SPATIAL ANALYSIS OF LONGLEAF PINE STAND DYNAMICS AFTER 60 YEARS OF MANAGEMENT

John C. Gilbert, John S. Kush, and Rebecca J. Barlow

ABSTRACT

There are still many questions and misconceptions about the stand dynamics of naturally-regenerated longleaf pine (*Pinus palustris* Mill.). Since 1948, the "Farm Forty," a forty-acre tract located on the USDA Forest Service Escambia Experimental Forest near Brewton, Alabama, has been managed to create high quality wood products, to successfully promote natural regeneration, and to minimize management costs. Management consists of periodic inventories, prescribed fire, and harvests, which have created an uneven-aged stand structure with a range of age classes. A GIS database was created by stem-mapping all pines greater than or equal to 3.1 inches dbh (diameter at breast height). This database contains information for over 5,000 trees and provides a unique opportunity to explore longleaf pine stand dynamics spatially. The variations in densities and size classes across the tract will be evaluated to provide information about how longleaf pine grows and the dynamics of long-term management.

INTRODUCTION

There are still many unanswered questions and misconceptions about the dynamics of naturally-regenerated, even-aged stands and uneven-aged management of longleaf pine (*Pinus palustris* Mill.). The longleaf pine ecosystem that once dominated the southern landscape has been decimated to small isolated patches scattered across the southeastern United States. Today, there is a growing interest in restoring functional longleaf pine ecosystems. Focusing on education and outreach opportunities for small-scale private landowners, who own a majority of the land and longleaf pine in the Southeast, is essential to the success of this movement (Miles 2009). Frequent fire and natural regeneration have sustained longleaf pine and are what perpetuated the climax forest across the landscape (Chapman 1932). More information about long term longleaf pine management and associated stand dynamics is essential for providing more opportunities and encouragement to landowners to not only restore longleaf pine but more importantly to maintain sustainable longleaf pine stands into the future.

To better understand longleaf pine stand dynamics and learn more about long-term management of longleaf pine, the "Farm Forty" was selected for study. The "Farm Forty" is a forty-acre tract located on the Escambia Experimental Forest, owned by T.R. Miller Mill Co. and managed by the U.S. Forest Service, near Brewton, Alabama. The "Forty" was established in 1948 as a demonstration area for the small private forest landowner (Boyer and Farrar 1981).

The preliminary inventory in 1947, outlined by Boyer and Farrar (1981) showed the stand was an under stocked second-growth longleaf pine forest averaging 35 to 40 years old, with 31 acres of longleaf pine and 9 acres of slash pine (*Pinus elliottii* L.). The management objectives for the tract were to create high quality wood products, to successfully promote natural regeneration, and to minimize management costs. Initially, the Forty was going to be managed with the goal of a 60 year rotation (Boyer and Farrar 1981). However, when the Forest Service moved to 120 year rotations for longleaf pine on their properties, the rotation for the Forty was extended (Barlow and others 2011). The site has been inventoried periodically with the management consisting of periodic harvests and prescribed burning. The results of the first 30 years of management and demonstration on the Farm 40 were reported by Boyer and Farrar (1981), and Barlow and others (2011) reported on the last 30 years, as well as summarizing the first 60 years.

Periodic harvests provided opportunities for regular income and to make stand improvements by removing lower quality trees and leaving higher quality trees. These thinnings were strategically planned to remove less growth and to create small gaps, which promoted natural regeneration for new age classes using the shelterwood method (Boyer and Farrar 1981). The shelterwood method, which consisted of selecting an area with potential cone-bearing longleaf pine trees, thinning this area to 30 square feet per acre of basal area, and then removing the overstory when a satisfactory amount of regeneration was present (Croker

John C. Gilbert, Research Associate, Longleaf Pine Stand Dynamics Laboratory, School of Forestry & Wildlife Sciences, Auburn University, AL 36849
John S. Kush, Research Fellow, Longleaf Pine Stand Dynamics Laboratory, School of Forestry & Wildlife Sciences
Rebecca J. Barlow, Assistant Professor and Extension Specialist, School of Forestry & Wildlife Sciences and Alabama Cooperative Extension Service

