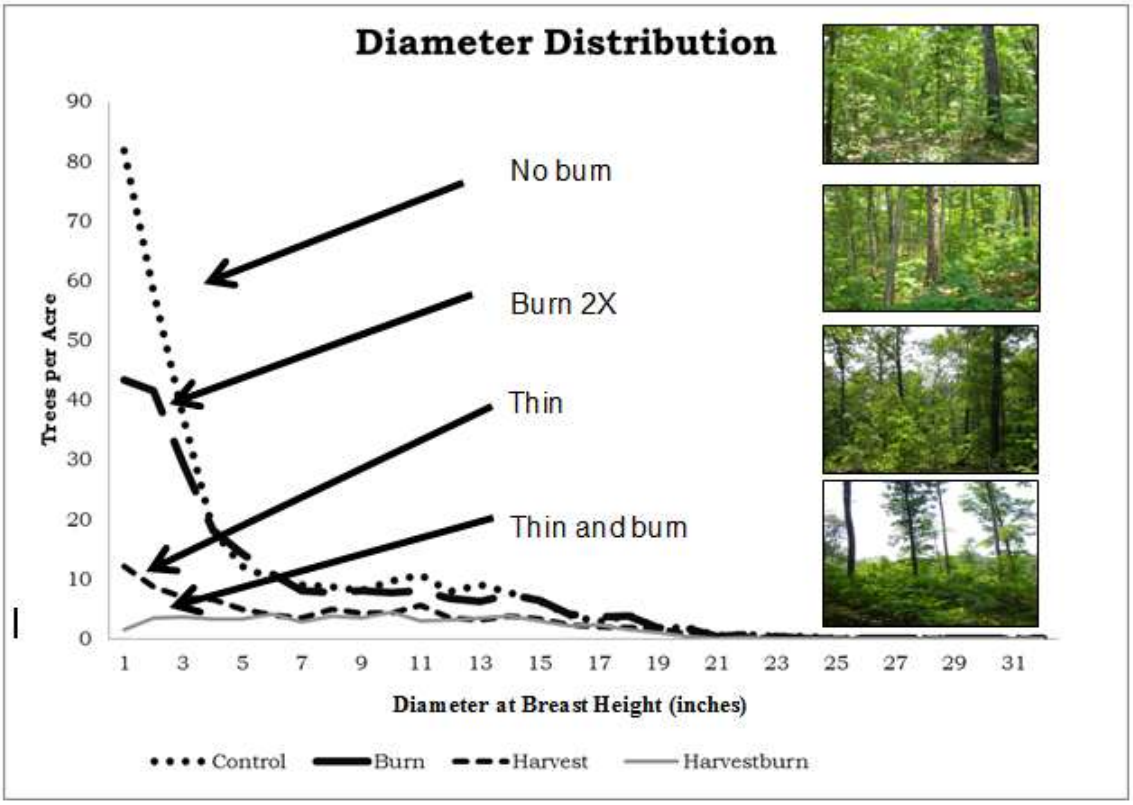


Figure 11.11. Prescribed fire reduces the density of the smaller-diameter trees, generally those smaller than 4 inches diameter at breast height. Greater reductions in stand density can be achieved by thinning where specific size classes of trees can be targeted for removal.

Salvage Harvest

The objective of a salvage harvest is to capture volume and value dead trees or of damaged or high-risk trees that may die in the near future. This volume and value would be lost if the stand was left to naturally decline and decay. The use of a salvage harvest can result from a wide range of disturbances including insect and disease outbreaks, wildfire, wind storms, ice damage, and flooding.

A widespread forest health issue impacting Missouri's forests, especially mature red oak–dominated stands of the Ozarks, is oak decline. Salvage harvesting is a commonly used practice for harvesting these dead or dying red oaks before they suffer additional volume and value loss from decaying in the woods. Widespread white oak decline has also been experienced throughout the state of Missouri and has led to common salvage harvesting of that species.

Forest disturbance is a natural process that occurs throughout the life of the stand. These disturbances create unique habitat that is beneficial to some organisms. There are several factors that need to be considered before conducting a salvage harvest operation.

- Does the increase in fuel loading from the disturbance create a serious wildfire threat?
- What is the potential for insect and disease outbreaks to occur?
- Is there enough product for the operation to be economically feasible?
- Is mortality significant enough to warrant the use of a regeneration method?
- Does the harvest need to be conducted as a sanitation to decrease the threat to adjacent stands

Figure 11.12. Aerial photo showing timber damaged by a wind storm. This timber was harvested through a salvage operation to ensure forest health and capture economic value.

Low-Intensity Management for Non-timber Values

Low-intensity silviculture practices may be appropriate to achieve landowner objectives addressing non-timber values, such as aesthetics, recreation, and conservation. This might include spot treatment of nonnative invasive plant species using herbicides, felling of hazard trees and snags near hiking trails, and thinning from below to open up natural canopy gaps to regenerate shade-intolerant tree species (e.g., oak species and shortleaf pine) either naturally and/or artificially through enrichment planting. A regime of low-intensity management would be appropriate within state and federal designated natural areas or similar sites where natural community conservation is the objective. For example, selective felling of overstory trees, either as scattered individuals or groups in a manner similar to single-tree or group selection respectively, could help to sustain natural communities characterized by a small-scale disturbances and subsequent gap dynamics.

Passive Management or Nonmanagement

Passive management is the processes of letting nature take its course. This is not a silvicultural system because the forest is not actively being managed. The objectives for using passive management vary, but could include areas where it would not be not economically viable for management (access, distance to market, lack of products, etc.), residential areas, recreation areas, or regulated primitive areas such as federally designated wilderness, where management activities are not socially acceptable. It could also include isolated natural communities such as cliffs where it is not biologically viable due to site considerations.

Agroforestry

Agroforestry is the intentional mixing of trees with crop and/or animal production systems to create economic, environmental, and social benefits. For a land-use practice to be called agroforestry, it typically must satisfy the four "i's": intentional, intensive, integrated, and interactive. There are five widely recognized categories of agroforestry practices in the United States:

1. Field, farmstead, and livestock windbreaks
2. Riparian and upland buffers that act as sponges and filters to protect water quality
3. Silvopastoral systems with trees, livestock, and forages growing together
4. Alley cropping, which integrates annual or perennial crops with high-value trees and shrubs
5. Forest farming where food, herbal (botanicals), and decorative products are grown under the protection of a managed forest canopy.

Anecdotal evidence suggests that America is losing some of its hardest "working trees" in agricultural landscapes. Recent high-crop and agricultural land prices, driven by the demand for biofuels and exports, have provided incentives for farmers to remove windbreaks and riparian buffers and expand the acreage of row-crop agriculture. Tree-based buffers, well designed and strategically placed, will support sustainable agricultural production by reducing soil erosion and nutrient runoff and conserving natural resources such as water and wildlife. These buffers also can do "double duty" when they are designed to produce economically valuable products (e.g., elderberry or "woody florals").

On smaller farms, unable to compete in large commodity markets, agroforestry may provide opportunities to produce specialty crops and livestock that can help make these operations profitable, while providing jobs and increasing wealth in rural communities. The public is demanding more food from local and regional systems, as evidenced by the increase in farmers markets. Agroforestry can be part of the means for our working lands to sustainably produce the food and other products that are likely to be demanded by local and regional markets.

The Center for Agroforestry at the University of Missouri is an international leader in providing science-based information on the application of agroforestry systems. Check out their website to learn more about agroforestry (centerforagroforestry.org).

Discouraged Harvest Practices

A basic requirement of sustainable forest management is consideration of the next stand when planning forestry operations in the current stand. Silviculture applies knowledge of tree species' biology in developing forestry prescriptions to meet landowner objectives. Forestry practices based on silviculture principles leave stands in a better condition than they were in at the time of entry, regardless of how the post-harvest stand might look. The point to keep in mind is silviculture methods are designed to improve conditions for meeting the management objectives of the landowner.

Any activity that puts short-term financial gain ahead of long-term forest health and economic viability is probably unsustainable and one that should not be practiced. This could include resource extraction, land conversion, or intensive livestock operations in forests and woodlands. Terms like diameter-limit cutting may sound official, but these exploitative practices are often used to pass off "high grading" (cut the best and leave the rest) as silviculture. With diameter-limit cutting, only trees greater than a specific diameter are harvested, typically large enough to be sold as sawtimber, while leaving behind smaller or poor-quality trees. Since these practices are not implemented to improve residual stand conditions for enhancing individual-tree growth and/or opportunities for regeneration and recruitment, exploitative harvesting practices, like diameter-limit cutting, are not silviculture.

An unfortunate outgrowth of maximizing short-term gain over long-term viability is the practice of liquidation cutting ahead of land divestiture. This extreme form of natural resource exploitation undercuts sustainable forest management not only by mining the forest of its standing value (i.e., liquidation cutting) but also through land conversion such as residential development (i.e., land divestiture). Land divestiture, in particular, is one of the biggest threats to sustainable forestry and agriculture.

Landowners should always ask forestry professionals to describe their prescriptions in detail and explain their reasoning for prescribing them in the first place. Keep in mind that the response needs to address management objectives. It is always a good idea to seek a second opinion before forest management actions are taken on your property.

Additional Resources

Forest Management for Missouri Landowners, Missouri Department of Conservation 2007. Available at mdc.mo.gov/node/5574

Silviculture of Forests in the Eastern United States. USDA Forest Service GTR-SRS-161. 2012. Available at srs.fs.fed.us/pubs/gtr/gtr_srs161/gtr_srs161_007.pdf

Chapter 12: The Fundamentals of Forest Regeneration

Topics Covered

- Silvicultural Treatments for Regeneration
- Best Management Practices for Regeneration on High Visibility Sites
- Best Management Practices to Control Invasive Species
- Best Management Practices for Cultural Resources
- Other Operational Considerations
- Natural Regeneration
- Artificial Regeneration
- Site Preparation and Release
- Regeneration of Common Missouri Forest Species
    - Upland Oak-Hickory
    - Shortleaf Pine
    - Bottomland Hardwoods
    - Mixed Species Stands
    - Sugar Maple
- Evaluating Regeneration Success
- References to Other Chapters
- Additional Resources

By definition, attention to regeneration is one of the major components of any silvicultural system. “Regeneration” is defined as the act of renewing tree cover by establishing young trees naturally or artificially. When making silvicultural prescriptions foresters integrate information about the landowner’s objectives, the silvics of the species desired for regeneration, site conditions and characteristics, economic considerations, societal values, and the abundance and quality of existing vegetation. Each of these factors contributes to the likelihood of regeneration success. Collectively, the following elements dictate the appropriate silvicultural treatments for regeneration.

Silvics is the study of the life history and general characteristics of forest trees and stands, with particular reference to environmental factors, and it is considered to be the basis of silviculture. The silvics of each species encompass numerous characteristics that affect the regeneration potential of that species, including its range and soil associations, tolerance to competition for water, light, and nutrients, reproduction and germination requirements, and growth strategy. As such, certain characteristics limit the likelihood for a species to

successfully regenerate or may require specific silvicultural treatments to achieve regeneration goals.

Ecological site classification is based on the physical location of a forest stand and broadly defines which species are able to establish, persist, and compete at a given site. A site is generally described by the combination of biotic and abiotic factors at a given location, with a single site identifiable when that combination of factors is sufficiently uniform to be distinguishable as a single entity. (See Chapter 11 for details on ecological site classification systems used in Missouri.)

Site quality is generally described in relation to the productivity of a given site. Productivity is the capacity of a site to yield a given amount of biomass (often described in terms of volume) over a period of time. The productivity of a site can be evaluated directly by measuring the timber volume or the relative growth over time. Historical records of standing volume or growth increment are often used to evaluate site productivity.

Site index is the most common method of describing site productivity. It involves an indirect measure that estimates the potential productivity of a given site. Site index is expressed in terms of the average height of dominant trees at a base age (often 50 years). Site index curves are available to determine site index, based on the relationships between tree height and age for most common tree species.

Forest soils can have a strong impact on the productivity of a site and can vary over small areas. Because soil properties affect the moisture and nutrients available for tree growth, analysis of soil characteristics is a critical step in selecting tree species that will best meet management objectives for a given site. Soil survey reports or maps offer general assessment of landscape soil features but may not be sufficiently detailed to help with small ownerships. Therefore, if soil properties are not known it is recommended that soil samples be sent to a laboratory for analysis of physical and chemical properties.

Selecting species with silvical characteristics that match the site conditions will reduce the intensity of silvicultural treatments needed to reach management goals. Characteristics of the site strongly control the regeneration potential of tree species and therefore provide the framework for silvicultural prescriptions and management activities. Each species may be expected to perform in a certain way given the silvics of the species and the site conditions. Silvicultural practices can be prescribed to modify some site conditions to improve the performance of selected species, but ultimately the characteristics of the site will determine the potential performance of the species present.

In some cases, the desired species can be easily regenerated using individuals that establish naturally, either from seeds, sprouts, or existing seedlings or saplings. In other cases, natural sources of regeneration are insufficient to reach the management objectives, and the regeneration must be established by planting seedlings or sowing seeds. Different techniques used for regeneration are associated with different levels of cost, needed equipment and manpower. Landowners must consider not only what species they desire, but what is feasible from the standpoint of their ability to spend time and dollars.

Important Terms Related to Regeneration

There are several important distinctions to consider related to the types and sources of forest regeneration.

Reforestation is the practice of reestablishing forest cover on a site that currently supports a forest. In many cases, the objectives of reforestation include replacing the existing forest with the species composition that currently occupies the site; however, in some circumstances it may be appropriate to reforest a site with species that differ from those in the existing canopy.

Afforestation is the establishment of a forest or stand in an area where the preceding vegetation or land use was not forest. Common examples of afforestation include establishing trees on abandoned or retired agricultural land and reclamation of mine lands. Often the regeneration practices differ between reforestation and afforestation scenarios; for example, natural regeneration is often used for reforestation but artificial regeneration is generally required during afforestation.

Natural regeneration uses new individuals that become established through natural processes to regenerate the forest.

Artificial regeneration is the establishment of new individuals through planting of seeds, seedlings, or saplings.

There are several ways in which natural regeneration is established in forests, and silvicultural treatments can be prescribed to encourage a particular source of regeneration. The common sources of regeneration in Missouri forests include regeneration from seed, sprouting, and advance regeneration. Understanding the ecology of regeneration for common species in Missouri is critical to applying appropriate silvicultural treatments for managing regeneration.

Regeneration from seed is the method of propagation in which new individuals initiate following the germination of seeds. Several steps must occur prior to the establishment of a new individual and at each of these steps there is the chance for failure, making regeneration from seed unpredictable for many species. For example, weather (late frost, drought, etc.) may inhibit flowering or fertilization or seed development, causing poor seed crops in any given year. Oaks and shortleaf pine produce variable seed crops from year to year and it is difficult to predict good seed years in advance. Other species, such as flowering dogwood or black cherry, may produce good seed crops every few years and may be better candidates for regeneration from seed.

Where seed is produced, species then have specific requirements for germination. These requirements may include contact with mineral soil, certain levels of soil moisture, or scarification of the seed prior to germination.

Trees have different strategies for reproduction from seed, and there is generally a trade-off between seed size and the number of seeds produced. Species like oak and hickories produce

large seeds, but these species produce relatively fewer seeds than species that produce small seeds, like black cherry. Seed size is often related to growth strategy of the species; for example, large seeds have carbohydrate reserves that allow seedlings to persist in high stress environments, while many small seeded species grow quickly and are less tolerant of stress.

The presence of a thick litter layer can reduce germination by creating a barrier between seed and the mineral soil, and disturbance events that expose mineral soil can increase the probability of germination. There is typically a better chance that enough seeds will reach suitable sites for germination for species that produce many small seeds as opposed to species that produce few large seeds.

Sprouting is vegetative, or asexual, reproduction in which the new individual originates from buds at the base of the stem, the collar of the root system, or along existing roots. Sprouts commonly originate from stumps that have been cut or from seedlings or saplings that experience aboveground dieback. Root suckering, or root sprouting, occurs when buds along the roots sprout, often following damage or dieback to the tree.

Most hardwood species sprout, although sprouting capability varies considerably among species. In particular, oaks are vigorous sprouters, often with rapid growth following sprouting due to the development of relatively large root systems. However, even among oaks the sprouting potential differs among species, with upland species (e.g., post oak, white oak, black oak) sprouting more readily than bottomland species (e.g., nuttall oak, pin oak, cherrybark oak). Reproduction from sprouts is some of the fastest growing and most competitive for many hardwood species and is especially important in the persistence of oak species. However, sprouting capacity is low for large-diameter and older trees. Shortleaf pine, the only pine native to Missouri, is unique among pines in that seedlings or saplings commonly sprout following stem dieback.

Advance regeneration includes seedlings that became established beneath the canopy of the existing stand. When the regeneration harvest is implemented, the advance regeneration is already in place and is released by canopy removal. At that point, the advance regeneration typically has a competitive advantage over individuals establishing from seed because they are of larger size.

Species with moderate to high shade tolerance are often well-suited for developing advance regeneration. In contrast, oak species often develop abundant advance regeneration due to the persistent resprouting of seedlings following dieback. With this strategy, oak seedlings can gradually develop beneath the existing canopies. If competition is too high or light levels are too low, the oak seedlings will dieback and resprout while gradually developing a robust root system. However, if light levels remain too low to support growth, regeneration will be limited to only the most shade-tolerant species.

When interested in regenerating species from advance regeneration, the abundance of advance regeneration should be assessed to determine the timing of silvicultural harvests that remove the canopy and release the new cohort of seedlings.

Artificial regeneration is required for situations in which sources of natural regeneration are absent or if the natural regeneration present on the site is insufficient to meet objectives. Afforestation typically requires artificial regeneration because the site is not forested prior to the regeneration effort. An exception may be if the afforestation site is adjacent to a forested area with a desirable species that successfully regenerates from easily dispersed seed. During reforestation, artificial regeneration may be required if the landowner's objectives include a shift in the species composition from what currently exists on the site, or if the amount of natural regeneration is too low to successfully regenerate the site. Common methods of artificial regeneration are direct seeding and planting seedlings or saplings.

In some situations, new forests can be established by distributing seed throughout the stand.

Direct seeding is similar to the process of natural regeneration from seed in that the seeds must end up in locations with suitable micro-environments for germination, persistence, and growth. However, direct seeding allows for control over the amount and distribution of the seed in the forest stand. Successful direct seeding often requires that large amounts of seed are collected and spread to increase the chances that seeds will fall into suitable micro-sites.

Broadcasting seed is the simplest type of direct seeding and consists of scattering seeds uniformly throughout the area being regenerated. With this method, some of the seeds are expected to not germinate because they will end up in unsuitable micro-sites or will be consumed by animals. Although seeding rates differ among species and site conditions, recommendations for successful regeneration from broadcast seed call for 1,000–2,500 seeds per acre for large-seeded species and 10,000–25,000 viable seeds per acre for species with small seeds.

To reduce the uncertainty of artificial regeneration from the broadcast method, seeds can be directly sown into the soil. This is often done either in strips or in specific locations where success is likely. Sowing seeds reduces the number of seeds required for stand establishment because the seeds are generally placed in suitable micro-sites for germination. In addition, this method is also preferred for species that require high seed moisture to remain viable, such as oaks.

To increase the chance for successful stand establishment, desirable seedlings can be grown in controlled nursery conditions and then planted on the forest site. Nursery production of seedlings eliminates the uncertainty in the germination and early persistence phases of regeneration in natural field situations. In addition, nursery production methods can target individuals with desirable genetics, resulting in high-quality seedlings that have a better chance of competing on the planting sites.

The two common types of seedlings produced for artificial regeneration are bare-root seedlings and container-grown seedlings. Bare-root seedlings are generally produced in outdoor seedbeds for one or two years, until the root systems and tops reach the desired size for planting. Foresters use a measure of the caliper, or basal diameter, of bare-root seedlings as a metric for seedling quality. When bare-root seedlings are of suitable size or age, they are removed from the seedbeds, the soil is separated from the root systems, and the seedlings are planted on the regeneration site. The rapid reestablishment of the root system following planting is essential to seedling survival and subsequent growth; therefore, selecting sites on which root expansion and development may occur is an important planning consideration when planting seedlings.

The George O. White State Nursery operated by MDC produces and sells bare-root seedlings of numerous tree and shrub species native to Missouri. To learn more about the nursery, including methods of ordering seedlings for your property, visit mdc.mo.gov/node/3986.

Container-grown seedlings differ from bare-root seedlings in that they are produced in trays or other containers that allow the root systems to develop within a controlled growth medium. When the seedlings reach a suitable size, they are removed from the containers, but the growth medium is retained around the root system. By this method, the root systems typically develop in continuous contact with a supply of nutrients and moisture; after planting, there is often less adjustment required for the individual to become established during root development. As a result, establishment success may be higher for certain species or on particularly harsh sites. However, container-grown seedlings require more intensive methods of production and are consequently more expensive than bare-root seedlings

Silvicultural Treatments for Regeneration

The silvicultural systems described in Chapter 11 were developed with specific consideration to the regeneration needs of different forests or species. Each silvicultural system was designed to control the structure, age, and composition of the regenerating forest by controlling the amount and distribution of seed sources, the amount of available space or resources for new plants, and the growing conditions at the forest floor. In general, the common silvicultural systems were designed for, and are well-suited for, natural regeneration of certain species or forest types. However, the sources of natural regeneration (whether from seed, sprouts, or advance regeneration) should be considered when prescribing silvicultural systems for regeneration.

While the regeneration method provides the framework for regeneration, additional silvicultural practices are often applied to improve the conditions of the site and enhance the establishment and growth of the desired regeneration.

Site preparation is applied prior to the establishment of regeneration and is used to improve the likelihood of germination or increase early growth.

Release treatments are applied after regeneration is established and serve to improve survival or growth. (See Chapter 13 for more details on release treatments.)

Irrigating and fertilizing young stands is also an option on sites with inherently low nutrient or water-holding capacities that may not be able to support certain species. The cost makes it impractical for nearly any situation in Missouri.

Site preparation treatments can be categorized by their method of application, with broad categories including prescribed burning, mechanical treatments, and chemical treatments.

Prescribed burning can be used to reduce the depth of the forest floor and expose the mineral soil, thereby improving the seedbed for germination of the naturally or artificially dispersed seeds. For example, prescribed burning is commonly used to encourage the regeneration of shortleaf pine, because a thick litter layer inhibits the necessary contact of the seed with mineral soil. By removing the aboveground biomass of existing vegetation, prescribed burning reduces the competition from non-target species immediately following application. The effect may be short-lived, however, if the competing species are vigorous sprouters. On the other hand, prescribed burning can be used to initiate regeneration if the sprouting species, such as oaks, are desirable.

Mechanical site preparation includes treatments that are applied through mechanical means, often using heavy equipment or chain saws. Some mechanical treatments are applied at or above the soil surface, with the primary objectives of preparing the seedbed or reducing competing vegetation on the site. Examples of such treatments include chopping, mowing, mulching, scalping, or scraping. These treatments reduce the aboveground vegetation by cutting or crushing it and can prepare the seedbed by exposing, or scarifying, the mineral soil. Other mechanical treatments, such as bedding, mounding, root-raking, or disking, are applied beneath the soil surface. These treatments are often more intensive because they can change the physical characteristics of the soils. In addition to preparing the seedbed and reducing competing vegetation, mechanical treatments can change the hydrology of the site, alter the distribution of organic matter in the soil, and affect the growing conditions of the micro-site.

Chemical treatments, or herbicides, can be very effective and offer managers a wide range of treatment options when competition control is the primary objective of site preparation. During site preparation it is often desirable to reduce the competing vegetation throughout the entire site; and broadcasting nonselective herbicides, such as glyphosate, can be appropriate. However, if management objectives include maintaining certain species or vegetation types that may be affected by the herbicides, only select herbicides can be used to target undesirable vegetation. The effectiveness of herbicides can also depend on the soil characteristics, weather conditions, the time of year, and the vegetation on the site. Because of that complexity, a certified herbicide applicator should be consulted during the planning and application of any herbicide treatment.

In instances where any of these silvicultural treatments will be applied, the use of Best Management Practices is recommended. These best management practices — on *Tending Treatments, Roads and Trails, Harvesting, Pesticide Use,* and *Fire Management* — are described in subsequent chapters.

Best Management Practices for Protecting Visual Quality

In addition, regeneration activities represent a unique opportunity for enhancing the scenic properties of forests with high visibility. Factors related to the visual quality of forest land include the size, density, and distribution of trees on the site, the composition and flowering characteristics of trees, and the silvicultural practices related to harvesting and regeneration.

- Regenerate or retain multiple species that vary in fall color and flowering characteristics.
- Use regeneration practices that maintain diversity in forest structure.
- Avoid planting rows oriented perpendicular to line-of-sight by planting in irregular patterns or using curved rows.
- Avoid planting scenic vistas with trees that will grow to block the view.

Best Management Practices to Slow the Spread of Invasive Species

Invasive species are generally described as those species that are highly competitive and can quickly establish throughout a new area, often by replacing the species that previously occurred. In many cases, invasive species are nonnative, or exotic, species that are introduced to an area outside of the species' natural range. Invasive species have the ability to disrupt natural ecosystem processes, and care should be taken to avoid spreading invasive species during forest regeneration.

- Prior to implementing management activities, scout for and locate invasive species infestations, consistent with the scale and intensity of operations.
- Plan management activities to limit the potential for the introduction and spread of invasive species.
- Plan for post-activity management of highly damaging invasive species.
- Consider the likely response of invasive species or target species when prescribing activities that result in soil disturbance or increased sunlight.
- Prior to moving equipment onto and off of an activity area, scrape or brush soil and debris from exterior surfaces, to minimize the risk of transporting propagules. If practical consider washing equipment.
- Take reasonable steps to avoid traveling through or working in small isolated populations of invasives during forest management activities. This will help minimize their movement to noninfested areas.
- Re-vegetate or reforest as quickly as feasible after site disturbance in order to limit the introduction or spread of invasives.
- Select plant materials that are site appropriate to favor establishment and vigor. Monitor for invasive species after planting.
- Limit the introduction and spread of invasives during reforestation or re-vegetation site preparation activities.

Best Management Practices to Protect Cultural Resources

Cultural resources can include a variety of assets related to the current or historic cultural influences of a site and may include physical objects such as artifacts, historic home sites or dwellings, or burial sites. Specific Best Management Practices for cultural resources commonly found in forested areas are located in the Appendix B.

- Avoid silvicultural practices that disrupt the soil surface, such as mechanical site preparation or plowing on sites with cultural resources.
- While standard tree-planting techniques are generally not a concern to cultural resources, trees should not be planted on burial sites or cemeteries.
- Consider restoring forest conditions on other cultural resource sites to provide protection for the site by sheltering the site from disturbance.

Other Operational Considerations

Although a wide range of silvicultural options are available for regeneration, there are several factors that landowners should consider when prescribing regeneration treatments. This section addresses some of the operational considerations.

Natural Regeneration

Operationally, natural regeneration is relatively simple because it relies on the existing trees or individuals to provide the regeneration source. However, the silvicultural treatments (harvesting, site preparation) used during natural regeneration require appropriate planning for successful implementation. When the natural regeneration source is seed, anticipating good seed years or being able to respond to a good seed year with the appropriate silvicultural treatments is important. Within a species, some trees are better seed producers than others, and evaluating individual seed production over time is an important consideration in regeneration planning. Tending treatments can be used to retain good seed producers within a stand. Understanding the composition and abundance of existing individuals is important when planning to use sprouts or advance regeneration as a regeneration source. If such regeneration sources are absent from the stand, planning well in advance may be required to develop the required abundance of advance regeneration.

Artificial Regeneration

There are several operational considerations that must be evaluated during artificial regeneration. During direct seeding, the seeding rate should be determined based on the species being established and the condition of the seedbed. Small-seeded species may require seeding rates of 10,000–25,000 seeds per acre, while large-seeded species such as oaks require seeding rates ranging from 1,000–2,500 seeds per acre. The probability of successful establishment will be higher on well-prepared seedbeds than on sites with no site preparation.

Using the proper procedures during collection, processing, handling, and storage of seed is critical to ensuring that seeds remain viable for regeneration. The seeds used for direct seeding

should be collected during an abundant seed year from high-quality trees with desirable growth and form. Seeds must be collected after reaching seed maturity, although this date during the year will vary by species, canopy position, location, and year. Various methods are available for testing seed development; a simple test for acorns is to put them in water and discard the acorns that float as being damaged or immature. To extend the storage period, seeds are generally stored in conditions that maintain low moisture content (5–10 percent) and low temperatures (0° C or below). Additional information on seed processing and storage can be found in *The Woody Plant Seed Manual*, USDA FS Agricultural Handbook 727 (available at nsl.fs.fed.us/nsl_wpsm.html).

For either seeding or planting nursery-grown individuals, it is important to collect seed from sites that are similar to and near the sites that are to be regenerated. “Provenance” is the term that describes the geographic source of seed, and the provenance of the seed can affect its performance in the field. For example, seed source location is closely related to the genetics of the seed, and the individuals on a given site are typically adapted to those specific conditions. Such adaptations may be related to climatic conditions, such as cold or drought tolerances, and regenerating poorly adapted genetic material can result in stand-level failures following harsh weather events.

When planting nursery-grown seedlings, the spacing and arrangement are often determined by the objectives for the stand. The initial spacing will affect the subsequent management needs and can affect the growth and development of the trees. Wide spacings allow more growing room for individual trees and often result in high diameter growth and early mast production but can reduce stem quality due to the development of branching. Planting at close spacings results in earlier crown closure, which can stimulate good stem form through rapid height growth and increased natural pruning. Moreover, planting at close spacing allows for higher mortality rates and increases the likelihood that enough individuals survive to regenerate the stand.

The appropriate spacing will therefore depend on the objectives of regeneration, as well as site productivity, the species being planted, and the future management actions. For example, planting at very close spacing would likely require a pre-commercial thinning to release growing space for desirable trees. If such a treatment is not prescribed in the management plan, it may be appropriate to use a wider spacing that would not require pre-commercial thinning.

Spacing (ft)	Trees per acre	Spacing (m)	Trees per hectare
3 x 3	4,840	0.9 x 0.9	11,954
4 x 4	2,723	1.2 x 1.2	6,724
5 x 5	1,742	1.5 x 1.5	4,303
6 x 6	1,210	1.8 x 1.8	2,988
7 x 7	889	2.1 x 2.1	2,196
8 x 8	681	2.4 x 2.4	1,681
9 x 9	538	2.7 x 2.7	1,328

10 x 10	436	3.0 x 3.0	1,076
12 x 12	303	3.7 x 3.7	747
15 x 15	194	4.6 x 4.6	478

The arrangement of plantations refers to the spatial pattern in which the seedlings are planted. The square, or grid, arrangement is the most common pattern used in plantations, but variations may be used to maximize growing space or meet other objectives. For example, hexagonal spacing often results in a more uniform stand in which the individual tree crowns fit together more cleanly than with grid spacing, resulting in a more even distribution of competition for individuals in the stand.

During planting, it is important that the seedlings are handled with care and that proper planting techniques are used. To avoid stress during initial seedling establishment, planting should not be done during harsh or unusual weather conditions (e.g., extremely wet, dry, or cold). During planting, the seedlings should be kept cool and moist to avoid the root systems drying out, and seedlings should be planted immediately after they are removed from the storage/transport unit.

Planting by hand can be done with a dibble bar or a shovel as long as several steps are taken:

- Create a hole with the proper depth to accommodate the root system.
- Plant the seedlings at the same depth as they were in the nursery.
- Allow the root system to spread out in the hole.
- Pack soil around the seedling to remove air pockets.

If the soils are not too rocky, seedlings can be planted from specialized equipment that is pulled behind a tractor and used to create a trench in the soil for planting.

Site Preparation and Release

Landowners may be limited by the operational costs of site preparation or release treatments. Because the cost of these treatments is often related to each treatment's intensity, some treatments or treatment combinations are not very practical for application. To reduce the need for intensive site preparation, it becomes important to match the right species to the site. Species that are well-suited for a site will need fewer site modifications for successful establishment and growth. In addition to cost, site characteristics can make the application of certain treatments difficult. For example, steep slopes or large boulders can limit the access of heavy equipment. Many soils in Missouri are rocky, which can make site preparation treatments that manipulate the soil (e.g., bedding, disking, root-raking) difficult. Understanding the operational limitations to these treatments is important when developing a regeneration prescription.

Regeneration of Common Missouri Forest Species

The state of Missouri covers a wide array of ecological settings that create a diverse patchwork of natural plant communities. The dominant tree species within these communities are often targeted by landowners for regeneration objectives, and the silvics of these species help to determine what silvicultural treatments may be appropriate. The following descriptions provide recommendations for the regeneration of common species or forest types in Missouri, but these examples do not include all potential species of interest or relevant silvicultural techniques.

Upland Oak-Hickory

Upland oak and hickory species are among the most common tree species in Missouri and occur in a variety of natural communities that occur on sites that range from dry sandstones to mesic glacial till and soils of loess deposits. Common upland oak-hickory species include white oak, black oak, scarlet oak, post oak, northern red oak, black hickory, shagbark hickory, and mockernut hickory. These species typically produce large seeds at irregular intervals and range in shade tolerance from intolerant to moderate. They generally grow slowly in the seedling stage and allocate much of their growth to the root system, eventually developing large root systems that can support frequent sprouting following top-kill.

Due to the sprouting potential of these species, clear-cutting or group-selection methods can be used if there are abundant densities of saplings in the sub-canopy. If large advance regeneration has developed on the site, these seedlings can also be released with canopy removal. Single-tree selection has been successfully used to regenerate oak forests in the Ozarks. This tends to favor more shade-tolerant species within the oak-hickory group (such as white oak) over other oak or hickory species.

Problems with oak-hickory regeneration can occur if large seedlings and saplings are not present on the site prior to regeneration harvests. Shelterwood treatments can be used to encourage the development of large advance regeneration by increasing light levels at the forest floor, and prescribed burning may be used to improve the seedbed for seedling establishment. If regeneration is already present in the stand, burning will top-kill the oak-hickory seedlings but they will sprout back vigorously. Artificial regeneration can be used for the establishment of upland oaks, but natural regeneration is generally sufficient for regenerating these sites.

Shortleaf Pine

Shortleaf pine is the only native pine in Missouri. It is typically associated with dry, acidic sites with soils derived from sandstone. Shortleaf pine is commonly associated with upland oak species that also compete well on dry sites.

Shortleaf pine is a periodic seed producer, with good seed crops expected every 3–7 years, and its seeds require contact with mineral soil for germination. Like most pines, shortleaf pine is intolerant of shade, and seedling growth is greatly reduced by competing vegetation. However,

shortleaf pine is unique among pines in that it re-sprouts following top-kill, which may be a strategy for regeneration in association with low-intensity fire.

The seed-tree or shelterwood methods can be used to stimulate seed production and increase light levels at the forest floor. Although the logging disturbance from these treatments may expose areas of mineral soil, site preparation may be required to further prepare the seedbed. Prescribed burning or mechanical scarification can be effective treatments for improving natural regeneration. Herbicides can additionally be used as site preparation or release treatments in order to encourage rapid growth of the established seedlings. Generally, clear-cutting without site preparation or release treatments will not be effective for natural shortleaf pine regeneration because of the fast growth of hardwood regeneration. Artificial regeneration techniques, including broadcasting seed or planting seedlings, may be used for shortleaf pine regeneration, but similar practices of site preparation and release will likely be necessary.

Bottomland Hardwoods

Bottomland hardwood stands occur in the seasonally wet sites associated with alluvial floodplains or topographic depressions. The site conditions in bottomland systems differ greatly from those in upland forests, often with more productive soils but with flooding stress and little available light or growing space due to intense competition with other species. Common bottomland hardwood species in Missouri include pin oak, overcup oak, cherrybark oak, cottonwood, silver maple, green ash, and sycamore. Pin oak and cherrybark oak are often favored as desirable species, either for wildlife habitat or as timber species (especially cherrybark oak). In many ways, these species differ from upland oak species in their regeneration strategies, with a greater dependence on seedlings than on sprouts for regeneration.

Silvicultural treatments are commonly used to control the composition of the regeneration in bottomland hardwoods, and to increase growing space and resources for desirable species. Herbicide or mechanical treatments that reduce the density of undesirable mid- and understory species can help promote oak species seedlings into advanced regeneration. Once there is sufficient advanced regeneration, canopy removal treatments such as group-selection, shelterwood, or seed-tree silviculture systems may be appropriate for increasing light levels so that the oak species can continue growth into the mid-story. Artificial regeneration can be used to establish desirable species in bottomland forests, but additional treatments are often needed to release these seedlings from competition for good survival and growth.

