Overcoming the Littleleaf Myth: Establishing a Shortleaf Pine Silvopasture on Redstone Arsenal

by

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Masters of Science in Forestry

Auburn, Alabama
August 4, 2012

Keywords: Agroforestry, Silvopasture, and Shortleaf Suitability

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Abstract

This study examines the potential for implementing agroforestry practices, subject to soil suitability parameters, relating to the establishment and long-term management of shortleaf pine (*Pinus echinata* Mill.*)* on Redstone Arsenal (RSA). Given the fact that shortleaf pine once had a significant presence in the north Alabama area, and that efforts are being made to reintroduce it in other areas of Alabama, following studies to determine the viability and suitability for such an undertaking, this project was motivated by an obvious need to fill the knowledge gap, relative to evaluating possibilities for its reintroduction as an integral component of an agroforestry system. A number of factors that are directly related to making such a determination will be addressed in this paper. These include the feasibility of an agroforestry management style, soil suitability, and economic, environmental, and ecological issues. The Arsenal provides an ideal site for such a research project, because of a commitment to assuring that the land is managed for timber, wildlife, water quality, recreation, preservation of existing cultural resources, and where possible, the restoration of those resources that have been depleted.

Acknowledgments

First, I would like to thank my Lord and Savior, Jesus Christ, for providing me with this opportunity. Also, I offer my sincere appreciation to Dr. Rebecca Barlow, my major professor, to Dr. Kathyrn Flynn, my co-major professor, and to Dr. John Kush, and Dr. Luben Dimov for serving as committee members. Their constant support and encouragement throughout my graduate career is greatly appreciated.

Special thanks go to Dr. Barlow for recognizing the need for this research, charting a new course, and for assisting with initiating the project. I am also grateful to Redstone Arsenal for allowing the research to be conducted on this site. Thanks to my co-workers, for their support during data collection and the initial implementation of this project. A special thanks goes to Matt Kachelman, who was always there to assist me in the map-making portion of this project.

Thank you to my parents, who instilled in me at an early age the importance of perseverance and hard work, and for supporting me throughout this process.

And finally, but certainly not least, to the loves of my life, my wife, Amanda, and children, Reese and John Luke, who allowed me to spend many late nights and weekends working toward the completion of this project. I cannot adequately express what their unwavering love and support mean to me, and to them, I offer my greatest thanks.

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Chapter 1

Introduction

Redstone Arsenal (RSA), located in Madison County, Alabama, and occupying approximately 38,100 acres, had its beginning in 1942, during World War II. It was originally called the Redstone Ordnance Plant and was constructed to supplement manufacturing and production at the nation's only chemical manufacturing plant, located at Edgewood Arsenal, Maryland. The name of the Redstone Ordnance Plant was changed to Redstone Arsenal in 1943. The term “Redstone”, according to Cagle (1961), was chosen because of the presence of red rocks and the soil coloration in this section of northern Alabama. In 1949, the neighboring Huntsville Arsenal was combined with Redstone Arsenal.

The land that the Army acquired to form Huntsville Arsenal and Redstone Ordnance Plant was comprised of rolling terrain, which contained some of the more fertile agricultural land in Madison County. Archaeological evidence suggests that this part of the Tennessee Valley was first inhabited over 2,000 years ago by a prehistoric Indian culture. Cotton, corn, hay, peanuts, livestock, and an array of fruits and vegetables were the main agricultural products cultivated by the inhabitants of this area during the early 1940's.

The soils of Redstone Arsenal reflect the fact that at one time cultivation was done with little regard to conservation practices. Most arable soils with slopes greater than 2% are eroded, and some areas are gullied. Although the amount of intensive row-cropping has been limited since the founding of the Arsenal, major soil disturbances required for construction and waste disposal are prevalent on large areas.

As part of an intensive natural resource management focus, Redstone Arsenal has an active forest management program, agriculture leases (including grazing and hay), and a wildlife management program. These efforts are geared to provide an innovative approach to practices that will ensure optimal use and preservation of resources. Redstone Arsenal's timberlands are characterized by diversity, with pine (both loblolly and shortleaf) covering 4,978 acres, hardwoods (both the red oak and white oak groups) covering approximately 6,601 acres, and mixed stands of eastern redcedar, hardwood, and pine covering 4,978 acres.

