UNIT II:

Foundations of Forest Management

CHAPTER 10

Forest Management Planning


NOPPADOL PAOTHONG

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 applies 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, and Historical Sites
- Environmental Evaluations
- Glossary/Helpful Internet Sites
- Supporting Documents/Stand Information

The common plan format can be accessed on the Natural Resource Conservation Service (NRCS) Field Office Technical Guide (FOTG) at ***http://efotg.sc.egov.usda.gov/efotg_locator.aspx?map=US***. Select the state and appropriate county, then select Section III, and click on the technical criteria-conservation activities plans folder. 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 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

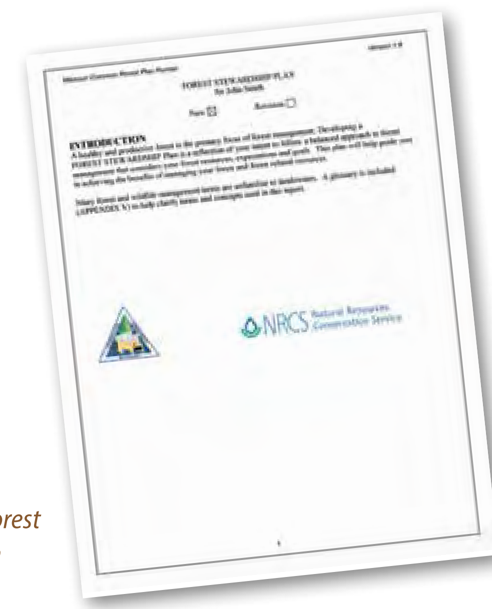

Figure 10.1. *A forest stewardship plan*

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.

CLIFF WHITE

Figure 10.2. *A professional forester can help landowners meet their goals and objectives by developing a forest stewardship plan.*

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, and 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, or 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 it 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 create 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.

References to Other Chapters

- For information on planning and identifying your goals and objectives see Chapter 11.
- For best management practices for implementing a timber sale see Chapter 15.
- See Appendix C for pre- and post-activity checklists.

Additional Resources

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

CHAPTER 11

Generally Accepted Principles for Silviculture

NOPPADOL PAOTHONG

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
- Agroforestry
- Discouraged Harvest Practices

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, 2010).

Ecological Classification System Project in Missouri

An ongoing collaborative effort by the Missouri Department of Conservation, Natural Resource Conservation Service (NRCS), U.S. Department of Agriculture 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).