Mixed Species Stands

Mixed species stands are those in which no single species occupies more than 80 percent of the stand density. Mixed species stands are common in Missouri. Regenerating mixed species can be challenging if the species present have different regeneration requirements. For example, in shortleaf pine–oak mixtures, oak species generally regenerate from advance regeneration or from sprouts, but shortleaf pine regenerates from seed or from sprouts. On most sites, oak regeneration will grow faster than shortleaf pine regeneration, making it difficult for

foresters to target both species simultaneously. Generally, managing mixed species stands is more complex than managing single-species stands but can be an effective strategy for meeting multiple management objectives.

In some cases, interplanting can be used as an artificial regeneration technique for establishing mixtures of species. Interplanting is the practice of planting new seedlings amid the natural regeneration of the existing stand. This technique may be used to supplement poor cohorts of natural regeneration or to introduce different species to the regeneration layer.

A similar technique, underplanting, can be used to artificially establish regeneration beneath an existing canopy when no desirable regeneration is present. With shade-tolerant species, underplanted seedlings may successfully recruit with little additional management, but canopy removal treatments are often required for less-shade-tolerant species. In Missouri, mixed species stands can often be established using natural regeneration, especially in the upland oak-hickory forests that often easily regenerate from advance regeneration or sprouting following canopy removal.

Sugar Maple

In Missouri, sugar maple is most commonly found in the northeastern part of the state, on mesic or dry-mesic sites that overlay loess, glacial till, or limestone/dolomite soils.

Sugar maple is one of the most shade-tolerant canopy species in Missouri, and seedlings can become established under dense canopies and heavy shade. Sugar maples produce fairly consistent seed crops, and seedlings can develop readily beneath forest canopies. Because of its shade tolerance, single-tree selection can be an effective silvicultural system for regenerating sugar maple, and there are few other species in Missouri forests that can compete with sugar maple in the shade of the forest canopy. Like many other hardwood species, sugar maple sprouts following top-kill. However, some of the other species that are found with sugar maple, such as the oaks and hickories, typically sprout more vigorously than sugar maple; consequently, regeneration methods that target sprouting, such as coppicing, will likely favor species other than sugar maple on most sites.

Evaluating Regeneration Success

It is important to be able to assess the abundance and development of the regenerating cohort to determine if management objectives are being met. However, because species vary in their regeneration strategies and a variety of silvicultural practices can be used to regenerate a forest there is no single metric that is appropriate for measuring regeneration success. Instead, foresters should use an understanding of the overall management objectives, the regeneration strategies of the desirable species, and the silvicultural practices used during regeneration in order to evaluate the status of stand regeneration.

Forest regeneration is a dynamic process that can be accomplished only over time. Because of that, it is important to consider when during stand development the regeneration is being

assessed, and it is recommended that the regeneration status be assessed at multiple points in time. For example, species or silvicultural practices that rely on sprouting or advance regeneration require the presence of desirable individuals prior to the application of the silvicultural treatment. If these individuals are not present, the silvicultural treatments will not result in the desired regeneration outcomes. In these situations, an assessment of the size and density of species in the regeneration layer is an important part of the regeneration planning process. In contrast, species that rely on regeneration from seed, such as shortleaf pine, often do not require individuals to be present prior to the application of regeneration silviculture.

For any of the silvicultural practices described above, it is important to evaluate the status of the regeneration following application of the silvicultural treatments. Ultimately, the minimum number of successfully regenerating individuals of the desired species must be greater than or equal to the number of individuals desired in the canopy at maturity. However, mortality is expected for individual seedlings and saplings over the course of stand development, which is one reason that plantations typically establish more seedlings than desired at rotation. For example, planting at a 10 x 10 foot spacing results in 436 seedlings per acre, but a mature stand will often have closer to 50 trees per acre. In addition to effects on stand structure and tree form, planting higher densities than required ensures that enough vigorous individuals survive to meet management objectives.

It is recommended that the regeneration status be assessed and documented (See Appendix C for an example of a pre- and post-operational checklist) within 5 years of the silvicultural treatment to determine if initial regeneration objectives have been met. This assessment should include a measure of the density of desirable seedlings or saplings in the regeneration layer. A reasonable guide is that it is not likely regeneration objectives will be met when fewer than **100 seedlings per acre** of the desirable species are present.

A second assessment should be made between ages 15 and 20 or when the stand begins to enter the stem exclusion phase (if applicable). At this point, the density and canopy position of the regenerating individuals are both important, because dominant individuals are most likely to survive this competitive phase. If fewer than 100 desirable individuals remain at this point, additional silvicultural treatments may be needed to improve the chances of an acceptable canopy at maturity.

References to Other Chapters

It is important to clearly define the landowner's objectives when prescribing silvicultural treatments for stand regeneration. Developing a management plan with a professional forester is important for identifying the desired objectives for stand regeneration and for considering limitations or management requirements for reaching such goals. (See Chapter 10.)

The characteristics of each tree species, including life history, growth patterns, morphology, competitive ability, longevity, and susceptibility to damaging agents, all contribute to the structure and function of the resulting forest stand. The variation in these characteristics among

species makes certain species particularly desirable for specific management objectives. For example, managing for wildlife habitat often emphasizes a mixture of hard mast and soft mast species, but managing for timber production often emphasizes species of high timber value. Foresters use an understanding of the silvics of individual species and the limitations of the site to prescribe realistic regeneration treatments that fit the landowner's objectives and financial capability. (See Chapter 10.)

Land managers must also consider other factors that affect how silviculture can be implemented to meet management objectives. Among these, protection of species of conservation concern, protection of valuable cultural resources, and maintenance of visual quality are all important considerations. These factors may not affect decisions in all management scenarios but warrant consideration when applicable. In many cases, working with a professional forester is the best way to identify and integrate these factors into silvicultural practices that meet the landowner's objectives. (See Chapter 3, 4, 6, and 11.)

Prior to beginning management activities, consult a professional forester, a Missouri Department of Conservation (MDC) private land conservationist, an MDC wildlife biologist, or an MDC natural history biologist for information about the occurrence of endangered or threatened species, species and natural communities of conservation concern, rare tree species, or sensitive communities present on or near the management area. These species and natural communities can be impacted by site preparation activities, by altering the existing vegetation, or by introducing new species. These professionals can help you modify management activities in order to maintain, promote, or enhance species and natural communities on the site. (See Resource Directory. (See Chapter 3)

The Appendix C includes a pre and post tree planting checklist that can be a helpful tool for managers to use in clarifying objectives, planned activities, and integrated management concerns. The checklist also has an area for evaluating and documenting planting success.

Additional Resources

Forest Management for Missouri Landowners, Missouri Department of Conservation 2007. Available at mdc.mo.gov/node/5574

Minnesota Forest Resources Council. Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers. 2005. Minnesota. Forest Resources Council, St. Paul, Minnesota. Available at frc.state.mn.us/initiatives_sitelevel.html

Wisconsin Forest Management Guidelines. PUB-FR-226, 2011. Available at dnr.wi.gov/topic/ForestManagement/guidelines.html

Unit III: Standards, Guidelines, and Best Management Practices

Chapter 13: Tending Treatments

Topics Covered

- Types of Tending Treatments
- Best Management Practices for Release Treatments
- Release and Thinning Methods
- Best Management Practices to Protect Soil and Water
- Best Management Practices to Protect Visual Quality
- Best Management Practices to Protect Cultural Resources
- Best Management Practices to Slow the Spread of Invasive Species
- References to Other Chapters
- Additional Resources

Types of Tending Treatments

Tending treatments deliberately remove some trees in order to benefit remaining trees and, by doing so, affect the character of the stand. These treatments may be done in conjunction with the regeneration harvest, as in the uneven-aged system, or at various times between regeneration events, as in the even-aged system. The term “intermediate treatment” is often used to describe tending of even-aged stands, since these treatments are applied between planned regeneration events or at an intermediate time during the rotation. “Timber stand improvement” (TSI) or “forest stand improvement” (FSI) are the terms commonly used to describe tending treatments in Missouri, particularly as a prescription for younger stands where trees are often too small to be sold for wood products. Traditionally, tending is not implemented to regenerate a new age class or cohort.

There are many silvicultural practices that are classified as tending treatments. Generally, they can be lumped into three categories: release treatments, thinning, and pruning.

Release treatments are applied to young seedlings in order to reduce competing vegetation (weeding), to free saplings from overtopping by undesirable competing trees of the same age (cleaning), or to release younger trees from overtopping by older trees (liberation).

Without release treatments, suppressed desirable trees may suffer long-term reductions in growth or even succumb to premature mortality. These practices differ from thinning in that they are traditionally implemented at an early stage of stand development before site resources are fully utilized, while thinning is typically applied to redistribute resources after full site occupancy.

Best Management Practices for Release Treatments

- Lower the cost of cleaning by releasing no more trees than are needed to reach a merchantable size (example: 150 trees per acre spaced approximately 17 feet apart).
- When deciding which trees to remove during cleaning, consider both overtopping trees and ones likely to become overtopping before the next scheduled entry.
- If timber quality is an objective, avoid removing too many neighbors during cleaning in order to retain future trainers.
- Deaden (girdle or herbicide) trees during liberation to minimize damage to desirable saplings.

Thinning is the practice of removing some trees to improve individual-tree growth and vigor, stand quality, and species composition. Often it's the weaker, less competitive trees that are marked for thinning, since they are more likely to succumb to mortality. By doing so, the landowner can realize economic return from trees that will likely die before final harvest.

There are a number of principles that apply to thinning decisions. If the size and form of the trees is not important, a large number of small trees will produce the most wood per acre. However, this may not yield the highest merchantable volume, since individual trees will be relatively small. If size and form of the trees is important, the trees in the stand should be spaced out to allow increased size per individual. This will not produce the maximum wood per acre but will likely produce the most merchantable wood per acre. This, in turn, may yield higher-value forest products and, consequently, higher future returns to the landowner. For a tree to utilize the space made available by thinning, the tree must be capable of fairly rapid growth following release. Generally speaking, old or unhealthy trees do not respond as well as young or healthy trees to the new space created by thinning. There is a natural tendency for trees of the same age class to self-organize by size with the largest trees with the largest crowns growing the fastest. These trees are most capable of utilizing new space created by thinning. Trees that have had less space will have successively smaller crowns and, consequently, lower growth vigor. Therefore, smaller trees in the stand have less ability to capture the space made available in a thinning.

The process of thinning often involves removing smaller trees that are unlikely to respond vigorously to new space, while leaving larger trees that have the ability to utilize the new space quickly. This approach is called thinning from below, since the smaller trees targeted for thinning

are also the shorter, overtopped trees. Thinning from below does not produce the most income in the short term but leaves the best possible forest for the future.

Thinning from above (taking the largest trees and leaving the smaller) is not usually recommended as it degrades the future potential of the stand.

A third alternative is called a proportional thinning in which trees from all size classes are removed and is a compromise between the two approaches described above.

A method of thinning that is not commonly used in Missouri is geometric thinning. In geometric thinning, trees are cut or retained on the basis of a predetermined spacing or density without consideration of their size or competitive position in the canopy. This method is applied mainly in plantations where entire rows are typically removed to achieve density management goals and is often referred to as row thinning.

Crop Tree Management

An alternative to thinning an entire stand down to a specific stocking level is crop tree management, which involves removing just the immediate competitors surrounding selected crop trees. More specifically, it is the trees whose crowns are in direct contact with the crop tree that are marked for removal. This approach to thinning is called a crown touching release. In fact, crown touching release can begin early in the life of a crop tree and, therefore, could be considered a release treatment. Crop tree management may be particularly appropriate for visually sensitive areas, since it generally maintains an unthinned canopy matrix between crop trees. More information can be found at na.fs.fed.us/pubs/ctm/ctm_index.htm

Precommercial thinning usually occurs when stands are relatively young and trees are not large enough to sell for wood products. Precommercial thinning generates no revenue for the landowner and is considered an investment in the future benefit of the stand, although precommercial thinning can also be used to harvest firewood.

Timber Stand Improvement

Timber stand improvement (TSI), also called forest stand improvement (FSI), is a class of tending treatments implemented to improve the quality of a residual stand. TSI operations improve residual stand quality by removing poorly-formed, defective trees and species with lower wildlife or timber value. TSI is often performed in younger stands to release slower-growing, desirable species (e.g., oaks) before they are outcompeted and overtopped. Removing drought-sensitive species or species susceptible to decline can also be considered a TSI operation, since these actions can improve stand health. Although TSI can be a commercial operation (i.e., generate revenue), this operation is often considered precommercial due to the smaller stems cut in younger stands or high defect of larger trees removed in mature stands.

Commercial thinning usually occurs when stands are older and trees are large enough to sell for wood products, which offsets or exceeds the cost of implementing the thinning. Although

commercial thinning is usually favored by landowners, one must consider the dynamics of tree growth (described above) and be aware that there are tradeoffs in all these decisions.

A market for woody biomass can make thinning of young, pole-timber stands (traditionally viewed as a precommercial thinning) a commercially viable option. However, the timber sale may need to integrate larger sawtimber trees along with smaller-diameter material slated for biomass harvesting in order to attract bids from loggers. For more guidance specific to woody biomass harvesting through thinning, see the Missouri Department of Conservation manual *Missouri Woody Biomass Harvesting Best Management Practices Manual*.

Thinning may be used for purposes other than increasing the growth of individual trees. For example, thinning can directly change the composition of the stand. This may be done for situations in which one species is particularly susceptible to a disease or pathogen. In Missouri, this is often applied to red oak species, which are susceptible to oak decline and red oak borers. In this situation, white oak species are favored as leave trees and red oak species favored for removal. The intent of this thinning is to leave trees that are less susceptible to future diseases. Thinning can be used as a tool for improving wildlife habitat. For example, thinning can result in significant crown expansion of soft-mast and hard-mast species, which in turn can increase the production of mast for wildlife. Thinning may also be used to reduce stand density when restoring woodland natural communities. See Chapter 11 for more details.

Release and Thinning Methods

Mechanical — Most cleaning, liberation, and thinning is applied by mechanically felling trees. Trees may also be girdled to create snags or to protect high-quality crop trees from felling damage. Liberation and thinning can be done with chain saws or machinery such as a harvester, while cleaning can be carried out with machinery or hand tools.

Chemical — If the trees are to be removed and left in the forest, herbicides may be a cost-effective choice. In this method, trees are killed using an herbicide. This is generally a low-cost solution to tree removal, which makes this an attractive approach for weeding, cleaning, and precommercial thinning. Chemical treatments may also be suitable in situations where the trees to remove are undesirable species capable of sprouting, since herbicide will kill the entire tree. See Chapter 16 for more information on herbicide applications.

A common precommercial tending treatment used to improve stand composition and residual tree vigor in young stands in Missouri is hack and squirt. With this technique, an ax or hatchet is used to create small wounds or frills in the stems of trees marked for removal, and herbicide is applied to the open wound, often by using a spray bottle. Since the treated stems die standing, there is a lower likelihood of residual stand damage.

Prescribed Fire — Prescribed fire can be used to reduce stand density. These prescribed burns are most effective at removing small-diameter trees in the understory and mid-story. Although larger trees may not be killed, fire can scar the base of tree stems, potentially degrading their quality and lowering their value. Compared to other methods, prescribed fire

is generally not as effective in removing undesirable trees as mechanical or chemical treatments are, and it is nonselective and may damage future crop trees. As a thinning tool, fire is unlikely to succeed at reaching specific stocking goals. Using prescribed fire to thin understory trees >2-inch DBH (diameter of the stem of a tree measured at breast height; see Glossary of Terms) is generally discouraged due to the negative impacts of this intense of a burn. In Missouri, prescribed fire is increasingly used as a tool to reduce the cover of understory and mid-story woody vegetation during woodland restoration. See Chapter 17 for more details on the use of prescribed fire.

Pruning — Pruning is the deliberate removal of lower branches. This is a common practice of arborists managing urban and landscape trees in order to protect utility lines and improve aesthetics. In forestry applications, pruning is mainly used to create knot-free wood suitable for high-value forest products including cabinetry, interior finish, furniture, and surface veneer. Pruning can be an expensive and labor-intensive operation, depending on the acreage to treat, numbers of trees to prune and branches to remove per tree, branch size, and height of branches along the stem. However, the potential return on investment associated with producing veneer or premium-grade boles can justify pruning.

Pruning is not a common forest management practice in Missouri. In part, this is related to the high cost per acre associated with pruning, which limits its application as an extensive management practice. Pruning is most suitable when applied to smaller areas, particularly those that are young and composed of high-value species. More details on pruning, including instructions on proper techniques, can be found at na.fs.fed.us/spfo/pubs/howtos/ht_prune/htprune-rev-2012-print.pdf

Best Management Practices to Protect Soil and Water

If mechanized equipment is used, refer to the Best Management Practices found in Chapters 14 and 15.

Best Management Practices to Protect Visual Quality

The aesthetics, or visual quality, of forested land can be an important consideration for land managers, especially in visually sensitive areas. Factors related to the visual quality of forest land include the size, density, and distribution of trees on the site; the composition and flowering characteristics of trees; and the silvicultural practices related to harvesting and regeneration.

- Favor multiple species that vary in fall color and flowering characteristics.
- Use practices that maintain or enhance diversity in forest structure.
- Leave untreated or selectively treated areas adjacent to travel routes and recreation areas.
- Deaden trees by girdling or herbicide injection to mitigate the negative visual impact of mechanical removal — this has the added benefit of creating snags for wildlife.
- Avoid high stumps in close proximity to roads and trails.

- Consider the use of dormant season, leaf-off treatments — slash without leaves are less apparent and decay over a shorter period of time with lower fuel loadings.

Best Management Practices to Protect Cultural Resources

The cultural resources found on forest lands are also important and include a variety of assets related to the current or historic cultural influences of a site. These may include physical objects such as artifacts, historic home sites or dwellings, or burial sites. On sites with important cultural resources, tending treatments that could potentially disrupt the soil surface, such as a thinning operation, should be carefully implemented to reduce the risk of damage to cultural resources. Specific Best Management Practices for cultural resources commonly found in forested areas are located in the Appendix B.

- Inspect sites prior to harvest to ascertain potential for cultural resources occurrence. Clearly mark or flag areas to avoid.
- Avoid physical disturbance of the soil surface if a site has significant cultural resources.
- Minimize wheel and tracked vehicle traffic on cultural resources sites.

Best Management Practices to Slow the Spread of Invasive Species

A potential problem during management activities is the spread of invasive plant species not previously found in the forest. Depending on the way you conduct tending treatments, you can increase or decrease these species.

- Prior to implementing management activities, scout for and locate invasive species infestations, consistent with the scale and intensity of operations.
- Plan management activities to limit the potential for the introduction and spread of invasive species.
- Plan for post-activity management of highly damaging invasive species.
- Consider the likely response of invasive plant species or target species when prescribing activities that result in soil disturbance or increased sunlight.
- Prior to moving equipment onto and off of an area with invasive species, scrape or brush soil and debris from exterior surfaces of the equipment in order to minimize the risk of transporting propagules. If practical, consider washing equipment.
- Take reasonable steps to avoid traveling through or working in small isolated populations of invasive species during forest management operations. This will help minimize their movement to noninfested areas.
- When conducting invasive plant removal, ensure that it is applied within the appropriate time window using suitable equipment and methods, such that introduction and spread of invasive species is limited.
- Be aware of and abide by state and federal regulations and quarantines that affect the movement of logs, coarse woody debris, and other tree parts due to the presence of invasive insects and diseases. Consult the Missouri Department of Agriculture for current quarantine information.

References to Other Chapters

It is important to define the landowner's objectives when prescribing silvicultural treatments. Developing a management plan with a professional forester is important for identifying the objectives for desired stand conditions and for considering limitations or management requirements for reaching such goals. See Chapter 11.

Variation in characteristics among species makes certain species particularly desirable for specific management objectives. For example, managing for wildlife habitat often involves a mixture of hard mast and soft mast species, but managing for timber production often emphasizes species of high timber value. Foresters use an understanding of the silvics of individual species and the limitations of the site in order to prescribe realistic treatments that fit the landowner's objectives and financial capability. See Chapter 10.

Soil productivity has economic implications in management. In areas with low site productivity, precommercial operations may not be economically feasible for improving wood production in the long term since overall tree growth potential is limited. Utilizing soil maps to determine soil productivity will help land managers make informed decisions on how and when to prescribe tending treatments. See Chapter 7.

Land managers must also consider other factors that affect how silviculture can be implemented to meet management objectives. Among these, protection of species of conservation concern, protection of valuable cultural resources, and maintenance of visual quality are all important considerations. These factors may not affect decisions in all management scenarios but warrant consideration when applicable. See Chapters 2, 4, and 6.

Prior to beginning management activities, consult a professional forester, a Missouri Department of Conservation (MDC) private land conservationist, an MDC wildlife biologist, or an MDC natural history biologist for information about the occurrence of endangered, threatened species, species and natural communities of conservation concern, rare tree species, or sensitive communities present on or near the management area. These species and communities can be impacted by tending treatments. These professionals can help you modify management activities in order to maintain, promote, or enhance species and natural communities on the site. See Resource Directory and Chapter 3 for more information.

If the operation includes the use of equipment with ground disturbance, refer to Close Out Operations in Chapters 14 and 15 for further guidance.

Additional Resources

Crop Tree Management for Eastern Hardwoods. Available at na.fs.fed.us/pubs/ctm/ctm_index.html

Forest Management for Missouri Landowners, Missouri Department of Conservation 2007. Available at mdc.mo.gov/node/5574

Minnesota Forest Resources Council. Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers. Minnesota Forest Resources Council 2005., Available at frc.state.mn.us/initiatives_sitelevel.html

Wisconsin Forest Management Guidelines. PUB-FR-226, 2011. Available at dnr.wi.gov/topic/ForestManagement/guidelines.html

Missouri Woody Biomass Harvesting Best Management Practices Manual. Missouri Department of Conservation 2009. Available at mdc.mo.gov/node/9806

Chapter 14: Forest Roads/Trails

Topics Covered

Forest Roads
Types of Roads
Best Management Practices for Road Planning and Design
Best Management Practices for Removing Creek Gravel
Minimizing Infrastructure
Best Management Practices to Reduce the Visual Impact of Roads
Best Management Practices to Protect Cultural Resources
Best Management Practices to Slow the Spread of Invasive Species
Best Management Practices to Protect Soil Productivity and Water Quality
Best Management Practices for Stream Crossings
Best Management Practices for Placing and Using Water Bars
Federally Required Best Management Practices for Roads in Wetlands
Best Management Practices for Road Maintenance
Closing Out a Road
References to Other Chapters
Additional Resources

Forest Roads

Forest roads provide a wide variety of benefits including access for management and recreation as well as forage and corridors for wildlife. However, forest roads over time can become compacted. Surface runoff can move tons of sediment from the roadbed into the surrounding property if the road is not properly constructed and maintained.

Sediment leaving the roadbed can be deposited into streams, reducing water quality. Areas with steep slopes, erodible soils, and wet soils are areas with the highest risk. Problems can be prevented by using best management practices that limit surface flow, that restrict road use when it is too wet, and that ensure the runoff is not connected to stream channels. There are many techniques that help you properly and sustainably construct and maintain access roads and trails.

Types of Roads

- Temporary roads

    - Temporary roads are only intended to be used short-term when the soil is firm.
    - Usually these roads are made using a skidder blade with a minimum amount of advance planning or design.

- Permanent seasonal roads
    - These are part of the permanent road system but should only be used when firm. These roads require proper planning in order to reduce impacts.
- Permanent all-season forest roads
- Permanent all-season roads will have gravel surfaces, side and wing ditches, and culverts. They are designed for year-round use. Even these roads can become too wet to use, especially for heavily loaded log trucks.

Figure 14.1. Log truck using a temporary road on a ridge top. The use of this road will need to be restricted to dry periods.

Always have a plan and a design before you build any new road or open an old road. Unplanned road construction may result in higher maintenance and reconstruction costs as well as negatively impacted water quality. A professional forester with experience in designing and laying out forest roads and supervising construction can provide valuable advice.

Best Management Practices for Road Planning and Design

- The development of a road plan should consider the following:
    - How much traffic will use it?
    - What kinds of vehicles will it need to support?
    - Will it be used year-round or only seasonally?
    - Identify property lines to avoid building roads on someone else‘s property.
    - Plan for close out of roads or a plan to continue future maintenance.
- Consult a fisheries biologist to make sure water quality is addressed.

- If the road you build enters a public road, you will need to contact the authority in charge in order to obtain proper permits. If it is a state road, you must contact the Missouri Department of Transportation (1-888-275-6636).
- Locate roads on better-drained soils if available. Soils with rocky surfaces should be utilized if possible.
- Place roads along the edge of a ridge or other locations that provide good surface drainage utilizing southern aspects when possible.
- Place roads away from streams, seeps, springs, wetlands, sinkholes, and caves.
- Walk the route and hang flagging once you determine the best location for the road. Your contractor or forester may suggest changes prior to construction based on their experience.
- If surface material is needed, use crushed rock instead of creek gravel. Permits may be required to use creek gravel, and in-stream habitat, water quality, and cultural resources could be negatively affected. If you do decide to use creek gravel, make sure to carefully follow the Best Management Practices for Removing Creek Gravel.

Best Management Practices for Removing Creek Gravel

It is important to be diligent and take due care when removing aggregate material from a stream. When done properly, sand and gravel can be removed with minimal harm to the stream and can allow you to use some of this material on your farm. However, removal does not address the causes of sand and gravel problems in the stream. It is important to remember that sand and gravel removal can create physical and economic problems for landowners above and below the removal area. If a removal technique is chosen, it should be conducted with the stream's stability in mind. You should consider the following steps to ensure minimal impacts to others and to avoid damaging streams.

- Apply for the appropriate permits. Most stream work requires permits from state and federal agencies. Be sure you comply with all applicable laws. Contact Missouri Department of Conservation Fisheries offices for assistance in applying for these permits.
- Restrict removal activities to sand and gravel bars that are loosely packed, in order to avoid damage to the stream. Bars covered with larger-sized materials that are well packed or vegetated are usually stable and should not be disturbed. Missouri Department of Conservation, Fisheries Division, personnel can help you find locations where gravel removal will minimize harm to the stream.
- Remove gravel above the water line and leave a 2-foot buffer of undisturbed material between the normal water line and the excavation area.
- Avoid removing sand and gravel within 25 feet of streamside vegetation. Vegetation holds gravel and soil, keeping bars and banks in place.
- Use approved stream bank erosion structures and avoid channel straightening or packing sand and gravel on eroding stream banks.

- When removal is completed smooth the area to avoid streambed erosion and other stream channel problems.
- Avoid using vehicles and heavy equipment in the water. If you must cross the stream, drive vehicles at right angles to stream flow.
- Sand and gravel removal should take place before March 15 and after June 15 to avoid harming spawning fish and their habitat.
- Keep fuel, oil, and other wastes out of the stream.
- Do not remove gravel from riffles (shoals) because they prevent erosion of the streambed. Riffles are very important to stream stability and are a major source of food and oxygen for aquatic life.
- Do not wash sand or gravel in the stream channel to avoid polluting the water with sediment. If you must wash sand or gravel, use a settling basin and wash your material outside the stream.

Minimizing Infrastructure

Roads take land out of production for the long term due to destruction of the soil structure, compaction, loss of permeability and porosity, and loss of the surface horizon due to erosion. Because of these effects, efforts should be made to keep the length and width of roads to a minimum without sacrificing safety. Development and use of a well-planned road system will allow for efficient access of as many acres as possible with the least amount of the site occupied by roads. No more than 1–2 percent of the management area should be occupied by roads.

When access is necessary in sensitive locations, minimize the number, length, and width of roads.

Minimize the number of new roads by using old roads. Most ridges in Missouri have been utilized as a road or trail at some point in the past and may be useable again if properly placed.

Take into account the following considerations when planning to reduce noise and visual impacts associated with the design and use of forest access roads:

- Noise from traffic, especially large trucks and heavy equipment operating on access roads, can be a concern to recreational users and nearby residents.
- There are potential increased costs involved in building forest access roads to accommodate visual quality concerns. There are also potential increased costs from using existing roads that require traveling greater distances.
- Visually appealing roads are often narrow with a canopy overtopping them. These types of roads generally do not dry out as quickly as wide day-lighted roads, and this can potentially reduce the number of days when the road is operable.

- Harvest roads used during wet periods can increase maintenance needs, create unsightly ruts and mud holes, and pump elevated levels of sediment out of the roadbed and onto adjacent lands.

Best Management Practices to Reduce the Visual Impact of Roads

- Minimize the number of roads in visually sensitive areas by using existing roads or trails where possible.
- Orient logging road entrances onto public roads to screen the harvest from view. Refer to Figure 14.2.
- When planning new roads, consider if the road will be visible from nearby vantage points such as scenic overlooks, rivers, or lakes.
- Consider viewing duration and visual penetration when planning roads. Refer to Figure 14.3.
- Avoid tracking mud onto highways by using appropriate road surface material.
- Road rights-of-way and road entrances should be cleaned of debris, stumps, and logging slash during construction. Avoid creating a corridor of debris.
- Utilize merchantable timber within road clearings. Cut trees so the tops land away from the road. This puts the slash further out of sight and reduces the need for lopping.
- Reduce the height of dozed clearing debris during road construction.
- Refer to Chapter 4 for general guidance for determining if an area is visually sensitive.

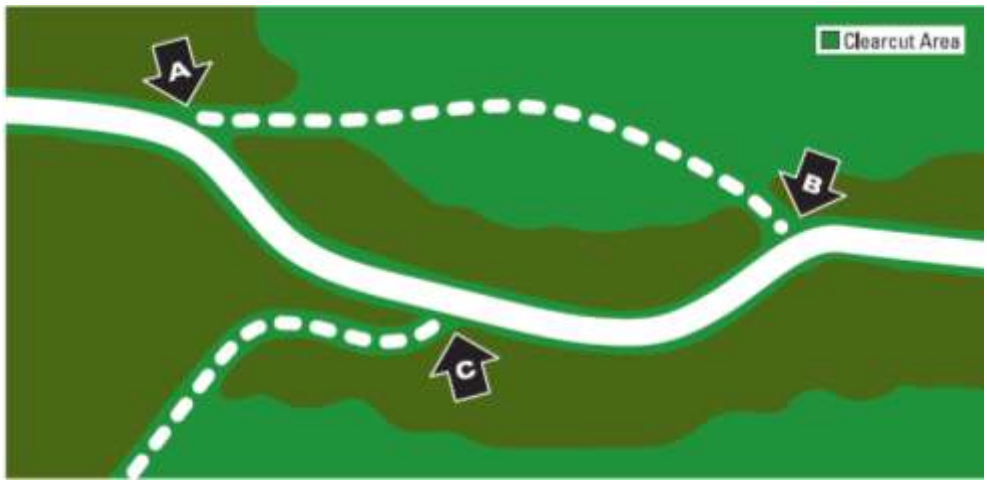


Figure 14.2. The logging road entrances at "A" and "B" permit excessive visual penetration directly into the harvest area. They also present a safety hazard by joining the main road on curves. A more preferred entrance location at "C" breaks the line of sight into the harvest area and also exits onto the main road at a 90° angle in a safe area. (Figure courtesy of Wisconsin Department of Natural Resources.)

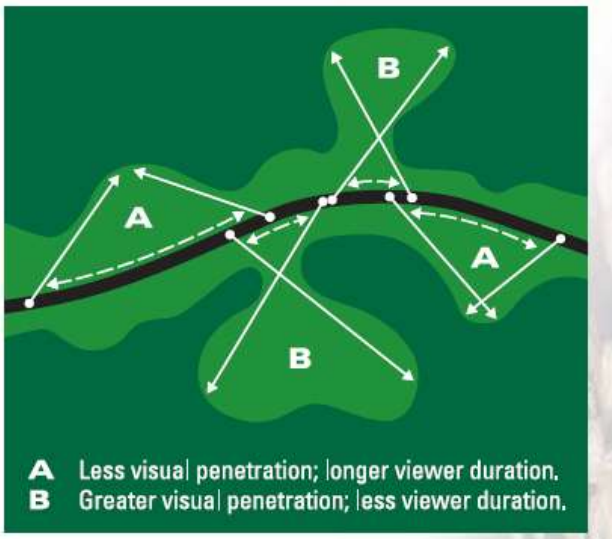


Figure 14.3. In this example, the harvest area has been designed so that the longer a viewer can see an area (viewing duration), the shorter the distance they can see (visual penetration). The goal is to provide some visual diversity, while at the same time reducing the apparent size of the harvest. The travel speed and road layout also affects the viewing duration. Fast travel speeds on straight roads provide less view durations than low speeds on curving roads. (Figure courtesy of Wisconsin Department of Natural Resources.)

Best Management Practices to Protect Cultural Resources

Activities that have a high potential to disturb cultural resource features include construction of access roads, log landings, and erosion control measures such as water bars. Sites where an activity disturbs the natural surface of the ground at a level that is deeper than plow depth (approximately 7 inches) should be carefully investigated for the presence of cultural resources. Specific Best Management Practices for cultural resources commonly found in forested areas are located in the Appendix B.

- Avoid known cultural resources sites if possible when building roads, landings, or erosion control features like water bars on skid trails.
- If cultural resource sites cannot be avoided, use “fill only” techniques to improve roads. Synthetic or natural covering such as treetops can be used to armor resources and protect their integrity. Remove tires and other synthetic materials after completion of the project. Natural materials may be left in place. Secure approval for covering from SHPO at MoDNR prior to placing fill over significant cultural resource sites.
- Minimize or eliminate maintenance (including widening) in or near cultural resource areas.
- Control erosion from road runoff to avoid impacts to adjacent cultural resources.
- Close roads and decommission sites close to important cultural resource sites once the forest management operation is complete.

The contact information for the state historic preservation officer is as follows:

State Historic Preservation Office (SHPO)
PO Box 176
Jefferson City, MO 65102
800-361-4827
573-751-7858
Email: moshpo@dnr.mo.gov

Best Management Practices to Slow the Spread of Invasive Species

Road construction, because of the level of disturbance, has significant potential to influence the spread or establishment of invasive species.

- Plan to conduct activities to minimize the spread of invasive species and control them where they currently exist. More information related to invasive species management is found in Chapter 9.
- Prior to moving equipment onto and off of an activity area, scrape or brush soil and debris from exterior surfaces, to the extent practical, to minimize the risk of transporting seeds. If practical consider washing equipment.
- Take reasonable steps to avoid traveling through or working in populations of invasives during forest management activities. This will help minimize the movement to noninfested areas.
- Prior to trucking, implement mitigation strategies to reduce the risk of transporting highly damaging invasive insect and disease species when present, to the extent practical. (i.e., do not haul EAB-infested ash trees beyond the quarantined area.)
- To the extent practical, use existing roads, skid trails, and landings to reduce disturbance, upgrading to ensure that water quality and site productivity is maintained and protected.
- Avoid constructing new roads, skid trails, and landings in areas infested with invasive species.
- Avoid spreading seeds and other propagules from infested to noninfested areas during road maintenance, reconstruction, new construction, and closure.
- Natural re-vegetation of haul roads, skid trails, and landings can help stabilize soil when re-vegetation is consistent with site conditions and goals. However, on disturbed sites with high potential for erosion, seeding and mulching may be warranted. Use locally sourced native seed or noninvasive cover crops (refer to seeding chart in Table 14.3, below) for re-vegetation, in order to minimize the threat of highly damaging invasive species' spreading. Use methods to minimize the amount of exposed, bare mineral soil.
- Ensure, to the extent practical, that fill and gravel are free of invasive species and their propagules, prior to placement on the site. Quarry rock is less likely to contain invasive plant seeds compared to creek gravel.

Best Management Practices to Protect Soil Productivity and Water Quality

- Plan to conduct activities during preferred operating periods when site and soil conditions are best for minimizing the impact of forestry practices on the natural resources. Preferred operating periods for a site may vary according to local and seasonal climatic conditions, equipment being used, and operating techniques.
- Minimize soil disturbance and removal of trees. Pile cleared debris on the lower sides of the road and cut banks.
- Construct road approaches to streamside management zones (SMZ), springs, sinkholes, caves, and wetlands in order to minimize surface runoff.
- Road grades should be kept at less than 8 percent. Where terrain necessitates a steeper grade, minimize the road section length.
- Forest roads should be designed to shed water. Water control methods include crowning the road, using the natural slope, side ditches, culverts, water turnouts (also known as wing ditches), broadbased dips, and water bars. Refer to specific guidance below.
- Avoid traffic during wet periods. This can increase maintenance needs, create unsightly ruts and mud holes, and accelerate the movement of sediment from the roadbed.
- Avoid tracking mud on to public roadways. It is dangerous to motorists and creates a negative visual impact.
- Avoid burying wood debris in the road base. Eventually the wood will rot, requiring repair and reconstruction.
- Avoid using invasive and exotic plants when seeding areas that were disturbed during road construction. Refer to forest roads invasive species BMPs above.

