UF | IFAS Extension
UNIVERSITY of FLORIDA

UF/IFAS PEER REVIEWED

CIR 1404
10.32473/edis-FR132-2022

Opportunities for Uneven-Aged Management in Second Growth Longleaf Pine Stands in Florida[1]

Jennifer L. Gagnon, Eric J. Jokela, Ajay Sharma, and Jason G. Vogel[2]

The Longleaf Pine Ecosystem

In pre-colonial times, longleaf pine (*Pinus palustris* Mill.) forests covered nearly 60 million acres of land in the southeastern United States, from southeast Virginia to central Florida, and west to the Gulf region of Texas. Since European settlement, the longleaf pine resource has steadily declined. In 1935, 20 million acres were found throughout the South (a 70% reduction), while in 1994 only 3.3 million acres remained (a 95% reduction; Barnett and Dennington 1992; Boyer 1990; Haywood and Grelen 2000; Jose, Jokela, and Miller 2006; US Forest Service 1999).

The decline in the longleaf pine resource can be attributed to several factors. First, extensive harvesting, particularly between 1900 and 1930, greatly reduced the area occupied by mature longleaf pine (Brown and Nowak 2013) and, hence, the availability of seed sources. Therefore, natural regeneration was both scarce and unpredictable. Second, a lack of understanding of the biological requirements of this species and seedling predation from feral hogs (Wahlenberg 1946) led to the failure of many regeneration efforts. Finally, and perhaps most importantly, many sites were converted to other commercially valuable species (mainly loblolly pine [*Pinus taeda* L.] and slash pine [*Pinus elliottii* var. *elliottii* Engelm]) or to other land uses such as agriculture (Haywood and Grelen 2000; Wahlenberg 1946).

As a result of this decline, much of the interest today in the restoration of Florida's native ecosystems has focused on longleaf pine. Of the 17.3 million acres of forested land in Florida, there are 2.1 million confirmed acres of longleaf pine. In other words, approximately 12% of Florida's forest area already includes a longleaf pine component (FDACS 2017), which can be beneficial for restoration efforts.

Longleaf pine forests today are managed for a variety of desired benefits including aesthetics, habitat diversity, nontimber forest products (such as pine straw production) and quality timber production. The longleaf pine forests have high species diversity in the understory and are the most diverse ecosystems in North America. The high-quality timber produced in longleaf pine forests generally has a higher wood density than timber from either loblolly pine or slash pine. The timber from mature longleaf pine trees is strong, rot-resistant, and knot-free (Platt and Rathbun 1993; Schmidtling 1986). Longleaf pine may be a suitable alternative to loblolly pine and slash pine on difficult sites, such as excessively well-drained sandhill soils that do not support acceptable growth rates for these other southern pine species. In addition, longleaf pine is generally considered to be less susceptible (not immune) to southern fusiform rust and is therefore a desirable species for many landowners to plant on high rust hazard sites (Schmidtling and White 1989).

1. This document is CIR 1404, one of a series of the School of Forest Resources and Conservation Department, UF/IFAS Extension. Original publication date January 2002. Revised June 2017 and March 2022. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication.

2. Jennifer L. Gagnon, project associate, Virginia Tech; Eric J. Jokela, professor emeritus, School of Forest, Fisheries, and Geomatic Sciences; Ajay Sharma, assistant professor, UF/IFAS West Florida Research and Education Center; and Jason G. Vogel, assistant professor, School of Forest, Fisheries, and Geomatic Sciences. UF/IFAS Extension, Gainesville, FL 32611.

Non-industrial private landowners own approximately 817,000 acres (38%) of the longleaf pine forests in Florida (FDACS 2017), so their management strategies have a large impact on the status of the resource. For non-industrial private landowners and land management agencies, whose main land management objective is something other than timber production (i.e., aesthetics, recreation, wildlife habitat, or soil or watershed protection), alternative silvicultural systems provide an opportunity to improve these services on their property.

The objective of this publication is to provide private landowners or other land management agencies a guide to an alternative to even-aged management for longleaf pine. The alternative approach uses a group selection system to create an uneven-aged stand structure, which could provide income from periodic timber harvests, while maintaining continuous tree cover. A discussion of traditional and alternative longleaf pine management practices follows, as well as a description of the process of converting an even-aged stand of mature longleaf pine to an uneven-aged stand.

Management Options for Longleaf Pine

Longleaf pine has traditionally been managed using even-aged silvicultural systems. With this approach, single-age-class stands are managed over a fixed period of time (a rotation) using intermediate cutting techniques (e.g., thinnings) to regulate stand density, control species composition, and improve stand vigor and health. Examples of even-aged silvicultural systems used with longleaf pine include the clearcut and shelterwood systems. In the clearcut reproduction system, all mature crop trees are harvested simultaneously at the end of the rotation. The site is then regenerated using either natural regeneration methods (by self-sown seed) or artificial regeneration methods (by directed seeding or planting). The shelterwood reproduction system uses two partial harvests to reduce the basal area of the stand to about 30 ft2/acre (the density that maximizes seed production of longleaf pine). Seed from the remaining mature trees is used to naturally restock the site, assuming a mineral soil seedbed is provided. Once regeneration is established, the parent overstory trees are removed. (There are examples of landowners leaving the overstory trees. Over multiple rotations, this practice, known as an irregular shelterwood system, can result in an uneven-aged stand.) Both the clearcut and the shelterwood systems have been shown to be effective even-aged systems for regenerating and managing longleaf pine (Brockway and Outcalt 2017; Croker 1979; Croker and Boyer 1976; Demers and Long 2000).