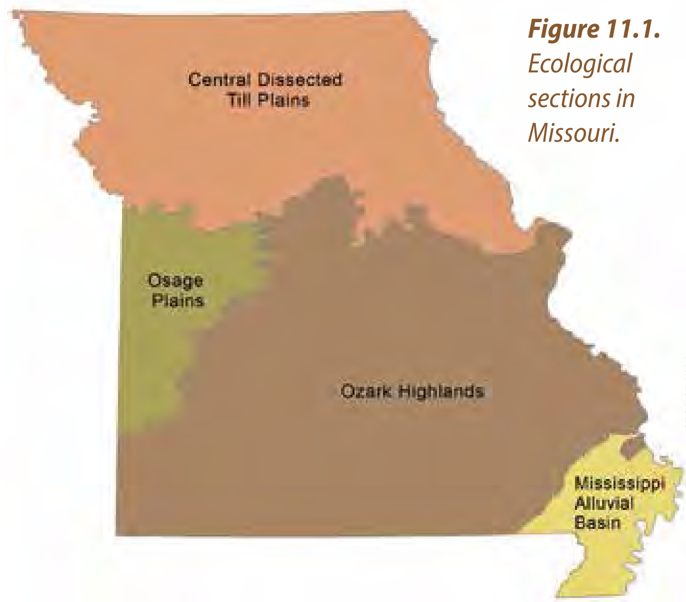

Figure 11.1. *Ecological sections in Missouri.*

GEORGE KIPP

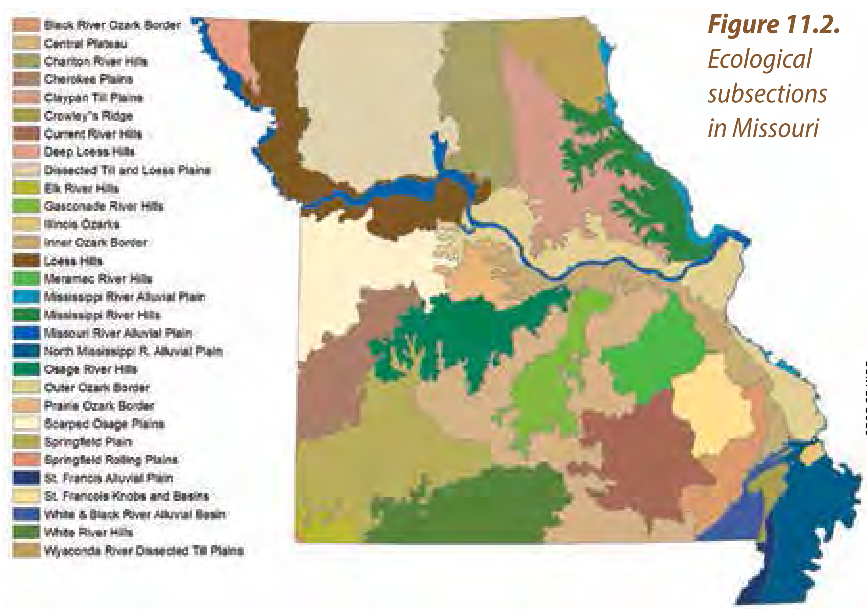

Figure 11.2. *Ecological subsections in Missouri*

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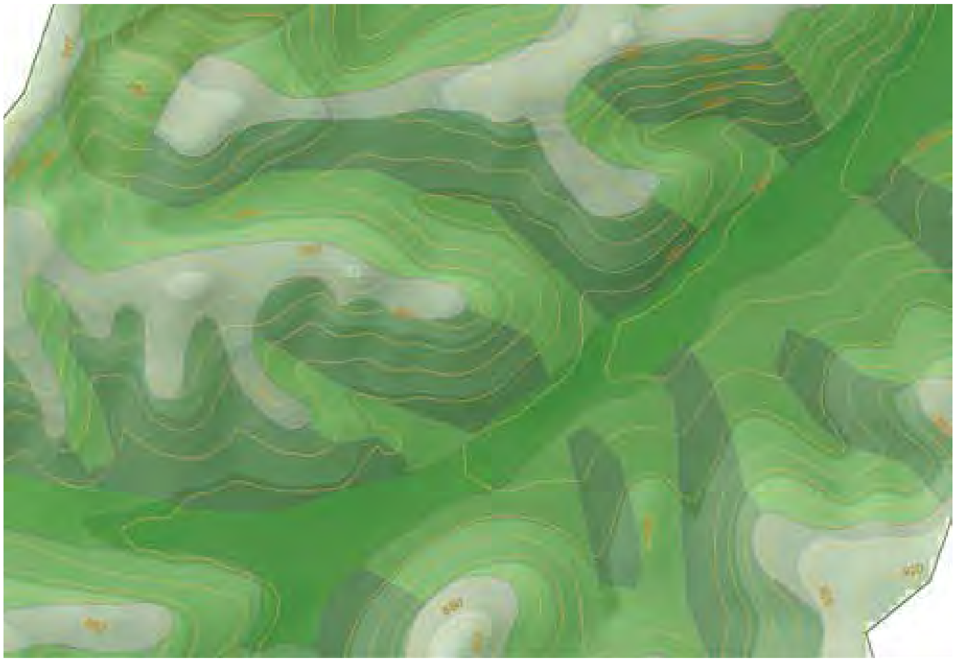
GEORGE KIPP

Figure 11.3. *Example of ecological sites at the stand level*

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 a description of its pre-settlement vegetation. 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, 2010) provides another system of classification for the plant communities in the state. In this system, Nelson (2010) 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 (2010) 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 midstory 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).