Precautions are needed to prevent soil, water, and wetland contamination when using fuels, lubricants, and other materials associated with heavy equipment operations. Proper planning will help prevent or minimize spills of fuels, lubricants, or other materials. A basic spill kit should be kept on-site.

Best Management Practices for Stream Crossings

Road building and vehicle travel across streams should be avoided whenever possible because it increases sediment in the water, reducing water quality. Planning in advance will reduce the number of stream crossings necessary or eliminate them altogether. The following recommendations are specific to stream crossings and should be used in addition to general road construction recommendations.

- All approaches to stream crossings, whether on temporary or permanent roads, should be made at gentle grades.
- Plan the location and type of stream crossings to minimize the number of stream crossings. Multiple stream crossings on the same stream may require a 404 permit.

- Cross streams only as needed, at narrow points, and at 90-degree angles. Locate crossings where stream banks are low, rocky, and level such as at riffles or at other level, shallow, and firm streambed locations.
- Use bridges or culverts to minimize erosion and to maintain normal stream flow. Consider clear-span bridges, bottomless arch culverts, and temporary stream crossings that retain the natural streambed. Use low-impact temporary portable bridges when possible. Plan culvert sizes to handle full bank flows.
- The County Soil and Water Conservation District technicians, MDC engineers, or MDC fisheries biologist (stream specialists) can advise you on temporary or permanent bridge construction, and on proper size, construction, and maintenance of culverts. If the culvert is too small, the road may wash out.
- Note: Stream crossings that have uses other than forestry or agriculture applications may require special permits (404 permits). These permits can be applied for at the US Army Corp of Engineers' office. Special BMPS are required in forestry and agriculture in order to be exempt from the permit process. (See Forest Wetland Road Construction.)
- Install properly sized culverts where permanent logging roads cross streams (Table 14.1). Avoid using culverts smaller than 15 inches in diameter. Small culverts plug frequently and are difficult to clear of debris.
- Avoid culverts on perennial or intermittent streams. They retard flows, change stream channel configuration, and change channel gradient. Below grade crossings or span crossings are preferable.
- Stabilize culverts, bridges, and crossings with coarse rock or large stones. Use natural materials or clean rock and remove when the operation is complete. Protect permanent crossings with coarse rock or large stones that will not be moved by high flows.
- Protect and stabilize approaches to fords with crushed rock extending at least 50 feet from both sides of the stream bank approaches. Do not use fine gravels to line the streambed in the crossing. Flows will remove and carry them downstream.
- Use turnouts so runoff water does not enter the stream directly from the road ditches; allow a sufficient width for a filter strip.
- Stabilize exposed soil using seed and mulch, hay bales, rock, and silt fences.
- Do not remove culverts from stream channels following logging if the crossing may be used again within 10 years. If this option is used, the culvert size becomes even more critical. A long-term structure may have to withstand a wider range of flood and flow conditions. Avoid crossing streams more than necessary to get the logs and woody biomass to the landing.
- Avoid any practice that alters the flow of stream water, including changes to the channel gradient or width.
- Do not use logs or brush topped with soil for temporary crossings. This material may be transported by the stream and adversely affect water quality.
- Avoid draining water carrying sediment and pollutants directly into streams or intermittent drainages. Diverting it off into the surrounding vegetation will filter out sediment and allow it to soak into the soil.

- Do not locate roads in streambeds.
- Avoid constructing roads inside SMZs. Roads should be constructed in SMZs only where necessary to cross streams.

Table 14.1. How to Determine Properly Sized Culverts

Drainage Area (acres)	Culvert Pipe Diameter (inches)
Less than 10	15
10	18
50	42
100	48
200	72

Water bars are a combination of a mound and a trench, angled at 30–45 degrees across skid trails and roads. Their purpose is to intercept, divert, and disperse water off exposed soil onto the forest floor where it will be filtered and where it will soak into the soil without causing erosion and sedimentation. Water bars form a significant, almost impassible bump and should be used only where machinery will no longer travel. Continued use will ruin water bars. If the forest owner wishes to continue use of the road for recreation or for cutting firewood, broad-based dips can be substituted for water bars. Other alternative methods may include open box culverts and conveyor belt structures.

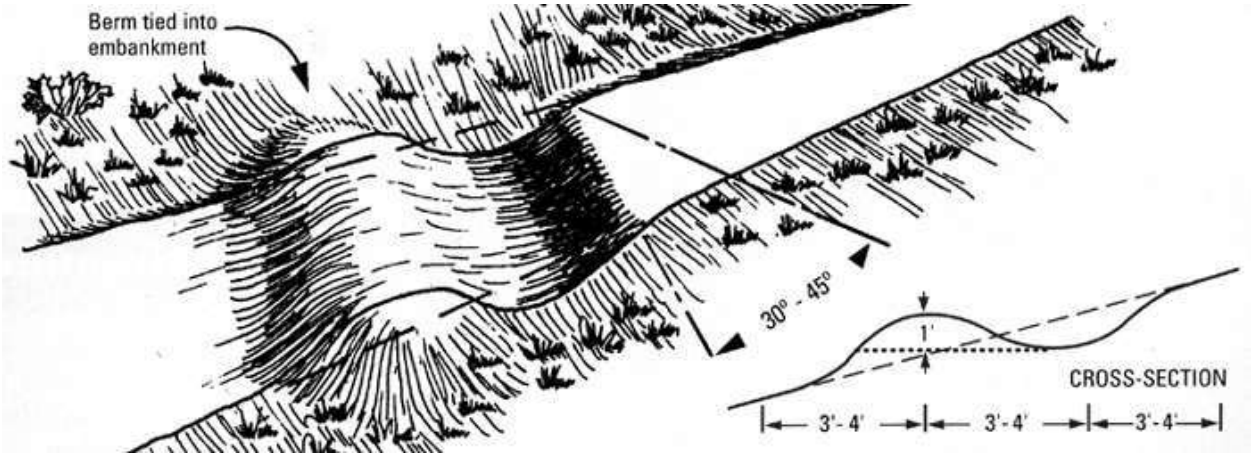


Figure 14.4. Water bar design (from *Wisconsin's Forestry Best Management Practices for Water Quality*, 1995). Make sure to have water bars angled at 30–45 degrees.

Table 14.2. Spacing between Water Bars

Road Grade (percent slope)	Approximate Distance Needed between Water Bars (in Feet)
1	**400**
2	**245**
5	**125**
10	**78**
15	**58**
20	**47**
25	**40**
30	**35**
35	**32**
40	**29**

Best Management Practices for Placing and Using Water Bars

- Water bars are generally built at a 30-degree angle. (See Figure 14.4.) If the angle is less than this, water will dam up and cut through water bars.
- The distance between water bars will vary from every 250 feet on gently sloping trails to every 40 feet or less on steep trails. (See Table 14.2.)
- The height of water bars will vary from 8 to 30 inches, with lower bars on gentle slopes and higher bars on steeper slopes.
- The bottom edge of a water bar should be open to allow water to flow freely out into the leaf layer on the forest floor where it will be filtered and soak into the soil.
- Avoid driving vehicles or equipment over water bars once they have been built.
- Avoid building water bars with blockages (such as stumps or logging debris) that prevent drainage.

Figure 14.5. Alternative water diversion structure using recycled conveyor belts in place of earth mounds.

Roads built for forest management in land described as a wetland under federal rules of Section 404 of the Clean Water Act are a special case. If the intended use is only for forest management, the construction and use are exempt from the permit requirements. To qualify, construction must comply with the following recommended best management practices:

Federally Required Best Management Practices for Roads in Wetlands

- Roads and skid trails in waters of the United States must be the minimum number possible. The width and length must match with the forest management need and local conditions.
- All roads must be located far enough from streams or water (except where water must be crossed) to minimize the amount of material put into the waters.
- The road must be designed to prevent the restriction of normal flows.
- The fill must be stabilized and maintained to prevent erosion during and after construction.
- Use of trucks, tractors, and other heavy equipment in water and adjoining wetlands must be minimized. Avoid operating equipment in wetlands if at all possible.
- Disturbance of natural plant life in water and wetlands must be minimized.
- The construction and maintenance of the road must not prevent natural movement of aquatic wildlife living in the water or wetland, especially migration.
- Borrow material must be taken from upland sources whenever possible.
- Road construction and maintenance must not harm any threatened or endangered species listed under the Endangered Species Act, including no destruction or damage to critical habitat for listed species.
- Fill material in breeding and nesting areas for migratory waterfowl, fish spawning areas, and wetlands must be avoided if any practical choice exists.
- The fill must not be located near a public water supply intake.

- The fill must not occur in areas of high shellfish (native clams) habitat.
- The fill must not occur in any part of the National Wild and Scenic River System.
- Fill material must be suitable and free from poisons.
- All temporary fills must be removed entirely and the area restored to its original elevation. Permanent roads requiring fill in jurisdictional wetlands may require CWA 404 permits.

Further state interpretations of the federally required best management practices for roads in wetlands are as follows:

- Avoid wetland impacts if possible.
- Minimize number of crossings.
- Cross at narrowest point if possible.
- Construct upland road approaches to wetlands so the surface runoff is diverted away from the road approach and does not enter the wetland.
- Maintain hydrological connectivity with at- or below-grade crossings (preferred) or culverts.
- Minimize elevation of roadbed to no more than 1 foot above existing natural ground elevation.
- Remove road fills after completion of operation.
- If landings are necessary in a wetland, build them to the minimum size required for the operation and to achieve the landowner's objectives.
- Avoid locating roads and landings in the wetland filters.
- Avoid operating equipment in areas of open water, springs, or seeps.
- Install culverts or bridges a maximum of 300 feet apart and at all natural drainage ways.
- Install at least one cross-drainage structure at each wetland crossing.
- For temporary roads, provide adequate cross-road drainage at all natural drainage ways.
- Temporary crossing structures include timber mats, culverts, bridges, and porous organic material such as corduroy or chunk wood.
- Temporary crossings should be removed promptly when work is complete. If organic material is used, remove as much as feasible, given site and material conditions.
- Any activities in wetlands must follow Missouri DNR and U.S. Army Corps of Engineers regulations.
- For permanent roads with fill, use permeable fill material for at least the first layer of fill.
- The height of roads on high ground should be less than 2 feet above the surrounding ground.
- Where a road crosses a stream, slough, swamp, or other wetland the fill should not be higher than the road at either end. Normally, the road should be 2–3 feet above the ground, but it may be higher in low areas.
- Main roads at streams should be bridged or built with culverts large enough and numerous enough with permanent structures of a size and frequency to carry the

expected flow of water. Where fords are used instead of bridges or culverts, they each must have a good rock base to protect the streambed.

- Soil must be stabilized around each structure where main roads cross seasonal or permanent streams with an average annual flow of 5 cubic feet per second or more. Structure stabilization is also required where rainwater runoff from the road can cause erosion and sedimentation.
- Where light-use roads cross seasonal or permanent streams, temporary bridges or culverts able to minimize interference with the flow of water should be used. When forest management use is completed, temporary bridges and culverts should be removed and the roads cross-ditched where needed to allow normal water flow.
- Get roadbed material from upland borrow pits whenever possible. The base of roads that cross sloughs or swamps may be logs, sand, or clay. Logs are preferred because they reduce the amount of fill required. Roads with only a sand or clay base gradually settle and must be built higher initially. Roads in swamps and river-bottom areas may be constructed with borrow material from a ditch along the upper side of the road and then capped with fill from an upland area.
- Continuous side ditches are preferred. Borrow ditches may be refilled if temporary roads are removed. They reduce the pooling of water on the upper side of the road if there are enough culverts to drain to the lower side.
- Ditch bottoms should follow surface contours, and culverts should be located in the lower areas.
- Ditches should not be required to carry water for more than one-quarter mile. They must also be separated from navigable water by vegetated filter strips.
- Avoid using ditches to convert wetlands into uplands.

Best Management Practices for Road Maintenance

- Culverts and ditches must be kept free of debris and obstructions. Ditches on newly constructed roads may require frequent cleaning and checking after each major storm until re-vegetation has occurred.
- Install water bars, broad-based dips, and other water control structures to moderate the flow of water on the road.
- Do not leave a berm on the side of the road; it will channel water down the road.
- Shape road surfaces periodically to maintain proper surface drainage. Fill in ruts and holes with gravel or compacted fill as soon as possible to reduce erosion potential.
- Temporary roads should be closed to reduce the maintenance costs associated with vehicular traffic. Consider doing the following before the last piece of equipment capable of doing road maintenance leaves the site:

    - Remove all temporary drainage structures and replace with water bars.
    - Remove any stream crossing structures and reshape the stream channel to its original contour.
    - Stabilize the roadbed, cut and fill slopes with seed, and mulch when necessary.

- If public access is a problem, close the road with a gate or some other structure, at a point where topography prevents vehicles from going around the closure device.

- Permanent seasonal roads should have controlled access to keep maintenance costs low.
- Seed and mulch any remaining disturbed surfaces.
- Check all drainage structures to ensure they are in proper working order.
- Periodically inspect the road to ensure drainage is being maintained.

Closing Out a Road

Natural re-vegetation of haul roads, skid trails, and landings can help stabilize soil when it is consistent with site conditions and goals. However, on disturbed sites with high potential for erosion, seeding and mulching may be warranted. Seeding a forest access road after completion of use helps prevent soil erosion while providing wildlife food and habitat. Seeding can also soften negative visual quality impacts.

A seed mix appropriate for the season should be applied to disturbed areas immediately following road construction in order to promote reestablishment of plant growth to reduce erosion (refer to Table 14.3).

Inspect and maintain any soil-stabilization practices installed before closing out operation.

When seeding and mulching exposed soil, use clean straw and not hay to avoid spreading invasive species such as Sericea lespedeza, kudzu, crown vetch, or others.

Table 14.3. Seeding Rates (pounds pure live seed per acre [PLS/ac] - single species)

BASE SEEDING RATES — POUNDS PURE LIVE SEED PER ACRE Species	**Base Rate (100 percent) Pure stand**	**Erosion Control Rating** (use 200 percent seeding rate and have a good to excellent rating for erosion control)	**Wildlife Habitat Rating** (use 100 percent seeding rate)	**Wet Soil Tolerance Rating**	**Drought Tolerance Rating**	**Seeding Dates: Spring**	**Seeding Dates: Fall/Winter**
Cool Season Legumes							
Alsike Clover	3.2	Good	Good	High	Low	Mar.1–May 31	Aug.1–Oct.15
Ladino Clover	3.0	Good	Fair	Medium	Low	Mar.1–May 31	Aug.1–Oct.15
Red Clover	6.1	Fair	Fair	None	Low	Mar.1–May 31	Aug.1–Oct.15

Alfalfa	7.5	Fair	Excellent	None	High	Mar.1–May 31	Aug.1–Oct.15
Warm Season Legumes							
Common Lespedeza	7.5	Poor	Excellent	Low	High	Mar.1–June 30	Oct. 1 – Mar.1
Illinois Bundleflower	14.5	Fair	Excellent	None	Medium	Mar.1–June 30	Oct. 1 – Mar.1
Partridge Pea	26.8	Fair	Excellent	None	Medium	Mar.1–June 30	Oct. 1 – Mar.1
Purple Prairieclover	5.8	Poor	Good	None	High	Mar.1–June 30	Oct. 1 – Mar.1
Roundhead Bushclover	6.3	Poor	Good	None	High	Mar.1–June 30	Oct. 1 – Mar.1
Showy Ticktrefoil	10.0	Fair	Excellent	None	High	Mar.1–June 30	Oct. 1 – Mar.1
Cool Season Grasses							
Canada Wildrye	15.3	Good	Excellent	Low	Medium	Mar. 1–May 31	Aug.1–Oct.15
Virginia Wildrye	15.0	Good	Excellent	Medium	Medium	Mar. 1–May 31	Aug.1–Oct.15
Orchardgrass	6.2	Fair	Excellent	None	Medium	Mar. 1–May 31	Aug.1–Oct.15
Perennial Ryegrass	7.3	Poor	Good	None	Low	Mar. 1–May 31	Aug.1–Oct.15
Redtop	1.7	Good	Good	Medium	Low	Mar. 1–May 31	Aug.1–Oct.15
Smooth Brome	8.0	Excellent	Fair	Low	Medium	Mar. 1–May 31	Aug.1–Oct.15
Timothy	3.1	Good	Excellent	Low	Low	Mar. 1–May 31	Aug.1–Oct.15
Warm Season Grasses							
Big Bluestem	8.0	Fair	Good	Medium	High	Mar. 1–June 30	Oct.1 – Mar.1
Composite Dropseed	2.3	Fair	Good	None	High	Mar. 1–June 30	Oct.1 – Mar.1
Eastern Gamagrass	8.0	Poor	Good	Medium	Medium	Mar. 1–June 30	Oct.1 – Mar.1
Indiangrass	7.8	Fair	Excellent	Low	Medium	Mar. 1–June 30	Oct.1 – Mar.1
Little Bluestem	6.4	Good	Excellent	None	High	Mar. 1–June 30	Oct.1 – Mar.1
Sideoats Grama	7.5	Good	Excellent	None	Medium	Mar. 1–June 30	Oct.1 – Mar.1
Switchgrass	4.7	Good	Good	Medium	Medium	Mar. 1–	Oct.1 –

						June 30	Mar.1
Warm Season Forbs							
Grayhead Coneflower	3.6	Fair	Good	None	Medium	NA	Oct.1 – Mar.15
Pale Purple Coneflower	16.4	Poor	Fair	None	Medium	NA	Oct.1 – Mar.15
Ox-eye False Sunflower	11.3	Poor	Fair	None	High	NA	Oct.1 – Mar.15
Wild Bergamot	1.4	Fair	Fair	High	Low	NA	Oct.1 – Mar.15
Foxglove Beardtongue	4.4	Fair	Fair	Medium	High	NA	Oct.1 – Mar.15

For mixtures: Use the single-species seeding rates from Table 14.3 for the appropriate site use multiplied by the desired seeding mixture percentages to determine the seeding rate per species. Final seeding rate for the mixture will equal each adjusted seeding rate added together.

For seeding Canada wildrye and Timothy as a conservation cover with each species making up 50 percent of the mix, the formula would be:

15.3 PLS pounds/acre X 50 percent = 7.6 pounds/acre seeding rate (Canada wildrye)
3.1 PLS pounds/acre X 50 percent = 1.5 pounds/acre seeding rate (Timothy)
Total PLS for seeding mixture = 7.6 lbs Canada wildrye + 1.5 lbs Timothy = 8.1lbs/acre total seeding rate.

References to Other Chapters

Prior to beginning management activities, consult a professional forester, a Missouri Department of Conservation (MDC) private land conservationist, an MDC wildlife biologist, or an MDC natural history biologist, for information about the occurrence of endangered or threatened species, species and natural communities of conservation concern, or sensitive communities present on or near the management area. These species and natural communities can be impacted by road construction and maintenance activities. The professionals can help you modify management activities in order to maintain, promote, or enhance species and natural communities on the site. See Resource Directory, and refer to Chapter 3 for more information.

Road construction activities in visually sensitive areas can have negative impacts on aesthetics. Refer to Chapter 4 for guidance on determining visually sensitive locations

Road construction activities can negatively impact cultural resources. Make sure to avoid or mitigate impacts by referring to the guidance below. Refer to Chapter 6 for general information related to cultural resources.

Invasive species can be spread through the use, maintenance, and construction of forest roads. Refer to invasive species guidance below to help stop the spread. Refer to Chapter 9 for general information on invasive species management.

Road construction and maintenance can negatively impact soil and water resources. Refer to the BMPs to minimize the impacts on soil productivity and water quality. Refer to Chapter 5 and Chapter 7 for more detailed information regarding potential impacts.

Additional Resources

A Landowner's Guide to Building Forest Access Roads. Richard L. Wiest. NA-TP-06-98. Radnor, PA

Forest Management for Missouri Landowners, Missouri Department of Conservation 2007. Available at mdc.mo.gov/node/5574

Missouri Woody Biomass Harvesting Best Management Practices Manual. Missouri Department of Conservation 2009. Available at mdc.mo.gov/node/9806

Missouri Watershed Protection Practices: Management Guidelines for Maintaining Forested Watersheds to Protect Streams. Missouri Department of Conservation, 2006. Available at mdc.mo.gov/sites/default/files/resources/2010/07/9331_6294.pdf

Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers. Minnesota Forest Resources Council, St. Paul, Minnesota, 2005. Available at frc.state.mn.us/initiatives_sitelevel.html

Wisconsin Forest Management Guidelines. PUB-FR-226 2011. Available at dnr.wi.gov/topic/ForestManagement/guidelines.html

Chapter 15: Timber Harvesting

Topics Covered

The harvest of forest products in Missouri can help meet the social, environmental, and economic values of forest sustainability. This chapter includes site-level guidance for timber harvesting to ensure that forests are healthy and viable for future generations.

One of the most significant social values that forests provide is the scenic landscape that people enjoy viewing. A goal of good management should be to buffer the visual impact of harvesting and other forest management activities.

In resource management, trade-offs must be evaluated. Not all values can be given highest priority. A properly conducted harvest will accomplish most of the forest management goals while reducing the impact on scenery and recreation. Considerations for protecting visual quality should always be included in harvest plans.

Best Management Practices for Protecting Visual Quality

- When planning timber harvest in sensitive areas evaluate the viewshed and modify harvest to utilize less aggressive cutting methods where appropriate, in regeneration harvests consider leaving at least 20 to 30 square feet basal area.
- Discuss planned management activities with adjoining landowners.
- Consider using less intrusive practices next to heavy cutting on adjacent ownerships.
- Consider the entire vegetative community in and near the harvest area. Understory trees and shrubs such as flowering dogwood and redbud, as well as colorful fall species such as black gum can be retained to reduce the visual impact of the harvest activities
- Look for colorful species and large trees to leave for variation. (Refer to Chapter 4 for a list of species with good color.)
- If the view from the road is not screened by a hill, high bank, or other landform, consider maintaining a 100-foot-wide buffer strip (screen) using irregular-shaped borders and feathered edges. Cut lightly within the buffer strip. Maintain residual trees, utilizing a distribution of sizes including large sawtimber to create a sufficient screen. Evaluate the soil profile for a fragipan layer or bedrock that will limit deep root development. These factors along with the soils, slope, and position can be used to avoid windthrow (see Figure15.2).
- In areas where the site slopes away, consider creating scenic vistas. In some situations harvesting or pruning lower branches may be desirable to open up panoramic views.
- Use cutting techniques that utilize the terrain to create a more natural appearance (see Figure 15.3).
- Shape cutting areas to shorten the line of sight and minimize the area that can be seen from one viewpoint. Consider using group selection harvesting rather than even–age regeneration cutting (clear-cutting) where applicable.
- Leave scattered groups of trees and clumps of woody vegetation in large cut areas. Refer to Leave Tree section in this chapter for details on how to specifically integrate leave trees into even-age regeneration harvests (clear-cutting).
- In a leave tree (reserve tree) marking, mark trees on the side away from the road to reduce the negative visual impacts after the completion of the harvest.
- Use most of the merchantable wood from harvested trees. Refer to the guidelines in this chapter for specifics about slash retention and product utilization.
- Pull down hung-up trees; cut down bent and broken trees.

- Cut stumps less than 12 inches high.
- Skidding should be done in a careful manner to protect residual trees. Use low-impact equipment; avoid erodible soils or steep areas. Refer to the residual damage BMPs in this chapter.
- Rutting should always be avoided in sensitive locations.
- Consider using dormant season, leaf-off logging. Logging slash without leaves is less apparent.
- Create narrow openings into a harvest area in order to limit the view from public roads, lakes, rivers, or recreation areas.
- Even-aged regeneration clear-cutting (less than 10 square feet of retained basal area) should be restricted to 40 acres or less, this includes the combination of all stands that are connected within an area. These areas need to be separated by a manageable unit (typical stand).
- Previously clear-cut area regeneration should exceed 10 feet in height or achieve canopy closure along at least 50 percent of its perimeter before additional clear-cutting occurs, in order to ensure that the total clear-cut area does not exceed 40 acres.
- Clear-cuts of 40 acres in size are not appropriate in highly fragmented forests in western and northern Missouri due to potential negative impacts on forest interior species.
- Due to potential negative forest health impacts, salvage harvesting may warrant the use of more aggressive management techniques, which could include even-age regeneration harvest (clear-cuts) exceeding 40 acres and exceptions to green-up requirements listed in this chapter.
- Consider slashing tops within 100 feet of public roads or visually sensitive areas so debris is no more than 3 feet high. This should be included in the bid specifications and in the harvest/sale contract. The time and effort required to conduct this practice will have a defined cost to the landowner. This should only be prescribed when an area is in a visually sensitive location and when meeting landowner objectives.

Forest Certification Note

When working on forest land that is enrolled in a forest certification system, it is important to know the standards that apply to that program and understand how to implement them. Some forest certification systems have guidelines concerning clear-cutting that differ from the guidelines provided here.

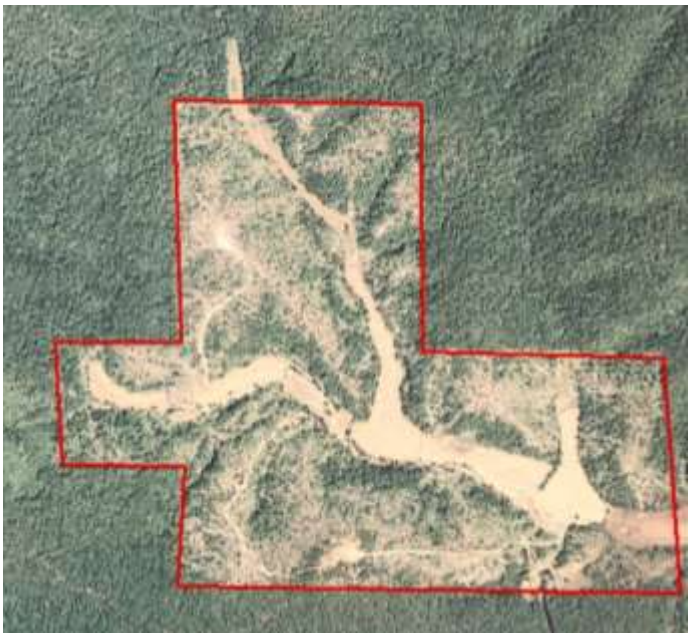


Figure 15.1. This aerial photo shows an adjoining property that has had a liquidation harvest. Plan to using less intrusive practices next to heavy cutting on adjacent ownerships.

Figure 15.2. Aerial photo showing landing (in blue circle) set back away from the road with a screen being used along roadway.

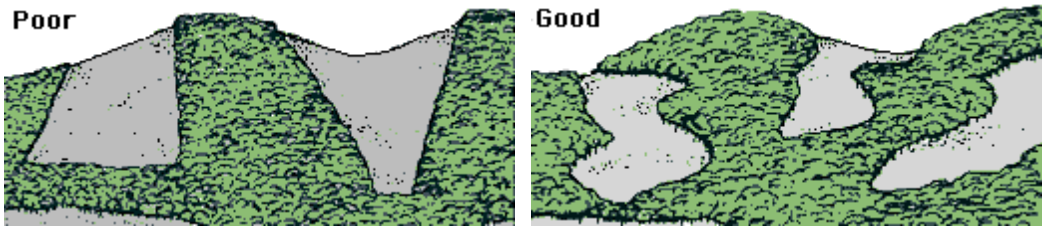


Figure 15.3. Design cuts to blend with the terrain. (From the *Woodland Owners' Guide to Oak Management*, University of Minnesota Extension.)

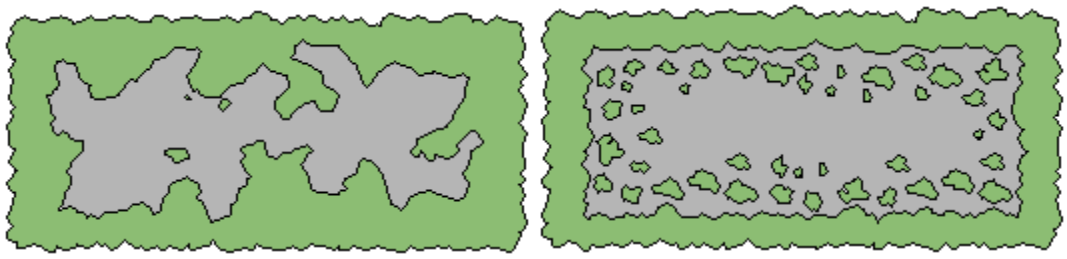


Figure 15.4. Irregular and feathered edges. Irregular or feathered edges are better than the straight edges of regeneration cuts (clear-cuts). Avoid creating abrupt changes from harvested areas to non-harvested areas. Create a gradual transition from areas that are to be heavily cut to areas that are to be lightly cut. An abrupt change results in what is known as a hard edge. This concentrates wildlife in a narrow strip, which favors predators. A feathered edge allows wildlife to nest and spread out, naturally reducing losses to predation. (*Woodland Owners' Guide to Oak Management*, University of Minnesota Extension.)

Figure 15.5. Consider multiple-stage cuts or other management methods such as shelterwood and uneven-age cutting to enhance visual quality. (Photo courtesy of Wisconsin Department of Natural Resources.)

Best Management Practices for Protecting Cultural Resources

Activities that have a high potential to disturb cultural resource features include construction of access roads, log landings, and erosion control measures such as water bars. When conducting activities that disturb the surface of the ground deeper than plow depth (approximately 7 inches), carefully investigate the site for the presence of cultural resources. More specific best management practices for cultural resources commonly found in forested areas are located in the Appendix B.

- Inspect sites prior to harvest to ascertain the potential for cultural resources occurrence. Clearly mark or flag areas to avoid.
- Exclude cultural resource areas from the timber sale area if feasible. Maintenance of undisturbed vegetation contributes to protection of cultural resources.
- Maintain un-harvested buffers around caves and sensitive natural features to avoid potential impacts to cultural resources, sensitive communities, and rare, threatened, or endangered species.
- Do not operate or park wheeled vehicles within the buffer zone of sensitive areas such as springs, seeps, or caves.
- Avoid tree removal and equipment operation adjacent to cemeteries, historic buildings, foundations, etc.
- Avoid operating wheeled or tracked vehicles on known cultural resources sites.
- Trees may be cut from cultural resource sites. Minimize surface disturbance. Cable logs from locations.
- Avoid cultural resource sites when locating roads, landings, or temporary skid trails.

Best Management Practices for Using Harvested Material

Utilization is market driven and varies throughout Missouri. Markets for biomass, pulpwood, pallets, and to a limited extent, residential firewood drive the markets for moderately defective and small-diameter logs. Mills sawing primarily for grade lumber, railroad ties, and cooperage typically do not want logs smaller than 13 inches in diameter on the small end of logs. Mills processing pallet logs can take logs to a 5-inch small-end diameter while pulp and fuel logs may be 3–4 inches in diameter on the small end. When harvesting, it benefits the landowner to ensure that logs are utilized for the highest valued product for which they are suitable.

- Log decks should clearly distinguish veneer, stave, or grade logs from lower-quality stems.
- Debris piles and cutoff logs remaining in the woods and in treetops should be short log segments, less than 3–4 feet in length, of small diameter, and/or should contain approximately 50 percent or more incipient decay, rot, hollow, shake, large knots, worm holes, stain, or other indicators of defective wood.
- Inspect log jobs to ensure that utilization objectives are being met.
- Encourage loggers to take advantage of all available markets for wood.

Figure 15.6. This logger is sorting different product at the landing to ensure high product utilization.

Best Management Practices to Slow the Spread of Invasive Species

- Learn to identify and control locally known invasive plants and pests in your area.
- Prior to implementing management activities, scout for and locate invasive species infestations, consistent with the scale and intensity of operations.
- Plan management activities to limit the potential for the introduction and spread of invasive species.
- Plan for post-activity management of highly damaging invasive species.
- Consider the likely response of invasive species when prescribing activities that result in soil disturbance or increased sunlight.
- Prior to moving equipment onto and off of an activity area, scrape or brush soil and debris from exterior surfaces to minimize the risk of transporting propagules. If practical, consider washing the equipment.
- Take reasonable steps to avoid traveling through or working in small isolated populations of invasives during forest management activities. This will help minimize the movement to noninfested areas.
- Prior to trucking, implement mitigation strategies to reduce the risk of transporting highly damaging invasive insect and disease species when present, to the extent practical.
- To the extent practical, use existing roads, skid trails, and landings to reduce disturbance, upgrading to ensure that water quality and site productivity is maintained and protected.
- Avoid constructing new roads, skid trails, and landings in areas infested with invasive plant species, where possible.
- Natural re-vegetation of haul roads, skid trails and landings, when it is consistent with site conditions and goals, can help stabilize soil. However, on disturbed sites with high potential for erosion or where invasive plant species are present, seeding and mulching

may be warranted. Use only noninvasive plants such as wheat or annual rye grass for this cover crop.

- Be aware of and abide by state and federal regulations and quarantines that affect movement of logs, coarse woody debris, and other tree parts due to the presence of invasive insects and diseases. Consult the Missouri Department of Agriculture for current quarantine information.

Best Management Practices for Protecting Soil Productivity and Water Quality

- A harvest plan should be completed before the harvest. The harvest plan should address landings, skid trails, and roads as well as other BMP issues.
- Use of the guidance found in Best Management Practices for Harvesting Woody Biomass (for biomass harvests) and the *Missouri Watershed Protection Practice* booklet should be required in all written harvest contracts.
- Always use Missouri Forest Products Association professionally trained loggers.
- Equipment maintenance should be performed outside of stream corridors.
- All lubricants and fuels should be stored outside the 100-year floodplain.
- Waste should be disposed of in a responsible manner,
- Equipment should be maintained to avoid fluids leaks.
- Basic spill kits should be located on-site.
- Plan to conduct activities when soil conditions will support harvesting equipment. Proper planning will minimize the impact of forestry practices on the natural resources. Preferred operating periods vary due to soil, local and seasonal climatic conditions, equipment being used, and operating techniques.
- Install temporary erosion control structures on landings and skid trails prior to periods of inactivity or prior to expected heavy rain events.
- Harvesting should be temporarily stopped when the soil is saturated to decrease the likelihood of erosion, rutting, and compaction. Logging can be moved to more stable areas or limited to felling trees only, or time can be focused on equipment maintenance until conditions have improved.
- The use of low-ground-pressure equipment may allow operations to continue, this may include small-sized equipment with large tires or tracked equipment.
- Whenever possible, winch logs from steep slopes, if conventional skidding could cause erosion that affects water quality.
- Avoid ruts 6 inches or greater for a distance greater than twice the length of a skidder (approximately 50 feet).
- Inspect soil-stabilization practices periodically. Inspect both during and immediately after harvest operations, to ensure that practices are implemented and functional.
- Avoid grazing forested areas. Grazing compacts soil, increasing erosion, and can potentially decrease soil productivity. It also prevents natural regeneration and can promote invasive species. Additionally, forest grazing is generally not effective at weight

gain on cattle and can be detrimental to livestock health from poisonous plants and difficult terrain.

- Avoid selling forest products without a written contract.

Figure 15.7. Timing is crucial to ensure that site productivity and water quality are not negatively impacted. This operation occurred when the soil was too saturated resulting in unacceptable rutting and damage to the site.

Streamside Management Zones

Streamside Management Zones (SMZs) or Riparian Management Zones (RMZ) are areas along intermittent and perennial streams and rivers that are important in maintaining water quality (refer to Chapter 5 to determine if a stream is an intermittent or permanent stream). Trees and other plants in SMZs are the “last line of defense,” slowing floodwater, filtering and trapping sediment to clean the water, and creating rich bottomland soil. SMZs require special treatment when harvesting timber/woody biomass and conducting other forest management activities in order to protect stream banks from erosion and provide shade to cool stream temperature. The deep moist soils of many streamside forests provide excellent growing sites where high-quality trees and bottomland tree species can grow. Caves, springs, sinkholes, and lakes are other special areas treated like SMZs.