The even-aged approach to management offers a variety of advantages. For example, even-aged management is easy to apply, and intermediate cuttings and other cultural practices (i.e., herbicide application) can be applied uniformly across the entire stand (Barnett and Baker 1991). Even-aged systems produce trees that are fairly uniform in size, which simplifies harvesting operations. There are, however, some disadvantages to even-aged management. The uniform stand offers fewer aesthetic, recreational, and wildlife benefits and may not produce significant income for 15 to 20 years (Barnett and Baker 1991). Clearcutting also makes a site prone to erosion and degradation.

Many private landowners are interested in uneven-aged management systems to maintain a diverse stand structure for recreation and wildlife habitat values (Butler et al. 2014). On public lands as well, there is an increasing interest in developing uneven-aged (multi-aged) stands of longleaf pine. For example, in Florida, the US Forest Service is converting over 250,000 acres of even-aged longleaf pine and mixed longleaf pine-slash pine stands to an uneven-aged structure, using the group selection system. While even-aged management systems create stands with trees of similar age and less variable size and form, uneven-aged management systems create structurally complex stands with different ages (at least three age classes) and sizes of trees representing the spectrum from large dominants to smaller seedlings and saplings (Figure 1). In a balanced uneven-aged stand, the ground area occupied by each age class is approximately equal, with a greater number of individual trees in the younger age classes (Figure 1).

Uneven-aged stands are created using the selection system. In the selection system, trees representing a range in size are harvested at fixed intervals (called the cutting cycle, which ranges from 10 to 25 years). Regeneration (either natural or artificial) occurs in the harvested openings. This management approach allows periodic harvests, while maintaining a continuous forest cover. Smaller, lower quality trees are also removed to improve the overall economic quality of the stand.

There are two main variations of the selection system. The first, referred to as the single tree selection system, involves removal of individual trees across the stand, creating small openings in which species can naturally regenerate (Figure 2).

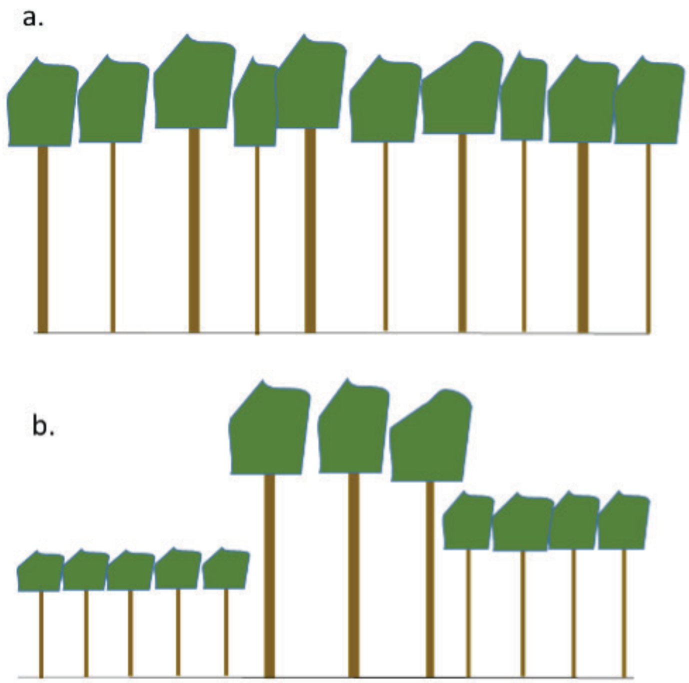

Figure 1. Stand profiles showing (a) even-aged stand structure and (b) balanced uneven-aged stand structure. The even-aged stand has one age class (i.e., the trees are approximately the same age). The uneven-aged stand, which in this example was developed using the group selection system, has three distinct age classes.
Credits: J. L. Gagnon

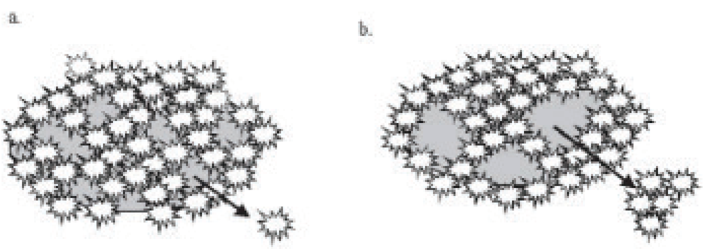

Figure 2. An aerial view provides a stand-level comparison of opening size and arrangement after harvest, and the trees removed during harvest using (a) the single-tree selection system and (b) the group selection system.
Credits: J. L. Gagnon