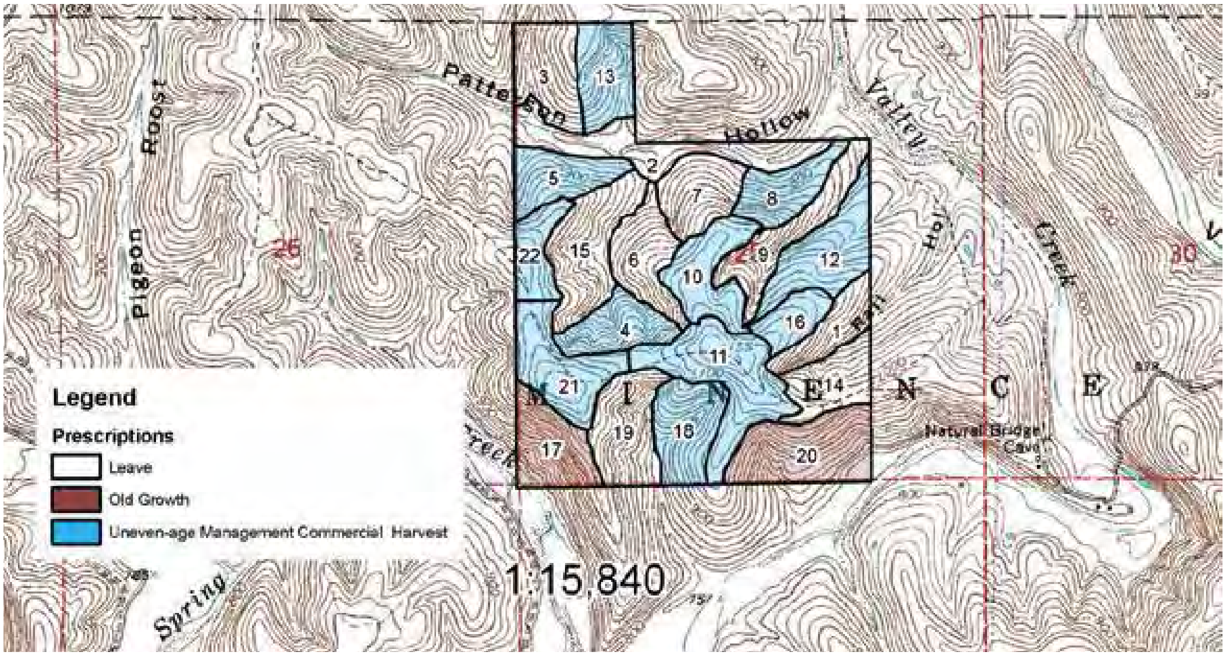

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Figure 11.4. *This forest management plan prescription map depicts the location and type of treatment.*

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 changes 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.

Figure 11.5. *Clear-cut harvests as they mature*

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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.


USDA FOREST SERVICE

Figure 11.6. *Seed-tree harvest*


NOPPADOL PAOTHONG

Figure 11.7. *Shelterwood harvest*

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

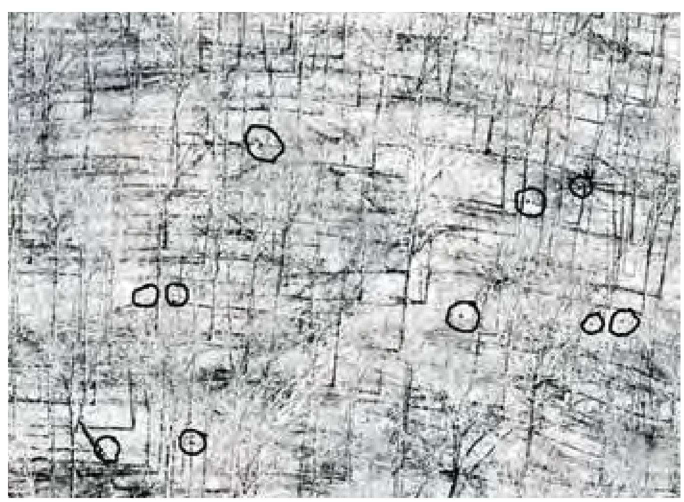
The following methods regenerate uneven-aged stands.