SMZs are composed of two parts. The primary filter strip starts at the top of the well-defined bank and extends 25 feet on both sides of the stream. A secondary filter strip varies in width depending on the steepness of the surrounding land. It is determined by multiplying the percent slope of the land immediately beyond the first 25-foot strip by a factor of 2. The resulting number is added to the 25-foot strip for the total width of SMZ to be protected.

Note: the width of an SMZ should always be at least 50 feet. To determine SMZ widths wider than 50 feet use the rule stated in this paragraph.

Example:

Percent slope is the rise/run x 100.

A rise in elevation of 5 feet over a distance of 25 feet is 5/25 = 0.2; 0.2 x 100 = 20 percent slope.

If the slope of the land beyond the first 25-foot strip is 20 percent, multiply 20 x 2 = 40 feet. The total SMZ is 25 feet + 40 feet = 65 feet on each side of the stream.

Figure 15.8 shows an SMZ. Table 15.1 lists the total width of filter strips for different slopes. These are the recommended widths to reduce the amount of sediment reaching streams from areas disturbed by logging or other activities.

Note: the exception to the SMZ rule stated previously is for large streams and rivers (third-order streams) with wide flat floodplains. These areas should have a minimum of 100-foot SMZs on each side of the stream.

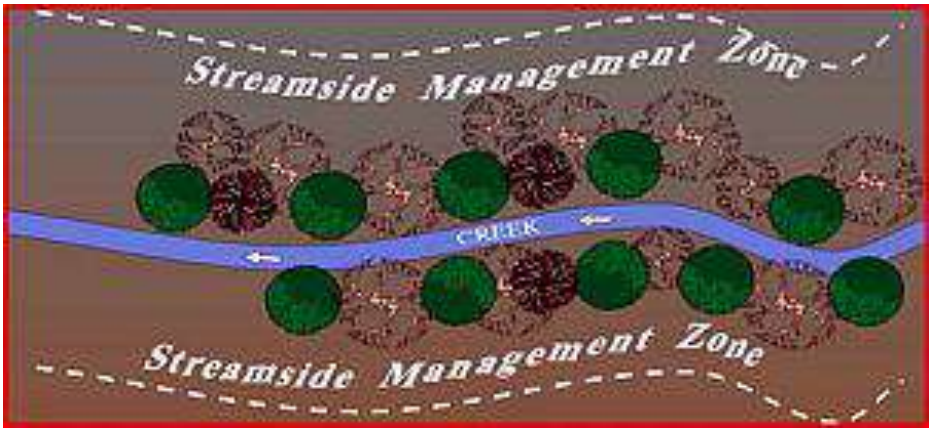


Figure 15.8. The Streamside Management Zone or SMZ along a creek.

Figure 15.9. A creek buffered by a Streamside Management Zone (SMZ).

Best Management Practices for Streamside Management Zones

- Always leave at least one-third of the typical size trees in the SMZ: 40 square feet of basal area (BA) or greater but not below C-level stocking (see Glossary) in a fully stocked stand of trees during an even-age regeneration or woody biomass harvest, but one-half to two-thirds of typical size trees is recommended in most cases. Logs and woody biomass should be cabled out of the primary zone (first 25 feet) of the SMZ.
- Use of heavy equipment, like log skidders and bulldozers, is permissible in SMZs, but special care is needed (see previous recommendation for an example).
- In SMZs and other special areas, pull fewer logs and less woody biomass behind the skidder in order to minimize rutting. Cut trees so they fall away from wetlands and other special features.
- Leave most trees on stream banks. Trees on south and west banks are especially critical for cooling water temperature. A closed canopy should be maintained in SMZs. Maintain or manage stands with large trees closer (approximately 50 feet) to the stream to provide shade and to establish a root system to stabilize the bank. Riparian trees also provide large woody debris for fish and invertebrate habitat. Leave “hydraulically important” trees that protect specific stream corridor areas.
- Try to leave a variety of tree species and sizes in SMZs/RMZs. Special exceptions may be needed in shade-intolerant tree species in order to regenerate the riparian forest; contact a professional forester for assistance.
- Avoid leaving treetops from harvesting activities in streams. Use directional felling to ensure treetops do not fall in streams. Naturally occurring trees and tops in water provide enough habitat, and tops may clog stream channels and damage bridges.

- Avoid exposing mineral soil during site preparation in an SMZ when heavy rain or snowmelt is likely to cause erosion and sedimentation.
- Avoid placing portable sawmills or log landings in SMZs/RMZs.
- Avoid leveling of gullies unless immediately seeded and mulched.

Table 15.1 SMZ Width by Slope

Slope of Land between Road and Stream (percent)	Width of Filter Strip for Common Logging Area (feet)
0	50*
10	50*
20	65
30	85
40	105
50	125
60	145

Note: All Streamside Management Zones require a 50-foot minimum distance.

Best Management Practices for Wetland Protection

Wetlands are areas where the soil is saturated and often covered with water for varying periods of time during the year. Wetlands support many natural communities with unique features and some endangered and rare species of wildlife and plants. Plants and animals in wetlands are adapted for life in saturated soils.

A professional forester or wetland specialist can provide important information before harvesting begins. They can locate, flag, and map the boundaries of wetlands to limit damage from harvesting equipment.

- Extend SMZs to include all adjoining wetlands. Always leave in the SMZ at least one-third of the typical size trees (40 BA or greater) in a fully stocked stand of trees during a harvest, but one-half to two-thirds is recommended in most cases. Logs and woody biomass should be cabled out of all primary zones in SMZs and wetland buffers.
- Write a sediment and erosion control plan using best management practices during nearby road construction.

- Avoid restricting the natural surface and subsurface flow of water under haul roads in wetlands by installing culverts periodically (provide adequate cross-road drainage).

Best Management Practices for Protecting Natural Features

Sinkholes are natural depressions or holes that occur where the underlying carbonate bedrock, such as limestone or dolomite, dissolves. They can vary in size and depth and may be bowl or chasm shaped. Forming gradually, underground sinkholes suddenly collapse, creating a direct connection between the surface and groundwater. They often are associated with an underlying cave and provide a source of food for creatures that never leave the cave.

Harvesting near sinkholes is permissible, but it poses a significant risk to cave systems, the creatures that live in them, and water quality. Leaky harvesting equipment is very common and may contaminate sinkholes if the harvesting operation is not properly supervised.

A cave is a natural opening extending beyond the zone of light and providing a home to some of the least common wildlife. This natural feature and the plants and animals that live there can be harmed by careless harvesting activities. Caves should always be located and protected when harvesting timber or woody biomass. Forested buffers around cave entrances provide valuable protection for this unique and sensitive habitat.

A spring is a point where water flows out of the ground — where the aquifer meets the surface. It may run year-round or only during certain times depending upon the amount of rain or snowmelt received.

- Locate and flag all sinkholes, caves, and springs prior to the start of harvesting.
- All sinkholes, regardless of size, require protection with at least a 100-foot buffer zone completely surrounding them. Limited harvesting within the buffer zone is permissible, but always leave in the zone at least one-third of the typical size trees (40 BA or greater) in a fully stocked stand of trees during a woody biomass harvest, although one-half to two-thirds is recommended in most cases. Logs and woody biomass should be cabled out of all buffer zones.
- The intent is not to buffer every depression; features that identify a sinkhole from other areas include recent slumping (soil movement), a rock rim, and/or a steep drop in elevation in the sinkhole.
- Be sure your timber sale contract contains language to protect resources from leaky harvesting equipment and follow through with frequent inspections of the harvesting activities.
- Protect unique sinkholes — flag a buffer around them to protect them from harm.
- Unique sinkholes must have one of the following: significant changes in elevation (30 percent slopes or greater), caves, permanent standing water, exposed rim rock, or different vegetation than the surrounding forest. These unique sinkholes should be buffered by at least 200 feet and no logging should take place.

- If harvesting is needed in unique sinkholes, contact a professional forester or biologist for advice.
- Maintain a buffer zone between harvesting and the edge of unique sinkholes. A buffer zone should be at least 200 feet in width starting from the rim of the sinkhole.
- Maintain a buffer zone around artificial upland water features such as ponds and wildlife watering facilities. The buffer should be at least 50 feet from the bank of the structure.
- Fens and seeps should have a minimum of 100 feet as a buffer surrounding them.
- Divert runoff from haul roads, skid trails, and log landings so it does not drain directly into sinkholes, caves, or springs.
- Establish staging areas for equipment, fuel and oil, chemicals, and other hazardous materials no closer than 200 feet from a sinkhole, cave, or spring.
- Leave a buffer zone between harvest areas and the cave opening — buffer zones should extend around the cave entrance and be 200 feet in width.
- Stockpile any excavated material well away from a cave opening so that the material cannot wash back into the opening.
- Leave a wide natural vegetated buffer area around any spring; the buffer should be a minimum of 200 feet in width.
- Utilize standard BMPs for SMZs when harvesting near streams and below springs.
- Limit harvesting in concave (bowl-shaped) areas that receive water from the surrounding landscape; the area should be harvested when the ground is dry to prevent rutting.
- Avoid disturbing soils in sinkholes with open swallets or underground streams.
- Avoid pushing soil, logging debris, or other waste materials into the bottom of any sinkhole, into any sinkhole opening, or into any drainage that ends in a sinkhole.
- Avoid draining equipment fluids onto the ground or parking logging equipment in the bottom of sinkholes.
- Avoid blocking or modifying cave entrances; avoid making loud noises near the entrance to caves.

Forest Certification Note

When working on forest land that is enrolled in a forest certification system, it is important to know the BMP standards that apply to that program and understand how to implement them. Some forest certification systems have very specific guidelines concerning the use of BMPs, and other programs require landowners to meet or exceed state recommended BMPs such as those presented here.

Skid Trails and Landings

Good management seeks to limit the soil area impacted by infrastructure (roads, landings, and primary skid trails) and carefully considers timing, the equipment being used, and harvesting methods. A harvest plan should be completed before the harvest. The harvest plan should also address landings, skid trails, and roads as well as other BMP issues. Try to locate road landings and primary skid trails on better-drained or gravelly soils. Planning considerations should include careful determination of the appropriate operating seasons for any given soil, as well as

using harvest layouts, strategies, and equipment that minimize the surface area of a site that will be impacted. The total amount of area occupied by primary skid trails and landings should be limited to no more than 10 percent of the area.

Best Management Practices for Skid Trails

- Avoid placing skid trails near known natural heritage resources.
- Flag the location of main skid trails before work begins. Minimize the number of skid trails needed to log the site efficiently and limit soil compaction. Use old skid trails if they are suitable.
- Avoid skid trails that drain water onto a landing. If possible skid uphill to the landing.
- Protect crop trees during harvesting. While flagging skid trails, mark trees for removal that will obviously be damaged during harvest. Use other marked or low-value trees, such as elm and hickory, and defective trees as bumpers.
- Minimize the number of stream crossings. Locate crossings at narrow points and cross directly at a 90-degree angle. Logging impact on streams must be minimized. Before crossing a stream, make a turnout or water bar that will shed water off the skid trail.
- Prevent runoff from skid trails from entering streams and wetlands by using water bars, side and wing ditches, broad-based dips, rolling dips, out-sloping, grade breaks, and other erosion control methods.
- Take advantage of natural turns and bends to shed water naturally and keep it from gathering speed and picking up and moving more soil.
- Repair, smooth, seed, and install water bars when skid trails are no longer needed.

Best Management Practices for Landings

- Avoid placing landings near known natural heritage resources.
- Landings should be kept small, yet with enough room for equipment operation, product sorting, and removal. Small landings are easier to clean up, do less damage, and are less visible.
- Consider using the landing to meet other management objectives such as a parking area along a recreational trail or as a wildlife opening. Planning these in advance will help you make informed decisions on the size and location of landings.
- The size and number of landings are affected by silvicultural considerations, the logging system used, sale size, and timber sale design.
- Topography can limit both the placement and number of landings.
- Always use old existing landings if suitable.
- Avoid installing landings in wetlands or SMZs.
- Locate landings for best economy and reuse on subsequent sales.
- Harvest areas furthest from landings first. Slash can then be used to cover skid trails, to slow water flow, and to protect the soil.

- Always pile debris from clearing new landings on the downhill side to reduce soil erosion impacts.
- When possible locate landings uphill on better-drained gently sloping sites.
- Natural re-vegetation of haul roads, skid trails, and landings when it is consistent with site conditions and goals can help stabilize soil. However, on disturbed sites with high potential for erosion, seeding and mulching may be warranted. Use only noninvasive plants such as wheat or annual rye grass for this cover crop (see Table 14.3).
- Avoid landings within view of travel routes or recreation areas. Use landforms and set them back in the woods as far as possible to decrease visibility.
- Avoid landings within a travel route right-of-way. This can result in a safety hazard and can have negative visual impacts.
- Before closing out a harvest operation, be sure to remove slash and other non-merchantable material. Back-blade landings and haul roads so they are smooth and free of ruts and mud holes. Seed exposed soil using seeding chart (see Table 14.3).
- If equipment oil changes are completed on the harvest area, the old oil and any containers, filters, etc, are to be removed from the harvest area for disposal.
- Pick up litter daily to keep the work area clean and visually appealing.

Figure 15.10. An example of a poorly planned and executed harvest operation. No BMPs on the landscape and large amounts of material left at the landing.

Figure15.11. Avoid skidding and loading from the road right-of-way.

Best Management Practices for Slash

Slash includes all residual woody material created by logging or timber stand improvement. It is unavoidable when harvesting timber. Slash treatment should be specified in a harvest plan as well as in the harvesting contract. The treatment of slash has a defined cost and should only be done to meet the goals and objectives of a management plan or when working in visually sensitive areas. Slash provides soil nutrients and shelter for wildlife.

- When thinning and commercial harvesting with a chain saw, retain a minimum of one-third of the harvest residue (tops, branches, etc.) on site, distributed throughout the harvested area. This is particularly important during biomass regeneration harvest operations. This slash provides important wildlife habitat for many species as well as the continuation of the carbon cycle on the site. Refer to Chapter 2 for more information.
- When thinning and commercial harvesting using a feller buncher or other mechanized harvester, leave one-third of treetops from sawtimber harvest and one-third of the typical-size small-diameter trees either on the ground or standing, distributed throughout the harvested area.
- Conduct harvest during leaf-off to minimize the appearance of slash.
- If moving slash on-site is desirable, use equipment that minimizes soil disturbance. Keep logging residue out of all streams, lakes, and open water wetlands, except in cases where residue placement is specifically prescribed for fish or wildlife habitat.
- Consider slashing tops within 100 feet of public roads or visually sensitive areas so debris is no more than 3 feet high. This should be included in the bid specifications and in the harvest/sale contract. The time and effort required to conduct this practice will

have a defined cost to the landowner. This should only be prescribed when an area is in a visually sensitive location and when meeting landowner objectives.

Retention of Snags, Dens, and Super Canopy Trees

Both snags and den trees provide essential food and cover for many species of wildlife. Snags are standing dead trees. Den trees are alive with a cavity in the trunk or limbs large enough to shelter wildlife. Snags enhance the quality of wildlife habitats, providing nesting, denning, feeding and roosting sites, as well as escape areas.

Once a tree dies, the slow process of decay begins and birds utilize the tree for perching, feeding, and nesting. As the center of the snag softens, birds such as woodpeckers hollow out nest holes, which are later used by chickadees, kestrels, and screech owls. Many birds eat insects from snags, which prevents serious insect and disease problems in other trees. Snags also support many other organisms including insects, reptiles, and amphibians.

Den trees provide homes and food for many species including squirrels, raccoons, bears, owls, woodpeckers, and wood ducks. Many birds, mammals, and reptiles use tree cavities throughout the year for nesting, cover, and protection from the weather. Most oak species make good den trees because they are long-lived and provide a preferred food source. Other species such as hickory, American elm, sugar maple, American sycamore, eastern cottonwood, ash, and basswood also make excellent den trees

Future den trees will show signs of rot, such as decayed branches, fungi, or wounds and scars.

Woodpecker activity also is a sign of disease or insect infestation. Good places for den trees are along streams and fence rows, as well as near small isolated woodlots. Not all old, damaged trees make good den trees, however.

Super-emergent or super-canopy trees are large-diameter trees with crowns that extend well above the plane of the forest canopy; ideally at least 50–75 percent of the crown or 20–25 feet. Such trees are of high importance in bottomland forests and riparian areas to provide nesting sites for bald eagles and other raptors, for heron rookeries, and as potential large cavity trees.

Best Management Practices for Wildlife Enhancement

- Refer to Table 15.2 for recommended snags and dens retention regarding forest cover pattern.
- If not enough snags are present, deaden live trees by cutting a band about 3–4 inches wide around the tree with an axe or girdling the tree with a chain saw. Avoid using crop trees.
- Leave all snags that can be safely left in harvest areas.
- Retain large diameter (16-inch) standing dead trees with loose bark for bat maternity habitat. If trees meeting this criteria are removed, harvest during the winter months.

- If den trees are not present, create a one-fifth-acre (105-foot-diameter) group of trees surrounding at least one large tree that could potentially become a den tree. This should be done for every 5 acres harvested.
- If all den trees cannot be left, at a minimum leave those trees with holes high in the tree. The retention of dens located >20 ft. high on the tree are important for many cavity using wildlife species

Table 15.2: Remaining Trees (per acre)

	Heavily Forested		Riparian Corridor		Bottomland Hardwoods	
	Dens	Snags	Dens	Snags	Dens	Snags
Minimum	3	3	25	12	12	3
Optimum	7	6	25	12	12	3

Note: Snags and dens > 10 inches in diameter are preferred — the larger the better.

- Where conditions allow, leave or establish per acre:
    - One snag larger than 20 inches DBH, for pileated and red-headed woodpeckers.
    - 4 snags between 10 and 20 inches DBH, for species such as flying squirrel and the American kestrel.
    - 2 snags between 6 and 10 inches DBH, for species such as the eastern bluebird and black-capped chickadee.

- Exceptions to the above den tree and snag guidelines may be made for a number of reasons, including:
    - Operator safety (of loggers, aerial spray applicators, and others).
    - Public safety (hazard trees near rights-of-way, along prescribed fire control lines, near recreation sites).
    - Alignment of skid trails.
    - Forest insects and diseases (such as oak wilt and pine bark beetles).

- On average 2–4 super canopy (super-emergent) trees per acre, or those that have the potential to become such trees, should be retained in riparian areas or bottomland forest to provide the needed structural diversity. Preferred tree species include oak, cottonwood, and sycamore.

Additional Considerations: Timber Marking

A common marking width covered by a timber marker during one pass is 40 yards (120 feet or 2 tree lengths). This equates to approximately 1 acre marked for every 125 yards traveled. Field technicians should use this reference to assist them in determining if enough snags or dens per acre are found within a given stand.

Federally Listed Bat Species

Habitats for imperiled bat species should be considered when conducting timber management activities. In Missouri, several species of bats are considered species of conservation concern. Two of those species, Indiana and gray bats, are federally endangered species and require special management considerations.

For more information about Indiana and gray bats and their habitats and stressors, please access the U.S. Fish and Wildlife website at the following links:

fws.gov/midwest/endangered/mammals/inba/index.html
fws.gov/midwest/endangered/mammals/grbat_fc.html

For more information on best management practices for protecting Indiana bats, in particular, go to mdc.mo.gov/node/9486.

Best Management Practices for Retaining Coarse Woody Debris

Coarse woody debris consists of stumps, downed trees, and treetops with limbs larger than 6 inches at the large end. Coarse woody debris has many roles, such as providing seed germination sites, cycling nutrients and energy, acting as reservoirs of moisture during droughts, and promoting soil development and watershed protection. It also provides good habitat for a variety of insects, salamanders, snakes, and small animals that form the lower levels of the food chain. Many predators, ranging in size from shrews to black bears, rely on the food they find while searching in coarse woody debris. Ensuring that adequate snags and reserve trees are left during regeneration harvests is critical in maintaining coarse woody debris levels through time. Large fallen trees can provide important habitat for up to 50 years.

- Intentionally retain large-diameter trees as a future source of large coarse woody debris.
- Choose hardwood logs to leave, as they provide more hollows and cavities and are favored by certain amphibians.
- Debris from a variety of tree species and sizes should be left. In general, bigger is better.
- Refer to slash management within this chapter for specifics about the retention of harvest residue to ensure soil productivity and wildlife habitat.
- Leave as many of the leaves and twigs (fine woody debris, or FWD) as possible on the harvesting site to encourage nutrient recycling and habitat for small animals.
- Avoid removing all coarse woody debris during biomass operations.
- Avoid leaving debris in places where it is likely to be swept into logjams that would cause water to cut around, eroding the bank and reducing water quality.

- Coarse woody debris left near permanent or seasonal water sources provides excellent wildlife benefits. If a site includes riparian areas, create 4 leave logs per acre in the riparian management zone, if fewer than this number already exist. The overall average number for the site, however, can remain at a minimum of 2 per acre.
- Exceptions to guidelines for providing coarse woody debris may be made for a number of reasons, including:

    - Alignment of skid trails.
    - Specific silvicultural applications (such as insect pests).

Best Management Practices for Retaining Leave Trees

Two general options are recommended for retaining reserve trees (live trees left unharvested). Plans for retaining leave trees may utilize one of the options below. When appropriate, they may use the two options in combination.

Option 1 — Clumps or Strips

- Retain leave trees in clumps or strips.

    - Benefits of clumping leave trees include:

        - Potential to meet multiple management objectives simultaneously.
        - Visual quality.
        - Equipment maneuverability.
        - Longevity and durability of leave trees.
        - Potential for greater biodiversity within clumps.
        - Easier application in larger harvest units.
        - Breakup of harvest area and reduction in apparent harvest size.
        - Better regeneration and growth of sun-loving species on the rest of the site.
        - Potential to provide nesting sites for some interior forest species when clumps exceed two acres.
        - Increased animal feeding efficiency and protection from predators.

- Distribute clumps throughout a harvest unit.
- Vary the size to be at least one-fifth or one-third acre in size.
- Locate clumps in draws and along protected slopes, near the edge of the stand on ridge-top locations, or just below the ridge if possible, to reduce the potential for windthrow.
- Leave travel lanes for wildlife in clear-cuts if the harvest area is wider than 300–400 feet.
- Center clumps around or coincide with such features as:

    - Sinkholes, wetland inclusions, and seasonal ponds.
    - One or more large active den trees or cavity trees or at least good candidates for potential cavities.
    - Mast trees.

- Raptor nests or rookeries.
- Sensitive communities or sites.

Figure 15.12. Wildlife clump within a clear-cut.

Option 2 — Scattered individuals

As an alternative or supplement to clumps or strips, employ scattered individual leave trees, especially if they are larger, wind-firm specimens of preferred species. Scattered leave trees may be easier to apply to small or narrow harvest units than clumps.

- Leave a variety of sizes and species of trees, along with the intended seed or shelter trees, to be retained during the final harvest.
- Plan for and protect integrity of reserve tree clumps in initial harvest entries.
- Prevent damage to leave trees in initial and follow-up harvest entries.
- Exceptions to the previous leave tree and snag guidelines may be made for a number of reasons:

  - Operator safety (of loggers, aerial spray applicators, and others).
  - Public and contractor safety (hazard trees near right-of-way, recreation sites, and roads.
  - Forest insects and diseases.
  - Shallow-rooted trees with little wind resistance. Avoid reserving individual trees on mid-slopes, ridge tops, or in other areas with thin soil.
  - Excessive shade inhibiting forest regeneration.

For the most part, these potential problems can be avoided by carefully designing the retention of reserve trees and considering their distribution and composition.

Note: During partial harvests such as thinnings and uneven-aged selection harvests, ensure that the remaining stand includes snags and den trees as recommended in Table 15.2.

Figure 15.13. Aerial photo showing a stand with scattered individual left within a shelterwood harvest and wildlife corridors left between clear-cuts.

Best Management Practices for Maintaining Mast

- Consider maintaining the diversity of mast sources on the site, as well as some level of current production of mast sources. For example, maintain landings as openings or avoid machinery operation in pockets of fruit-producing shrubs.
- When other factors are equal, favor mast producers over non–mast producers.
- Use long-term rotation ages to provide mast for wildlife. Uneven-aged management (UAM) is a silvicultural management strategy for this practice. See Figure 15.14.
- Consider using directional tree felling to avoid damaging soft mast trees such as dogwood, cherry, mulberry, and persimmon.
- Refer to Table 15.3 for a list of hard and soft mast species.

Table 15.3. Hard and Soft Mast Species	
Hard Mast Species	**Soft Mast Species**

oaks, hickory, pecan, walnut, hazelnut, and pine seed	serviceberry, pawpaw, hackberry, sugarberry, dogwoods, hawthorns, persimmon, spicebush, red mulberry, black gum, black cherry, wild plums, sumacs, Carolina buckthorn, gooseberries, wild roses, blackberries, raspberries, dewberries, elderberry, sassafras, green briars, coral berry, blueberries, grapes, hollies, pokeweed, and poison ivy, black locust

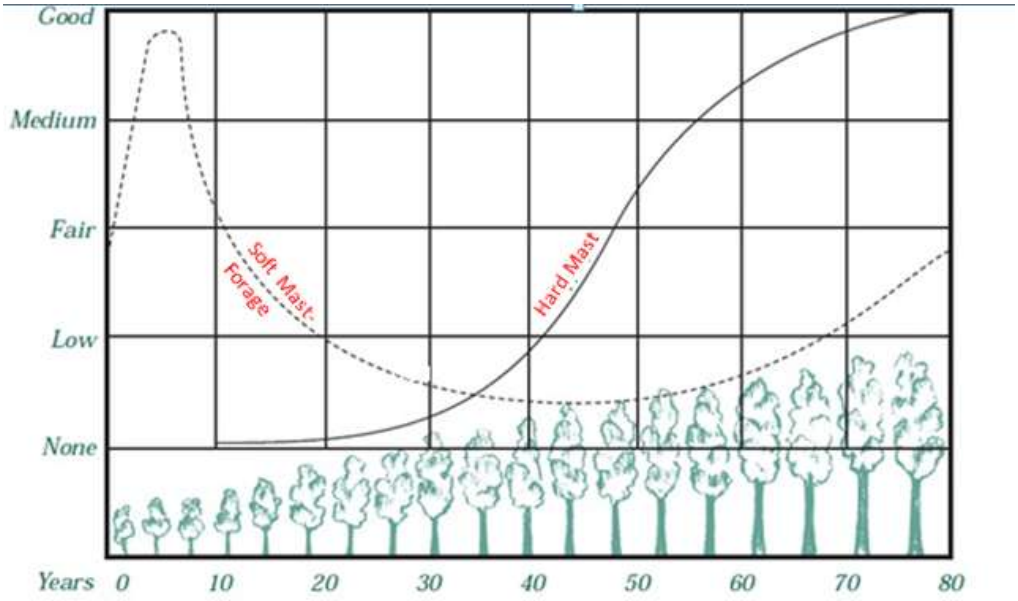


Figure 15.14. Relationship of hard mast and soft mast (forage) in an oak-hickory forest with stand age.

Best Management Practices for Protecting Residual Trees

Trees should not be marked for cutting unless they can be safely and efficiently felled without excessive damage to the residual stand. Damage to leave trees incurred during timber harvesting can negatively impact individual-tree health and vigor. Damage to the residual stand will result in quality, volume, and value losses. When implemented carefully, residual stand damage can be minimized, although some damage is unavoidable. Pre-harvest planning and layout of landings and primary skid trails can help to minimize residual stand damage. Oversight of the logging crew may also help to minimize damage to the residual stand.

- Directionally fell trees to avoid damaging residual trees, while enhancing skidding efficiency.
- Only mark trees for harvest that can be safely felled without damaging residual trees.
- Remove limbs of felled trees before skidding (i.e., avoid whole-tree skidding).
- Keep residual stand damage to less than 10 percent of leave trees.

- Keep spatial extent of primary skid trails to less than 10 percent of harvest area.
- If partial harvesting with plans to reenter in the near future (e.g., shelterwood or selection system), consider a skid trail layout to accommodate not only present but future entries.
- Keep skid trails at least 20 feet from high-value leave trees.
- Leave unacceptable growing stock (UGS) trees or high stumps to serve as “bumpers” between skid trails and high-value leave trees and/or patches of reproduction.
- Mark and instruct the logger to protect desirable saplings and poles.
- Harvest when soils are dry or frozen.
- Avoid harvesting from spring to early summer when cambium is growing and bark is easily removed (i.e., peeling stage).
- Use the smallest equipment possible and size trails to accommodate equipment.
- Layout a well-planned primary skid trail system.
- Avoid wet spots and poorly drained areas.
- Use straight and gently curving skid trails.
- If wolf trees are to be killed as part of a liberation treatment, consider girdling, which will help protect more desirable trees from felling damage while benefiting wildlife through snag creation.
- If regenerating with the shelterwood method, pay close attention to the length of time it takes for regeneration development to reach 2 inches in basal diameter as compared to the time that is intended to lapse before the final cut. Logging when the regeneration is larger than 2 inches can negatively impact future crop trees.
- Avoid damaging residual trees when skidding tree-length logs, some locations may require bucking trees in the woods to reduce impacts.
- Consider using leaf-off logging in sensitive areas.
- Consider leave-tree marking when using mechanical felling.
- Use automated felling machinery only if the operator is skilled in protecting residual trees.
- Mark trees for cutting that will obviously be damaged by the felling of larger-diameter trees.
- Woody biomass should be harvested at the same time as saw-log harvests to avoid reentry.

Figure 15.15. This logger is using a small cable skidder to minimize residual damage.

Figure 15.16. When using mechanized felling equipment, it is important to take special care to avoid residual damage such as this.

Consult a Forester and Hire a Professionally Trained Logger

Sustainable forestry demands a skilled workforce of trained foresters and loggers with the adaptability, knowledge, and experience to manage forest resources sustainably. A professional forestry operation is a complex process involving numerous steps and the coordination of activities before, during, and after the harvest. When forestry operations are conducted by an untrained workforce, there is a greater risk of unsustainable practices that do not achieve landowner objectives, can cause negative site impacts, and can reduce future stand productivity. This is why it is critical for a landowner to consult a professional forester before effecting a timber sale and to consider only those bids submitted from skilled and reputable logging firms.

In Missouri, there are two programs that train and certify loggers: Master Logger and Professional Tree Harvester. Both these programs provide loggers with the knowledge and skills for executing best management practices before, during, and after forest operations that help to ensure forests are managed sustainably with multiple values in mind. Give preference to loggers certified by either Master Logger or Professional Tree Harvester when evaluating bids. Visit mdc.mo.gov/node/4186 for contact information for professional Missouri foresters and loggers.

Best Management Practices for Implementing a Timber Sale

Just as important as knowing how to harvest properly is knowing how best to go about initiating a timber sale in order to begin the harvest. MDC's Call Before You Cut Program can provide a packet of information called *The Landowners Guide to a Successful Harvest*. This resource will provide a wealth of information and professional contacts to assist you with conducting a sustainable timber harvest. To receive your free packet, call 1 877-564-7483 or go to callb4ucut.com.

- Know what you have to sell — Start by selecting the trees to harvest and mark only the trees for removal that accomplish your forest management objectives. Once marking is complete, estimate the volumes and products to be sold.
- Determine what your timber is worth — Value is based on many factors, including species, size, and quality of trees marked for harvest; site accessibility; and distance to mills. MDC publishes quarterly regional and statewide trend reports in saw-log stumpage prices by species for the state of Missouri. The best way to determine the value of your timber, however, is to offer it for sale to the open market and request bids from as many potential buyers as possible.
- Determine a selling method — The two methods of selling timber commonly used are sealed bid and negotiation. This is an individual decision that should include open and honest communication between parties.

    - Sealed bid – This process starts by informing potential buyers of an upcoming timber sale. Buyers are given a length of time (usually 4–6 weeks) to inspect the trees and

submit bids. Each buyer is allowed only one bid, and later bids always are rejected. Bids are reviewed at the pre-specified time, and a buyer is selected. If no bids meet minimum price, then you have a right to refuse all bids. This process can be repeated until a suitable bid is made. The sealed bid is the method recommended for private landowners.

- Negotiation – This method involves face-to-face discussions with a single buyer. This process often results in a price below what the timber is worth, because the buyer has no competition and the seller is often unaware of the value of his/her timber.

- Figure out the payment method you want — The two payment options commonly used for a timber sale are lump-sum and yield sales.

  - Lump-sum sale — This entails a single payment made to the landowner before harvest. Since this form of payment is based on estimated volume of standing timber, the sale price is dependent on the accuracy of your estimate of the volume and value of timber for sale. The lump-sum sale is the simplest and least risky method for the landowner, provided that he or she has an accurate estimate of timber value.
  - Yield sale — In this sale the landowner is paid a certain amount for each product cut. This method requires that someone, usually at the mill, scales the volume of products after harvest. This method is less risky to the buyer, since the buyer pays for the volume that is actually harvested rather than an estimate of standing volume. The landowner shoulders the risk in a yield sale, since tracking the logs is difficult once they leave the property. It is recommended that scaling occurs at the landing, and stumpage is paid before logs leave your woodlot.

- Advertise your sale — The key to advertising your sale is to provide accurate and reliable information on the sale and to distribute this information to as many potential buyers as possible. The sale notice should include:

  - Your name and contact,
  - Location of the sale,
  - Description of trees to be sold,
  - Type of bid and method of payment expected,
  - Times to inspect the sale,
  - Whether a down payment to bind the contract is required and how much,
  - Descriptions of other details that will addressed in a timber sale contract.
  - The Missouri Forest Products Association will also advertise timber sales on its website.

- Find a professionally trained logger — Contact your local MDC forester or consulting forester. Go to moforest.org to find a list of professionally trained loggers.

- Draw up a timber sale contract — A contract protects the interests of both the seller and the buyer and must be agreed upon and signed by both parties. The contract does not need to be complex, but it should reflect what you and the logger have agreed to with respect to the sale. You may want to have a lawyer draft or review your contract. It is important that you include the provisions that you feel are important regarding your property. There is an example contract in the Appendix D.
- Supervise the timber harvest — One of the most important things you can do during the harvest is to inspect it periodically and have the sale administered by a professional forester. This provides oversight on the operation as it is taking place. It also is a good idea to walk the site with the logger prior to the harvest. During this walk, get to know the logger and clearly define your objectives for harvesting in the first place. A logger who is familiar with you and your objectives will likely do a better job.
- Practice good forestry — It is important that good forestry practices are applied during and after a harvest operation. Follow the best management practices set out in this manual in order to ensure that the harvest will be sustainable and will meet your forest management plan objectives.

Best Management Practices for Closing Out a Harvest Operation

- Inspect and maintain any soil-stabilization practices installed. Do not move the skidder from the harvest site until the water bars and other work have been completed.
- Rehabilitate landings and skid trails in order to mitigate soil compaction and help reduce erosion. This could include disking, seeding, and mulching.
- Natural re-vegetation of haul roads, skid trails, and landings when it is consistent with site conditions and goals can help stabilize soil. On disturbed sites with high potential for erosion, seeding and mulching may be warranted. Use seed appropriate for the season on main skid trails, landings, and roads that will be closed. A seeding chart is located in Chapter 14.
- For jobs finished in the winter, use straw or bark mulch on areas most likely to erode.
- Avoid removing soil from the general harvest area to rehabilitate roads, landings, and skid trails. Use already-disturbed soil, if needed, rather than disturbing additional soil.

References to Other Chapters

Timber harvesting activities can potentially impact soil and water resources. The goal is to minimize this impact, to maintain soil productivity, and to protect water quality. A decrease in soil productivity could affect the level of timber harvesting the forest can sustain, as well as other forest values, such as wildlife habitat and biodiversity. The assistance of professional foresters and soil consultants can aid you in meeting your sustainable forest management goals. Information and assistance are available from the Missouri Department of Conservation, the USDA Natural Resources Conservation Service (NRCS), or University Extension. Detailed soil maps of your property are available from the NRCS on the CARES and Web Soil Survey website: cares.missouri.edu and websoilsurvey.nrcs.usda.gov/app/HomePage.htm. Refer to

BMPs in this chapter minimize the impacts to soil productivity and water quality. Refer to Chapter 5 and Chapter 7 for more detailed information regarding potential impacts.

The NRCS Ecological Classification System (ECS) is currently under development. This tool will help you make informed decisions based on slope, aspect, geology, soil properties, and potential vegetative communities. Once ECS is completed, this tool will provide valuable assistance when developing a forest management plan. More information on ecological classification systems is located in Chapter 11.