and Boyer 1975). Periodic prescribed burning every 2 to 3 years and switching from the dormant to the growing season has maintained the site and prepared the seedbed for regeneration (Boyer and Farrar 1981, Barlow and others 2011). The combination of periodic harvests using this regeneration method, periodic prescribed burning, and extending the rotation has created a sustainable uneven-aged stand structure on the Forty with a range of age classes including seedlings to trees over 100 years old (Barlow and others 2011). It is a living demonstration for what a small scale private landowner can do with 40 acres and has been showcased during field days, which were often annual during the first 30 years, where products from the harvest were displayed for visitors to see in context to the residual stand (Croker 1987). With over 60 years of extensive management records and demonstrations to private landowners, the Forty provides a unique opportunity to utilize spatial technology to better understand longleaf pine stand dynamics and the effects of long-term management. Opportunities through spatial analyses offer the ability to take an in-depth look at species and size distributions, regeneration potential, current gap dynamics, and future harvest locations across the Forty.

METHODS

To evaluate the current stand dynamics of the Forty after 60 years of management, a GIS (geographical information system) database was created. ESRI's ArcGIS 9.3.1 was used for all of the spatial data creation and analysis. The first steps in creating the database were to compile information and create layers for past inventories, harvests, and prescribed burning records. An existing stand map created by Boyer in 1977 was also digitized and added as spatial layers. GPS (Global Positing System) coordinates were collected for the Forty's corners, roads, and streams. These layers were then used to update the stand map from 1977 and to see how the Forty has changed over the past 30 years. To complete a detailed spatial analysis of the stand, all pines greater than or equal to 3.6 inches dbh (diameter at breast height) were stem-mapped. The stem-mapping was completed by setting strategic points across the Forty and recording sub-meter GPS locations for each point. A survey laser was setup at each point and used to calculate the azimuth and distance from the points to the surrounding trees while a dbh and species was also being recorded for each tree. The coordinates for each tree were calculated, and a tree layer shapefile was created for all of the trees. A soils layer, aerial photograph, and topographic maps were also clipped to the boundary of the Forty and added to the database.

With the tree layer, a spatial analysis looking at tree size and species distributions could be completed. The next step was to evaluate the regeneration potential for longleaf pine. For adequate natural regeneration across the site using the shelterwood method, there needs to be at least 30 square feet per acre of productive longleaf pine seed trees scattered evenly across the site, which are generally 30 years old or greater and 10 inches dbh and greater (Croker and Boyer 1975). This is very important considering the short seed dispersal range of longleaf pine. About 71 percent of longleaf pine seed falls within 66 feet of the parent tree with a maximum distance of 100 feet (Boyer 1963, Croker and Boyer 1975). To evaluate the potential for longleaf pine regeneration by looking at possible seed dispersal patterns, a layer was added by creating multiple ring buffers of 66 feet and 100 feet around all longleaf pines 10 inches dbh and greater. The seed production of longleaf pine generally increases until the trees are 15 inches dbh (Croker and Boyer 1975). An additional layer was created by adding the 66 and 100 feet buffers around longleaf pines 14 inches dbh and greater because these are the trees often left by managers as the parent trees. The areas outside of the buffers were evaluated by overlaying the tree layer to see what size trees and species were present. These layers provided information about regeneration potential for longleaf pine by looking at possible seed dispersal patterns, but density information is also needed to evaluate the potential for future harvests and natural regeneration using the shelterwood method.

The 1977 stand map differentiated the age classes and species mix across the Forty. The Forty was plotted on graph paper on a 20 by 20 grid where each square represented 0.1 acre. Since harvests generally created small gaps on the Forty and were often single tree or group selection, the next step was to create spatial layers to divide the Forty into 0.1, 0.4, and 1.6 acre units. A layer was created to divide the Forty on a 20 by 20 grid of 0.1 acres per unit for 400 units representing a gap removing possibly only one tree or more trees. For a small group selection where a few trees might be harvested, a layer was created for a 10 by 10 grid of 0.4 acres per unit for 100 units. Creating a layer for a 5 by 5 grid of 1.6 acres per unit with 25 units represents a larger gap where numerous trees might be removed. The tree layer was then clipped to each of these layers, and trees per acre and basal area per acre were calculated for all pines, longleaf pine, and potential cone-bearing longleaf pine in each unit. Using the criteria from Croker and Boyer (1975), basal area per acre values were classified by regeneration potential into categories of less than 30, 30 to 45, 45 to 80, and greater than 80 square feet per acre. Trees per acre values were calculated and used to identify areas where high basal area values were the result of many small trees or a few large trees. Side-by-side comparisons could then be made for all pines, longleaf pine, and potential cone-bearing pines for each of the grid patterns representing various harvest sizes. Roads, streams, and tree locations by size and species were

added to the layouts for more information to aid decision making. The comparisons could be used to evaluate the locations of existing gaps and identify potential areas for harvests and natural regeneration using the shelterwood method by looking at basal area, trees per acre, species, and the location and size of trees across the Forty.