Single-tree selection is when individual trees are harvested indefinitely on a periodic cutting cycle that may be 15–25 years long (Figures 11.9 and 11.10). 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 has been used successfully to regenerate shade-tolerant species such as sugar maple throughout the Eastern U.S. In Missouri 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 through small openings created by periodic harvests of less vigorous and selected mature trees.

MICHAEL BILL

Figure 11.8. *This shelterwood harvest retained saw log pine throughout the stand. The stand is transitioning towards a two-aged stand as the regeneration reaches the canopy.*



DALE DUFER, TAKEN FROM GULDIN ET AL. 2008

Figure 11.9. *View of an approximate one-acre area of Pioneer Forest, Shannon County, where stumps from individually selected and harvested trees have been circled.*

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 11.11). 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.

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.

COURTESY OF PIONEER FOREST

COURTESY OF PIONEER FOREST

Figure 11.10. *Before-harvest (above) and after-harvest (below) from a single-tree selection harvest on Pioneer Forest*

RANDY JENSEN, MOFEP

Figure 11.11. *Aerial view of group selection harvest*

Figure 11.12. *Two woodland indicator plants: Big bluestem (*Andropogon gerardii*) (left), Cream Wild Indigo (*Baptisia bracteata*) (right)*

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 midstory 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 midstory 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.

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, 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

Lead Plant (*Amorpha canescens*)
Big Bluestem (*Andropogon gerardii*)
Purple Milkweed (*Asclepias purpurascens*)
Four-Leaved Milkweed (*Asclepias quadrifolia*)
Yellow False Foxglove (*Aureolaria grandiflora*)
Cream Wild Indigo (*Baptisia bracteata*)
Ohio Horse Mint (*Blephilia ciliata*)
Sand Sedge (*Carex muhlenbergii*)
New Jersey Tea (*Ceanothus americanus*)
Butterfly Pea (*Clitoria mariana*)
False Toadflax (*Comandra umbellata*)
Prairie Coreopsis (*Coreopsis palmata*)
Dittany (*Cunila origanoides*)
Purple Prairie Clover (*Dalea purpurea*)
Round-Leaved Tick Trefoil (*Desmodium rotundifolium*)
Lax-Flowered Panic Grass (*Dichanthelium laxiflorum*)
Pale Purple Coneflower (*Echinacea pallida*)
Rattlesnake Master (*Eryngium yuccifolium*)
Purple Joe Pye Weed (*Eupatorium purpureum*)
Flowering Spurge (*Euphorbia corollata*)
Downy Gentian (*Gentiana puberulenta*)
American Ipecac (*Gillenia stipulata*)
Oblong Sunflower (*Helianthus hirsutus*)
Flax-Leaved Aster (*Ionactis lineariifolia*)
Hairy Bush Clover (*Lespedeza hirta*)
Trailing Bush Clover (*Lespedeza procumbens*)
Slender Bush Clover (*Lespedeza virginica*)
Rough Blazing Star (*Liatris aspera*)

Figure 11.13. *Restored woodland at Peck Ranch Conservation Area*

Scaly Blazing Star (*Listris squarrosa*)
Hoary Puccoon (*Lithospermum cansecens*)
Bradbury Bee Balm (*Monarda bradburiana*)
Sampson's Snakeroot (*Orbexilum pedunculatum*)
Violet Wood Sorrel (*Oxalis violacea*)
Wild Quinine (*Parthenium integrifolium*)
Prairie Phlox (*Phlox pilosa*)
White mountain mint (*Pycnanthemum albescens*)
Slender Mountain Mint (*Pycnanthemum tenuifolium*)
Little Bluestem (*Schizachyrium scoparium*)
Royal Catchfly (*Silene regia*)
Starry Campion (*Silene stellata*)
Rosinweed (*Silphium integrifolium*)
White Goldenrod (*Solidago hispida*)
Downy Goldenrod (*Solidago petiolaris*)
Rough Goldenrod (*Solidago radula*)
Showy Goldenrod (*Solidago speciosa*)
Elm-Leaved Goldenrod (*Solidago ulmifolia*)
Indian Grass (*Sorghastrum nutans*)
Blue Aster (*Symphiotrichum anomalum*)
Azure Aster (*Symphiotrichum oolentangiense*)
Spreading Aster (*Symphiotrichum patens*)
Prairie Aster (*Symphiotrichum turbinellum*)
Yellow Pimpernel (*Taenidia integerrima*)
Goat's Rue (*Tephrosia virginiana*)
Wing-Stem (*Verbesina helianthoides*)
Culver's Root (*Veronicastrum virginicum*)
Bird's Foot Violet (*Viola pedata*)