Prior to beginning a timber sale, consult a professional forester, a Missouri Department of Conservation (MDC) private land conservationist, an MDC wildlife biologist, or an MDC natural history biologist for information about the occurrence of endangered or threatened species, species and natural communities of conservation concern, rare tree species, or sensitive communities present on or near the management area. These species and natural communities can be impacted by harvesting activities, site preparation activities, by altering the existing vegetation, or by introducing new species. These professionals can help you modify management activities to maintain, promote, or enhance species and natural communities on the site. See Resource Directory, and refer to Chapter 3 for more information.

Timber harvesting activities in visually sensitive areas can have negative impacts to visual quality. Refer to guidance in this chapter when conducting activities in visually sensitive areas. Refer to Chapter 4 for guidance on determining visually sensitive locations.

Consider the potential spread of invasive species when conducting timber harvest activities. Refer to Chapter 9 for more information.

Timber harvesting activities can negatively impact cultural resources. It is important to take the proper steps to avoid or mitigate impacts. Refer to the guidance in this chapter. Refer to Chapter 6 for general information related to cultural resources.

Additional Resources

Forest Management for Missouri Landowners, Missouri Department of Conservation 2007. Available at mdc.mo.gov/node/5574

Missouri Watershed Protection Practices: Management Guidelines for Maintaining Forested Watersheds to Protect Streams. Missouri Department of Conservation, 2006. Available at mdc.mo.gov/node/9331

Missouri Woody Biomass Harvesting Best Management Practices Manual. Missouri Department of Conservation 2009. Available at mdc.mo.gov/node/9806

Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers. Minnesota Forest Resources Council 2005. Available at frc.state.mn.us/initiatives_sitelevel.html

Wisconsin Forest Management Guidelines PUB-FR-226 2011. Available at dnr.wi.gov/topic/ForestManagement/guidelines.html

Chapter 16: Pesticide Use

Topics Covered

- Pesticides
- Integrated Pest Management
- Characteristics That Determine a Chemical's Likelihood of Impacting Water Quality
- Soil and Site Characteristics That Influence Whether a Chemical Will Reach Groundwater or Surface Water
- Certified Applicators and Operators in Missouri
- Selecting the Appropriate Chemical
- Selecting an Application Method
- Best Management Practices for Spills and Emergency Response
- Best Management Practices to Protect Visual Quality
- Best Management Practices to Slow the Spread of Invasive Species
- Best Management Practices to Protect Cultural Resources
- Best Management Practices for ANY Chemical Use
    - General Best Management Practices
    - Timing and Weather Considerations
    - Maintain an Adequate Spill Containment Kit
    - Transportation of Chemicals
- Mixing and Loading Operations
- Pre-application and Application Activities
- Storage of Chemicals
- Protecting Water Resources
- Equipment Clean-Up; Container and Waste Disposal
- References to Other Chapters
- Additional Resources

Pesticides

Pesticides are defined as any material that is applied with the intent kill, attract, repel, interrupt, or regulate growth rates of plants or pests. Pesticides include a wide assortment of chemicals with specialized names and functions; they are often grouped according to what they control. Some of the most common groups used in forestry include herbicides, insecticides, fungicides, growth regulators, and repellents.

Applications of pesticides can assist in meeting forest management objectives by promoting the establishment, survival, growth, or maintenance of desired tree species. Timber Stand Improvement (TSI) recommendations often include the use of pesticides as a cost-effective

silvicultural activity. The acreage involved in TSI can vary depending on many variables, but the application rates will generally always be small.

As a standard best practice, prescriptions should call for the least amount of pesticide necessary to achieve management objectives. Use alternatives to chemical pesticides when they are legal, cost effective, and a viable option for meeting management objectives.

When pesticides are used, select the least-toxic and the narrowest spectrum products labeled for the target species. Follow all applicable label requirements, best management practices, and Missouri Department of Agriculture regulations.

Integrated Pest Management

Integrated Pest Management (IPM) is a concept that recognizes ecological, social, and economic values in resource planning and management.

IPM in a forest ecosystem is the process of managing a forest with all available tools so that potentially destructive organisms such as insects and diseases are maintained at a level that is below an economic or damage threshold. These tools are used in conjunction with forest management practices designed to meet the overall goals of the landowner. IPM tools include establishing acceptable pest thresholds (economic or damage), applying preventive cultural practices, and monitoring. Mechanical controls, biological controls, and chemical controls (including the use of pheromones) are all considered when developing an IPM approach.

As a rule of thumb, forest management practices that encourage good growth also produce more pest-resistant stands. Typically, pest problems arise in stands that are under stress. Many stress factors, but not all, are caused by poor management practices that can be avoided with proper guidance and planning. Many insects, diseases, and plants do not significantly impact a landowner's management objectives. A careful evaluation of the potential impact of these organisms should always take place before deciding to use a pesticide application. Pesticides should be considered as part of an overall program to control pest problems and not the sole solution.

There is a wide variety of chemicals available for use, and their individual characteristics are equally diverse. One of the more important concerns is what level of risk those characteristics pose to water quality.

Characteristics That Determine a Chemical's Likelihood of Impacting Water Quality

- Solubility is the ability of a chemical to dissolve in water. The greater the solubility, the greater the chance that the chemical will leach to groundwater or move as a solution in surface water. Chemicals with very low water solubility tend to remain at the soil surface and can potentially move into surface water when attached to sediment runoff.

- Adsorption is the inherent ability of a chemical to attach to soil particles. Some chemicals stick very tightly to soil, while others are easily dislodged. Adsorption rates increase as soil organic matter increases. The greater a chemical's ability to adhere to soil particles, the less the potential for that chemical to move (except by soil erosion in surface runoff). Conversely, the lower a chemical's ability to adhere to soil particles, the greater the potential for that chemical to leach into groundwater or move in solution in surface runoff.
- Half-life is the time it takes for a chemical in soil to be degraded so that its concentration decreases by one-half. Each chemical will have successive half-lives, which will continually decrease its concentrations by one-half. The persistence of the chemical in soil is the time it takes for the chemical to degrade to the point where it is no longer active. Chemicals that do not break down quickly can be a hazard if they move into groundwater or surface water in toxic forms.

Soil and Site Characteristics that Influence Whether a Chemical Will Reach Groundwater or Surface Water

- Soils that are deep, high in organic matter, medium to fine textured (silty or clayey), and structurally sound are relatively good at "capturing" chemicals until they can be broken down by microbial activity.
- The greater the depth to groundwater, the more the filtering action of the soil.
- Soils that are shallow (less than 20 inches) or coarse textured and permeable are more likely to leach chemicals.
- Soils that are crusted or compacted are more likely to encourage chemical runoff in surface water.
- Surface water contamination can easily occur when chemicals are applied to sites adjacent to lakes, streams, wetlands, and natural drainage ways. If there is a quick conduit from the surface to the water table, such as a sinkhole, chemicals can be washed directly into the groundwater.

Forest Certification Note

When working on forest land that is enrolled in a forest certification system, it is important to understand which standards apply and how to implement them. All forest certification systems require compliance with state and federal regulations that govern the use of pesticides. Additionally, some forest certification systems may not allow the use of certain pesticides, regardless of the label recommendations.

Certified Applicators and Operators in Missouri

The Missouri Department of Agriculture regulates commercial applications of pesticides and any application for restricted use pesticides with the Missouri Pesticide Use Act. This is to protect the health and welfare of the citizens of Missouri and to prevent adverse effects to the environment. These certified applicators and operators must know how to read a pesticide label

and be able to follow directions in order to use them properly and safely. There are three types of certified applicators and operators in Missouri:

- **A certified commercial applicator** is authorized to use, supervise the use of, or determine the need for the use of, any pesticide, whether classified for restricted use or for general use, while engaged in the business of using pesticides on lands of another as a direct service to the public in exchange for a fee or compensation.
- **A certified noncommercial applicator** is authorized to use, or to supervise the use of, any pesticide that is classified for restricted use only, on lands owned or rented by the applicator or their employer.
- **A certified public operator** is authorized to use, or to supervise the use of, any pesticide that is classified for restricted use, in the performance of their duties as an official or employee of any agency of the state of Missouri, or any political subdivision thereof, or any other governmental agency.

Selecting the Appropriate Chemical

When the decision has been made to use a pesticide application, you need to know that it is the right pesticide for your particular pest management needs, whether the pesticide can be used safely under your application conditions, and how much product you need for the treatment area.

Before applying the pesticide, read the label in order to determine:

- What safety measures must be followed.
- Where you can legally use the pesticide.
- When to apply the pesticide. Consider factors such as the life cycle of the pest, pesticide characteristics, and its potential to contaminate the soil, surface water, and groundwater.
- How to apply the pesticide properly. This includes selecting the proper personal protection equipment and proper application methods, equipment, and formulations.
- If any special use restrictions apply, such as reentry into treated area or prohibitions against certain types of application methods or equipment.
- If any restrictions apply on the use of the pesticide, such as environmental conditions (weather), buffers, and potential for drift.

Selecting an Application Method

The pesticide application method you choose depends on the nature and habits of the target pest, the characteristics of the target site, the properties of the pesticide, the suitability of the application equipment, and the cost and efficiency of alternative methods. Your choice is often predetermined by one or more of these factors. To make an effective, safe, and efficient application, read the label first, and make certain the application equipment is properly selected, operated, calibrated, and maintained.

There are several application methods including, but not limited to, broadcast, directed spray, foliar, basal, cut stump, hack and squirt, or spot and soil application. Your choice should be based on careful consideration of the nature and habits of the target, site, pesticide chosen, available equipment, cost, efficiency, and effectiveness. Care should be taken to minimize drift, overspray, soil disturbance, visual impacts, etc. and to avoid surface- and groundwater contamination.

If endangered, threatened, or special-concern species are known to be present, select pesticides, application methods, and equipment with consideration to protect those species.

A spill is the release of a pesticide or compound into the environment, including air, water, soil, etc., in any manner other than its intended use. Although accidents and emergencies involving pesticides are rare, unfortunately they can and do occur. Many pesticide accidents can be traced to applicator carelessness or misuse. Pesticide spills and accidents can result in water, soil, and air contamination; damage to plants; injury to livestock, wildlife, or pets. They can also endanger the health of the applicator or other people.

Best Management Practices for Spills and Emergency Response

- Familiarize yourself with the labels and Material Safety Data Sheets (MSDS) for the pesticide. These are a source of cautionary information and data.
- Maintain a spill containment and clean-up kit appropriate for the site and all materials.
- Should a spill occur, treat it properly. The recommended steps include the following:

    - Protect yourself. Be sure you wear the necessary protective clothing and equipment so that you do not expose yourself to the material.
    - Follow the Three Cs:

        - Control: Control the spill (stop the leak), for instance, a smaller container that is leaking can be placed inside a larger container.
        - Contain: Contain the spilled material in as small an area as possible. Do everything possible to keep it from spreading or getting worse. You may need to construct a small dam with a shovel or absorbent material such as fine sand or pet litter. It is important not to allow any chemical to get into any body of water, including storm sewers.
        - Clean up the spill: Specific recommendations regarding clean-up procedures can be obtained from the chemical manufacturer. The chemical manufacturer lists an emergency number on the product label, which anyone can call for information regarding how to respond to an emergency situation that involves a specific product. The MSDS for the product will also outline what to do in case of a spill.

Best Management Practices to Protect Visual Quality

- In highly sensitive areas consider non-herbicide treatment methods.

- Favor band treatment or spot treatment over broadcast treatment. This may include the use of a hack and squirt method, an herbicide application method where single or multiple cuts are made on a tree stem using a hatchet. The cut is then filled with the desired herbicide using a spray bottle.
- Leave untreated or selectively treated areas adjacent to travel routes and recreation areas.
- Favor late-season or dormant-season herbicides.

Best Management Practices to Slow the Spread Invasive Species

Pesticides can be an effective tool in the control of invasive species. In some cases, they may be the only useful treatment. There are potential tradeoffs, however. Pesticides are very rarely species specific. Attempted control of pest species may impact non-target plants and animals, depending on the chemical used and the timing and application. Learn to identify and control locally known invasive plants and pests in your area.

- Consider the likely response of invasive species or target species when prescribing activities that result in soil disturbance or increased sunlight.
- When conducting invasive plant removal, ensure that it is applied within the appropriate time window using suitable equipment and methods, such that introduction and spread of invasive species is limited.

Best Management Practices to Protect Cultural Resources

- Avoid applying pesticides to grave markers, buildings, foundations, or other significant cultural resource features or objects. Many pesticides are corrosive and may adversely affect the integrity of marker stones or other objects.
- Some pesticides may result in a bare soil condition that results in vulnerability to erosion, exposing buried artifacts. Potential for erosion should be considered when applying broad spectrum burn-down pesticides.
- Best Management Practices for Common Cultural Resources can be found in Appendix B.

Best Management Practices for ANY Chemical Use

During pesticide operations, the overall goal is to minimize the risk of causing harm to people or non-target plants and animals. Certain types of operations pose more risk than others: aerial applications represent the highest level of risk; ground equipment applications involve somewhat less risk; and hand applications are perhaps the least risky, though still warranting attention. Risk also increases according to the increased amount of chemical involved. Prudent use of chemicals requires careful consideration of a number of factors to ensure that this activity is conducted responsibly.

General Best Management Practices

- **Know the law:** Federal and state regulations about pesticides are designed to protect the public and the environment from potential adverse effects of pesticides. It is the applicator's responsibility to be familiar with these laws and to comply with the requirements. Laws and regulations about pesticide use are constantly evolving. It is the applicator's responsibility to stay current on legal requirements at all government levels. By complying with federal and state pesticide laws, the applicator not only avoids penalties but also ensures that pesticides are handled and applied in as safe a manner as possible.
- **Read the label:** The pesticide product label is the main method of communication between a pesticide manufacturer and pesticide users. The information printed on or attached to the pesticide container is the label. By law, pesticide users are required to comply with all the instructions and to use the directions found on the pesticide product label. Labeling includes the label itself plus all other information referenced on the label or received from the manufacturer about the product when you buy it. The labeling gives you instructions on how to use the product safely and correctly.
- **Conduct on-site meetings prior to applications:** The contractor, landowner, and resource manager should meet on-site prior to moving equipment onto a site. Such meetings can help assure common understanding of landowner objectives, contract specifications, and site conditions.

Timing and Weather Considerations

- Only apply chemicals under favorable weather conditions.
- Avoid applying pesticides when the likelihood of significant drift exists. Use a drift control agent when appropriate.
- Consider applying pesticides near dawn or dusk, when wind speeds are generally lowest.
- Follow the directions on the label that tell you not to spray when the wind speed is above a certain threshold.
- Limit broadcast applications to appropriate temperature and relative humidity conditions. High temperatures enhance loss of volatile pesticides and the rate of evaporation of droplets. Relative humidity also influences the rate of evaporation, with the rate increasing as humidity decreases.

Spill Containment Kit

- Detergent or soap.
- Hand cleaner and water.
- Activated charcoal, adsorptive clay, kitty litter, or other adsorptive materials.
- Lime or bleach to neutralize pesticides in emergency situations.
- Tools such as a shovel, a broom, a dustpan, and containers for disposal.
- Protective clothing and equipment.

Transportation of Chemicals

- The safest way to transport pesticides is secured in the back of a truck. Do not carry chemicals in the passenger compartment of any vehicle.
- Inspect all containers prior to loading; ensure that all caps, plugs, and bungs are tightened.
- Select transportation routes to minimize the impact of a potential spill on water quality.
- Never leave pesticides unattended.
- Have a copy of the label and MSDS along with emergency numbers handy.

Mixing and Loading Operations

- Handlers who mix and load concentrated pesticides have an especially high risk of accidental exposure and poisoning.
- Review the label before opening the container to ensure you are familiar with and understand current use directions.
- Avoid mixing more than you need or can apply at one time. Once mixed, many pesticides do not store well; and they can leave residual in containers, tanks, or lines if not cleaned out immediately.
- Mix and load pesticides outside of riparian management zones and, where practical, in upland areas.
- Exercise care and caution during mixing and loading of pesticides.
- Avoid mixing near wells or where pesticide spills could enter open water or wetlands.
- Fill equipment from water sources before introducing pesticides into mixing or application equipment.
- Do not leave a spray or mix tank unattended while it is being filled.
- Provide an air gap between the water source and the mixture surface to prevent back siphoning.
- Avoid filling pesticide mixing or application equipment directly from a public water supply unless the outlet from the public water supply is equipped with a backflow prevention device.
- Avoid filling pesticide mixing or application equipment directly from surface water unless the equipment contains proper and functioning anti-back-siphoning mechanisms.
- Triple rinse all empty plastic and metal pesticide containers and add the rinse water to the spray solution.

Pre-application and Application Activities

- Ensure that pesticide applicators are properly licensed in the appropriate category by the Missouri Department of Agriculture when a license is required.
- Mark the boundaries of the area for treatment.
- Read and follow all label directions carefully prior to using.
- Prevent chemical leaks from equipment. Check all equipment for leaking hoses, connections, and nozzles.
- Calibrate spray equipment to apply chemicals uniformly and in the correct quantities.

- Employ the lowest reasonable equipment pressure when applying pesticides.
- Select a nozzle type that produces the largest drops at a given rate and pressure appropriate to the chemical being applied.
- During application, periodically check for leaking hoses and connections and for plugged or worn nozzles.
- During the application continue to monitor weather conditions. Wind speed or direction may change and force you to stop the operation.
- Make certain to post the treatment area, if desired or required.
- Keep records of all pesticide applications, including the date, rate of application, application method, applicator information, weather conditions, and results.

Storage of Chemicals

- If you store pesticides, you must protect and secure the area to keep out unauthorized people and animals. Also post signs that clearly indicate you store pesticides in the building. Read and follow the storage statements on the label.
- Locate storage facilities at sites that minimize the possibility of impacts on water quality in case accidents or fires occur.
- Select unloading and operational storage locations where spills resulting from accidents or vandalism will not have impacts on water quality.
- Use storage buildings that have floors constructed of concrete or other impermeable materials, so that spills are easy to clean up. Storage buildings should contain drains or sills with sumps large enough to contain the contents of the largest container being stored.
- Avoid storing pesticides for extended periods of time. To prevent deterioration, mark each container with its date of purchase and use older products first; buy only what you need.

Protecting Water Resources

- Avoid broadcast application methods within filter strips and riparian management zones. Appropriate treatments within filter strips and riparian management zones include:

    - Use of pesticides labeled for aquatic use.
    - Manual or mechanical treatments.
    - No treatment.
    - Spot, banded, cut stump, basal bark, or hack and squirt type treatments.

- Avoid applying pesticides directly to water except where the pesticide is specifically labeled for application to water. When the pesticide does not have a full aquatic label, avoid riparian management zones, filter strips, or other reserve areas adjacent to all streams, lakes, wetlands, and ditches that contain water at the time of application. Always refer to the label to determine legal use and application.
- Avoid applying herbicides in areas where the chemicals can kill stabilizing vegetation on slopes, gullies, and other fragile areas subject to erosion that drain into surface water.

- Increase the width of the filter strip when using toxic to highly toxic insecticides.

Equipment Clean-Up; Container and Waste Disposal

- Rinse mixing apparatus at least three times. Apply rinsate in spray form to the area to be treated, being sure not to exceed label recommendations.
- Clean equipment in areas where pesticide residues will not enter streams, lakes, wetlands, or groundwater.
- Rinse all empty plastic and metal pesticide containers three times and add the rinse water (rinsate) to the spray solution. To triple rinse containers properly:

    - Empty the pesticide into the spray tank and allow for the pesticide container to drain.
    - Fill the container 10–20 percent full with water (or solvent, in some cases), rinse and pour the rinse water into the spray tank.
    - Repeat the previous step two more times and apply rinsate to the spray site.
    - Apply all leftover solutions and rinsates to the treatment area, being sure not to exceed label recommendations.

- Puncture and flatten containers not intended for return to the manufacturer.
- Refer to the product label for additional information on proper disposal of rinsed and punctured containers.

References to Other Chapters

Prior to beginning management activities, consult a professional forester, a Missouri Department of Conservation (MDC) private land conservationist, an MDC wildlife biologist, or an MDC natural history biologist for information about the occurrence of endangered or threatened species, species and natural communities of conservation concern, rare tree species, or sensitive communities present on or near the management area. These species and natural communities can also be impacted by pesticides. This is particularly important in Karst areas of the state. These professionals can help meet your pesticide use objectives, while also maintaining, promoting, or even enhancing these special resources. See Resource Directory and refer to Chapter 3.

Consider visual quality impacts when prescribing the use of pesticides. Dead and dying vegetation can result in negative visual impacts in areas with high visibility. Refer to Chapter 4 for guidance on determining visually sensitive locations and methods that can help mitigate concerns.

Cultural resources can be negatively impacted by the corrosive nature of some pesticides. Also erosion on cultural sites can be accelerated where pesticides have eliminated all vegetation. Be sure to include any concerns for protecting these resources when developing plans for pesticide treatment. Refer to Chapter 6 for general guidance in identifying and protecting cultural resources.

Additional Resources

Missouri Department of Agriculture can be contacted at mda.mo.gov/plants/

National Pesticide Applicator Certification Core Manual is avaiable at U.S. Environmental Protection Agency, Office of Pesticide Programs. nasda.org/9381/Foundation/11379/11383/6684.aspx

Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers. Minnesota Forest Resources Council 2005.. Available at frc.state.mn.us/initiatives_sitelevel.html

Wisconsin Forest Management Guidelines. PUB-FR-226 2011. Available at dnr.wi.gov/topic/ForestManagement/guidelines.html

Chapter 17: Fire Management

Topics Covered

- Fire Management
- Prescribed Fire Management
- Objectives That May Favor the Inclusion of Prescribed Fire Practices
- Potentially Negative Impacts of Prescribed Fire
- Critical Elements of a Prescribed Fire Plan
- Firing Techniques
- Fire Behavior
- Firebreaks
- Smoke Management
- Best Management Practices to Protect Soil Productivity and Water Quality
- Best Management Practices to Protect Cultural Resources
- Best Management Practices to Slow the Spread of Invasive Species
- Best Management Practices to Protect Visual Quality and Minimize Smoke Intrusions
- Wildfire Prevention and Management
- References to Other Chapters
- Additional Resources

Fire Management

Since the conclusion of the last glacial epoch some 10,000 years ago, Missouri's natural landscape has been shaped by fire (e.g., Pyne 1982, Ladd 1991). Ignition sources included both lightning and deliberate Native American burning. Because of this, a majority of Missouri's terrestrial natural communities depended on periodic fires to maintain their biological integrity and ecological function. Examples of this include the extensive tallgrass prairies and open grassy woodlands that once dominated northern and western Missouri and the millions of acres of shortleaf pine systems in the eastern and southern Missouri Ozarks. Prior to European settlement, the prevailing fire regime consisted of relatively frequent, low-intensity, dormant-season fires.

Uncontrolled or ecologically inappropriate fires can have destructive consequences for both natural and human systems. Forest management plans and activities should directly evaluate fire from two perspectives: (1) the extent to which ecologically appropriate prescribed fire is used to attain management goals and enhance ecological system integrity; and (2) awareness of the potential destructive consequences of wildfires and poorly planned prescribed fire to natural resources, infrastructure, and property.

Fire is not appropriate for all sites in the contemporary environment, despite the fact that virtually all of Missouri's landscape was once shaped and maintained by fires. Some silvicultural

and wildlife habitat goals are not compatible with the application of fire, though some wildlife habitats and wildfire mitigation practices can be enhanced through a carefully developed and carefully implemented fire management program.

Therefore, the application of fire must be determined on a case-by-case basis. Factors to consider include past and current conditions, short- and long-term site goals, ecological context, costs, risk factors, potential for successful use of alternative treatments, and the human and biological context of the surrounding landscape.

This chapter is divided into two sections. The first outlines factors essential in using prescribed fire safely and appropriately. The second discusses wildfire mitigation and protection of resources from fire damage.

Prescribed Fire Management

Prescribed fire is the intentional application of fire to natural fuels, under specific weather and site conditions, to accomplish planned land management objectives. Like all management practices, prescribed fire requires careful planning, experienced practitioners, and suitable equipment in order to ensure safe, successful attainment of management objectives and to prevent adverse effects.

First and foremost, any application of prescribed fire must be designed and implemented to ensure the safety of people, infrastructure, and surrounding lands. Like all natural processes, fire can be either positive or negative in its impacts, depending on the site-management objectives and fire behavior, which in turn is influenced by landscape factors, fuels, and weather conditions. Fire is a powerful force that, under certain conditions, can have massively destructive consequences to both natural systems and human infrastructure and life. At the same time, carefully designed and implemented prescribed fire is one of the most biologically effective and cost-efficient management tools to achieve specific land management goals.

Objectives That May Favor Inclusion of Prescribed Fire Practices

- Improving wildlife habitat for woodland and grassland species:
    - Increasing ground-layer browse, soft mast and small seed sources, and insect availability for wildlife.
    - Increasing quality and diversity of native vegetation or restoring certain natural systems.
    - Sustaining habitat for targeted species of conservation concern such as the federally listed Mead’s milkweed.
    - Increasing flowering rates and pollinator habitat.
    - Increasing northern bobwhite and turkey nesting and brood rearing.

- Improving watershed quality, especially after vegetation response that increases infiltration and reduces runoff and also by promoting erosion-resistant ground-layer vegetation.
- Reducing heavy fuel loads and potential for severe destructive wildfires; protection of infrastructure and improvements from future severe fires.
- Cost-efficient attainment of silvicultural objectives, particularly for shortleaf pine or initial site preparation.
- Managing certain invasive species.
- Reducing levels of certain destructive tree pests and diseases.
- Creating higher-quality hunting and recreational opportunities.
- Improving visual quality, recreational opportunities, and landscape aesthetics.
- Reducing the ground- and mid-story vegetation layer to reduce shading and allow for the establishment of desirable shade-intolerant timber species.

Potentially Negative Impacts of Prescribed Fire

- Reduction in timber quality due to scarring and defect.
- Allowing specific invasive species to expand or become established.
- Increased erosion, particularly in degraded or over-shaded stands with reduced ground-cover vegetation.
- Impacts to wildlife habitat:
    - Reduced habitat for species of conservation concern (e.g. head firing mesic slopes could impact some salamander and snail species).
    - Removal of coarse woody debris that provides wildlife habitat.
    - Potential direct impacts to nesting wildlife in some seasons.
    - Growing season fires can have direct impacts on herptiles and should be used sparingly.
- Damage to fire-sensitive infrastructure and improvements.
- Destruction of fire-sensitive cultural resources.
- Short-term negative post-burn visual impacts (blackened vegetation).
- Smoke-sensitive factors on neighboring lands.
- The use of prescribed fire, without fire free intervals, can potentially result in a lack of recruitment into the overstory.
- Burning with heavy fuel loads due to downed woody debris can kill or damage trees.
- Growing season burns can damage or destroy individual or whole stands of trees.

Critical Elements of a Prescribed Fire Plan

Professional resources available to assist with determination of management goals and prescribed fire suitability include consulting foresters, MDC foresters, MDC private lands conservationists, MDC natural history biologists, MDC wildlife biologists, USFWS private lands services staff, and NRCS conservationists. For additional contact information, see the Resource Directory.

Fire, even prescribed fire, is not a single uniform process. Depending on fuel types and conditions, topography, and weather, a wide range of fire behavior is possible on a single site. Most management objectives involving prescribed fire require a certain range of acceptable fire behavior characteristics to be successful. Prescribed fire activities must be carefully planned and implemented to meet these criteria.

Training in the preparation of burn plans and implementation of prescribed burns is available from workshops presented by state and federal agencies, including MDC and NRCS. Any prescribed fire activities must be based on a detailed and carefully designed and reviewed burn plan. An example is shown in the Appendix C.

A burn plan should include:

- Site description and size
- Vegetation and fuels description, including fuel sizes and type, fuel loads, fuel moisture, and fuel distribution
- Long-term and/or short-term management objectives
- Potential hazards, escape routes, and safety zones
- Access routes, travel zones, and limitations to vehicle/ATV travel
- Landscape context, including neighboring lands and their fuels and fire-sensitive resources
- Fire-line (firebreak) criteria, including type, specifications, location, and advance preparation needed
- Acceptable weather parameters and required duration of acceptable weather, including temperature, humidity, wind speed, wind direction, atmospheric stability and mixing height, etc.
- Required equipment, including personal protective gear
- Crew numbers and qualifications
- Communications
- Ignition and holding plans
- Pre-burn notification and permit requirements; emergency contacts
- Contingency response plans
- Smoke management
- Mop-up and post-burn actions

Firing Techniques

Each firing technique will produce different effects and results. Fire intensity and heat can vary depending on the firing technique. Time exposed to heat can vary, as well as the amount of smoke and the ability to control the prescribed burn. The firing technique used to ignite a prescribed fire is a determining factor as to how successful the prescribed burn will be and if the desired management objectives will be met.

- **Backing Fire —** This is fire spreading, or ignited to spread, into (against) the wind or downslope. A fire spreading on level ground in the absence of wind is a backing fire. A backing fire will often produce lower heat but will allow for longer exposure to the heat or flame.
- **Strip Head Fire —** This is a series of lines of fire ignited near and upwind (or downslope) of a firebreak or backing fire so they burn with the wind (or upslope) toward the firebreak or backing fire. A strip head fire will often produce increased heat, flame length, and overall fire intensity.
- **Flanking Fire —** This is a firing technique consisting of treating an area with lines of fire set into the wind, which burn outward at right angles to the wind.
- **Grid or Spot Ignitions** – These are a method of igniting prescribed fires in which ignition points are set individually at predetermined spacing with predetermined timing throughout the area to be burned; also called the point source ignition technique.
- **Ring Head Fire —** This is a fire started by igniting the full perimeter of the intended burn area so that the ensuing fire fronts converge toward the center of the burn. Set around the outer perimeter of a resource to establish a protective black-line-buffer. A ring head fire will often produce the greatest fire intensity of all firing techniques.

Fire Behavior

One of the most critical and variable factors influencing fire behavior is weather. As one would expect, higher temperatures increase fire behavior, making the fire burn hotter and faster, typically with increased flame lengths. Wind speed similarly influences fire behavior, by increasing available oxygen and preheating and drying downwind fuels. Wind is also a critical factor for spreading embers ahead of the flame front and under certain conditions can cause spot fires some distance ahead of the active flame front.

Fires traveling with the wind (called head fires) have the fastest rates of spread, longest flame lengths, and greatest intensity. Fires burning against the wind (called backing fires) have slower rates of spread, shorter flame lengths, and lower intensities, although they may release more heat per unit area since they heat a given area for a longer period. Fires traveling perpendicular to the wind (called flanking fires) tend to have intermediate behavior between head fires and backing fires. Prescribed burn ignition patterns generally aim to create a safe downwind burned zone via a backing fire, before using some combination of flanking and head fires to complete the burn.

Topography influences fire behavior directly through two factors, slope and aspect. Topography can also profoundly influence local weather conditions and thus exerts a major effect on fire behavior. It is not uncommon for local anomalies of topography to produce localized winds that are directly opposite the prevailing overhead winds. Thus, a careful analysis of weather and topography must be an element of every fire management plan, whether for prescribed fire management or for wildfire control.

Slopes influence fire behaviors because of convection and preheating, making fires spread more rapidly and with more severe fire behavior uphill rather than downhill. Slopes can also cause burning material to tumble out of the unit and pose an escape risk. Aspect is important because south and west slopes tend to be warmer and drier than slopes facing east and north, causing different fuel types and fire behavior.

Humidity has a critical influence on fire behavior, with lower humidities producing increased fire severity, rate of spread, and ignition potential. Humidity fluctuates throughout the day, with the lowest humidities typically attained in midafternoon and the highest in early morning darkness, so prescribed fire plans should take these factors into account. Changing humidities throughout the day can also produce sharp differences in fire behavior within a few hours on any given unit. Fire crew members should be briefed about what to expect throughout the burn period based on best available weather forecasts.

Fuel moisture affects fire behavior and is influenced by humidity, growing season, time since the last rain, size and drying characteristics of the fuel. Fine fuels such as grasses dry within a few hours, while large logs may remain moist for many months. Using these variable fuel moisture characteristics can be an effective tool to retain coarse woody debris for wildlife habitat within burn units and should be an element of fire management plans where appropriate.

Firebreaks

Fires are contained within prescribed fire units through the use of fire lines, also called firebreaks. These are natural or constructed barriers or interruptions in fuel beds. Examples of natural firebreaks include streams, ponds, and bedrock exposures.

Constructed firebreaks include roads, ditches, and raked lines. Sometimes firebreaks serve not so much as a complete barrier to fire but only as a reduced fuel load that allows a crew to safely use the line as a control point during ignition. An example of this would be a mowed fire line in a grassland or grassy area. In this case, water or suppression tools must be used during ignition to prevent escapes, but the mowed line reduces fuel loads to make this safe for the crew to do so.

Sometimes burned zones are created in advance to serve as firebreaks; this can be accomplished through prescribed burning of a downwind or adjacent unit, or by burning a strip, called a blackline, to serve as a firebreak. Firebreaks should be sufficiently wide to at least contain the fire under highest intensity conditions specified in the prescription, but ecological

considerations or site management objectives may impose restrictions on fire-line size, configuration, and location. In most cases fire-line width should be at least 2.5 times the height of the adjacent fuel.

In all cases, fire lines should be designed and installed to avoid damaging unique ecological features, wetlands, and cultural resources, and should not contribute to increased erosion or other potentially negative impacts. Refer to Chapters 14 and 15 for specific best management practices for roads and trails. Fire-line activities may promote invasive species, so care should be taken to ensure that equipment is cleaned before initiating construction, and soil disturbance is minimized.

Smoke Management

Smoke is an issue that must be considered when planning and implementing prescribed fires. Because it will always travel beyond the burn unit, managers must ensure that prescribed fire activities comply with local air quality regulations and do not adversely impact road visibility or proximal smoke-sensitive resources, and that they do not create problems for area residents.

Smoke transport and dispersion is maximized by burning under unstable atmospheric conditions. During night and morning hours the atmosphere is typically more stable, causing smoke to lay in valleys and other low-lying areas. This is called an inversion, and as the air warms through the day the atmosphere becomes unstable, which is more conducive to smoke dispersion. Smoke dispersion is generally far better in daylight hours than at night.

Many elements of the prescription may influence smoke production. Wet fuels generate more smoke than dry fuels, and backing fires produce less smoke than head or flank fires.

As with any other forest management activity, applying accepted best management practices assures that the activity will be carried out in a responsible manner.

Best Management Practices to Protect Soil Productivity and Water Quality

- Carefully select fire-line locations and consider weather, fuel, soil, and topographic conditions in the burn area in order to minimize impacts on water quality.
- Avoid burning piles of slash in riparian management zones.
- Use natural or existing barriers (e.g., roads, streams, and lakes) wherever possible, or wet lines for fire lines where bladed or plowed fire lines will erode soil and degrade water quality.
- Avoid plowed and bladed fire lines in riparian management zones except where necessary to control wildfire.
- Where appropriate, protect the largest coarse woody debris from prescribed burning. Avoid prescribed burning after prolonged dry periods as large coarse woody debris (100 and 1,000 hour fuels) will be dry (<20 percent fuel moisture) and will be more susceptible to being consumed by the fire.

- Prescribed burning should be carried out when the vegetative response to fire is the fastest, or when the duration of soil exposure to the elements is the shortest. If this is not possible, use appropriately sized, unburned buffer strips between burn areas and stream channels to minimize these impacts.
- When possible, avoid prescribed burning in wooded corridors during April and May to avoid reducing hydraulic roughness and minimize tree mortality. Unless necessary, don't use head fire through riparian corridors. Burn intensity in wooded riparian corridors is normally low; prescribed burn ignition strategies should be undertaken that allow for burns to naturally extinguish as the flaming front enters a riparian corridor.
- Repeated intense burns may affect soil productivity. When conducting prescribed burns, use low- or moderate-burning intensity so that the minimum amount of forest floor is consumed consistent with meeting the objectives of the burn.
- Fall burning should generally be avoided on steep slopes with erodible soil, especially in areas with sparse ground-layer vegetation. Soils are more vulnerable to erosion processes during the winter months when there is no vegetation or organic litter on the site.

Best Management Practices to Protect Cultural Resources

If no historic buildings or burial monuments are present, prescribed fire is unlikely to adversely affect most cultural resources. The greatest potential may be exposure of sensitive artifacts by soil disturbance during fire-line installation involving ground disturbance or erosion from heavy and prolonged precipitation while ground is bare from the fire. Identification of important cultural resources in a fire management unit prior to implementation will allow avoidance of negative impacts. Precautions and preparations designed to protect cultural resources during prescribed fire should serve also to provide some level of preservation in the event of wildfires. Specific best management practices for cultural resources commonly found in forested areas are located in the Appendix.