The second type of selection system is referred to as group selection. In this system, groups of trees are removed in patches ranging from 0.2 acres to 5 acres in size throughout the stand (Figure 2), allowing for potential regeneration of the more shade-intolerant species such as longleaf pine (provided seedbed requirements are met; Brockway and Outcalt 2017; Brockway and Outcalt 1998; McGuire, Mitchell, Moser, et al. 2001; Marquis 1978; Matthews 1989). Canopy openings larger than 2 acres may also be referred to as patch clearcuts. However, for the purposes of this paper, they will be referred to as gaps. In both single tree and group selection, canopy openings can be regenerated using either natural or artificial means (e.g., planting). These harvested groups mimic canopy gaps created by natural biotic and abiotic events (e.g., insects, windthrow, and lightning). Generally, the group selection management system has lower logging costs than the single-tree selection management system.

There are numerous advantages to uneven-aged management (using both the single-tree and group selection systems). Stands with a variety of age classes are less likely to suffer catastrophic damage from insect outbreaks, disease, or low-intensity fire because, usually, only one age class of trees is susceptible to any one damaging agent. For example, longleaf pine seedlings are susceptible to brown spot needle blight, but saplings and mature trees are not. A brown spot needle blight outbreak in an uneven-aged stand may result in high seedling mortality, but trees in the other age classes will not be damaged. Another advantage of uneven-aged management is that periodic income can be obtained from high-value products at relatively short intervals over time. Also, due to the continuous presence of large trees (the entire stand is never totally liquidated), the selection system creates stands with high aesthetic values and diverse wildlife habitat (Barnett and Baker 1991; Farrar and Boyer 1991; Paudyal et al. 2018), while providing excellent protection to the site against erosion and degradation. However, both single-tree and group selection systems may involve higher logging costs than even-aged systems and are sometimes difficult to apply (Barnett and Baker 1991). Also, without careful attention, there is the potential for substantial losses due to damage to the residual stand during harvesting operations.

Because longleaf pine is intolerant of both shade and competition from mature overstory trees, openings created in closed-canopy forests using the single tree selection system may not be large enough for adequate natural regeneration to become established. Seedlings in small openings (<1/3-acre) compete directly with adjacent mature trees for limited site resources (i.e., water, mineral nutrients; Farrar and Boyer 1991). Fine root competition from mature residual trees on good quality sites may extend 50 feet into openings, and may be even higher on poor sites (Boyer 1993). Any established longleaf pine regeneration in these small openings would have slow growth rates (Brockway and Outcalt 1998; Farrar and Boyer 1991) and young trees may suffer higher mortality from periodic prescribed burning (Gagnon, Jokela, Moser, et al. 2003) than young trees in larger openings.

In spite of these difficulties, the single-tree selection system has been used successfully in some open-canopied longleaf pine forests. In fact, gaps as small as ¼ of an acre can be large enough for seedlings to reach maximum growth (Landers, Van Lear, and Boyer 1995) if the surrounding overstory is open enough (basal area approximating 50 ft^2/ac or lower) to allow adequate light to reach the forest floor and if competition with woody understory plants is minimal (Brockway and Outcalt 2017).

The use of the group selection system in longleaf pine forests is not without challenges, either. The larger canopy openings created in the group selection system compared to smaller openings in single-tree selectionmay allow for a greater abundance of woody understory vegetation. Pecot et al. (2007) found that root competition from the understory vegetation also decreased longleaf pine seedling growth. Additionally, large canopy openings may not have adequate needle-fall to carry prescribed fire effectively through the openings (Mitchell et al. 2006).

Despite the limitations, both single-tree and group selection systems offer promising alternative options for managing longleaf pine for multiple benefits. However, the group selection system is logistically simpler to implement compared to single tree selection. Group selection is also a simpler and more effective approach to convert existing even-aged longleaf pine to uneven-aged stands. Due to these reasons, the rest of this publication will primarily focus on the application of the group selection system in longleaf pine.

Longleaf Pine Ecology

The first step in developing a viable group selection management system for longleaf pine involves a review and understanding of the ecology of the species. Specifically, the management strategy must match the habitat, reproduction, germination, and growth requirements of the species. Table 1 summarizes the biological factors that are important for regenerating and managing longleaf pine. These biological requirements can be met using the group selection system while creating a structurally complex uneven-aged stand.

The following example describes the process of converting an even-aged longleaf pine stand into a uneven-aged stand structure using the group selection system.

Conversion of Longleaf Pine Stands from Even-Aged to Uneven-Aged

A hypothetical stand with the following characteristics will be used to illustrate an example of the group selection system in a flatwoods site condition.

Stand Description

- 45 acres
- 60-year-old naturally regenerated longleaf pine (currently on site)
- Site index 70 (base age 50 years)
- Previously unthinned
- 230 trees per acre, 114 ft2/acre basal area (Ashton and Kelty 2018)
- Current standing volume = 16 thousand board feet (MBF- Scribner)/acre (US Forest Service 1929)
- Product objective: Pole and sawtimber production (Dennington 1990)

Assumptions

1. Mature longleaf pines that surround regenerated openings do not have adverse effects on growth and survival of seedlings within the openings.