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 below ground; if top-killed by fire, the cotyledons remain protected and provide some of the nourishment needed to re-sprout 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 re-sprout 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 midstory 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 saw logs, 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 for 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

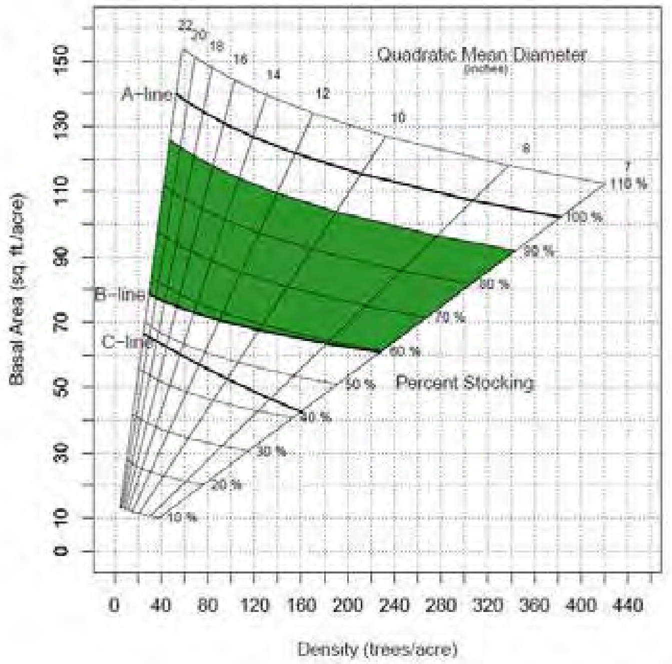


__Figure 11.14.__ Gingrich (1967) stocking chart for oaks and hickories where the quadratic mean diameter at breast height is > 7 inches. Stocking at the A line (100 percent stocking) represents the average maximum density that occurs in the absence of management treatments. The B line (56 to 58 percent) 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).

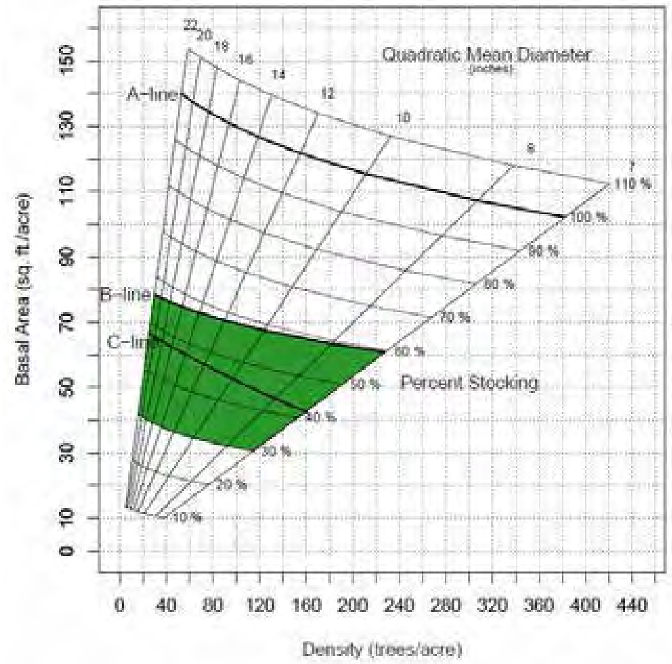


__Figure 11.15.__ Gingrich (1967) stocking chart for oaks and hickories where the quadratic mean diameter at breast height is > 7 inches. Open woodlands are tended below the B line but at greater than 30 percent stocking (shaded area), the point at which the structure and composition begins to resemble that of a savanna. For regenerating forests and woodlands, stocking is reduced below the B line.