- Consider alternatives such as herbicide use, mowing, or other non-erosion-causing practices for fuel break maintenance on areas where prescribed fire will be used on a recurring basis.
- Protect below-ground archaeological sites from compaction and rutting.
- Avoid high intensity fires around burial monuments.
- Plan fire frequency to preserve ground cover and large woody debris, limiting the potential erosion effects to cultural resources.
- Best Management Practices for Common Cultural Resources can be found in Appendix B.

Best Management Practices to Slow the Spread of Invasive Species

- Incorporate invasive species considerations into the planning of prescribed burns.
- Consider the likely response of invasive species or target species when prescribing activities that result in soil disturbance or increased sunlight.

- Avoid placing firebreaks where there are infestations of invasive species.
- Avoid spreading invasive seeds and other propagules from infested to noninfested areas during prescribed fire activities and firefighting activities.
- Following a prescribed burn or wildfire, rehabilitate soil disturbance related to suppression activities, especially bladed or plowed fire lines, where invasive species establishment is likely.

Best Management Practices to Protect Visual Quality and Minimize Smoke Intrusions

- When working in visually sensitive areas, consider the visual quality impacts of blackened vegetation and plan timing and scale of operations to minimize impacts.
- Consider whether smoke from prescribed burn activities will impact people or visually sensitive areas such as high vehicular traffic areas, residential/business areas, and other areas with an increase in public use and interaction such as campgrounds and parks. Plan prescribed fire activities to minimize these impacts.

Wildfire Prevention and Management

Wildfires are unplanned, uncontrolled ignitions in natural fuels. Typical ignition sources include lightning, arson, and accidental ignitions. Wildfires have tremendous destructive potential for both humans and natural systems and can pose large-scale major threats to health and safety.

Forest and woodland owners should be aware of the potential impacts of wildfires and delineate steps to be taken to minimize wildfire potential. They should outline responses in the event of a wildfire. For certain fire-sensitive resources such as residences and high-value timber stands, permanent or semi-permanent firebreaks such as forest access roads and trails can be used to reduce potential for wildfire damage.

Managers can assist landowners in implementing a variety of practices to strategically reduce the potential for significant wildfire damage. These practices include reducing fuel loads on neighboring units through mechanical treatment, harvest, or prescribed fire, as well as actions such as mowing, limb pruning, raking, and slash removal.

Additional protection for structures may also include fire-resistant construction techniques, fire-resistant landscaping practices, strategic design and placement of roads and driveways, and careful management of infrastructure and surrounding vegetation to prevent fuel accumulations. More detailed information is available from Firewise (Under “Additional Resources” at the end of this chapter).

Community Wildfire Protection Plans can also be used to help at-risk communities in planning to minimize the potential for negative impacts from wildfire. These plans are developed in collaboration with communities and agencies interested in reducing wildfire risk (Under “Additional Resources” at the end of this chapter).

References to Other Chapters

Prior to beginning management activities, consult a professional forester, a Missouri Department of Conservation (MDC) private land conservationist, an MDC wildlife biologist, or an MDC natural history biologist for information about the occurrence of endangered or threatened species, species and natural communities of conservation concern, rare tree species, or sensitive communities present on or near the management area. These species and natural communities can be impacted by site preparation activities, by altering the existing vegetation, or by introducing new species. These professionals can help you modify management activities to maintain, promote, or enhance species and natural communities on the site. See Resource Directory. Refer to Chapter 3 for more information.

Prescribed fire activities create blackened vegetation and smoke, which can have short-term negative impacts to visual quality. Refer to Chapter 4 for guidance on determining visually sensitive locations.

Consider the potential spread of invasive species when preparing for and conducting prescribed fire activities. Refer to Chapter 9 for more information. Depending on the site, circumstances, and invasive species, fire can either help control invasive species or result in their spread and proliferation. Careful analysis, planning, and implementation are required for successful outcomes.

Prescribed fire activities can negatively impact cultural resources, so make sure to plan to avoid them or mitigate impacts. Refer to Chapter 6 for general information related to cultural resources.

Additional Resources

Technical terms have been defined by the National Wildfire Coordinating Group (NWCG) and can be reviewed at nwcg.gov/pms/pubs/glossary/g.htm

The Oak Woodlands & Forests Fire Consortium: Our mission is to provide fire science information to resource managers, landowners, and the public about the use, application, and effects of fire. Within these pages you should expect to find information on “everything fire”: oakfirescience.com/

Wildland Fire Incident Management Field Guide: The fire-line hand book has recently been replaced by NWCG document PMS 210, the Wildland Fire Incident Management Field Guide. Available at nwcg.gov/pms/pubs/pubs.htm

Firewise: Information on ways to protect homes located in fire-prone areas is available at firewise.org

Fire Adapted Communities: Information on ways to protect homes located in fire-prone areas is available at fireadapted.org/

Florida Division of Forestry: Information on the use of prescribed fire to protect homes and benefit ecosystems is available at prescribed-fire.org

National Fire Plan: Information on the impact of wildfires on communities and the environment is available at fireplan.gov

National Interagency Fire Center: Wild-land fire information, fire statistics, and links to other agencies are available at nifc.gov

The Nature Conservancy: Information on the use of prescribed fire and training is available at conservationgateway.org/ConservationPractices/FireLandscapes/Pages/fire-landscapes.aspx

Northern Prairie Wildlife Research Center: Information on the use of fire in wildlife management is available at npwrc.usgs.gov

U.S. Forest Service, Fire and Aviation Management: Information about wildfire activity and situation reports, fire management, training, fire use, and fire prevention is available at fs.fed.us/fire/

Coalition of Prescribed Fire Councils: The goal of the Coalition is to create one voice to assist fire practitioners, policy makers, regulators, and citizens with issues surrounding prescribed fire use. More information is available at prescribedfire.net/

Wisconsin Forest Management Guidelines. PUB-FR-226, 2011. Available at dnr.wi.gov/topic/ForestManagement/guidelines.html

Chapter 18: Forest Recreation Management

Topics Covered

Forest Land and Recreation
Best Management Practices for Providing Recreational Opportunities
Fee-Based Activities

Forest Land and Recreation

One of the most prominent reasons most people choose to own forest land is to have a place to enjoy outdoor recreation. The range of opportunities they desire can include such activities as hunting, fishing, hiking, nature study, and camping. Often owners even consider the manual labor involved in maintaining and improving their property as much a recreational activity as it is work.

In order to enhance recreational opportunities landowners frequently build roads and trails, clearings for a campsite, rustic cabins, or more elaborate second homes. Fishing ponds are also a popular development on private forest lands. Appropriate attention to how these improvements are implemented is important in order to minimize negative impacts to the property's natural and cultural resources. Carefully planned developments may even enhance these resources in specific instances.

Increasingly, some landowners are providing recreational opportunities for a fee, using this as a way to generate income from their property. Most of the related developments are the same but may include more campsites, more trails, or larger buildings. Hunting is probably the most commonly offered fee-based recreational activity, and enhancing habitat may become the most significant landowner objective.

Best Management Practices for Providing Recreational Opportunities

In order to protect or improve natural and cultural resources while enhancing recreational opportunities on forested properties the following general considerations may be useful.

- Clearly identify desired recreational uses in the overall forest management plan.
- The plan should also specify actions needed to meet multiple objectives. For example, building one road for logging and hunting access is certainly more desirable than building two roads, one for logging and a separate one for hunting.
- Look for instances where achieving a management objective may conflict with providing a sought-after recreational opportunity. For example, if a landowner identifies and wants to protect a heron rookery, then he or she would want to restrict ATV riding to other parts of the property.

- When constructing roads, trails, or facilities follow the best management practices prescribed in Chapter 14.
- Monitor the condition of roads and trails and restrict use when recreational activities threaten to cause damage to soil and water resources. Soil damage and potential subsequent stream sedimentation can be caused by recreational vehicles (ATVs, pickups, dirt bikes, mountain bikes), horses, or by the trampling of too many hiking boots.
- Roads and trails should be placed on the land so that they are safe and enjoyable travel ways that “work with the land rather than against it.” The goal is to minimize travel hazards like steep slopes, soil erosion, and damage to streams. In some cases, an owner may want to rehabilitate or close an old road, or a part of it, if it is eroding a hillside.
- When planning recreational developments, consult a professional forester, a private land conservationist, a wildlife biologist, or a natural history biologist for information about the occurrence of endangered or threatened species of conservation concern. These special resources (i.e., rare tree species, sensitive communities, or unique sites) on or near the property can enhance landowners’ enjoyment of their property but may also need special care and concern.
- Planning should also identify cultural resource issues in terms of both protection and interpretation. The Department of Natural Resources State Historic Preservation Office may be able to assist with known sites. If no information is available, field inspections should be conducted before development plans are finalized to determine the presence or absence of cultural resources. Soil disturbance represents the most common threat to cultural resources, so knowing their location, or likely occurrence, and minimizing development in those areas is the most important management consideration. At the same time observing cultural resources can certainly add to recreational experiences. For example, routing an access trail up next to an old cemetery, historic springhouse, or long-abandoned smokehouse can add interest to a recreational outing.
- Leave flowering trees during vegetative management, create scenic vistas, and improve visual quality in other ways to enhance most recreational experiences.
- Management activities to enhance wildlife habitat are concurrently enhancing recreational experiences. It is important to consider what species are involved in the desired recreational activity and implement the appropriate management measures that promote the best habitat.
- Minimize any negative effects on habitat. For example, you may not want to push in a road so a cabin can be built in an area that has been a preferred roosting site for wild turkeys. Planning with careful attention to the full suite of management objectives is an important tool.
- Carefully laid-out logging trails can later be used for hiking trails.
- Where fitting to the ecological land type, silvicultural techniques can favor more recreationally friendly areas such as open pine woodlands.

- Different regeneration methods can favor species with more desired visual qualities such as sugar maple or yellow poplar.
- Identify and eliminate hazard trees, block abandoned wells, and keep trails away from steep eroding slopes in order to keep users safe. Common sense and regular inspections of the property will generate the set of precautions that a landowner deems most appropriate to the situation.

Fee-Based Activities

Depending on land management objectives, development of a hunting lease enterprise offers many landowners the opportunity to supplement their income while enhancing wildlife habitat on their property. Hunting leases are an example of the broader concept of a recreational lease — an agreement between a person who controls access to property and a person who wishes to use the property for recreation. The lease grants an individual the right to participate in a specified recreational activity on a specific tract of property for a certain time and fee.

A hunting lease is an agreement between the landowner (lessor) and hunters (lessees) to grant access to land to hunt game (and conduct other specified activities) for a specified period of time. Hunters usually pay an agreed-upon dollar amount per acre or per hunter.

Commercial campgrounds represent another income-generating objective but need to be pursued in light of a full understanding of the market potential for such a development. They are expensive to construct and maintain and would not be profitable without sufficient numbers of users.

Appendix A: A Backgrounder on Forest Certification

Forest certification is a way for the manufacturers of wood and paper products to provide assurances that the wood or wood fiber used in their product comes from a forest that has been properly managed.

The assurances provided are generally that the forest is managed and wood is harvested in a way that protects and enhances soil, water, cultural, and natural resources. Under the required management regime, consideration is given to providing wildlife habitat and enhancing biological diversity. Wood is produced under a system that yields a long-term sustained volume. Reforestation is accomplished in a timely manner. Harvested wood is not wasted. Forests are adequately protected from fire, insect, and disease damage. The aesthetic impacts from harvesting trees are mitigated, and landowners, operators, and manufacturers are held accountable for compliance with all applicable state, local, national, and international laws.

Verification that these assurances have been met is accomplished through independent evaluations conducted by third-party auditors who are trained and qualified according to national standards for audit professionals.

Once verification has been completed, manufacturers can place a label on their products signifying that the wood contained in each labeled product comes from a properly managed forest.

This background paper provides information on who is responsible for overseeing certification systems and where certification currently stands as an industry practice.

Primary Certification Systems

There are five organizations that are most relevant to current and any future certification activity in Missouri. Each has a somewhat different emphasis and lexicon, and they all have their core supporters. They are not necessarily exclusive of one another, and in some instances one system is designed to be supportive or complementary of a second system. There are some landowners and producers who subscribe to multiple systems.

The Forest Stewardship Council

The Forest Stewardship Council (FSC) came into existence in 1993. Its overall governing body, the general assembly, is international and consists of all members, who must designate themselves as part of the economic chamber, a social chamber, or an environmental chamber. Each chamber is allotted equal weight in decision making, and voting is further weighted to give the developing countries of the southern hemisphere equal say to the developed countries of

the northern hemisphere. A board of directors that is similarly balanced is elected by the general assembly.

Their international headquarters are located in Bonn, Germany. At that level, FSC establishes principles and criteria that apply across all countries. There are ten principles, each with multiple criteria. As an example of the level of specifics applied internationally, Principle 5, “Benefits from the Forests,” states: “Forest Management Operations shall encourage the efficient use of the forest’s multiple benefits and services to ensure economic viability and a wide range of environmental and social benefits.”

There are five criteria intended to support this particular principle. An example is Criterion 5.1, which states: “Forest Management should strive toward economic viability, while taking into account the full environmental, social and operational costs of production, and ensuring the investments necessary to maintain the ecological productivity of the forest.”

In each country where FSC is utilized, a national level body is formed. FSC-US is headquartered in Minneapolis, Minnesota. The national body is structured similarly to the international organization and has the responsibility for establishing indicators under each criterion. These indicators are the measurable requirements involved in becoming certified. An example is Indicator 5.1.a under Criterion 5.1, which states: “The forest owner or manager is financially able to implement core management activities, including all those environmental, social and operating costs, required to meet this Standard, and investment and reinvestment in forest management.” Indicators are applicable all across all U.S. forests.

In addition, there are limited instances where the national body has adopted more specific standards at the regional level. For example Indicator 6.3.g includes further guidelines for the Ozark-Ouachita Region, which, among other things, state: “Even-aged opening sizes are limited to a maximum of 20 acres.”

Qualified auditors must be accredited by FSC.

Manufacturers who want to use the FSC label on their product must achieve a “Chain-of-Custody Certification,” which ensures there is a system in place to track what wood comes from certified forests. There are several label options available depending upon the percentage and type of acceptable content in the product.

For smaller landowners and manufacturers, FSC provides a process for “Group Certification” where several enterprises can join together in order to lower costs.

Complete, more detailed information can be found at fsc.org.

The Sustainable Forestry Initiative, Inc.

The Sustainable Forestry Initiative, Inc. (SFI) began as a reporting requirement for members of the American Forests and Paper Association (AFPA) in 1994. By 1998 it had evolved into a

system for third party certification of forest lands to the SFI Standard. By 2002 it had officially separated from AFPA to become an independently governed, nonprofit organization that manages a certification system applicable to operations in the United States and Canada.

It is governed by an 18-member board of directors comprised of six members from each of three chambers — economic, environmental, and social. Replacements to the board are nominated and selected by existing members. They approve revisions to the SFI Standard, requirements for on-product labeling, and all other elements of governance.

Auditors must be accredited by the Standards Council of Canada (SCC) or the American National Standards Institute–American Society for Quality (ANSI-ASQ) National Accreditation Board, otherwise known as ANAB. Audits must be conducted according to processes consistent with the requirements of the International Organization for Standardization (ISO) 17021:2006 conformity assessment and in accordance with principles contained in ISO 19011:2002 Guidelines for Quality and/or Environmental Management Systems Auditing.

Participants must have a written policy to achieve 14 overall principles that cover such topics as forest productivity and health, protection of water resources, protection of biological diversity, and responsible fiber sourcing. Supporting these principles are seven objectives that apply to land management operations, six objectives that apply to operations involved in fiber procurement, and seven objectives that apply to either of those operations. Under each objective there are one or more performance measures, and under each performance measure there are several indicators.

An example of this structure is:

Objective 3. Protection and Maintenance of Water Resources. To protect water quality in rivers, streams, lakes and other water bodies.

- Performance Measure 3.1. Program participants shall meet or exceed all applicable federal, provincial, state and local laws and meet or exceed best management practices developed under Canadian or U.S. Environmental Protection Agency–approved water quality programs. Indicators:

    1. Program to implement state or provincial best management practices during all phases of management activities.
    2. Contract provisions that specify conformance to best management practices.

In order to use the on-product label, primary manufacturers must be certified in compliance with those portions of the SFI Standard that are required for fiber procurement operations, namely, Objectives 8–20 and their accompanying performance measures and indicators. Secondary manufacturers who want to label their products must pass a Chain-of-Custody audit verifying that the wood they are using is from an SFI certified primary producer.

There are no specific group certification systems under SFI, but this would not prohibit a group of entities from seeking certification together, as long as the audit process met ISO standards as outlined above.

More information is available at sfiprogram.org.

The American Forest Foundation

The American Forest Foundation (AFF) has been in existence since the 1940s and has had as one of its primary programs the American Tree Farm System (ATFS) since inception. In 2006 the AFF board of directors established procedures for developing "Standards of Sustainability for Forest Certification." Subsequently, all members of ATFS were group certified by independent auditors working with each state as a separate group and with audit costs paid by AFF. The program is currently in transition to a system whereby members of ATFS will have the option to become group certified by paying a separate fee.

ATFS determines who is qualified to verify conformance and establishes the acceptable procedures for doing so. By direction of the AFF board of directors, members of the panel who draft standards must represent a "cross-section of forestry community leaders with a stake in AFF's Tree Farm Program, or a sincere interest in forest sustainability on small private forest ownerships in the US."

The system is available to anyone in the United States owning 10 or more acres of woodland and is comprised of eight standards, under which are performance measures and accompanying indicators. An example of their structure is:

- Standard 4: Air, Water and Soil Protection — Forest management practices maintain or enhance the environment and ecosystems, including air, water, soil and site quality.
- Performance Measure 4.1 — Forest owner must meet or exceed practices prescribed by State Forestry Best Management Practices (BMPs) that are applicable to the property.
- Indicator 4.1.1. — Forest owner must implement specific BMPs that are applicable to the property.

For purposes of compliance with SFI's objectives for fiber procurement operations, AFTS certified lands are recognized as a certified source of wood.

Additional information is available at forestfoundation.org.

Programme for the Endorsement of Forest Certification

Originally established as the Pan-European Forest Certification System in the mid-1990s and primarily focused on private forest landowners in Europe, this organization eventually evolved into the Programme for the Endorsement of Forest Certification (PEFC). As such PEFC establishes criteria as to what constitutes a credible forest certification system, and certification

organizations from across the globe can petition to become part of the PEFC Mutual Recognition umbrella.

This allows systems to be tailored to a national level recognizing the unique circumstances and culture of each country, at the same time allowing those systems to be judged at the international level as credible. Once endorsed by PEFC, wood certified under that national-level system can move more freely across international boundaries under reciprocal understandings of mutual recognition.

Headquartered in Geneva, Switzerland, PEFC has endorsed more than 30 systems worldwide, including SFI and ATFS. It is governed by a general assembly composed of both representatives of endorsed certification systems and international stakeholders such as the International Laborers' Organization, which oversees global standards for the rights of workers. The general assembly selects a board of directors who support the work of the general assembly and the organization as a whole.

Criteria for endorsement cover such topics as governance structure, decision-making processes, chain-of-custody requirements, labeling procedures, and topics that must be addressed by a certification standard. In total there are more than 300 criteria that must be met. An example of their structure is:

- 5 Specific requirements for SFM standards
- 5.1 Criterion 1: Maintenance and appropriate enhancement of forest resources and their contribution to the global carbon cycle.
- 5.1.1 Forest management planning shall aim to maintain or increase forests and other wooded areas and enhance the quality of the economic, ecological, cultural and social values of forest resources, including soil and water. This shall be done by making full use of related services and tools that support land-use planning and nature conservation.

Petitions for endorsement are evaluated by independent expert contractors hired and overseen by the board of directors and ultimately voted on by the general assembly.

More information is available at pefc.org.

The International Organization for Standardization

The International Organization for Standardization (ISO) was established in 1947 and sets voluntary standards that cover just about any aspect of technology and business. As with PEFC, this organization is also headquartered in Geneva, Switzerland. Members comprise a network of national-level standard-setting bodies, such as the American National Standards Institute in the United States (already been mentioned under the information for SFI).

ISO is governed by the member institutes.

SFI draws on ISO standards to define what constitutes an acceptable audit process and scope

In addition, many organizations use the ISO Standard 14001:2004 to structure their certification program. ISO 14001 defines a system that can be used to manage an entities risk for impacting the environment. It defines the elements of the environmental management system that must be in place and how those elements should be utilized.

For example, ISO 14001 requires that there be a documented environmental policy and method in place to ensure that the policy is implemented, maintained, and communicated to all employees. Using ISO 14001 as the basic structure, organizations can build a system of compliance for a forest certification standard knowing that their system has a high likelihood of being successfully implemented and maintained.

Auditors that are qualified to conduct ISO verifications meet the same requirements as those qualified to do SFI verifications. Some organizations have both their ISO system and their SFI compliance audited together.

The Current State of Forest Certification

Worldwide more than one-fourth of the world's industrial round wood production comes from a certified operation. As of 2012, approximately 500 million acres of forest were certified in the United States and Canada.

In Missouri, forest certification has been more slowly adopted than perhaps in any other state in the country with a significant acreage of forest land. The LAD Foundation's approximate 180,000 acres is certified to the FSC standard. With transition currently underway, it is not known how many Missouri ATFS members will remain certified. There are no acres certified to the SFI standard in the state. There are also no in-state primary producers certified to SFI's set of fiber procurement objectives, though a couple of paper mills located out of state procure chips in Missouri and are SFI certified. There are a small number of primary producers who have an FSC Chain-of-Custody Certificate.

When certification first began, there was a presumption that it would be adopted based on the marketplace paying more for certified wood and paper products. This "market premium" has been realized in some limited instances but not in a widespread fashion. Instead, major customers have driven the movement toward certification more as a requirement for doing business with their organization. This need to maintain market access has made its presence felt in the paper industry and the commodity lumber market. There has also been applicability in the growing "green building" market. By and large, products manufactured in Missouri (barrel staves, pallets, railroad ties, and grade hardwood lumber) have not experienced the market pressure that would drive the state's primary producers into a certification program.

From a resource health and sustainability standpoint, credible research has shown that where certification is widely adopted there have been measurable improvements in the benefits produced by forest management.

Appendix B: Best Management Practices for Common Cultural Resources

Criteria of Cultural Resources

Criteria for National Register Evaluation of Cultural Resources can be found at achp.gov/nrcriteria.html.

The following are best management practices for different types of cultural resources that may be encountered in Missouri. The BMPs are derived and modified from BMP guidance used for public land management by the Missouri Department of Conservation on public lands.

Best Management Practices for Prehistoric Burial Mounds and Rock Cairns

In Missouri, prehistoric mounds are earthen structures that may have a variety of shapes and were likely constructed primarily for burial purposes. Cairns, on the other hand, may be one of two construction types depending on function. Burial cairns are constructed of rock or rock and earth and are usually low in height and wide in diameter. Cairns used as boundary or trail markers, for example, are constructed of rock and are narrow and more conical or columnar in shape.

Prehistoric burial mounds and cairns are a very sensitive and endangered cultural resource. They are considered sacred by Native American peoples. For this reason, burials are afforded some protection under the Missouri Revised Statutes 194.400-410. Because grave goods are sometimes associated with burial mounds and cairns, they are sought-after targets for looters who will dig to steal artifacts and human remains for display and profit.

Key features identifying a prehistoric burial mound or rock cairn include:

- Circular, conical, oblong, or other earthen features that do not resemble the natural surroundings.
- Mounds are generally no smaller than 15 feet in diameter and may have a diameter up to 150 feet, or larger.
- Burial mounds and cairns are often located on terraces, or bluffs overlooking major rivers or permanent streams.
- Prehistoric materials such as chipped chert flakes, prehistoric tools (projectile points, blades, etc.), or pottery may be located in the vicinity of the mound or cairn.
- Cairns can be U-shaped, square, rectangular, or conical.
- Cairns can vary from a small, loose pile of stones to more elaborate construction.

Management Recommendations

- Prior to construction or any land-disturbing activities in the vicinity, the established buffer should be marked off with flagging tape. Flagging should be removed at the conclusion of the project so it does not draw attention to the site.
- Identify potentially destructive threats to the burial mound or cairn and address these threats on a case-by-case basis. To deter erosion and to aid in camouflage, the growth of naturally occurring, minimally invasive, plants (i.e., tall grasses, scrub brush, poison ivy, etc.) on and around the mound is encouraged. Avoid planting trees on or around the mound as the roots may have an unwanted, destructive effect on the mound and/or the associated burial(s). If the mound lies on a stream bank in an area of high erosion, take appropriate measures to slow or stop the erosion process, if possible.
- If small saplings are growing on the mound or cairn, they may be removed if their roots are growing no greater than 4–6 inches below the surface. Larger saplings should be cut off at the ground and the stump treated to prevent regrowth.
- Generally prehistoric burials occurred within the central portion of a mound or cairn. Erosion, farming, flooding, or other disturbance may soften the profile or scatter mound construction material. A buffer around the identified mound area should be maintained around the mound to prevent disturbance of artifacts that may be scattered. Excavation or other forms of disturbance should be avoided within the buffer area established for protection. Do not drive or park heavy equipment in the buffer area. Refrain from removing vegetation.
- If a timber harvest is planned in the area around the burial site, the mound and buffer should be flagged and clearly marked prior to the start of operations. Remove temporary markers upon harvest completion to protect the anonymity of the site.
- If a burial site is found during normal operation, STOP all ground disturbing activities with a minimum 150’ circumference buffer zone. Avoid driving vehicles and unnecessary walking on the site. At no point should vehicles of any sort be driven onto or across mounds or other burial sites. Constructed trails, roads or other paths should not be located adjacent to burial mounds or cairns to prevent disturbance.

Best Management Practices for Caves and Rock Shelters

A cave is a natural underground void. Prehistoric peoples have made use of caves for shelter, burial, and religious sites. Since items placed in caves are protected from the climate and thus somewhat preserved, caves are an archaeological treasure for learning about these people. Missouri has some 6,300 recorded caves, more than any other state in the Union.

A rock shelter is a shallow cave-like opening at the base of a bluff or cliff. Rock shelters are natural rock overhangs that form natural shelters, which prehistoric and historic humans often used as living places and storage spaces and for burials. As a result of these activities, trash, tools, and other artifacts were often left behind.

Previously occupied caves or rock shelters often have the following indicators:

- Historic materials located in the vicinity (i.e., glass, metal, ceramics).
- Prehistoric materials located in the vicinity or located downslope (i.e., chipped chert flakes, prehistoric tools, or ceramics).
- Prehistoric drawings, etchings, petroglyphs (images pecked or scratched into the rock surface), or pictographs (painting done with pigment on rock) in or around the mouth or walls of the cave or shelter.
- Other historic or prehistoric sites or features found in the vicinity such as rock cairns or burial mounds.

Buffer Zone Management Recommendations

- Since artifacts are often outside the cave, around the perimeter, as well was inside (vertical or horizontal entrances), a buffer up to 100 feet around the outer diameter of the mouth should be protected by a buffer, vertical or horizontal openings.
- No ground-disturbing activities should be conducted within the established buffer or on the land in the overhang of the mouth of a horizontal entrance (no hand or machine excavation, no driving or parking heavy equipment, no large-scale vegetation removal).

Recommended Practices for Caves and Rock Shelters

- Prior to any silvicultural (including road construction) activities in the vicinity of the cave, the 100-foot buffer can be marked off with flagging tape at 50-foot intervals or by marking larger tree trunks along the buffer perimeter with spray paint that will be noticeable by logging crews.

Cave Management Recommendations

Caves are a vital cultural resource. Along with projectile points and ceramics, caves oftentimes yield artifacts made of organic material (leather, cloth, etc.) because of their natural protection from the elements. These artifacts can offer important information about prehistoric people and their way of life.

- Construction or potentially ground-disturbing activities within a minimum 100-foot buffer zone should be avoided. This buffer should be put in place to ensure that possible artifacts and features around the mouth are not disturbed. Take appropriate measures to further secure the location.
- Avoid planting trees at or around the opening as the roots may have an unwanted destructive effect on the features or associated artifacts. If small saplings are growing inside the mouth of the cave, they may be removed if their roots are growing no greater than 4–6 inches below the surface. Larger saplings should be cut off at the ground and the stump treated to prevent regrowth.

The key recommendation for management of a cave is protection.

Best Management Practices for Cemeteries

A cemetery is an area set apart for or containing graves, tombs, or funeral urns. Cemeteries are also referred to as graveyards or burial grounds. Cemeteries can include many large, modern tombstones and graves, or they can be small family plots with historic headstones.

Cemeteries, including small family plots whose boundaries may not be defined, are addressed by Missouri Revised Statutes Chapter 214, which allows public access.

Some key identifiers of undefined cemeteries:

- Mounds or indentations in the ground fitting the size of a grave.
- Evidence of carved headstones, footstones, or limestone slabs.
- Indications of fencing: fallen wooden or metal posts and wire.

Buffer Zone Management Recommendations for Cemeteries with Undefined Boundaries

- Graves may be present without headstones and may lie outside of the easily identified gravesites. A buffer of up to 100 feet should be established around the identifiable outer diameter of the cemetery. No ground-disturbing activities should be conducted within this buffer (no hand or machine excavation, no driving or parking heavy equipment, no large-scale vegetation removal).
- Prior to any construction or ground-disturbing activities in the cemetery area and the 100-foot buffer, mark the boundary with flagging tape or by marking larger tree trunks along the buffer perimeter with spray paint that will be noticeable by construction or maintenance crews.
- When a cemetery is encountered, STOP all construction or ground-disturbing activities within a 100-foot buffer. This buffer ensures that possible burials around the perimeter of the cemetery are not disturbed. Take appropriate measures to further secure the location if needed. Although not as common as prehistoric burial looting, looters will also plunder historic cemeteries in search of buttons, jewelry, etc. Civil War burials are particularly vulnerable to looting.

Cemetery Maintenance Recommendations

- Do not disturb headstones in any way, including resetting, scrubbing, rubbing, or enhancing in any manner.
- Identify destructive threats to the cemetery and address these threats on a case-by-case basis. Avoid planting trees on or around the graves as the roots may have an unwanted destructive effect on the plot.
- The general spraying of caustic chemicals such as commercial herbicides or weed killers should not be used around historic cemetery stones, as this may severely erode or rapidly deteriorate the stones. However, direct treatment of a stump, such as with a paintbrush or other controlled application, is acceptable to prevent regrowth.

- Vegetation may be mechanically removed if the roots have not grown deeply into the grave, grave depression, or through fallen, cracked head- or footstones. Vegetation growing in graves or grave depressions should be manually cut off at the ground, and the stump should be treated to prevent regrowth. Likewise, vegetation growing through fallen head- or footstones should be manually cut off just above the headstone and the stump should be treated, using a paintbrush or other controlled application, to prevent regrowth.

Best Management Practices for Charcoal Production Sites

Charcoal pits are the remnants of charcoal production sites generally related to charcoal production in Missouri's iron industry. Although charcoal was not actually made in pits, the term "charcoal pit" is the common term used in Missouri and elsewhere. The term "pit" denotes the remains of a temporary charcoal production facility and is sometimes interchanged with the term "kiln," which usually indicates a larger-scale operation. Later charcoal kilns supplied briquettes for home use.

Charcoal production was one of the most important, costly, and dangerous parts of iron production at Missouri iron furnaces. Early furnaces using charcoal as a fuel were often established in remote, isolated locations because they required extensive woodlands from which to produce charcoal, as was the case with the Missouri iron industry (Wettstaed 2003).

Some key indicators often used to identify a charcoal pit:

- An area of soil darker than the surrounding soil, usually in a circle, with an average diameter of 30–35 feet and 6 inches deep. Larger, or multiple, charcoal pits may have been a more permanent operation and may have the remains of a house place and/or outbuildings in association.
- Many charcoal pits have been located on creek terraces adjacent to the base of the slope.
- Charcoal kilns are actual structures where charcoal was made and generally indicate later, larger-scale production of charcoal. Charcoal kilns are generally rectangular structures with a domed or gabled roof constructed of brick or reinforced concrete.

Charcoal Pit and Kiln Management Recommendations

Charcoal pits and kilns are important because they offer valuable insight into the history of the Missouri iron and briquette industries.

- When a charcoal pit or kiln is encountered, STOP all construction or ground-disturbing activities within a minimum 25-foot buffer zone. This buffer should be put in place to ensure that the site and its perimeter, which could contain buried materials, are not disturbed. Take appropriate measures to further secure the location if needed.

- Identify potentially destructive threats to the site, and address these threats on a case-by-case basis.
- Brush hogging, mowing, and routine maintenance is allowed in the area of the charcoal pit or kiln as long as no subsurface damage occurs to the feature.
- Caustic chemicals such as commercial herbicides or weed killers should not be used adjacent to charcoal kilns, as this may severely erode or rapidly deteriorate the stone, concrete, or brick construction.

The key recommendation for management of a charcoal pit is avoidance, while kilns may be preserved or removed with proper documentation.

References

Wettstaed, James R., *Cutting It Back and Burning It Black: Archaeological Investigations of Charcoal Production in the Missouri Ozarks*. IA, *The Journal of the Society for Industrial Archeology* 29.2 (2003): 40 pars. 9 Jan. 2009. Available at historycooperative.org/journals/sia/29.2/wettstaed.html.

Massengale, Robert, *"Black Gold: A History of Charcoal in Missouri,"* 2006. Available at AuthorHouse.com and enter the book's ID number: 37830.

Best Management Practices for Foundations

Introduction, Definition, and Identification

Building foundations offer information about architectural design, exact locations of historic buildings, and human use of the structure. Foundations tend to be one component of larger sites.

Some key markers to look for when attempting to identify a historic foundation:

- Large concrete blocks, sometimes laid out in the shape of a square or rectangle.
- Brick rubble or large, cut stones, and stone or brick piers.
- Historic materials located in the vicinity (i.e., glass, metal, ceramics).
- Large depressions in the ground, remains of a cellar or basement area.

Buffer Zone Management Recommendations

- Often there are additional features left behind besides the foundation. Other historic features like privies, trash dumps, wells, cisterns, etc., may not be visible.
- Historic artifacts and features are usually found around the foundation, sometimes near the ground surface. A minimum 100-foot buffer of avoidance around the perimeter of the foundation should be adhered to or adjusted to include other features as noted above. No ground-disturbing activities should be conducted within this 100-foot buffer zone (no hand or machine excavation, no driving or parking heavy equipment, no large-scale vegetation removal).

- Prior to any construction or ground-disturbing activities in the vicinity, the buffer can be marked off with flagging tape or by marking larger tree trunks along the buffer perimeter with spray paint that will be noticeable by logging crews.
- Historic foundations are important because they mark an area of cultural activity and associated artifacts that can provide clues about the people who occupied the area. Foundations used for only a short period of time often look unremarkable but can be accurately dated and provide information on when and how the structure was used and often by whom.
- When a foundation is encountered during a logging operation or ground-disturbing activities STOP ALL activities. Contact the SHPO for information on the importance of the site. Take appropriate measures to secure the location if needed.
- For previously unrecorded foundations or structures, avoid all disturbance until the status of the site can be determined.
- Avoid planting vegetation near foundations as the roots may have an unwanted destructive effect. Vegetation may be mechanically removed if the roots have not grown through the foundation. Vegetation growing in the foundations should be cut off at the ground and the stump treated to prevent regrowth.
- Caustic chemicals such as commercial herbicides or weed killers should not be used around historic foundations, as this may severely erode or rapidly deteriorate the stone or brick.
- Identify potentially destructive threats to the foundation and address them on a case-by-case basis.

The key recommendation for management of a historic foundation is protection. Regular visits are recommended to ensure that unauthorized disturbance or looting is not occurring.

Not all foundations are historically significant and may not need to be maintained and protected, but this should be determined by the cultural resources coordinator in consultation with the State Historic Preservation Office.

Best Management Practices for Timber Industry Sites

Historic logging took place from roughly the 1800s to the early 1900s to supply charcoal fuel for iron ore smelting, to produce railroad ties, and to supply raw materials for the wood products industry including logs for sawmills and pulpwood for the pulp and paper industry.