Current budget constraints necessitate that a new focus be placed on implementing management techniques that will potentially generate new revenue streams. This approach will hopefully allow for these programs to become less dependent on Army funding. As part of this effort, Redstone Arsenal has partnered with local universities for technical/research support to more closely analyze alternative management strategies such as agroforestry. The numerous benefits of these partnerships/relationships are obvious, and Redstone Arsenal is committed to promoting and fostering these alliances that can generate mutually positive outcomes for all parties involved.

Redstone Arsenal's current management approach emphasizes both sustainment, and where possible, the restoration of cultural and natural resources. In contrast to some approaches, Redstone Arsenal's focus is on an ecosystem preservation-based style.

Current practices, including select thinning, prescribed burning, and other techniques, which closely mimic the natural disturbance regime, makes the idea of shortleaf regeneration on Redstone Arsenal a viable option. This is significant, since natural/anthropogenic disturbances are largely responsible for the vitality of existing shortleaf pine stands.

Despite limitations on currently available research, there is an increasing level of interest relating to shortleaf and agroforestry in the State. At the Shortleaf Pine Conference, held in Huntsville, Alabama, in September 2011, a number of speakers addressed issues related to shortleaf pine and its future. According to many land managers, conservationists, and forest ecologists, shortleaf pine continues to decline across its natural range, and its future is uncertain. Using Forest Inventory and Analysis (FIA) data, Oswalt (2011) indicated that the greatest concentration of the species is in older, large-diameter stands and disturbance patterns, different from naturally occurring ones, plague regeneration.

As previously mentioned, shortleaf pine populations have shown a substantial decline. Of the 30.4 million total acres of pines planted in the 1990's, less than 485,000 acres were planted in shortleaf compared to 21.3 million of loblolly (South and Buckner 2003). This has been attributed to several factors including the prevalence of littleleaf disease (*Phytophtora cinnamoni*), the rapid growth of loblolly, and extensive logging or land use changes (Campbell et al. 1953; Guldin 1986; Mattoon 1915).   Littleleaf is a disease affecting mainly shortleaf pine on approximately 15 million acres across the South and Southeast. It occurs from Virginia to Mississippi, with a northward extension into Tennessee. It is believed to pose extensive problems for management in Mississippi, Georgia, Alabama, South Carolina, North Carolina, Virginia, and Tennessee (Fowells 1965). Although little can be done pertaining to land use changes, due to regulatory and land-use requirements, the "littleleaf myth" can be addressed by providing relevant information pertaining to soil suitability that minimizes the potential for the occurrence of littleleaf disease.

Because of Redstone Arsenal's commitment to resource sustainability and best management strategies, this location is ideally suited for the implementation of a research project that will incorporate shortleaf pine restoration and silvopasture into a one-site working system. This could generate much needed information that would serve to "narrow" the existing knowledge gap regarding shortleaf pine and agroforestry in Alabama. This research will not only provide non-industrial private forest landowners (NIPF) and other government officials with a view of an often under-utilized system for this area, but it will also justify a place for a declining species.

Agroforestry is a management style that combines agricultural and forestry technologies to create more diverse, productive, and sustainable land-use systems. This practice focuses on meeting a number of landowner objectives, including those which are economic, environmental, and social in nature. The emphasis is on maximizing diversity in contrast to simple crop yield. This management style can provide for a more balanced income stream than that typically generated by conventional forestry and agriculture.

Silvopasture is an agroforestry practice that is specifically designed for the production of trees, tree products, forage, and livestock as a single integrated system. This management approach combines timber and pastures to produce sawlogs, while at the same time providing forage, shelter, and shade for livestock. Such a system provides for increased biodiversity and protects water quality by acting as a buffer from agricultural practices. In addition, trees provide a deep rooting system that captures excess nutrients that have leached below the rooting zone of agronomic crops. Through root turnover and litterfall, trees recycle nutrients and place them back into the system, thus enhancing nutrient use efficiency (Allen et al. 2004).

Long-term benefits that might be derived from implementation of these alternative approaches will be carefully considered, and this is part of Redstone Arsenal's overall plan to constantly strive to seek out new and better ways to manage natural resources. This thesis will examine the potential for inclusion of shortleaf pine in an agroforesty system. An exploration of related aspects, including a better understanding of suitable soils and implementation techniques, will provide landowners with the knowledge and ability to make an informed decision regarding whether or not their property is suited for this management regime.

1. Chapter 2 presents an overview of the study location and management practices currently being conducted there. The chapter explains the benefits, needs, and potential outcomes of this research, and discusses how this information can be applied to other federal and private land-holdings.