RESULTS AND DISCUSSION

A total of 5,197 trees were stem-mapped on the Forty. Longleaf pine accounted for 89 percent or 4629 trees. Average dbh of the longleaf pine was 7.8 inches and with a maximum of 22.3 inches. Other pines represented 11 percent including 555 slash pines and 13 loblolly pines (*Pinus taeda* L.). The average dbh for slash pine was 13.5 inches with a maximum of 29.5 inches. The average dbh for loblolly pine was 12.4 inches with a maximum of 28.2 inches. The stem-map shows that the site is predominantly longleaf pine, with scattered loblolly pine and slash pine dominating the northeast corner of the Forty. The stem-map also shows that slash pine is intermixed with longleaf across the eastern side of the Forty. Since the stem-map shows the location of all pines on the Forty within the specified criteria, it provides opportunities to plan future harvests to provide periodic income and to promote natural regeneration, while monitoring areas down to the individual species.

Using buffers around potential cone-bearing longleaf pine to look at the regeneration potential for the Forty, gaps in the potential seed dispersal distances were mainly in the areas around the slash pine documented in 1977 and in regeneration areas where recent overstory removal cuts were completed and the regeneration had not reached 3.6 inches dbh. Areas around the stream and in the north portion of the Forty were also highlighted as potential regeneration problems, which were impacted by Hurricane Ivan (Barlow and others 2011). Longleaf pines smaller than the stem-map criteria were located near or in these areas and may provide a seed source in the future, but close monitoring and evaluation is needed in these areas in the future. These results show the success and sustainability of past management on the Forty, with opportunities to continue managing longleaf pine into the future. To start identifying areas with suitable parent trees for future harvests, layers showing buffers around longleaf pine 14 inches dbh and greater were also used. Areas where these buffers overlap provide a starting point, but the areas need to be classified using the basal area recommendations for the shelterwood method.

The 0.1, 0.4, and 1.6 acre grids were used to show densities for all pines, longleaf pines, and potential cone-bearing trees, where basal area values were used to identify areas of interest for thinnings to promote longleaf pine natural regeneration. Comparing basal area values for all pines to longleaf pine for each grid showed that slash pines were inflating the basal areas along the eastern side of the Forty. The trees per acre calculations also showed areas where basal areas were high due to large amounts of small trees in the older regeneration areas and due to areas with clusters of large trees. These layers can be helpful when looking at the Forty as a whole and when trying to understand the stand dynamics down to size and species level, but using these layers alone to make management decisions for longleaf pine natural regeneration can provide unrealistic estimates and cause regeneration failures. The basal area calculations for potential cone-bearing longleaf pine provided better estimates for future harvests when looking at single tree, small group, and large group selections.

When the Forty was divided by the 1.6 acre grid for large group selections, there were 20.8 acres in the less than 30 square feet per acre class, 9.6 acres in the 30 to 45 square feet per acre class, and 9.6 acres in the 45 to 80 square feet per acre class. There were no units where basal area was greater than the 80 square feet per acre class. After removing the areas dominated by slash pine and that were damaged by Hurricane Ivan, the units with less than 30 square feet of basal area were mainly areas that had already been naturally regenerated and contained trees less than the stem-map criteria. The next step was to look for opportunities for small group selections and single tree selections. Using the 0.4 acre grid for small group selections, there were 21.6 acres in the less than 30 feet square feet class, 10.4 acres in the 30 to 45 square feet per acre class, 6.4 acres in the 45 to 80 square feet per acre class, and 1.6 acres in the greater than 80 square feet per acre class. When using the 0.1 acre grids to look at single tree selections, 22.4 acres were in the less than 30 feet square feet class, 7.2 acres in the 30 to 45 square feet per acre class, 7.1 acres in the 45 to 80 square feet per acre class, and 3.3 acres in the greater than 80 square feet per acre class. The layers for small group and single tree selection thinnings provide a better look at how longleaf pine grows by highlighting areas supporting over 150 square feet per acre that could be missed by focusing on a larger area. Some areas had three 14 inch dbh longleaf pines in a 0.1 acre unit, and there was a maximum basal area of 137.4 square feet per acre on a 0.1 acre gap.