Some key markers to look for when attempting to identify historic timber industry sites:

- Tram or railroad remnants — spikes and timbers, graded beds or plateaus indicating old track locations, or culverts and bridges associated with tram remnants.
- Metal artifacts — machinery, harnesses, and tools, all of which may be complete or fragmented.

- Collapsed structures — dilapidated buildings that may indicate sawmills or other timber-related structures.
- Historic materials — located in the vicinity such as glass, metal, or ceramics, which could indicate the location of temporary timber camps, for example.

Management Recommendations for timber industry sites

- When a timber industry cultural site is encountered during construction, STOP all construction or ground-disturbing activities.
- Identify potentially destructive threats to the site and address them on a case-by-case basis.

The key recommendation for management of a historic timber-related site is protection. Not all sites are historically significant and may not need to be maintained and protected, but this will need to be determined in consultation with the State Historic Preservation Office.

Appendix C: Management Activity Pre-activity and Post-activity Check Sheets

Missouri Forest Pre-Harvest Checklist

1. Landowner's Name: _____ Phone Number: _____
   Address/City/State/Zip: _____

2. Logger's Name: _____ Phone Number: _____
   Address/City/State/Zip: _____

   Certified Master Logger? Yes No
   PTH Certificate #_____

3. Today's Date: _____ Contract Length: _____Expiration Date: _____
4. Forest Property Location: County _____ Section_____ Township _____ Range _____
5. List how the property lines are identified: _____
   _____
6. Acreage to be harvested:_____

   Harvest type:
   ____ Thinning
   ____ Timber Stand Improvement (TSI)
   ____ Clear-cut
   ____ Shelterwood cut
   ____ Selection cut (single tree or group)
   ____ Salvage
   ____ Other (Please specify):

   _____

   a. Does harvesting meet recommendations in forest management plan? □ Yes □ No
   b. Were wildlife habitat needs (snags, dens, coarse woody debris, etc.) considered in this harvest? □ Yes □ No
      What actions will be taken during the harvest to address wildlife habitat needs?
      _____
   c. Are cultural resources located on the property? Yes □ No
      Are they being avoided by the harvest operation? Yes □ No
      What actions will be taken to mitigate impacts to cultural resources?
      _____
      _____
   d. Are there natural features (springs, seeps, fens, caves, glades, etc.) or species of concern present? List and describe management needs.
      _____
      _____
   e. Are there any known invasive species or other forest pest threats located in the sale area? Yes □ No
      What actions will be taken during the harvest to avoid spreading these pests?
      _____
      _____
   f. Does the harvest area contain any stands in visually sensitive locations as identified by the forest management plan? Yes No

What actions will be taken during the harvest to mitigate these impacts (indicate on attached map)?
_____
_____

7. Sale Layout: Where are the access roads, landings, and main skid trails? (*Show on attached map*.)
   a. Attach a map (this can be a hand drawing on a topographical map)
   b. Are the log landings and main skid trails flagged? Yes No
   c. Will existing roads (ER), new roads (NR), or reworked roads (RR) be used? *(check all that apply)*: □ ER □ NR □ RR

8. **Best Management Practices: Circle Yes or No. If No, explain the proposed alternative to be used or why the BMP is not applicable.**

Yes No **a**. Construct all roads, landings, skid trails, outside SMZs. **Explain alternative:**
_____
_____

Yes No **b**. SMZs have been identified and will be a minimum of 50 feet wide, will have minimal or no exposed mineral soil, and have been determined based on *Missouri Watershed Protection Practice.* **Explain alternative:**
_____
_____

Yes No **c**. Haul road entrances will be graveled up to the public highway when necessary to reduce mud on the road. **Explain alternative:**
_____
_____

Yes No **d**. Log landings will be constructed as small as practical, adequately drained, and constructed outside of any SMZs. **Explain alternative:**
_____
_____

Yes No **e.** A minimum of one-third of the overstory trees will be left in the SMZs. **Explain alternative:**
_____
_____

Yes No **f.** Out-slope roads will be used whenever possible, or ditches to move water off the road, and properly sized culverts at intervals specified in the *Missouri Watershed Protection Practice***. Explain alternative**:
_____
_____

Yes No **g**. On non-ditched roads, use broad-based dips and/or grade breaks at intervals specified in the *Missouri Watershed Protection Practice.* **Explain alternatives:**
_____
_____

Yes No **h**. Temporary water bars or turnouts will be placed on skid trails to control potential erosion during any temporary shut-down periods. **Explain alternative:**
_____
_____

Yes No **i.** Permanent water bars will be installed at 30–45 degrees to the road or skid-trail surface and at intervals specified in the *Missouri Watershed Protection Practice.* **Explain alternative:**
_____
_____

Yes No **j.** Stream crossings for haul and skid roads shall be avoided when possible.
- Streams should be crossed at right angles (90°). Divert water from road prior to the crossing with a water diversion device or break in grade.
- Portable bridges will be used when practical and culverts used when necessary.
- Streams to be forded shall have banks and stream bottom armored with oversized, clean rock.
- All stream crossings shall be restored

Explain alternative: _____
_____

Yes No **k**. Does the harvest ensure that all clear-cuts are less than 40 acres and meet green-up requirements? **Explain alternative:** _____

_____

Yes No **l.** Logging slash shall be removed from the channel of streams. **Explain alternative:** _____
_____
_____

Yes No **m.** Harvest (sale) closeout procedures shall be completed.
Water bars will be built on skid trails and haul roads that will not have vehicular traffic.
The following areas will be seeded and mulched according to seeding guidelines found in the *Missouri Watershed Protection Practice*: landings, roads within filter strips, stream crossings, haul roads and skid trails.
Indicate the seed mixture that will be used: _____
Explain alternative: _____
_____

Yes No **n**. All trash, such as used oil filters, hydraulic buckets, oil jugs, equipment, parts, and other items will be removed from the harvest site. **Explain alternative:**
_____
_____

Yes No **o.** If woody biomass is being harvested, list BMPs being used from *BMPs for Woody Biomass Harvesting*. List all that apply and explain what actions will be taken: _____
_____
_____

Yes No **p.** All spring poles shall be cut and slash height not to exceed 5 feet with 100 feet of roads with high public use.
Explain alternative: _____
_____
_____

Yes No **q.** Are residual damage BMPs being followed? **Explain alternative:** _____
_____
_____

Yes No **r.** In regeneration area, are leave trees being retained to meet management objectives? **Explain alternative:** _____
_____

Yes No **s.** Will the required amount of snags and dens be left in the harvest area? **Explain alternative:** _____
_____

9. What logging system will be used? List the type of equipment:_____
_____

ADDITIONAL NOTES/COMMENTS

_____

_____

_____

_____

MISSOURI FOREST POST-HARVEST CHECKLIST

1. Landowner's Name: _____ Phone Number: _____
   Address/City/State/Zip: _____

2. Logger's Name: _____Phone Number:_____
   Address/City/State/Zip: _____

   Certified Master Logger? Yes No
   PTH Certificate #_____

3. Today's Date: _____ Date contract finished _____
4. Forest Property Location: County _____ Section_____ Township _____ Range _____
5. List how the property lines are identified:_____
   _____
   _____

6. Acreage harvested:_____
   Harvest type: ____ Thinning
   ____ Timber Stand Improvement (TSI)
   ____ Clear-cut
   ____ Shelterwood cut
   ____ Selection cut (single tree or group)
   ____ Salvage
   ____ Other: (Please specify):
   _____
   _____

   a. Does harvesting meet recommendations in forest management plan? †Yes †No

   b. Were wildlife habitat needs (snags, dens, coarse woody debris, etc.) considered in this harvest? †Yes †No What is the corrective action for future harvests?
      _____
      _____

   c. Are cultural resources located on the property and were they avoided by the harvest operation Yes †No What is the corrective action for future harvests?
      _____
      _____
      _____

   d. Were there natural features (springs, seeps, fens, caves, glades, etc.) or species of concern present? Yes No Were they properly protected during the timber harvest? Yes No
      What is the corrective action for future harvests? _____
      _____
      _____
      _____

   e. Were there any known invasive species or other forest pest threats located in the sale area? Yes †No
   f. Are they expanding or present in areas other than known locations before the harvest? Yes No

g. What is the corrective action for future harvests?
_____

h. _____
_____
_____

i. Does the harvest area contain any stands in visually sensitive locations as identified by the forest management plan? Yes No

j. Were proper actions taken during the harvest to minimize these impacts (indicate on attached map)? Yes No

k. What is the corrective action for future harvests?
_____

l. _____
_____
_____

7. Sale Layout: Where are the access roads, landings, and main skid trails? (*Show on attached map.*)
   a. Attach a map (this can be a hand drawing on a topographical map)
   b. Were log landings and main skid trails flagged and located as defined on map? Yes No
   c. Were the roads identified on the pre-harvest plan used and maintained? Yes No
   What is the corrective action for future harvests?

_____
_____
_____

8. Best Management Practices: Circle Yes or No. If No, explain the proposed alternative or what is the corrective action for future harvests.

Yes No **a**. Were all roads, landings, and skid trails constructed outside SMZs? **Explain alternative:** _____
_____

Yes No **b**. Were SMZs identified and were they a minimum of 50 feet wide, with minimal or no exposed mineral soil, and determined based on *Missouri Watershed Protection Practice*? **Explain alternative:** _____
_____

Yes No **c**. Were haul road entrances graveled up to the public highway when necessary to reduce mud on the road? **Explain alternative:** _____
_____

Yes No **d**. Were log landings constructed as small as practical and adequately drained and constructed outside of any SMZs? **Explain alternative:** _____
_____

Yes No **e.** Was a minimum of one-third of overstory trees left in the SMZs? **Explain alternative:** _____
_____

Yes No **f.** Were out-slope roads used whenever possible, or ditches to move water off the road, and were properly sized culverts used at intervals specified in the *Missouri Watershed Protection Practice*? **Explain alternative**:_____
_____

Yes No **g**. On non-ditched roads, were broad-based dips and/or grade breaks used at intervals specified in the *Missouri Watershed Protection Practice*? **Explain alternatives:** _____
_____

Yes No **h**. Were temporary water bars or turnouts placed on skid trails to control potential erosion during any temporary shut-down periods? **Explain alternative:** _____
_____

Yes No **i.** Were permanent water bars installed at 30–45 degrees to the road/ skid trail surface and at intervals specified in the *Missouri Watershed Protection Practice*? **Explain alternative:** _____
_____

Yes No **j.** Were stream crossings for haul and skid roads avoided when possible?
Were streams crossed at right angles (90°)?
Was water diverted from road prior to the crossing with a water diversion device or break in grade?
Were portable bridges used when practical and culverts used when necessary?
Did streams to be forded have banks and stream bottom armored with oversized, clean rock?
Were all stream crossings restored?

Explain alternative: _____

_____

Yes No k. Were all clear-cuts less than 40 acres and did they meet green-up requirements? **Explain alternative:** _____

_____

Yes No l. Was Logging slash removed from the stream channels? **Explain alternative:** _____

_____

Yes No m. Were harvest (sale) closeout procedures completed?
Were water bars built on skid trails and haul that did not have vehicular traffic?
Were the following areas seeded and mulched according to seeding guidelines found in the *Missouri Watershed Protection Practice*: landings, roads within filter strips, stream crossings, haul roads and skid trails?
Indicate the seed mixture used: _____
Explain alternative: _____

Yes No n. Was all trash, such as used oil filters, hydraulic buckets, oil jugs, equipment, parts, and other items removed from the harvest site? **Explain alternative:**_____

Yes No o. If woody biomass was harvested, list the BMPs used from *BMPs for Woody Biomass Harvesting.* List all that apply and explain what actions were taken:_____

_____

_____

Yes No p. Were all spring poles cut, and did slash height not exceed 5 feet with 100 feet of roads with high public use? **Explain alternative:**_____

Yes No q. Were residual damage BMPs followed? **Explain alternative:** _____

_____

Yes No r. In regeneration area, were leave trees retained to meet management objectives? **Explain alternative:**_____

_____

Yes No s. Were the required amount of snags and dens left in the harvest area? **Explain alternative:** _____

_____

9. What logging system was used? List the type of equipment:_____

_____

_____

ADDITIONAL NOTES/COMMENTS _____

_____

_____

_____

_____

_____

_____

_____

PRE-TREATMENT CHECKLIST: TREE PLANTING

- **Landowner's Name: _____ Phone Number: _____**
  Address/City/State/Zip: _____
- **Contractors's Name: _____ Phone Number: _____**
  Address/City/State/Zip: _____
- **Pesticide Applicator License#_____**
-
- **Today's Date: _____ Contract Length: _____ Expiration Date: _____**
- **Forest Property Location: County _____ Section_____ Township _____ Range _____**
- **List how the property lines are identified:**
  _____
  _____
  _____
- **Acreage to be treated:_____**
- **Spacing _____ Trees per acres_____**
- **Planting type: ____ Hand plant**
- **____ Tree planter**
- _____
- **Does practice meet recommendations in forest management plan?† Yes † No**
- **Will wildlife habitat needs (snags, dens, coarse woody debris, mast, super canopy trees)considered in this treatment?† Yes † No What actions will be taken during the treatment to address wildlife habitat needs?**
  _____
  _____**Are cultural resource located on the property and are they being avoided by the planting operation Yes † No What actions will be taken during the treatment to address cultural resources needs?**
  _____
  _____**Are there natural features (springs, seeps, fens, caves, glades, etc.) or species of concern present? List and describe management needs.**
  _____
  _____
- **Are there any know invasive species or other forest pest threats located in the treatment area Yes † No What actions will be taken to avoid spreading these pests**
  _____
  _____
- **Does the treatment area contain any stands in visually sensitive locations as identified by the forest management plan Yes No What actions will be taken during the treatment to minimize these impacts (indicate on attached map)**
  _____
  _____
- **Planting Area Layout:**
- **Attach a map (this can be a hand drawing on a topographical map):**

ADDITIONAL NOTES/COMMENTS _____
_____
_____

POST-TREATMENT CHECKLIST: TREE PLANTING

- **Landowner's Name: _____ Phone Number: _____**
  Address/City/State/Zip: _____
- **Contractors's Name: _____ Phone Number: _____**
  Address/City/State/Zip: _____
- **Pesticide Applicator License#_____**
- **Today's Date: _____ Contract Length: _____ Expiration Date: _____**
- **Forest Property Location: County _____ Section_____ Township _____ Range _____**
- **List how the property lines are identified:**
  _____
  _____
  _____
- **Acreage treated:_____**
- **Spacing _____ Trees per acres_____**
- **Planting type: ____ Hand plant**
- **____ tree planter**
- _____
- **Did practice meet recommendations in forest management plan?† Yes † No**
- **Were wildlife habitat needs (snags, dens, coarse woody debris, mast, super canopy trees)considered in this treatment?† Yes † No What actions will be taken during the treatment to address wildlife habitat needs?**
  _____
  _____
- **Are cultural resource located on the property and were they avoided by the planting operation Yes † No What actions were taken during the treatment to address cultural resources needs?**
  _____
  _____
- **Are there natural features (springs, seeps, fens, caves, glades, etc.) or species of concern present? List and describe management needs.**
  _____
  _____
- **Are there any know invasive species or other forest pest threats located in the treatment area Yes † No What actions were taken to avoid spreading these pests**
  _____
  _____
- **Does the treatment area contain any stands in visually sensitive locations as identified by the forest management plan Yes No What actions were taken during the treatment to minimize these impacts (indicate on attached map)**
  _____
  _____
- **Planting Area Layout:**
- **Attach a map (this can be a hand drawing on a topographical map):**
- **ADDITIONAL NOTES/COMMENTS** _____
  _____
  _____

PRE–TENDING TREATMENT CHECKLIST

- **Landowner's Name: _____ Phone Number: _____**

  Address/City/State/Zip: _____

- **Contractor's Name: _____ Phone Number: _____**

  Address/City/State/Zip: _____

- **Pesticide Applicator License_____**
- **Today's Date: _____ Contract Length: _____ Expiration Date: _____**
- **Forest Property Location: County _____ Section_____ Township _____ Range _____**
- **List how the property lines are identified:**

  _____

  _____

  _____
- **Acreage to be treated:_____**
- **Tending type: ____ Commercial thinning**

  ____ Timber Stand Improvement (TSI)

  ____ woodland thinning
- **____ Salvage**
- **____ Other: (Please specify):**

  _____
- **Does treatment meet recommendations in forest management plan?†Yes † No**
- **Were wildlife habitat needs (snags, dens, coarse woody debris, mast, super canopy trees)considered in this treatment?†Yes † No What actions will be taken during the treatment to address wildlife habitat needs?**

  _____
- **Are cultural resource located on the property and are they being avoided by the treatment operation Yes † No What actions will be taken mitigate impacts to cultural resources?**

  _____
- **Are there natural features (springs, seeps, fens, caves, glades, etc.) or species of concern present? List and describe management needs.**

  _____
- **Are there any know invasive species or other forest pest threats located in the sale area Yes † No What actions will be taken during the treatment to avoid spreading these pests**

  _____
- **Does the treatment area contain any stands in visually sensitive locations as identified by the forest management plan Yes No What actions will be taken during the treatment to mitigate these impacts (indicate on attached map)**

  _____
- **Treatment Area Layout: (where are the access roads, landings, and main skid trails(if applicable)- *show on attached map*)**
- **Attach a map (this can be a hand drawing on a topographical map):**
- **Are the log landings and main skid trails flagged? Yes No NA**
- **Are existing roads (ER), new roads (NR), or reworked roads (RR), Used or Not Applicable (NA)?**
- ***(check all that apply)*: † ER †NR †RR NA**

1. **Best Management Practices**

Circle Yes or No; If No, explain the proposed alternative to be used or why the BMP is not applicable.

Yes No a. Construct all roads, landings, skid trails, outside SMZ's. **Explain alternative**

_____

Yes No b. SMZ's have been identified and will be a minimum of 50' wide, will have minimal or no exposed mineral soil and have been determined based on *Missouri Watershed Protection Practice* **Explain alternative**

_____

Yes No c. Haul road entrances will be graveled up to the public highway when necessary to reduce mud on the road. **Explain alternative:**

_____

Yes No d. Log landings will be constructed as small as practical, be adequately drained and constructed outside of any SMZ's. **Explain alternative:**

_____

Yes No e. A minimum of 1/3 of the overstory trees will be left in the SMZ's. **Explain alternative:**

_____

Yes No f. Out-slope roads whenever possible or ditch water off the road and use properly sized culverts at intervals specified in the *Missouri Watershed Protection Practice*. **Explain alternative**:

_____

Yes No g. On non-ditched roads, use broad-based dips and/or grade breaks at intervals specified in the *Missouri Watershed Protection Practice.* **Explain alternatives**

_____

Yes No h. Temporary water bars or turn-outs will be placed on skid trails to control potential erosion during any temporary shut down periods. **Explain alternative:**

_____

Yes No i. Permanent water bars will be installed at 30- 45 degrees to the road/ skid trail surface and at intervals specified in the *Missouri Watershed Protection Practice.* **Explain alternative:**

_____

Yes No j. Stream crossings for Haul and Skid roads shall be avoided when possible.

- Streams should be crossed at right angles (90°). Divert water from road prior to the crossing with a water diversion device or break in grade.
- Portable bridges will be used when practical and culverts used when necessary.
- Streams to be forded shall have banks and stream bottom armored with oversized, clean rock.
- All stream crossings shall be restored

Explain alternative:

_____

Yes No k. Logging slash shall be removed from the channel of streams **Explain alternative:**_____ _____

Yes No m.. Harvest (sale) closeout procedures shall be completed.
Water bars will be built on skid trails and haul roads that will not have vehicular traffic.
The following areas will be seeded and mulched according to seeding guidelines found in the *Missouri Watershed Protection Practice*: landings, roads within filter strips, stream crossings, haul roads and skid trails.
Indicate the seed mixture that will be used:

_____

Explain alternative:

_____

Yes No n. All trash, such as used oil filters, hydraulic buckets, oil jugs, equipment, parts and other items will be removed from the treatment site. **Explain alternative:**

_____

Yes No o. If woody biomass is being harvested list BMP's being used from *BMPs for Woody Biomass Harvesting*. List all that apply and explain what actions will be taken

_____

Yes No p. All spring poles shall be cut and slash height not to exceed 5' with 100' of roads with high public use. **Explain alternative:**

_____

Yes No q. Are residual damage bmps being followed Explain alternative:___

_____

Yes No r. Were the required amount of snags and dens left in the harvest area. Explain alternative

_____

- **What management practice chemical/ mechanical or other will be used? List the type of equipment:**

_____

_____

ADDITIONAL NOTES/COMMENTS _____

_____

_____

_____

POST–TENDING TREATMENT CHECKLIST

- **Landowner's Name: _____ Phone Number:** _____

  Address/City/State/Zip: _____

- **Contractor's Name: _____ Phone Number:** _____

  Address/City/State/Zip: _____

Pesticide Applicator License_____

1. Today's Date: _____ When contact was complete
2. Forest Property Location: County _____ Section_____ Township _____ Range _____
3. List how the property lines are identified: _____
   _____
4. Acreage to be treated:_____

   Tending type: ____ Commercial thinning
   ____ Timber Stand Improvement (TSI)
   ____ woodland thinning
   ____ Salvage
   ____ Other: (Please specify): _____

   a. Does practice meet recommendations in forest management plan? □ Yes □ No
   b. Were wildlife habitat needs (snags, dens, coarse woody debris, mast, super canopy trees)considered in this treatment? □ Yes □ No What is the corrective action for future treatments?
      _____
   c. Were cultural resource located on the property and were they avoided by the tending treatment operation Yes No What is the corrective action for future treatments? _____
      _____
      _____
   d. Were natural features (springs, seeps, fens, caves, glades, etc.) or species of concern present?Yes No Were management needs addressed. Yes No What is the corrective action for future treatments
      _____
      _____
   e. Were there any know invasive species or other forest pest threats located in the treatment area Yes □ No Were actions were taken to avoid spreading these pests Yes No What is the corrective action for future treatments
      _____
      _____
   f. Does the treatment area contain any stands in visually sensitive locations as identified by the forest management plan Yes No Were actions taken during the treatment to minimize these impacts (indicate on attached map) Yes No What is the corrective action for future treatments
      _____
      _____
5. Treatment Area Layout: (where are the access roads, landings, and main skid trails(if applicable)- *show on attached map*)
   a. Attach a map (this can be a hand drawing on a topographical map):
   b. Were the log landings and main skid trails flagged? Yes No NA
   c. Were existing roads (ER), new roads (NR), or reworked roads (RR) used or Not Applicable (NA)? *(check all that apply)*: □ ER □ NR □ RR NA
6. **Best Management Practices** **Circle Yes or No; If No, explain the proposed alternative or w**hat is the corrective action is needed for future treatments**.**

Yes No a. Construct all roads, landings, skid trails, outside SMZ's. **Explain alternative:**_____
_____

Yes No b. SMZ's have been identified and will be a minimum of 50' wide, will have minimal or no exposed mineral soil and have been determined based on *Missouri Watershed Protection Practice* **Explain alternative:**_____
_____

Yes No c. Haul road entrances will be graveled up to the public highway when necessary to reduce mud on the road.
Explain alternative: _____

_____

Yes No d. Log landings will be constructed as small as practical, be adequately drained and constructed outside of any SMZ's.
Explain alternative: _____
_____

Yes No e. A minimum of 1/3 of the overstory trees will be left in the SMZ's. **Explain alternative:**_____
_____

Yes No f. Out-slope roads whenever possible or ditch water off the road and use properly sized culverts at intervals specified in the *Missouri Watershed Protection Practice***. Explain alternative**:_____
_____

Yes No g. On non-ditched roads, use broad-based dips and/or grade breaks at intervals specified in the *Missouri Watershed Protection Practice.* **Explain alternatives:**_____
_____

Yes No h. Temporary water bars or turn-outs will be placed on skid trails to control potential erosion during any temporary shut down periods. **Explain alternative:** _____
_____

Yes No i. Permanent water bars will be installed at 30- 45 degrees to the road/ skid trail surface and at intervals specified in the *Missouri Watershed Protection Practice.* **Explain alternative:**_____
_____

Yes No j. Stream crossings for Haul and Skid roads shall be avoided when possible.

- Streams should be crossed at right angles (90°). Divert water from road prior to the crossing with a water diversion device or break in grade.
- Portable bridges will be used when practical and culverts used when necessary.
- Streams to be forded shall have banks and stream bottom armored with oversized, clean rock.
- All stream crossings shall be restored

Explain alternative: _____

Yes No l. Logging slash shall be removed from the channel of streams **Explain alternative:**_____
_____

Yes Nom.. treatment area closeout procedures shall be completed.
Water bars will be built on skid trails and haul roads that will not have vehicular traffic.
The following areas will be seeded and mulched according to seeding guidelines found in the *Missouri Watershed Protection Practice*: landings, roads within filter strips, stream crossings, haul roads and skid trails.
Indicate the seed mixture that will be used: _____
Explain alternative: _____
_____

Yes No n. All trash, such as used oil filters, hydraulic buckets, oil jugs, equipment, parts and other items will be removed from the treatment site. **Explain alternative:**
_____
_____

Yes No o. If woody biomass is being harvested list BMP's being used from <u>*BMPs for Woody Biomass Harvesting*</u>. List all that apply and explain what actions will be taken:_____
_____
_____

Yes No p. All spring poles shall be cut and slash height not to exceed 5' with 100' of roads with high public use. **Explain alternative:___**
_____
_____

Yes No q. Are residual damage bmps being followed Explain alternative:___
_____
_____

Yes Nor. In regeneration area are leave trees being retained to meet management objectives Explain alternative:_

Yes No s. Were the required amount of snags and dens left in the harvest area. Explain alternative

7. What management practice chemical/ mechanical other were used? List the type of equipment:
_____
_____

ADDITIONAL NOTES/COMMENTS _____
_____

CHEMICAL APPLICATION RECORD

Applicator:		Date:	
Tract Name:		County:	
Pesticide:		Acres:	

Purpose:	

Method of Application:	

Chemical Rate:		Water Rate:	
Additive Rate:		Sprayer Pressure:	

Speed:		Boom Spray Width:	
Nozzle Size:		Number of Tips:	

Chemical Name:		Brand Name:	
Chemical Name:		Brand Name:	
Chemical Name:		Brand Name:	
Chemical Name:		Brand Name:	

	Time:	Temp:	Wind Speed:	Wind Dir.:	Ac. Treated
Starting:					
Stopping:					
Starting:					
Stopping:					

Comments:

Mixing Instructions:
Spraying Instructions:

Date Competed: _____

Missouri Department of Conservation Prescribed Burn Plan

PROJECT DESCRIPTION	
Area/Field, Stand or Unit No	
Prepared by:	**Date:**
RX Burn Boss approval:	**Date:**
Location description (attach map):	
Acreage:	
Site description:	
Sensitive areas:	
Risk Assessment Value (attach Risk Assessment Worksheet):	

PRESCRIPTION			
Burn objectives:			
Preferred timing:			
Desired fire behavior:			
Conditions needed:		Range	Ideal
	Temperature		
	Relative humidity		
	1 hr. fuel moisture		
	10 hr. fuel moisture		
	Midflame windspeed		
	Wind direction		

BEHAVE run results:			
Burn area fuel model(s			Adjacent area fuel model(s):
	Head	Back	Head
Rate of spread (ch/hr or ft/min)			
Heat/unit area (BTU/ft^2)			

Fireline intensity (BTU/ft/sec)			
Flame length (ft)			
Smoke management: Desired atmospheric conditions: Mixing height): Ventilation rate Air quality restrictions that apply:			
Firelines:.			
Adjacent fuels:			

8005
8006

PROJECT RESOURCES		
Prescribed Fire Burn Boss:		
Crew size:		
Ignition/holding crew(s):.		
Suppression crew(s):		
Other crew members:		
Hand equipment:	Number	Assignment
Drip torches		
Backpack pumps		
Swatters		
Broom rakes		
Chain saws		
Backpack blowers		
Belt weather kit or Kestral		
Other:		
Mechanized equipment:	Number	Assignment
ATVs		
Tractor		
Pickup with water unit		
Dozer		
ATV water unit		
Pulled water unit		

Other:		
Other equipment:	Number	Assignment
Matches		
Portable radios		
Blower fuel		
Drip torch fuel		
Bolt cutters		
Pliers		
Drinking water		
Food		
Compass		
Aerial photos, maps, topos		
First aid kits		
Cell phone		
Other:		
Other:		

LOGISTICS
Weather monitoring:
Public notifications:
Ignition plan (attach map):
Contingency plans: **Fire out of prescription**. **Moderate escapes**. **Major escape:**

BURN PLAN REVIEW AND APPROVAL
Low risk assessment (value 8-13) – Forestry, Wildlife or Private Land Services Regional Supervisor* Signature: Date:
Moderate risk assessment (value 14-22) – Forestry and Wildlife or Private Land Services Regional Supervisor

Signature:	Date:
Signature:	Date:
High risk assessment (value 23+) – Fire Management Coordination Team	
Signature:	Date:
Fisheries Regional Supervisor approval if riparian zones involved	
Signature:	Date:
Natural History Biologist approval if Natural Area involved	
Signature:	Date:
RE-APPROVAL**	
I certify that this burn plan is still valid and the risk criteria (new construction, fuels, etc.) have not changed.	
RXBB Signature:	Date:
I certify that this burn plan is still valid and the risk criteria (new construction, fuels, etc.) have not changed.	
RXBB Signature:	Date:
I certify that this burn plan is still valid and the risk criteria (new construction, fuels, etc.) have not changed.	
RXBB Signature:	Date:
I certify that this burn plan is still valid and the risk criteria (new construction, fuels, etc.) have not changed.	
RXBB Signature:	Date:

***** Regional Supervisors must be Incident Commander (IC) or Prescribed Fire Burn Boss (RXBB) qualified to sign. If a Regional Supervisor lacks this experience, they will select a member of their staff who is qualified as an IC or RXBB to sign on their behalf.

** A burn plan may be used for repeat burns of an area without rewrite if the Prescribed Fire Burn Boss certifies that the plan is still valid and none of the risk assessment criteria (such as new construction or developments, fuel type, smoke impacts, etc.) have changed.

DAY OF BURN CHECKLIST

Area/Field, Stand or Unit No.:

Date:

Burn Day Checklist (Go/No Go):

Refer to contents of Burn Plan

_____ Notifications made

_____ All equipment present and in working order

_____ Personnel on site with proper personal protective equipment

_____ Personnel briefed on procedures and contingencies

_____ Personnel briefed on communications and safety zones

_____ Backup resources available

_____ Weather within prescription Time: _____

Wind speed: _____ Direction:_____

Temperature: _____ RH: _____

_____ First aid kits fully stocked

Emergency medical services: _____

Name Phone

I certify that all items on the checklist are “go” for the burn:

_____

Prescribed Fire Burn Boss

POST-BURN EVALUATION

Weather

Pre-burn
Time: _____
Temperature: _____
Relative humidity:_____
Windspeed: _____
Direction: _____

Post-burn
Time: _____
Temperature: _____
Relative humidity:_____
Windspeed: _____
Direction: _____

Fire behavior

Rate-of-spread: _____
Flame lengths: _____

Circumstances of any erratic fire behavior:

Smoke dispersal during burn:

Percent of area burned:

Amount of fuel consumed:

Any public interest during burn – pro or con:

Appendix D: Timber Sale Contract.

TIMBER SALE CONTRACT

_____of _____, Missouri, herein after called the Buyer, agrees to purchase from _____ of _____, Missouri, herein after called the Seller, the designated timber specified below:

WITNESSETH:

ARTICLE I. The Seller hereby agrees to sell to the Buyer, subject to the terms listed below, all of the timber specified below, on a certain tract owned by the Seller, located in _____, Section _____, Township _____, Range _____, County of _____, State of Missouri, located on ___ acres, more or less.

ARTICLE II. The Buyer agrees:

1. To cut only those trees marked with a fresh orange paint spot. Trees marked with an "X" may be cut if desired.

2. Trees other than those specified above may be cut only for access on areas used for roads and landings.

3. To pay the Seller a lump price of $_____when the contract is signed to pay for the trees designated for cutting.

4. To pay three times the stumpage value per tree, a penalty rate, for each tree that is cut which is not designated for cutting.

5. To keep fields, fences, roads and streams free from treetops and other logging debris at all times.

6. To hold and save the Seller, his officers, agents or employees, harmless from any or all liability on account of any claim whatsoever, for wages, supplies, equipment, damage and injury to persons or property arising in connection with any activity conducted or undertaken by the Buyer, his agents or employees under the terms of this contract.
7. That this contract cannot be transferred to another party without the written permission of the Seller.

ARTICLE III. The following conditions known as Best Management Practices and referenced in the Missouri Conservation Department publication "Missouri Watershed Protection Practices" apply to the sale of said forest products and will be adhered to by the Buyer:

1. All roads constructed and used during the cutting and transportation of forest products shall follow the contour with slope grades of 8 percent or less maintained, except where terrain or the use of existing roads requires short, steep grades necessitating the construction of water diversion measures (water bars, broad-based dips, turnouts, culverts) installed at the proper intervals.

2. New roads will be constructed to allow for proper drainage.

3. Except at stream crossings, roads will not be constructed within ____ feet (the corresponding Streamside Management Zone (SMZ)) of any stream, pond or lake on the property.

4. All exposed soil at stream crossings will be stabilized with gravel, grass and mulch, or silt fences to prevent erosion and sedimentation.

5. Under no circumstances will temporary stream crossings made of logs and brush piled in the stream and covered with soil be permitted.

6. Wheeled and tracked equipment are not allowed within ____ feet (the SMZ) of any stream, pond or lake on the property. Trees marked for cutting within the SMZ should be chain saw felled and cable winched out.

7. Log decks, portable sawmills or chippers are not allowed within ____ feet (the SMZ) of any stream, pond or lake on the property.

8. All roads on and adjacent to the sale area used by the Buyer shall be reshaped, seeded and mulched, and have water diversion structures installed upon completion of the sale as prescribed in "Missouri Watershed Protection Practices."

9. All human garbage, tires, cables, used lubricants, fuels, fluids and containers used by the Buyer shall be removed from the sale area and disposed of properly by the Buyer.

10. The Seller or Forester in charge may temporary terminate hauling and/or skidding during periods of wet soil conditions should these operations be causing or likely to cause damage beyond normal wear and tear to the roads and trails. The number of working days that the Buyer's operations are terminated for this reason shall be added to the term of this contract upon request of the Buyer.

ARTICLE IV. The Buyer further agrees to cut and remove said timber in strict accordance with the following conditions:

1. To waive all claims to the above described trees unless they are cut and removed on or before _____, 20___.

2. To cut all spring poles and pull all lodged trees to the ground.

3. To do all in his power to prevent and suppress forest fires on or threatening the sale area.

4. To protect from unnecessary injury young growth and other trees not designated for cutting.

5. To repair damage caused by logging to fences, bridges, roads, trails or other improvements damaged beyond ordinary wear and tear.

6. To allow the owner to cut and remove any portion of a tree left on the ground by the Buyer after he has removed his products.

ARTICLE V. The Seller agrees to the following conditions:

1. To guarantee title to the forest products covered by this agreement and to defend it against all claims at his expense.

2. To grant or secure necessary entry and right-of-way to the Buyer and his employees on and across

the area covered by this agreement, and also other privileges usually extended to Buyers.

ARTICLE VI. It is mutually understood and agreed by and between the parties hereto as follows:

1. All timber included in this agreement shall remain the property of the Seller, and shall not be removed until paid for in full.

Signed in duplicate this _____ day of _____, 20___.

_____ _____
(Witness) (Buyer)

_____ _____
(Witness) (Seller)

_____ _____
(Witness) (Seller)

ACKNOWLEDGMENT

STATE OF _____

COUNTY OF_____

On this _____ day of _____, 20_____ before me personally appeared _____ to be known to be the person(s) described in and who executed the foregoing instrument and acknowledged that _____ executed same as _____ free act and deed.

In Testimony Whereof, I have hereunto set my hand and affixed my official seal, at my office in _____, the day and year first above written.

My commission expires _____

_____
NOTARY PUBLIC

Resource Directory

In Missouri several organizations, associations, and individuals can provide publications, technical advice, educational programs, and financial assistance to help you manage your woodlands. Start with your local Conservation Department or University Outreach and Extension office. The staff will assist you or help you find the appropriate agency or individual for your land management decisions. Below are other available resources.