2. Chapter 3 presents information relative to methods and criteria for determining soil suitability for both shortleaf pine production and agroforestry management. One of the major drawbacks to shortleaf pine management is the concern about littleleaf disease. In an effort to alleviate that concern, this chapter explores soil composition,

characteristics, and soil types for which shortleaf would be most tolerant and for which littleleaf would least likely occur.

3. The fourth chapter examines the benefits of an agroforestry management style and how these benefits can coincide with landowner objectives. A description of the need for additional research, relating to shortleaf pine in agroforestry, is addressed and a planting analysis describing site preparation, configuration, and the evaluative process for this research project is presented.

CHAPTER 2

Literature Review

2.1. Shortleaf Pine: A Historical Perspective

Shortleaf pine (*Pinus echinata* Mill.) is an important part of the forest landscape, providing merchantable timber products, numerous wildlife benefits, and offering the potential for landowners to incorporate it in a number of management scenarios. This species was identified and named by Philip Miller, a Scottish botanist, in 1768. Other common names for shortleaf (depending on locale) include: shortstraw pine, yellow pine, southern yellow pine, shortleaf yellow pine, Arkansas soft pine, Arkansas pine, and old field pine (Lawson and Kitchens 1983). Historically, trees commonly reached ages of 200 to 300 years and were characterized by a long, clean, straight bole with little taper and a short crown. These qualities made shortleaf highly desirable as sawtimber, and they make it an excellent choice in today's market as well. However, despite its desirable characteristics, shortleaf populations have shown a substantial decline. This has been attributed to several factors including the prevalence of littleleaf disease (*Phytophtora cinnamoni*), the rapid growth of loblolly, and extensive logging or land use changes (Campbell et al. 1953; Guldin 1986; Mattoon 1915).

Sargent (1884) notes that shortleaf was a dominant part of Alabama's landscape, representing 2.3 billion board feet of commercial quality products. Shortleaf pine has the widest range of any southern pine, and is most tolerant of a variety of sites, growing in 22 states and covering more than 440,000 square miles. Its range extends over more than 11 degrees of latitude and as late as 1915 shortleaf pine was reported to be in 24 states, including the areas of southeastern New York, New Jersey, Pennsylvania, southern Ohio, Illinois, and Missouri to eastern Oklahoma, south to northern Florida and west to northeast Texas.

In the late 1800s and early 1900s, the vast majority of virgin shortleaf stands (both pure and mixed) were harvested, which resulted in mainly understocked stands being left (Gagnon and Johnson 2009). Shortleaf's desirability as quality saw timber spurred the demand, and large areas were harvested and not regenerated. As a consequence, shade-tolerant hardwoods began to dominate and in the absence of natural disturbances to create an ideal seedbed for its germination and to control competing vegetation, shortleaf began a steady decline (Gagnon and Johnson, 2009). Over time, regeneration efforts have not improved. Of the 30.4 million total acres of pines planted in the 1990's, less than 485,000 acres were planted in shortleaf compared to 21.3 million of loblolly (South and Buckner 2003). Conversions from shortleaf stands to loblolly plantations have been made based on shorter rotations and yield characteristics of loblolly (Williston and Balmer 1980), and thereby producing negative implications for maintaining the genetic integrity of shortleaf within its native range. Hybridization between the two species has been noted west of the Mississippi, with a substantial number of cases being reported in central Arkansas (Lawson 1990; Edwards and Hamrick 1995; Raja et al. 1998; Chen et al. 2003). According to Guldin (1986), vast plantings of loblolly pine north of its native range, and often in forest operations, has had negative effects on shortleaf stocking.

Mattoon (1915) classified existing shortleaf ranges as either botanical or commercial (See Figure 1). Botanical ranges represent areas suitable for growth, whereas the commercial range represents locations of optimum production. The commercial range covers most of the botanical range except the portion that lies in the states north of Virginia and in the Ohio River Basin. Production reaches its maximum over the gently rolling and hilly country of the Mississippi Basin in northern Louisiana, most of eastern Arkansas, eastern Oklahoma, and eastern Texas (Mattoon 1915).