2. Trees over 45 years old exhibit a minimal growth response to thinning.

3. Damage to the residual stand (i.e., scarring and soil compaction) from harvests and thinning operations will be minimal.

4. Planting of longleaf pine seedlings in rows will be used to regenerate the created gap openings.

Reproduction Cuts

Group selection openings will be harvested on a 15-year cutting cycle (Figure 3). Using a 45-year rotation, this amounts to harvesting fifteen acres per cutting cycle.

Figure 3. A recently harvested group selection opening in a second-growth stand of longleaf pine in the Apalachicola National Forest.
Credits: J. L. Gagnon

The fifteen acres will be allocated among five 3-acre gaps within the stand (Figure 4).

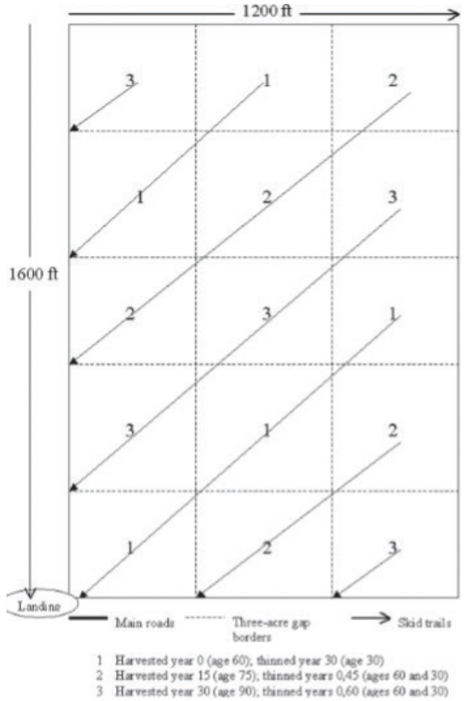

Figure 4. Schematic of a hypothetical 60-year-old, second-growth, even-aged longleaf pine forest, managed under a group selection system (based on recommendations in McGuire, Mitchell, Moser, et al. (2001)). Note: The gaps do not need to be rectangular. Circular or irregular shapes will work as well. Not to scale.
Credits: J. L. Gagnon

Since the age of the current, naturally regenerated stand is 60 years (the average age of longleaf pine stands in Florida), the ages of the trees harvested in the first three cutting cycles will be 60, 75, and 90 years, respectively. Once the even-aged stand is fully converted to an uneven-aged stand, the difference between the oldest and the youngest trees in the artificially regenerated gaps will be 45 years. The artificially regenerated trees planted in the created gaps will be harvested at age 45. The rotation age for the naturally regenerated and the artificially regenerated trees differs because naturally regenerated stands require longer rotations to produce volumes of sawtimber comparable to those of planted stands (Dennington 1990). For example, at age 60, a naturally regenerated stand would be expected to yield 16 thousand board feet of timber (MBF)/acre (Scribner), while at age 45, a planted stand would yield about 22 MBF/acre (Scribner) (US Forest Service 1929).

A 15-year cutting cycle allows for adequate growth between harvests to ensure operable volumes, and it falls within the recommended range of cutting cycles for this species. Sawtimber revenues occurring at 15-year intervals may be preferable to pulpwood revenues occurring at 20–25 year intervals. The large (3-acre) gaps that are created with this management system should reduce detrimental edge effects that may impact seedling survival and growth within the openings (Farrar and Boyer 1991; Outcalt and Outcalt 1994). Skid trails should be oriented in the direction of the planted rows and should be wide enough to facilitate future harvesting and thinning operations and to minimize damage to trees in the residual stand. The size and the location of the gaps and the positioning of the skid trails parallel to the planted rows simplify both marking and timber harvesting operations.

Regeneration

Site disturbance resulting from harvesting should sufficiently scarify the soil for planting. If there is excessive woody vegetation in the openings, a prescribed surface fire may be used to reduce competing vegetation. Some additional site preparation (i.e., herbicide application) may also be required before planting in areas with heavy understory competition or oak (*Quercus* spp.) encroachment (Brockway and Outcalt 2000; Grace and Platt 1995).

Although longleaf pine can be regenerated by both natural and artificial means, artificial regeneration by planting is recommended for this example of a group selection system because of the sporadic nature of longleaf pine seed crops, the bare mineral soil requirement for natural germination, and the heavy seed predation pressures commonly found with this species (Table 1). These three factors make natural regeneration of longleaf pine somewhat unreliable. Artificial regeneration also helps to ensure prompt and uniform seedling establishment (US Forest Service 1999). Spacing and density can be manipulated to meet specifications for desired products. When relying upon natural regeneration for longleaf pine, canopy openings are limited to about 0.7 acres to ensure adequate seedfall throughout the created gap (effective seed dispersal distance of longleaf pine is about 100 ft). However, there is no biological limit to the size of openings when artificial regeneration is used.