The Center for Agroforestry at the University of Missouri

203 Anheuser-Busch Natural Resources Building
Columbia, MO 65211
573-884-2874
573-882-1977
Email: musnragroforestry@missouri.edu

The Center for Agroforestry at the University of Missouri, established in 1998, is one the world's leading centers contributing to the science underlying agroforestry, the science and practice of intensive land-use management combining trees and/or shrubs with crops and/or livestock.

Agroforestry practices help landowners to diversify products, markets, and farm income; improve soil and water quality; sequester carbon and reduce erosion, nonpoint source pollution, and damage due to flooding; and mitigate climate change.

Conservation Federation of Missouri

728 W Main
Jefferson City, MO 65101-1559
573-634-2322
confedmo.org

In 1935, sportsmen from throughout Missouri came together to form the Conservation Federation of Missouri (CFM). They organized with the purpose of taking conservation out of the realm of politics. Their initiative petition campaign resulted in the creation of the Missouri Department of Conservation, a nonpolitical conservation agency that has been a model for other states. Since then, the Federation has undertaken many successful battles to ensure that Missouri continues to be the leading state in conservation policies and funding. In 1976, CFM spearheaded successful passage of the conservation sales tax to create stable broad-based funding for Missouri's forests, fauna, and fish. Today CFM is the largest and most representative conservation group in Missouri. It is a citizens' organization with 80 clubs and more than 85,000 members. CFM is the Missouri affiliate of the National Wildlife Federation.

Forest and Woodland Association of Missouri

520 West 103rd Street, #347

Kansas City, MO 64114
818-645-5399
forestandwoodland.org

The Forest and Woodland Association of Missouri (FWAM) is a citizen advocacy group for forestry issues. They work in conjunction with other forestry organizations like The Missouri Tree Farm Program and University of Missouri Forestry Extension to provide field days on woodland management for wildlife and timber production. They are also the only forest landowner advocate for forestry related legislation.

Missouri Consulting Foresters Association

missouriforesters.com

Private foresters furnish a variety of forest management activities on a fee basis. Services include all types of appraisal work: timber land, timber sales, ornamental shade tree damage or value, timber theft, damage to trees due to chemicals, construction, storms, etc. Consultants also perform all phases of timber sale: mark trees to be harvested, summary tally the marked trees by species and board-foot volume, determine estimated value, solicit bids, assist in the sale, provide timber sale contracts, and supervise harvesting operations. They also handle a broad spectrum of work, including forest, wildlife, recreation, and water management; insect and disease identification and control recommendations; tax information, tree planting, timber stand improvement, pruning, thinning, and boundary marking. Often consultants can provide these services at a more intensive level, provide a quicker response, offer unlimited repeat services, and spend more time with a client than public foresters can. A directory of consulting foresters in Missouri can be obtained from the state forester, the extension forester, or the Missouri Consulting Foresters Association.

Missouri Department of Agriculture

PO Box 630
Jefferson City, MO 65102
573-751-2462
mda.mo.gov

The Missouri Department of Agriculture licenses and regulates applicators of pesticides. With the assistance of other state and federal agencies, it also conducts surveys to locate and control the spread of serious insect pests and plant diseases. The DOA establishes preservative retention standards for treated timber products. It also helps pecan and other nut growers, fish farmers, and produce growers market their products.

Missouri Department of Conservation

PO Box 180
Jefferson City, MO 65102
573-522-4115
mdc.mo.gov

The Missouri Department of Conservation, through its Forestry Division, offers free technical advice and services to landowners. Professional foresters can give on-the-ground advice and assistance on tree planting, woodland management, fuel wood cutting, timber stand improvement, harvesting and marketing, wildfire protection, insect and disease detection, and woodland wildlife management. Foresters will prepare management plans and give advice on available financial assistance programs. If you are a landowner, you can receive cost-share payments for specific forestry practices, such as timber stand improvement and tree planting. (Also see Farm Service Agency and Natural Resources Conservation Service.)

The Forestry Division operates the George O. White State Forest Nursery at Licking, Mo. You can purchase tree and shrub seedlings at minimal cost for conservation plantings on private lands. Obtain order forms at your local Conservation Department, University Outreach and Extension, Soil and Water Conservation District office, or on the web at mdc.mo.gov. You can order from November through mid-February on a first-come-first-served basis.

Missouri Department of Natural Resources

PO Box 176
Jefferson City, MO 65102
800-334-6946
dnr.mo.gov

The Department of Natural Resources (DNR) regulates standards for air, water, minerals, and energy. It also administers the extensive system of state parks and historic sites in Missouri. Staff members in the Division of Geology and Land Survey restore original public land survey corners to ensure accurate location of property boundaries. DNR's soil and water conservation program promotes good farming practices to prevent erosion and runoff. The staff help counties form soil and water conservation districts to encourage watershed protection and proper land management.

The Missouri Soil and Water Districts' Commission develops statewide resource conservation programs. These programs are administered locally by county Soil and Water Conservation Districts (SWCDs) in affiliation with the USDA Natural Resources Conservation Service (see USDA section on the following pages). Currently, a state-funded soil and water conservation cost-share program offers financial incentives to agricultural landowners if they install erosion control projects and practices. A soil and water conservation loan interest-share program offers rebates to landowners for authorized conservation projects. Eligible projects for either program include establishment or protection of woodlands. For more information, contact your local SWCD office.

Missouri Forest Products Association

505 East State Street
Jefferson City, MO 65101
573-634-3252
moforest.org

Missouri Forest Products Association is dedicated to serving and promoting the forest products industry of Missouri. Founded in 1970, MFPA has more than 300 members representing the primary and secondary wood industry, supplier and service industries, loggers, and landowners. MFPA advocates sustainable management and sound stewardship of Missouri's forests in order to benefit current and future generations.

Missouri Nut Growers Association

missourinutgrowers.org

The Missouri Nut Growers Association is a nonprofit organization of growers of pecan, walnut, hickory, and other nut species. The common interest of all these individuals is growing and promoting Missouri-grown nuts. Members can exchange ideas, tour nut groves and plantations, obtain information about planting and growing nut trees, and keep informed about current research. Meetings are held four times a year, usually at a grower's farm.

Missouri Forest Resources Advisory Council (MoFRAC)

mofrac.org

The Missouri Forest Resources Advisory Council facilitates communication among all who are interested in Missouri's forests in order to assure long-term forest health, productivity, and sustainability. With a membership of more than 30 organizations, the Council serves as a sounding board or in an advisory capacity for agencies and organizations regarding planning, operations, programs, policies, or legislation affecting forestry. Ensuring that timber harvest serves forest management has been a primary concern of the Council since its inception.

Missouri State Tree Farm Committee

c/o Missouri Forest and Woodland Association
520 West 103rd Street, #347
Kansas City, MO 64114
818-645-5399

The Tree Farm Program is a national program sponsored by wood-using industries and coordinated by the American Forest Foundation to promote sound forest management on privately owned woodlands. To qualify as a tree farm, your woodlands must be privately owned, 10 acres or more in size, managed for production of timber and forest products, and protected from fire, insects, disease, and grazing. You can have a forester inspect your woodlands to help you develop a management plan and to determine whether your woods qualify for the Tree Farm system. Owners of certified woodlands receive woodland management information and a green-and white Tree Farm sign to post on their land. Every year, Missouri tree farmers are recognized for wise forest management through the Outstanding State Tree Farm awards sponsored by the State Tree Farm Committee. Contact the committee or your local forester for more information.

Walnut Council, International

Wright Forestry Center
1007 N 725 W
West Lafayette, IN 47906-9431
765-583-3501
Fax: 765-583-3512
walnutcouncil.org

The Walnut Council includes walnut growers, researchers, foresters, and walnut buyers and manufacturers. Their common interest is growing and using black walnut trees. Landowners exchange ideas and discuss problems at the annual meeting. They also can obtain information about planting, growing, and tending black walnut trees for nut, lumber, and veneer crops at the meeting or from the office. As a member of the Walnut Council International, you may join the Missouri chapter for closer-to-home information.

University of Missouri–Columbia School of Natural Resources

203 Anheuser-Busch Natural Resources Building
Columbia, MO 65211
573-882-7242
snr.missouri.edu

As a land-grant institution, the University of Missouri has three functions: teaching, research, and extension. The School of Natural Resources (a part of the College of Agriculture, Food and Natural Resources) offers undergraduate and graduate programs in forest resource management, forest recreation, urban forestry, and industrial forestry. The school also has degree programs in fisheries and wildlife; soils and atmospheric science; and parks, recreation, and tourism. Faculty research focuses on the natural resources of Missouri. The school also administers centers for agroforestry, tourism, and water quality.

USDA Cooperative Extension Service, University Outreach and Extension

103 ABNR
Columbia, MO 65211
573-882-6446
extension.missouri.edu

The Cooperative Extension Service provides technology transfer in cooperation with local and state extension services through land-grant universities such as the University of Missouri–Columbia and Lincoln University. University Outreach and Extension offices are located in each county of Missouri.

USDA Farm Service Agency

601 Business Loop 70 West, Suite 225
Columbia, MO 65203

573-876-0932
fsa.usda.gov/FSA/stateoffapp?mystate=mo&area=home&subject=landing&topic=landing

The Farm Service Agency (FSA) administers the Conservation Reserve Program (CRP). This program is available in all counties in Missouri. The CRP offers cost-share incentives that provide landowners the opportunity to carry out conservation and environmental practices that result in long-term public benefits. Trees as well as wildlife-cover practices are eligible for cost-share assistance. In addition to cost-share assistance, CRP provides10–15 year annual rental payments to those producers who participate in the program. The FSA also assists the USDA Forest Service in administering the Stewardship Incentives Program (SIP). Under this program, cost-share assistance is available for a wide range of forestry-related practices. You can discuss eligibility requirements and fill out applications for CRP or SIP at the county FSA office where your farm is located.

USDA Forest Service Mark Twain National Forest

401 Fairgrounds Road
Rolla, MO 65401
573-364-4621
fs.usda.gov/mtnf

The U.S. Forest Service manages the federal lands of the Mark Twain National Forest in Missouri, providing the multiple benefits of timber, recreation, watershed protection, grazing, and wildlife. The staff conduct research on oak silviculture and management. The Forest Service cooperates on programs designed to benefit private woodland owners.

USDA Forest Service Northern Research Station

202 Anheuser-Busch Natural Resources Building
Columbia, MO 65211-7260
573-875-5341
nrs.fs.fed.us

Laboratory staffs conduct forest and wildlife research on upland forests in Missouri and surrounding states. Research information is available on silviculture and ecology of hardwood forests, growth and yield, oak flowering and acorn production, forest wildlife, propagation, ground covers, old-growth forests, site productivity, and ecosystem management.

USDA Natural Resources Conservation Service

601 Business Loop 70 West, Suite 250
Columbia, MO 65203
573-876-0900
nrcs.usda.gov/wps/portal/nrcs/site/mo/home/

The Natural Resources Conservation Service (formerly the Soil Conservation Service) provides technical assistance and guidance to land users, groups, and units of government to help protect, develop, and wisely use soil, plant, air, water, and animal resources. NRCS programs

and initiatives include reducing erosion, improving water quality, preventing floods, enhancing fish and wildlife habitat, promoting good land use, and conserving soil, water, and other natural resources. NRCS administers cost-sharing programs with forestry-related uses. Producers can discuss eligibility requirements, fill out applications for these programs, or request technical assistance at any of the county field offices in Missouri. Check your telephone directory under U.S. Government for your local NRCS office

Credits and Acknowledgments

Development Process

In 2012–2013, the Missouri Department of Conservation and more than a dozen partner organizations and agencies developed the Missouri Sustainable Forest Management Guidelines.

To help shape and develop this product, five technical teams were assembled. These teams are comprised of subject matter experts from resource management agencies, forest researchers, and members of various organizations from the Missouri Forest Resources Advisory Council (MOFRAC). The teams were charged with developing best management practices related to forest management activities. One elected member from each team served on an integration team who compiled the individual team products into one comprehensive document. The teams met during several technical team meetings held over the twelve months to help structure and develop this product. The practices recommended by these technical teams were integrated into a comprehensive document that will define site-level sustainable forest management for Missouri. The final document was peer reviewed, based on the best available scientific research, and was presented for public comment to ensure that it achieved the social, environmental, and economic objectives for sustainability.

Missouri Sustainable Forest Management Guidelines Project Technical Team Members

Project Coordinator

Michael Bill MDC Resource Forester

Soil Productivity Team

Dennis Meinert, DNR Soil Scientist
John Kabrick, Forest Service Northern Research Station Researcher
Brad Mckee, MDC Private Lands Conservationist
Keith Goyne, Soil Science Researcher University of Missouri
Ross Glenn, MDC Forester
Clayton Lee, Missouri Tree Farm System

Visual Quality Team

Dave Massengale, Forester Silviculturlist MTNF
Steve Shifley, Forest Service Northern Research Station Researcher
Randy Jensen, Resource Scientist MDC
Dave Larsen, University of Missouri Researcher
Becky Fletcher, MDC Forester
Lynn Barnickol, Consulting Forester Association
Joe Alley, Society of American Foresters
Steve Jarvis, Missouri Forest Products Association

Steve Frist, Missouri Forest Products Association

Wildlife Habitat Team

Nate Goodrich, NRCS Forester
Dan Dey, Forest Service Northern Research Station Researcher
John George, MDC Regional Wildlife Biologist
Gary Oakley, MDC Forester
Randy Jensen, MDC Forest Resource Scientist
John Burk, Biologist National Wild Turkey Federation
Ed Keyser, Forest and Woodland Association

Cultural and Heritage Resources Team

Hank Stelzer, University of Missouri Extension
Bob Gillespie, MDC Natural History Biologist
Bill Goodwin, MDC Policy Coordination (retired)
Phil Sneed, MDC Forester
Shauna Marquardt, US Fish and Wildlife Service
Doug Ladd, The Nature Conservancy
Hank Dorst, Mark Twain Forest Watchers

Silviculture Guidance Team

Dan Dey, Forest Service Northern Research Station Researcher
Dave Larsen, University of Missouri Researcher
John Kabrick, Forest Service Northern Research Station Researcher
Steve Shifley, Forest Service Northern Research Station Researcher
Matt Olson, MDC Resource Scientist (Silviculturalist)
Ben Knapp, University of Missouri Researcher

Integration Team Participants

Ross Glenn, MDC Forester
Steve Jarvis, Missouri Forest Products Association
Steve Frist, Missouri Forest Products Association
John George, MDC Wildlife Biologist
Hank Dorst, Mark Twain Forest Watchers
Matt Olson, MDC Resource Scientist (Silviculturalist)
Michael Bill, MDC Forester/Project Coordinator
Marvin Brown, Consultant Contractor

Glossary of Terms

Excerpts from *The Dictionary of Forestry*, ed. John A. Helms; from *The Terrestrial Natural Communities of Missouri*, by Nelson (Missouri DNR); *Forest Stand Dynamics*, by Oliver and Larson (Mcgraw–Hill, 1990); and *Missouri Woody Biomass Harvesting Manual, 2009.*

Note: definitions from Helms are starred. Definitions from Nelson and other sources are not. Definitions including information in brackets are localized to Missouri conditions.

* **Abiotic** — pertaining to the nonliving parts of ecosystems, such as bedrock, soil particles, air, water.

* **Acceptable Growing Stock** (AGS) — merchantable trees that are not large enough to be mature but are desirable species, form, and quality and would be satisfactory as crop trees in a final stand on the site or have potential to be grown for a future intermediate cut.

* **Advance Regeneration** — seedlings or saplings that develop or are present in the understory.

* **Aesthetics** — pleasing in appearance or pleasing to the senses.

* **Alfic Soils or Alfisol** — soil order describing moderately weathered soils with a clay-rich B horizon and a base saturation of >35 percent that have typically developed under tree-dominated vegetation — moderately fertile soils.

* **Artificial Regeneration** — a group or stand of young trees created by direct seeding or by planting seedlings or cuttings; synonym for artificial reproduction.

* **B level** — fully stocked stand where all growing space is being utilized. Theoretically, there would be no gaps or room to grow between tree crowns.

* **Basal Area** — (1) the cross-sectional area of a single stem, including the bark, measured at breast height (4.5 feet above the ground); (2) the cross-sectional area of all stems of a species or all stems in a stand measured at breast height and expressed per unit of land area.

Broad-Based Dip — a drainage structure designed to drain water off a dirt road while in use for vehicles maintaining normal haul speeds; also called a rolling dip.

Buffer Strip — a barrier of permanent vegetation established or left undisturbed downslope from disturbed forest areas to filter out sediment from runoff before it reaches a watercourse. Buffer strips help stabilize stream banks, protect floodplains from flood damage, and provide important fish and wildlife habitat.

Bumper Trees — trees along skid trails that are used by the skidder driver to help guide a drag of logs up the hill toward the landing. These trees will be severely damaged. Trees used as bumper trees should be trees designated for harvest or inferior trees not intended or desired for future growth.

* **C level** — understocked stand where all of the growing space is not being utilized. There should be no gaps in the canopy. On a slower growing site, such as a post oak woodland, it should take approximately 12–15 years to reach B level stocking.

* **Cavity tree** — a live tree with a cavity large enough to shelter wildlife. For wildlife purposes, these should be at least 6 inches DBH and 10 feet tall. Long-lived species such as oaks, hickories are preferred.

Coarse Woody Debris — treetops, stumps, fallen trunks or limbs more than 6 inches in diameter at the large end.

* **Community** — an assemblage of plants and animals living together and occupying a given area. Note: (1) in a closed community, plants are so completely utilizing the site that they exclude (or give the appearance of excluding) further entrants; (2) classifying a community as closed is subjective and is based on onetime measurements or observations.

Contour — an imaginary line on the surface of the earth connecting points of the same elevation; a line drawn on a map connecting points of the same elevation.

Crop Tree — a tree having a dominant or co-dominant crown, and a stem having good form and with little to no defects that would prevent the tree from reaching biological maturity. Crop trees are selected for special treatment due to certain virtues, usually with a future product in mind. Virtues include species, form, growth rate, potential future products, match to site growing conditions, etc.

Culvert — a pipe of either metal or concrete or a constructed box-type conduit, through which water is carried under roads.

DBH — the diameter of the stem of a tree measured at breast height (4.5 feet; 1.37 meters) from the ground.

Ephemeral Stream — water flow with runoff from rain or snowmelt; the water table never reaches the streambed.

Erosion — the process by which soil particles are detached and transported by water, wind, and gravity to some downslope or downstream point.

Evenage Management System (EAM) — a forest management strategy that results in stands of trees all nearly the same age.

Felling — the act of cutting down standing trees.

Fen — a peat-accumulating wetland that has received some drainage from surrounding mineral soils and usually supports marsh-like vegetation including sedges, rushes, shrubs, and trees. Note: Fens are less acidic than bogs and derive most of their water from groundwater rich in calcium and magnesium.

Fine Woody Debris — leaves, twigs, tops, limbs, and other woody debris less than 6 inches in diameter at the large end.

Ford (Stream Crossing) — a place in a stream or river that is shallow enough to be crossed by wading, on horseback, or in a wheeled vehicle.

Forester — (1) In Missouri, “any individual who holds a Bachelor of Science degree in Forestry from a regionally accredited college or university with a minimum of two years of professional forest management experience,” as defined in Senate Bill 931, 2008. (2) In general, a professional engaged in practicing the science and art of forestry. Foresters may be credentialed by states or other certifying bodies and may be licensed, certified, or registered. An example is the Society of American Foresters Certified Forester credential. The requirements for each credentialing program differ but usually include at least a baccalaureate degree in forestry and success in passing a comprehensive examination.

Forest Road — an access route for vehicles into forest land.

* **Fragipan** — a natural subsurface horizon with very low organic matter, high bulk density, or high mechanical strength relative to overlying and underlying horizons, which typically has redoximorphic features, is slowly or very slowly permeable to water, is considered root restricting, and usually has few to many bleached, roughly vertical planes that are faces of coarse or very coarse polyhedrons or prisms. Note: a fragipan has hard or very hard consistency (seemingly cemented) when dry but shows a moderate to week brittleness when moist.

Glacial Till — a mixture of clay, silt, sand, mud, gravel, and boulders deposited by a glacier.

Harvesting — the felling, skidding, loading, and transporting of forest products such as sawlogs, stave logs, veneer, pulpwood, pine poles, posts, etc.

High Grading — the removal of the most commercially valuable (high-grade) trees, often leaving a residual stand composed of trees of poor condition or species composition. Note: High grading may have both genetic implications and long-term economic or stand health implications.

Intermittent Stream — a watercourse with water flow only during wet seasons but still with well-defined banks and natural channels. It may contain seasonal pools during dry periods. The water table is above the streambed at certain times but not always.

Invasive Exotic — any species, including its seeds, eggs, spores, or other biological material capable of propagating that species that is not native to the ecosystem; and whose introduction does or is likely to cause economic or environmental harm or harm to human health (from invasive.org). Examples of invasive exotics are kudzu, emerald ash borer, Japanese honeysuckle, euonymus, Asian longhorned beetle, tree-of-heaven, gypsy moth, Japanese beetle, garlic mustard, tall fescue, and zebra mussel.

Karst — topography with sinkholes, caves, and underground drainage that is formed by dissolution of a layer or layers of soluble bedrock, usually limestone, dolomite, or gypsum.

Landform — literally “the lay of the land” (i.e., terrain features such as hills, plains, bottomland).

Log (Woody Biomass) Landing — a place where logs or tree-length materials are assembled for loading and transport; also called log deck, log yard, or bunching area.

Logging Debris — the unused and generally unmarketable woody material such as large limbs, tops, cull logs, and stumps that remains after timber harvesting.

Lopping — cutting large branches on treetops to reduce their visibility near roads and other areas where the public may find the view offensive.

Mast — fruit, seeds, and nuts from trees that provide food for wildlife; further defined into soft mast, such as persimmon, and hard mast, such as acorns.

* **Mesic** — of sites or habitats characterized by intermediate moisture conditions (i.e., neither decidedly wet nor dry); a soil moisture class used to describe soils that are moderately well drained.

Mineral Soil — the portion of soil originating from rock that has eroded and broken down into small particles.

Mulch — any loose soil covering of organic residues such as grass, straw, or wood fibers that helps to check erosion and stabilize exposed soil.

* **Native Species** — (1) an indigenous species that is normally found as part of a particular ecosystem; (2) a species that was present in a defined area prior to European settlement.

* **Natural Disturbance** — disturbance regimes that shape a natural community's structure and composition, including windstorm, ice storms, tornadoes, drought, fire, flood, elk, bison grazing, herbivory, insect and disease outbreaks. Management practices are often undertaken to emulate or mimic to some degree natural disturbance.

Perennial Stream — a watercourse that flows throughout the year in a well-defined channel; same as a live stream.

Pesticides — chemicals that are used for the control of undesirable insects, disease, vegetation, animals, or other forms of life.

* **Prescribed Burn** — to deliberately burn wild-land fuels in either their natural or their modified state and under specified environmental conditions, which allows the fire to be confined to a predetermined area and produces the fire-line intensity and rate of spread required to attain planned resource management objectives; includes maintenance type fire.

Regeneration — (1) the young tree crop replacing older trees removed by harvest or natural disaster; (2) the process of replacing old trees with young trees.

Regeneration Cutting — any removal of trees intended to assist regeneration already present or to make regeneration possible.

Riparian Management Zone (Streamside Management Zone) — an area along the banks of streams and bodies of open water where extra precaution is necessary in carrying out forest practices in order to protect the stream bank and water quality.

Rotation (Period) — the period of time required to establish a forest stand from seed or planted seedling, grow the trees to financial or biological maturity, harvest the crop, and prepare for the next stand.

Sawtimber (Tree) — logs cut from trees with minimum diameter and length and with stem quality suitable for conversion to lumber. Hardwoods must be at least 11 inches DBH or larger to be considered sawtimber.

Seep (Seepage) — (1) any wetland areas with soils fed by groundwater saturation or a local perched water table; (2) water escaping through or emerging from the ground along an extensive line or surface, as contrasted with a spring where the water emerges from a localized spot; (3) percolation, or the slow movement of gravitational water through the soil.

* **Shade-Tolerant** — having the capacity to compete for survival under shaded conditions.

* **Silviculture** — the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis.

Sinkhole — a surface depression resulting from the solution of underlying carbonate bedrock and possibly the collapse into an underground cavern. Sinkholes shall have delineated protection zones when the sinkhole contains vegetation, natural communities, and/or geological features distinguished from the surrounding area. (Definition from *U.S. Forest Service Mark Twain Forest Plan Implementation Guide*.)

Site Preparation — a forest activity to remove unwanted vegetation and other material and to cultivate or prepare the soil for reforestation; includes bulldozing, brush hogging, and use of herbicides.

Skid — moving logs or felled trees along the surface of the ground from the stump to the log landing.

Skidder — a large tractor-like machine used to pull logs from the place where they were cut to the log landing/deck. Skidders have very large rubber tires with 4-wheel drive. They have a blade in the front used to push dirt and small trees out of the way. There are cable skidders and grapple skidders. Cable skidders require the driver to stop, get off the skidder, and set the cable around each log. Grapple skidders allow the driver to back up to each log and grab it. Good work can be done by both types of skidder if the driver is skilled; grapple skidders generally do more damage.

Skid Trail — a temporary, heavily used pathway to drag felled trees or logs to a log landing.

* **Slash** — treetops, branches, leaves, and other tree parts left after a timber harvest.

* **Slope Percent** — the grade of a hill expressed in terms of a percentage; a vertical rise of 10 feet and a horizontal distance of 100 feet equals a 10 percent slope.

* **Snag** — (1) a standing dead tree from which the leaves and most of the branches have fallen; (2) a standing section of the stem of a tree, broken off usually below the crown; (3) a sunken log or submerged stump or tree; (4) the projecting base of a broken or cut branch on a tree stem. Note: For wildlife habitat purposes, a snag is sometimes regarded as being at least 10 inches in diameter at breast height and at least 6 feet tall; a hard snag is composed primarily of sound wood, generally merchantable; a soft snag is composed primarily of wood in advanced stages of decay and deterioration.

* **Stocking Percent** — the extent to which a given stand density meets a management objective, expressed as a percentage.

* **Streamside Management Zone** (SMZ) — See Riparian Management Zone

* **Succession** — the gradual supplanting of one community of plants by another. NOTES: (1) The sequence of communities is called a sere, or seral stage. (2) A sere whose first stage is open water is termed a hydrosere; and one whose first stage is dry ground is termed a xerosere. (3) Succession is primary (by pioneer species) on sites that have not previously borne vegetation, secondary after the whole or part of the original vegetation has been supplanted, allogenic when the causes of succession are external to and independent of the community (e.g., accretion of soil by wind or water, or a change of climate), and autogenic when the developing vegetation is itself the cause.

Swallet — a place where water disappears underground in a karst region; swallet is commonly used to describe the loss of water in a streambed.

Timber Stand Improvement (TSI) — a thinning made in immature stands to improve the composition, structure, condition, health, and growth of remaining trees.

Ulitisol — The dominant "red clay" soils in the southern United States, often having a pH less than 5. The high acidity and low amounts of major nutrients, such as calcium and potassium, make these soils poorly suited for agriculture without the aid of fertilizer and lime. They can be easily exhausted and require careful management but can support productive forests.

Uneven-Age Management System (UAM) — a planned sequence of treatments designed to maintain and regenerate a stand with three or more age classes.

Visually Sensitive Area — pertains to outdoor scenes that people see, an range for a detail of the landscape such as a spring or to landscape scale such as a scenic vista overlook of a watershed. See Aesthetics.

Water bar — a hump or small dike-like drainage structure used to divert water in closing skid trails, retired roads, and fire lines.

Watershed — an area of land that drains rain and snowmelt into a stream or river. Size is relative to the use of the information. Size may range from a single creek draining only a few acres to a large river where water comes from many states, like the Mississippi River.

Water Turnout — the extension of an access road's drainage ditch into a vegetated area to provide for the dispersion and filtration of storm water runoff; also called a wing ditch.

* **Wetland** — (1) a transitional area between aquatic and terrestrial ecosystems that is inundated or saturated for periods long enough to produce hydric soils and support hydrophytic vegetation; (2) a seasonally flooded basin or flat. Note: The period of inundation is such that the land can usually be used for agricultural purposes.

* **Wildlife** — (1) all non-domesticated animals; (2) non-domesticated vertebrates, especially mammals, birds, and fish, and some of the higher invertebrates, for example, many anthropoids.

* **Woodland** — (1) a forest area; (2) a plant community in which, in contrast to a typical forest, the trees are often small, characteristically short-boled relative to their crown depth, and forming only an open canopy with the intervening area being occupied by lower vegetation, commonly grass.

* **Woodland Structure** — a woodland is characterized by wide-spreading tree crowns and an open understory of grasses, forbs, and shrubs. Canopy closure is generally 30–70 percent.

Woody Biomass — “small-diameter trees, branches, and the like (brush, treetops) — that is generated as a result of timber-related activities in forests” (U.S. Government Accountability Office).

*** Xeric** — pertaining to sites or habitats characterized by decidedly dry conditions.

References

Biebighauser, T.R. 2011. A Guide to Creating Vernal Ponds. U.S. Department of Agriculture Forest Service. 66 p. http://www.fs.fed.us/outdoors/naturewatch/resources/Creating-Vernal-Ponds.pdf

Dey, D.C.; Brissette, J.C.; Schweitzer, C.J.; Guldin, J.M. 2012. Silviculture of Forests in the Eastern United States. In: LaFayette, R.; Brooks, M.T.; Potyondy, J.P.; Audin, L.; Krieger, S.L.; Trettin, C.C., eds. Cumulative Watershed Effects of Fuels Management in the Eastern United States. GTR-SRS-161. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 7-40

Fishel, F. 2003. Pesticide laws and regulations. Columbia, MO: University of Missouri Outreach and Extension. 4 p.

Gingrich, S.F. 1967. Measuring and evaluating stocking and stand density in upland hardwood forests in the central states. Forest Science. 13: 38-52.

Hansen, E.; Fletcher, R.; Cashore, B.; McDermott, C. 2006. Forest certification in North America. Corvallis, OR: Oregon State University Extension Service. 11 p.

Helms, J.A., ed. 1998. The Dictionary of Forestry. Bethesda, MD: Society of American Foresters. 210 p.

Jensen, R.G.; Kabrick, J.M.; Zenner, E.K. 2002. Tree cavity estimation and verification in the Missouri Ozarks. In: Shifley S.R.; Kabrick, J.M. eds. Proceedings of the Second Missouri Ozark Forest Ecosystem Project Symposium: Post-treatment Results of the Landscape Experiment. Gen. Tech. Rep. NC-227. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Research Station. 114-129.

Johnson, P.S.; Shifley, S.R.; Rogers, R. 2009. The Ecology and Silviculture of Oaks, 2nd edition. Wallingford, Oxfordshire. UK: CAB International. 580 p.

Jones, G.T.1993. A Guide to Logging Aesthetics: Practical Tips for Loggers, Foresters and Landowners. Ithaca, NY: Northeast Regional Agricultural Engineering Service. 28 p.

Ladd, D. 1991. Reexamination of the role of fire in Missouri oak woodlands. In: Burger, G.V.; Ebinger, J.E.; Wilhelm, G.S., eds. Proceedings of the Oak Woods Management Workshop. Charleston, IL: Eastern Illinois University: 67-80.

McEvoy, T.J. 2004. Positive Impact Forestry: A Sustainable Approach to Managing Woodlands. Washington D.C.: Island Press. 268 p.

Minnesota Forest Resource Council. 2005. Sustaining Minnesota Forest Resources: Voluntary Site Level Guidelines for Landowners, Loggers, and Resource Managers. St. Paul, Minnesota.

Missouri Department of Conservation. 1985. Management of Snag and Cavity Trees in Missouri. Jefferson City, MO. 21 p.

Missouri Department of Conservation. 1986. Forest Land Management Guidelines. Jefferson City, MO. 81 p.

Missouri Department of Conservation. 1986. Management of old growth forests in Missouri. Jefferson City, MO. 16p.

Missouri Department of Conservation. 1991. Wildlife Species Management Guidelines. Jefferson City, MO.
Missouri Department of Conservation. 2000. Wildlife Management for Missouri Landowners, 3rd edition. Jefferson City, MO. 90 p.
Missouri Department of Conservation. 2003. Forest Management for Missouri Landowners. Jefferson City, MO. 108 p.
Missouri Department of Conservation. 2006. Missouri Watershed Protection Practice Management Guidelines for Maintaining Forested Watersheds to Protect Streams. Jefferson City, MO. 28 p.
Missouri Department of Conservation. 2009. Missouri Woody Biomass Harvesting Best Management Practices Manual. Jefferson City, MO. 44 p.
Missouri Department of Conservation. 2009. Watershed and Stream Management Guidelines for Lands and Waters Managed by Missouri Department of Conservation. Jefferson City, MO.
Missouri Department of Conservation. 2010. Missouri's Forest Resource Assessment and Strategy: Seeking a Sustainable Future for Missouri's Forest Resources. Jefferson City, MO. 222 p.
Nelson, P. 2005. The Terrestrial Natural Communities of Missouri, revised edition. Missouri Natural Areas Committee. Jefferson City, MO. 550 p.
Nigh, T.; Shroeder, W.A. 2002. Atlas of Missouri Ecoregions. Jefferson City, MO: Missouri Department of Conservation. 213 p.
Nyland, R.D. 2002. Silviculture Concepts and Applications, 2nd edition. Long Grove, IL: Waveland Press, Inc. 682 p.
Oliver C.D.; Larson B.C 1996. Forest Stand Dynamics, updated edition. New York, NY: Wiley & Sons, Inc. 520 p.
Perkey, A.W.; Wilkins, B.L.; Smith, H.C. 1993. Crop Tree Management in Eastern Hardwoods. USDA Forest Service. Northeastern Area, State and Private Forestry. NA-TP-19-93. 54 p.
Pflieger, Bill L. 1989. Aquatic Community Classification System for Missouri. Aquatic Series No. 19. Jefferson City, MO: Missouri Department of Conservation,.
Pyne, S.J. 1982. Fire in America: A Cultural History of Wildland and Rural Fire. Seattle, WA: University of Washington Press. 654 p.
Raeker, G.; Moser, W.K.; Butler, B.J.; Fleming, J.; Gormanson, D.D.; Hansen, M.H.; Kurtz, C.M.; Miles, P.D.; Morris, M.; Treiman, T.B. 2011. Missouri Forest 2008. Resource Bulletin NRS-54. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 55 p.
Randall, C.; Hock, W.; Crow, E.; Hudak-Wise, C.; Kasai, J., eds. 2012. National Pesticide Applicator Certification Core Manual. Washington, DC: National Association of State Departments of Agriculture Research Foundation. 238 p.
Shifley, S.R.; Brookshire, B.L.; Larsen, D.R.; Herbeck, L.A. 1997. Snags and down wood in Missouri old-growth and mature second-growth forests. Northern Journal of Applied Forestry. 14(4): 165-172.
Shifley, S.R.; Aguilar, F.X.; Song, N.; Stewart, S.I.; Nowak, D.J.; Gormanson, D.D.; Moser, W.K.; Wormstead, S.; Greenfield, E.J. 2012. Forests of the Northern United States.

General Technical Report NRS-90. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 202 p.
Smith, D.M.; Larson, B.C.; Kelty, M.J.; Ashton, P.M.S. 1997. The Practice of Silviculture: Applied Forest Ecology, 9th edition. New York, NY: Wiley & Sons, Inc. 537 p.
South Carolina Forestry Commission. 1994. South Carolina's Best Management Practices for Forestry. Columbia, SC. 64 p.
Steele, Michael; Smallwood, Peter; Terzaghi, William B.; Carlson, John E.; conteras, Thomas; McEuen, Amy. 2004. Oak dispersal syndromes: do red and white oaks exhibit different dispersal strategies? Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. pp. 72-77.
USDA Forest Service. 2011. National report on sustainable forests—2010. Report FS-979. Washington, D.C.: U.S. Department of Agriculture, Forest Service, Northern Research Station. 210 p.
Wallendorf, M.J.; Porneluzi, P.A.; Gram, W.K.; Clawson, R.L.; Faaborg, J. 2007. Bird response to clear cutting in Missouri Ozark forests. Journal of Wildlife Management. 71(6): 1899-1905.
Wiest, R.L. 1998. A Landowner's Guide to Building Forest Access Roads. NA-TP-06-98. Radnor, PA. http://www.na.fs.fed.us/spfo/pubs/stewardship/accessroads/accessroads.htm
Wisconsin Department of Natural Resources. 2011. Wisconsin Forest Management Guidelines. PUB-FR 226. Madison, WI.