There are opportunities across the Forty for numerous large group, small group, and single trees selection thinnings with even more opportunities for various combinations. Comparing all three grid layers provides more information about longleaf pine stand dynamics by looking at the variations in density across the Forty. In an uneven aged stand like the Forty, basal areas and trees per acre values need to be used with caution because of dense clusters and large diameter trees to prevent future regeneration failures

from management decisions. Isolated patches of longleaf pine without 30 feet square feet of basal area should be checked for adequate regeneration and closely monitored in the future. Using all tree grid layers and adding the tree layers showing size classes and species can help provide more accurate information for decision making. These thinning opportunities can be strategically planned to continue providing regular income and to promote natural regeneration, as managers have done in the past.

CONCLUSIONS

The results of the GIS database for the Forty reinforce that this type of management with longleaf pine can be successful for a private landowner with 40 acres. It has the benefits of providing periodic income with low management costs, sustainability, opportunities for multiple use management, and requires strategic planning for harvests. The Forty has been managed for over 60 years with over 20 periodic harvests, including annual harvests for field days (Boyer and Farrar 1981, Barlow and others 2011). The stem-map and evaluations of the Forty show what the managers have been doing on the ground is successful and sustainable. This effort provides scalable management techniques that can be applied to larger landscapes or smaller stands. It requires visiting the stand, looking for regeneration, thinning carefully, and strategically planning harvests.

The data reminds users to use basal area and trees per acre with care when managing. Large trees can skew these numbers that can create unrealistic management activities on the ground that can result in regeneration failure for longleaf pine. The database and layouts can be utilized for future management by providing a type of decision support tool for future harvests, regeneration areas, and monitoring. The stem-map can also be used in future marking during harvests to target the slash and loblolly pine and continue to promote longleaf pine regeneration in these areas. It will be important to update the database over time. As the 5-year inventories are completed, the stem-map and database can be updated. Adding more detailed information about age distributions and regeneration would also be very beneficial to the database and spatial analysis of the Forty.

Since stem-mapping 40 acres is not an option for most landowners and land managers, the database and associated maps can also serve as education and extension tools showing the benefits and success of long-term management of longleaf pine for private forest landowners, researchers, and conservation professionals. The Forty and the layouts provide visual examples for small-scale private landowners showing longleaf pine management options, stand dynamics, and the benefits of natural regeneration. In 2009, the 60th anniversary of the Farm 40 was celebrated with a highly successful forestry field day for landowners and forestry professionals. It was also featured in a Gold Award winning video titled *60 years on the Farm 40: Longleaf pine management for the private landowner*. The Farm Forty will continue to be a living demonstration and provide small-scale private landowners with ideas for successful opportunities with longleaf pine on their properties.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Tom Croker, Jr., Dr. William Boyer, and Dr. Robert Farrar, Jr., for their work on the Farm 40, the USDA Forest Service, Ron Tucker and David Dyson, Lee Roper, Jonathan Copeland, Michael Dillon, David Walker, and Mark Caldwell, Jim Elledge and Longleaf Consultants, LLC for all of their assistance with data collection, and TR Miller Mill Company for leasing the land.

LITERATURE CITED

Barlow, R.J., J.S. Kush, and W.D. Boyer. 2011. Sixty years of management on a small longleaf pine forest. Southern Journal of Applied Forestry. 35(1): 50-53.

Boyer, W.D. 1963. Longleaf pine seed dispersal. US For. Serv. Res. Note SO-3. US For. Serv., Southern For. Exp. Stn. 2 p.

Boyer, W.D. and R.M. Farrar, Jr. 1981. Thirty years of management on a small longleaf pine forest. Southern Journal of Applied Forestry. 5(2):73-77.

Chapman, H.H. 1932. Is the longleaf type a climax? Ecology 13: 328-334.

Croker, T.C., Jr. 1987. Longleaf pine: a history of man and a forest. USDA Forest Service Forestry Report R8-FR 7. US Forest Service: Atlanta, GA. 37 p.

Croker, T.C., Jr. and W.D. Boyer. 1975. Regenerating longleaf pine naturally. US For. Serv. Res. Pap. SO-105. US For. Serv., Southern For. Exp. Stn. 26 p.

Miles, P.D. Sep-26-2009. Forest inventory mapmaker web-application version 4.0. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. [Available only on internet: www.ncrs2.fs.fed.us/4801/fiadb/index.htm]