Another advantage of artificial regeneration is that it provides an opportunity to use genetically improved seedlings. Improved longleaf pine seed is being developed, which has higher survival rates and earlier emergence from the grass stage than unimproved seed sources (Schmidtling 1986; White et al. 2018). The improved longleaf pine seedlings are readily available from the Florida Forest Service Nurseries (FDACS 2021).

Artificial regeneration of longleaf pine can result from direct seeding or planting of bare-root or containerized seedlings. Containerized seedlings are more expensive but usually have higher survival rates due to decreased transplant shock, which results in a greater ability for the seedlings to compete with understory vegetation. In general, containerized longleaf seedlings are easier to plant, have an extended planting season, and initiate height growth earlier than direct seeded or bare-root seedlings (Barnett, Lauer, and Brissette 1989; Boyer 1984; Boyer 1988). The high survival and rapid growth rates of containerized seedlings result in better yields, which may in turn offset the higher initial planting costs associated with their use. Containerized longleaf pine seedlings (minimum root collar diameter 0.4 in.) (Barnett, Lauer, and Brissette 1989) can be planted (either by hand or machine) at a density ranging from about 450 to 700 trees per acre (e.g., approximately 8 ft x 12 ft to 6 ft x 10 ft spacing). Staggered spacing can be used to create a more natural appearance (Figure 5).

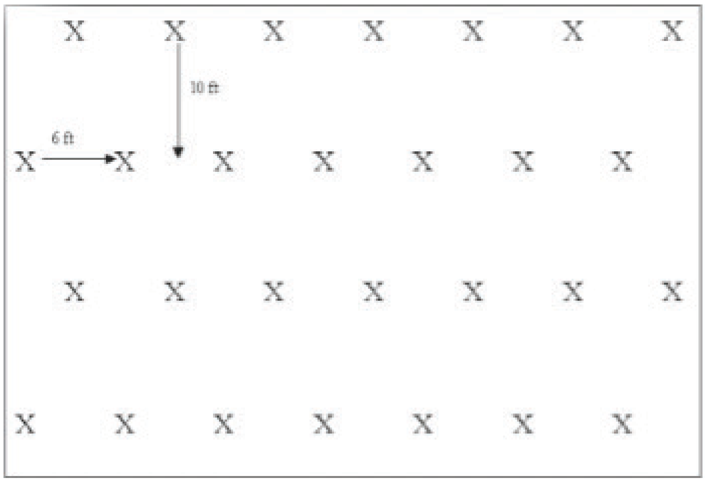

Figure 5. Schematic of a staggered 6 ft x 10 ft spacing, where X represents individual seedlings (not to scale).
Credits: J. L. Gagnon

Although containerized seedlings can be planted throughout the year, survival is best when they are planted under moderate weather conditions. The traditional planting season for longleaf pine in Florida occurs from November through February, although there has also been successful planting of containerized longleaf pine seedlings in late summer. Additional information on planting southern pines is available in a number of other Extension publications (Croker and Boyer 1976; Demers 2011; Dennington and Farrar 1983; Duryea 1998; Dyson and Brockway 2015; South 2006).

Intermediate Operations

To provide more economic volumes and revenues, thinnings should be timed to coincide with group selection harvests. Thinning (which removes some trees to provide adequate growing space for the remaining trees) beginning at about age 30 years is recommended for the remainder of the stand (residual basal area should be about 80 ft2/acre [Dennington 1990]).

Prescribed surface fires can be used on a two- to three-year burning cycle to minimize fuel loads and to control understory and woody vegetation (Duryea 2000). Regular competition control is necessary to encourage growth and survival of longleaf pine seedlings. A three-year burn cycle is currently being used successfully on the National Forests in Florida to maintain longleaf pine-wiregrass (*Aristida stricta* Michx.) ecosystems (US Forest Service 1999). Although longleaf pine is fairly resistant to fire damage, the seedlings are susceptible to injury during the initial stages of active height growth. Therefore, fire should be postponed during this stage and not resumed until seedlings are over 3 feet high. To minimize damage to longleaf pine seedlings, cool prescribed burns at this stage of development should occur during the winter months. When the trees are taller than 10 to 15 feet, low-intensity burns could be prescribed in other seasons, assuming that fuel loads are low to moderate.

Using prescribed fire in the larger openings could be difficult in some cases. One of the primary fuels for prescribed fire is pine needles. Needle fall from surrounding trees may drop off significantly towards the center of the gaps. Depending on the type of understory vegetation, this could result in fire not carrying well across the opening (Mitchell et al. 2006). In these instances, chemical control of competing vegetation may be required.