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 firelines, roads, or natural firebreaks 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 11.14 and 11.15). For managing open woodlands, stocking levels lower than B level, typically between 30 and 60 percent are preferred; and for managing closed woodlands, stocking levels at or above B level (60 percent stocking) 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 11.16).

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.

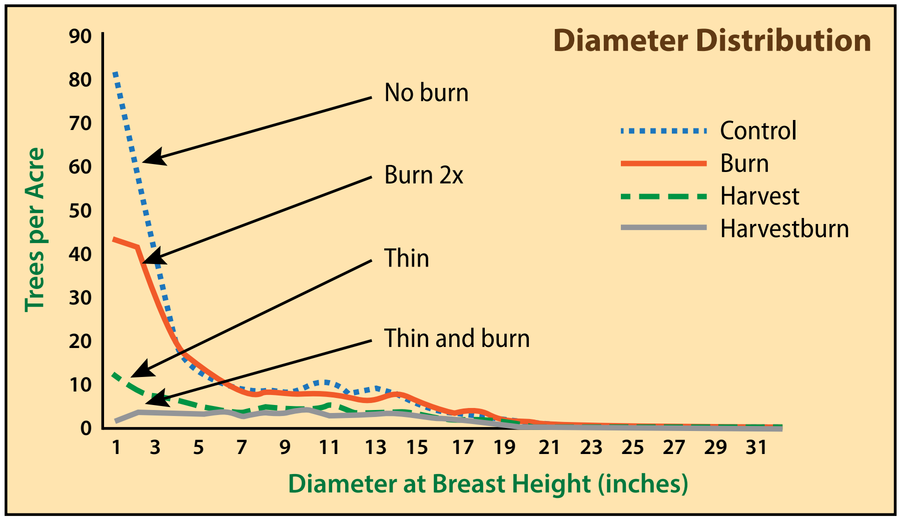


__Figure 11.16.__ Prescribed fire reduces the density of the smaller-diameter trees, generally those smaller than 4 inches diameter at breast height. Greater reductions in stand density can be achieved by thinning where specific size classes of trees can be targeted for removal.

USDA FOREST SERVICE

Effect of Burning and Thinning on Diameter Distributions of Woodlands

With increase in fires frequency stem density of smaller trees is reduced over time, this can impact future regeneration and recruitment into the canopy over time, but also has the potential to increase herbaceous response due to increased sunlight.

Salvage Harvest

The objective of a salvage harvest is to capture the volume and value of 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?

MICHAEL BILL

Figure 11.17. *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.*

Federally Listed Bat Species

Habitats for imperiled bat species should be considered when conducting salvage harvest activities. Missouri is home to three federally-endangered bat species (**gray bat**, **Indiana bat**, and **Ozark big-eared bat**) and one bat species (**northern long-eared bat**) that is proposed for listing under the Act. See Chapter 3 for more about threatened and endangered species.

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***.

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.

JIM RATHERT

Figure 11.18. *Fens are a special type of wetland natural community. These areas are typically avoided and are not managed other than for control of woody encroachment.*

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.

Figure 11.19. *This tract of land has been high-graded and has been put on the market for resale. The timber was liquidated and no best management practices were installed on the site.*

NOPPADOL PAOTHONG

References to Other Chapters

- For more in-depth information on forest regeneration and methods for artificial and natural regeneration see Chapter 12.
- For more information on tending methods see Chapter 13.

Additional Resources

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

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

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***.

CHAPTER 12

The Fundamentals of Forest Regeneration

Topics Covered

- Silvicultural Treatments for Regeneration
- BMPs for Visual Quality
- BMPs to Slow the Spread of Invasive Species
- BMPs to Protect 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

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 fewer, larger 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 re-sprouting 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 re-sprout 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.