The group selection system as described above would also have the same potential for landowners interested in converting loblolly or slash pine stands (natural or artificially regenerated) to longleaf pine (Franklin 2009; Hu, Knapp, Wang, et. al 2016). For example, rather than harvesting a mature slash pine stand all at one time and regenerating it to longleaf pine, a more gradual species conversion process could be prescribed using the group selection method in conjunction with planting longleaf pine in the group openings. An advantage of this approach would be that portions of the mature overstory canopy would remain intact, thereby supporting other ecosystem benefits and services (e.g., mature stand structure attributes, aesthetics, wildlife habitat, understory community (Kirkman, Mitchell, Kaeser, et. al 2007), while also providing needle cast for fuel to carry prescribed fire through the area (Jack, Hiers, Mitchell, et. al 2010).

Disadvantages

There are many advantages associated with using the group selection system with longleaf pine. There are, however, a few potential problems with the system. While the group selection system has shown early success in regenerating longleaf pine in several experimental trials, its long-term suitability remains to be tested. The implementation of a group selection system is more complicated compared to a simple clearcut operation. Since only small portions of the stand are cut during a logging operation, the cost of logging could be higher and the likelihood that residual trees could be damaged is increased. Potential decreases in yields due to increased competition between overstory and understory trees, as well as decreased volume production from periodic prescribed burning are possible (Matthews 1989), which may make this method less productive than even-aged management systems. Therefore, landowners primarily interested in commodity production may find this management approach less appealing than even-aged systems (McGuire, Mitchell, Moser, et al. 2001).

Conclusion

The group selection silvicultural system represents an uneven-aged management strategy useful for longleaf pine. Although traditional even-aged management systems will continue to be used with this species, the group selection system offers many additional potential advantages, including periodic income from high-quality sawtimber, continuous presence of large trees on site, diverse wildlife habitat, soil and watershed protection, and high aesthetic and recreation values. The stands created using this system are based on sound biological principles, and they can be used to develop diversity in forest structure at the stand and landscape level. Along with the use of prescribed fire, these diverse strands of trees help restore a native ecosystem that once dominated much of the southeastern United States.

Non-industrial private landowners interested in managing their forestland using the group-selection approach are encouraged to consult with a professional forester. The forester can facilitate implementation of these guidelines by evaluating the site, estimating current timber volumes, drafting a timber sale contract, and assisting with regeneration efforts. They will also be able to evaluate landowner opportunities for federal cost share assistance programs for non-industrial forest landowners. Additional information on forest management, including incentives programs can be found on the University of Florida Forestry Information website at https://programs.ifas.ufl.edu/florida-land-steward/.

Literature Cited

Ashton, P. M. S. and M. J. Kelty. 2018. *The Practice of Silviculture: Applied Forest Ecology*. John Wiley & Sons, Inc. New York.

Barnett, J. P., and J. B. Baker. 1991. "Regeneration Methods." In *Forest Regeneration Manual*, edited by M. L. Duryea and P. M. Dougherty. Kluwer Academic Publishers, The Netherlands.

Barnett, J. P., and R. W. Dennington. 1992. "Return to Longleaf." *Forest Farmer* 52:11–12.

Barnett, J. P., D. K. Lauer, and J. C. Brissette. 1989. "Regenerating Longleaf Pine with Artificial Methods." In Proceedings of the Symposium on the Management of Longleaf Pine. U.S. For. Ser. Gen.Tech. Rep. SO-75.

Boyer, W. D. 1984. "First-Year Survival of Planted Longleaf Pine Bare-Root and Containerized Stock as Affected by Site Preparation and Release." In Proceedings of the Third Biennial Southern Silvicultural Conference. U.S. For. Ser. Gen.Tech. Rep. SO-54.

Boyer, W. D. 1988. "Effects of Site Preparation and Release on the Survival and Growth of Planted Bare-Root and Container-Grown Longleaf Pine." Georgia For. Res. Pap. No. 76.

Boyer, W. D. 1990. "Longleaf Pine." In *Silvics of North AmericaVolume I: Conifers*, edited by R. M. Burns and B. H. Honkala. U.S. For. Ser. Ag. Handbook 654.

Boyer, W. D. 1993. "Long Term Development of Regeneration under Longleaf Pine Seedtree and Shelterwood Stands." *Southern Journal of Applied Forestry* 17:10–15.

Brockway, D. G., and K. W. Outcalt. 1998. "Gap-Phase Regeneration in Longleaf Pine Wiregrass Ecosystems." *Forest Ecology and Management* 106:125–139.

Brockway, D. G., and K. W. Outcalt. 2000. "Restoring Longleaf Pine Wiregrass Ecosystems: Hexazinone Application Enhances Effects of Prescribed Fire." *Forest Ecology and Management* 137:121–138.

Brockway, D. G., and K. W. Outcalt. 2017. "Influence of Reproduction Cutting Methods on Structure, Growth and Regeneration of Longleaf Pine Forests in Flatwoods and Uplands." *Forest Ecology and Management* 389:249–259.

Brown, M. J., and J. Nowak. 2013. Florida, 2011—Forest inventory and analysis fact sheet. E-Science update SRS-071, Asheville, NC: US Department of Agriculture Forest Service, Southern Research Station. 5 p.

Butler, B. J., J. H. Hewes, B. J. Dickinson, K. Andrejczyk, S. M. Butler, and M. Markowski-Lindsay. 2016. "Family Forest Ownerships of the United States, 2013: Findings from the USDA Forest Service's National Woodland Owner Survey." *Journal of Forestry* 114 (6): 638–647, https://doi.org/10.5849/jof.15-099

Croker, T. C., Jr. 1979. "Longleaf Pine: The Longleaf Pine Story." *Journal of Forest History* 23:32–43.

Croker, T. C., Jr. and W. D. Boyer. 1976. Regenerating Longleaf Pine Naturally. U.S. For. Ser. Res. Pap. SO-105.

Demers, C., A. Long, and P. Minogue. 2011. "Longleaf Pine Regeneration." *EDIS* 2011 (1). https://journals.flvc.org/edis/article/view/118867

Dennington, R. W. 1990. "Regenerating Longleaf Pine with the Shelterwood Method." U.S. For. Ser. Mgmt. Bull. R8-MB 47.

Dennington, R. W., and R. M. Farrar Jr. 1983. "Longleaf Pine Management." U.S. For. Ser. For. Rep. R8-FR3.

Duryea, M. 1998 (Revised). Planting Southern Pines. Circular 767. 14p. Gainesville: University of Florida Institute of Food and Agricultural Sciences.

Duryea, M. L. 2000. Forest Regeneration Methods: Natural Regeneration, Direct Seeding and Planting. Circular 759. 13p. Gainesville: University of Florida Institute of Food and Agricultural Sciences.

Dyson, D. S., and D. G. Brockway. 2015. Intensive Longleaf Pine Management for Hurricane Recovery: Fourth-Year Results." In *Holley, A. Gordon; Connor, Kristina F.; Haywood, James D., eds. Proceedings of the 17th biennial southern silvicultural research conference. e–Gen. Tech. Rep. SRS–203, Asheville, NC: US Department of Agriculture, Forest Service, Southern Research Station: 447–454.* (Vol. 2015, pp. 447–454).

Farrar, R. M. Jr. 1996. "Fundamentals of Uneven-Aged Management in Southern Pine." Edited by W. K. Moser and L. A. Brennan. TTRS Misc. Pub. No 9.

Farrar, R. M. Jr., and W. D. Boyer. 1991. "Managing Longleaf Pine under the Selection System: Promises and Problems." In Proceedings of the Sixth Biennial Southern Silvicultural Research Conference. U.S. For. Ser. Gen. Tech. Rep. SE-70.

FDACS. 2017. Florida Longleaf Pine Ecosystem Geodatabase. https://www.fdacs.gov/Forest-Wildfire/Our-Forests/The-Florida-Longleaf-Pine-Ecosystem-Geodatabase

FDACS. 2021. Tree Seedlings for Sale/Pricing-for-Tree-Seedlings. https://www.fdacs.gov/Forest-Wildfire/For-Landowners/Programs-for-Landowners/Tree-Seedlings-for-Sale/Pricing-for-Tree-Seedlings

Franklin, R. 2009. "Converting Planted Loblolly Pine (or Slash Pine) to Longleaf Pine: An Opportunity." Clemson Extension Forestry Leaflet 31. 5 p. https://americaslongleaf.org/media/qcbfus0q/converting_loblolly_to_longleaf.pdf

Gagnon, J. L, E. J. Jokela, W. K. Moser, and D. A. Huber. 2003. "Dynamics of Artificial Regeneration in Gaps within a Longleaf Pine Flatwoods Ecosystem." *Forest Ecology and Management* 172:133–144.

Grace, S. L., and W. J. Platt. 1995. "Effects of Adult Tree Density and Fire on the Demography of Pregrass Stage Juvenile Longleaf Pine (*Pinus palustris* Mill.)." *Journal of Ecology* 83:75–86.

Haywood, J. D., and H. E. Grelen. 2000. "Twenty Years of Prescribed Burning Influence the Development of Direct-Seeded Longleaf Pine on a Wet Pine Site in Louisiana." *Southern Journal of Applied Forestry* 24:86–92.

Hu, H., B. O. Knapp, G. G. Wang, and J. L. Walker. 2016. "Silvicultural Treatments for Converting Loblolly Pine to Longleaf Pine Dominance: Effects on Ground Layer and Mid-Story Vegetation." *Applied Vegetation Science* 19:280–290. doi:10.1111/ avsc.12217

Jack, S. B., J. K. Hiers, R. J. Mitchell, and J. L. Gagnon. 2010. "Fuel Loading and Fire Intensity Effects on Longleaf Pine Seedling Survival." In Proceedings of the 14th Biennial Southern Silvicultural Research Conference, edited by J. A. Stanturf. pp. 275–279. USDA Forest Service, Southern Research Station [General Technical Report SRS-121], Asheville, NC, US.

Jose, S., E. J. Jokela, and D. L. Miller. 2006. *The Longleaf Pine Ecosystem – Ecology, Silviculture and Restoration*. Springer. 438 p.

Kirkman, L. K., R. J. Mitchell, M. J. Kaeser, S. D. Pecot, and K. L. Coffey. 2007. "The Perpetual Forest: Using Undesirable Species to Bridge Restoration." *Journal of Applied Ecology* 44:604–614.