DAVID STONNER

Figure 12.1. *Oak stump sprouting*


DAVID STONNER

Figure 12.2. *Oak regeneration resulting from stump sprouting and advance regeneration after a clear-cut harvest in the Ozarks.*

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.


SARAH EGLY

Figure 12.3. *Using a tree planter to plant seedlings as part of a riparian buffer*

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 Forest 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.

DAVID STONNER

Figure 12.4. Lifting seedlings from the George O. White State Forest Nursery

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

MIKE GASKINS

Figure 12.5. Site prep using a dozer to rip the soil to prepare the seed bed for planting

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, Fire Management, and Forest Recreation Management — are described in subsequent chapters.

BMPs 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. Some basic guidelines can help to ensure forest regenerations maintain visual quality:

- ➤ Regenerate or retain multiple species that vary in fall color and flowering characteristics.
- ➤ Use regeneration practices that maintain diversity in forest structure.

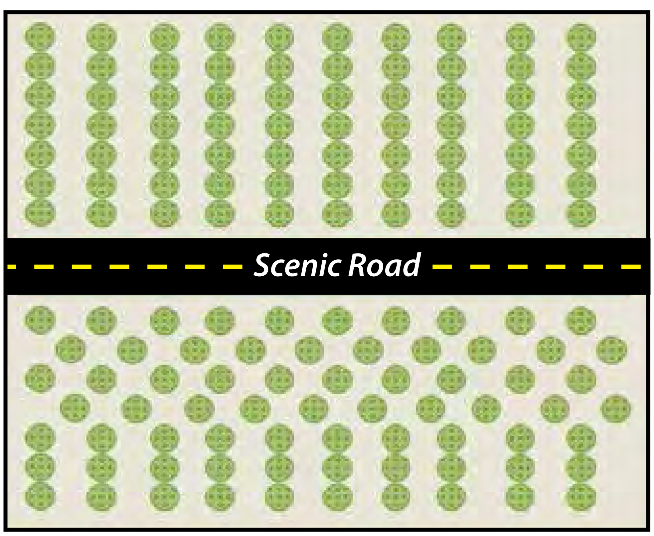


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Figure 12.6. *To avoid the perception of unnatural straight rows (shown above the road), plant irregular or offset rows for the first few rows along a scenic road (shown below the road) to discourage visual penetration and increase the perception of a natural stand.*

- ➤ 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.

BMPs 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.
- ➤ Revegetate 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 revegetation site preparation activities.

BMPs 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 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 necessary 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 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 × 3	4,840	0.9 × 0.9	11,954
4 × 4	2,723	1.2 × 1.2	6,724
5 × 5	1,742	1.5 × 1.5	4,303
6 × 6	1,210	1.8 × 1.8	2,988
7 × 7	889	2.1 × 2.1	2,196
8 × 8	681	2.4 × 2.4	1,681
9 × 9	538	2.7 × 2.7	1,328
10 × 10	436	3.0 × 3.0	1,076
12 × 12	303	3.7 × 3.7	747
15 × 15	194	4.6 × 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 all 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 understory. 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.

Figure 12.7. *Abundant advanced white oak regeneration in the understory*

Figure 12.8. *Pine regeneration in a shelterwood cut*

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 midstory. 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 × 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 five 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 per acre remain at this point, additional silvicultural treatments may be needed to improve the chances of an acceptable canopy at maturity.

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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 Chapters 10 and 11.
- 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 Chapters 10 and 11.
- Land managers must also consider other factors that affect how silviculture can be implemented to meet management objectives. Among these, protection of valuable cultural resources, and maintenance of visual quality are 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 Chapters 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.
- Invasive species can be spread through forest regeneration activities. Refer to invasive species guidance above to help slow the spread. Refer to Chapter 9 for general information on invasive species management.
- Appendix C includes a pre- and post-tree-planting checklist that can be a helpful tool for managers to use in clarifying objectives, planning activities, and integrating management concerns. The checklist also has an area for evaluating and documenting planting success.

Additional Resources

Forest Management for Missouri Landowners, revised edition. 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. 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***.