Landers, J. L., D. H. Van Lear, and W. D. Boyer. 1995. "The Longleaf Pine Forests of the Southeast: Requiem or Renaissance?" *Journal of Forestry* 93:39–44.

McGuire, J. P., R. J. Mitchell, B. E. Moser, S. D. Pecot, D. H. Gjerstad, and C. W. Hedman. 2001. Gaps in a Gappy Forest: Plant Resources, Longleaf Pine Regeneration, and Understory Response to Tree Removal in Longleaf Pine Savannas." *Canadian Journal of Forest Research* 31:765–778.

Marquis, D. A. 1978. "Application of Uneven-Aged Silviculture and Management on Public and Private Lands." In "Uneven-aged Silviculture and Management in the United States." U.S. For. Ser. Timber Mgmt. Rsh. Washington D.C.

Matthews, J. D. 1989. *Silvicultural Systems*. Clarendon press, Oxford. 284 p.

Mitchell, R. J., J. K. Heirs, J. J. O'Brien, S. B. Jack, and R. T. Engstrom. 2006. "Silviculture that Sustains: The Nexus between Silviculture, Frequent Prescribed Fires, and Conservation of Biodiversity in Longleaf Pine Forests of the Southeastern United States." *Canadian Journal of Forest Research* 36:2713–2723.

Outcalt, K. W., and P. A. Outcalt. 1994. "Longleaf Pine: An Assessment of Current Conditions." (Unpublished)

Paudyal, R., T. V. Stein, H. K. Ober, M. E. Swisher, E. J. Jokela, and D. C. Adams. 2018. "Recreationists' Perceptions of Scenic Beauty and Satisfaction at a Public Forest Managed for Endangered Wildlife." *Forests*. 9:241.

Platt, W. J., and S. L. Rathbun. 1993. "Dynamics of an Old-Growth Longleaf Pine Population. In Proceedings of the 18th Tall Timbers Fire Ecology Conference, edited by Hermann, S.M. (ed). TTRS.

Schmidtling, R. C.1986. "Relative Performance of Longleaf Compared to Loblolly and Slash Pines under Different Levels of Intensive Culture." In Proceedings of the Fourth Biennial Southern Silvicultural Research Conference. U.S. For. Ser. Gen. Tech. Rep. SE-42.

Schmidtling, R. C., and T. L White. 1989. "Genetics and Tree Improvement of Longleaf Pine." In Proceedings of the Symposium on the Management of Longleaf Pine. U.S. For. Ser. Gen. Tech. Rep. SO-75.

South, D. B. 2006. "Planting Longleaf Pine at Wide Spacings." *Nature Plants*. 7:79–88.

Shoulders, E. 1985. The Case for Planting Longleaf Pine." In Proceedings of the Third Biennial Southern Silvicultural Research Conference. U.S. For. Ser. Gen. Tech. Rep. SO-54.

U.S. Forest Service. 1929. "Volume, Yield, and Stand Tables for Second-Growth Southern Pines." U.S. For. Ser. Misc. Pub. No 50.

U.S. Forest Service. 1999. Final EIS for the Revised Land and Resource Management Plan for National Forests in Florida. U.S. For. Ser. Mgmt. Bull. R8-MB-83B.

Wahlenberg, W. G. 1946. *Longleaf Pine. Its Use, Ecology, Regeneration, Protection, Growth and Management*. Charles Lathrop Pack Forestry Foundation. Washington D.C. 429p.

White, T. L., M. L. Duryea, and G. L. Powell. 2018. "Genetically Improved Pines for Reforesting Florida's Timberlands." *EDIS* 2018 (1):6 https://doi.org/10.32473/edis-fr007-2017

Table 1. Biological characteristics of longleaf pine important in developing a management plan. (Adapted from Barnett and Dennington; Boyer 1990; Boyer 1993; Croker 1979; Demers and Long 2000; Wahlenberg 1946).

Climate	Temperature: 60–70°F hot summers/mild winters
	Rainfall: 43–69" annually
Soils	Sandy, acidic, low organic matter—Ultisols, Entisols, Spodosols
	Wet, poorly drained sites to dry, rocky mountain ridges
Seed production	Heavy seed crops (50 to 60 seeds/cone) every 5 to 7 years
Cone production	Maximized in stands with approximately 30 ft2/acre basal area
	Dominant and codominant trees with diameters at breast height > 10"
Seedfall	Late October through early November
Seeds	4200 clean seeds/lb, winged
Dispersal	Wind, maximum distance 120'
Seedbed requirement	Bare mineral soil, low competition. Prescribed fire within one year of planting/seedfall
Germination	One week after reaching bare mineral soil
Growth	Stemless grass stage lasting 2 to many years; intolerant of competition and shade; growth comparable to slash pine and loblolly pine on cultivated and fertilized sites
Pests	Brown-spot needle blight, seed predators, grazing animals, and feral hogs
Fire	Resistant, except during early height growth