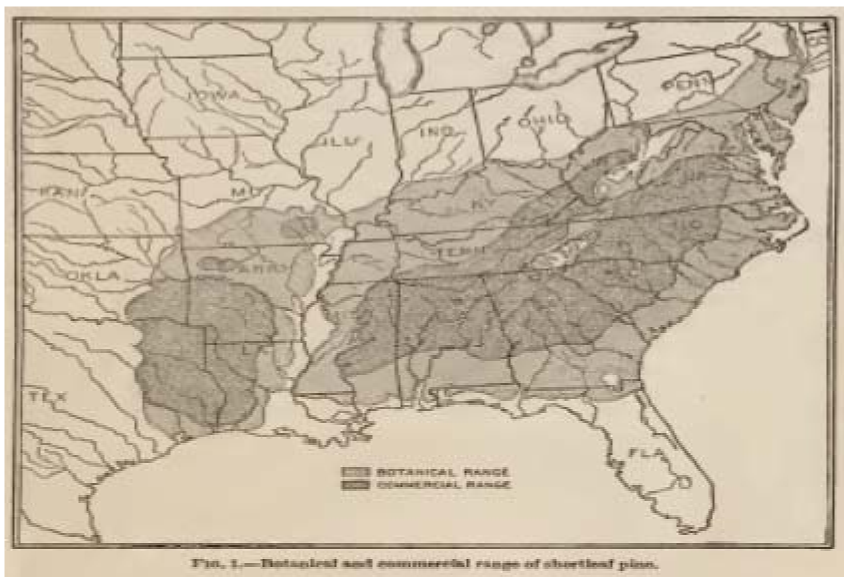

Figure 1. Native range map of shortleaf pine (Mattoon 1915)

2.2. Fire Adaptations and Frequency

Shortleaf pine is generally recognized as being a fire-adapted species (Garren 1943, Masters et al. 2003), while being termed fire resistant by others (Lawson 1990). This can be attributed to shortleaf developing a thick bark very early in the seedling and sapling stage that protects the cambium from fire injury (Guldin 1986). This trait is thought to be an adaptation to frequent low-intensity surface fires (Schwilk and Ackerly

2001). Over most of the shortleaf range, fire intervals are shorter, thus allowing the post-fire sprouting ability of the species to have an advantage over other pines and enhancing its ability to compete with hardwoods suppressed by periodic fires. The J-shaped crook, which is characteristic of the shortleaf, is formed at the base of the stem in 60 to 80 days. Axillary and other buds develop in the vicinity of the crook near the ground line, and it is these buds that sprout when the upper stem is burned or severed later in life (Stone and Stone 1954).

Shortleaf pine's adaptation to fire was a major reason for it remaining in a wide range of landscape configurations and through millennia of human landscape manipulations, prior to European alteration of land use patterns (Mann 2002). Mattoon (1915) noted a gap in the shortleaf's range in the Lower Mississippi Valley and two gaps in the Appalachian Mountains. Frost's (1998) range approximation explains the lack of shortleaf along the lower Mississippi, as he labels this region non-pyrophitic, while high elevations of the southern Appalachians and high plateaus in West Virginia are labeled as being in the 25-100-year fire cycle regimes (See Figure 2). Topography and climate combine to limit fire activity and the related limited establishment and persistence of shortleaf in these areas.

Shortleaf is one of the few pines that will sprout from the base following top-kill (Garren 1943; Fowells 1965). This adaptation has been observed in trees up to 8 years old (Mattoon 1915), and about 8 ft tall in the South (Garren 1943). Dormant buds are found along the main stem and main branches and where these latent buds receive some protection, the plant will sprout from either location even if completely defoliated by fire (Matton 1915, Little and Somes 1956). Trees developing from sprouts typically develop good form and have the ability to produce a commercial product (Mattoon 1915, Little and Somes 1956). Mattoon (1915) also notes the occasional occurrence of double-stemmed trees, which presumably resulted from stem development from two sprouts expressing equal dominance.

Mature shortleaf trees are notably resistant to mortality from crown scorch (Komarek 1981) and will survive if terminal buds are not killed even if the complete crown is scorched (Wade and Johansen 1986). The needles of shortleaf apparently do not burn as readily as other southern pines (Komarek 1981). This may be attributed to some combination of needle configuration and lower flammability. Fire, as a silvicultural tool, is used to reduce the quantity of hazardous fuel, to manage competing hardwoods and herbaceous vegetation, for wildlife habitat management, for restoration and maintenance of an ecosystem, and to perpetuate fire-dependent species such as shortleaf pine (Van Lear et al.1985; Masters 1991a; Wade 1989; Masters et al. 2003).

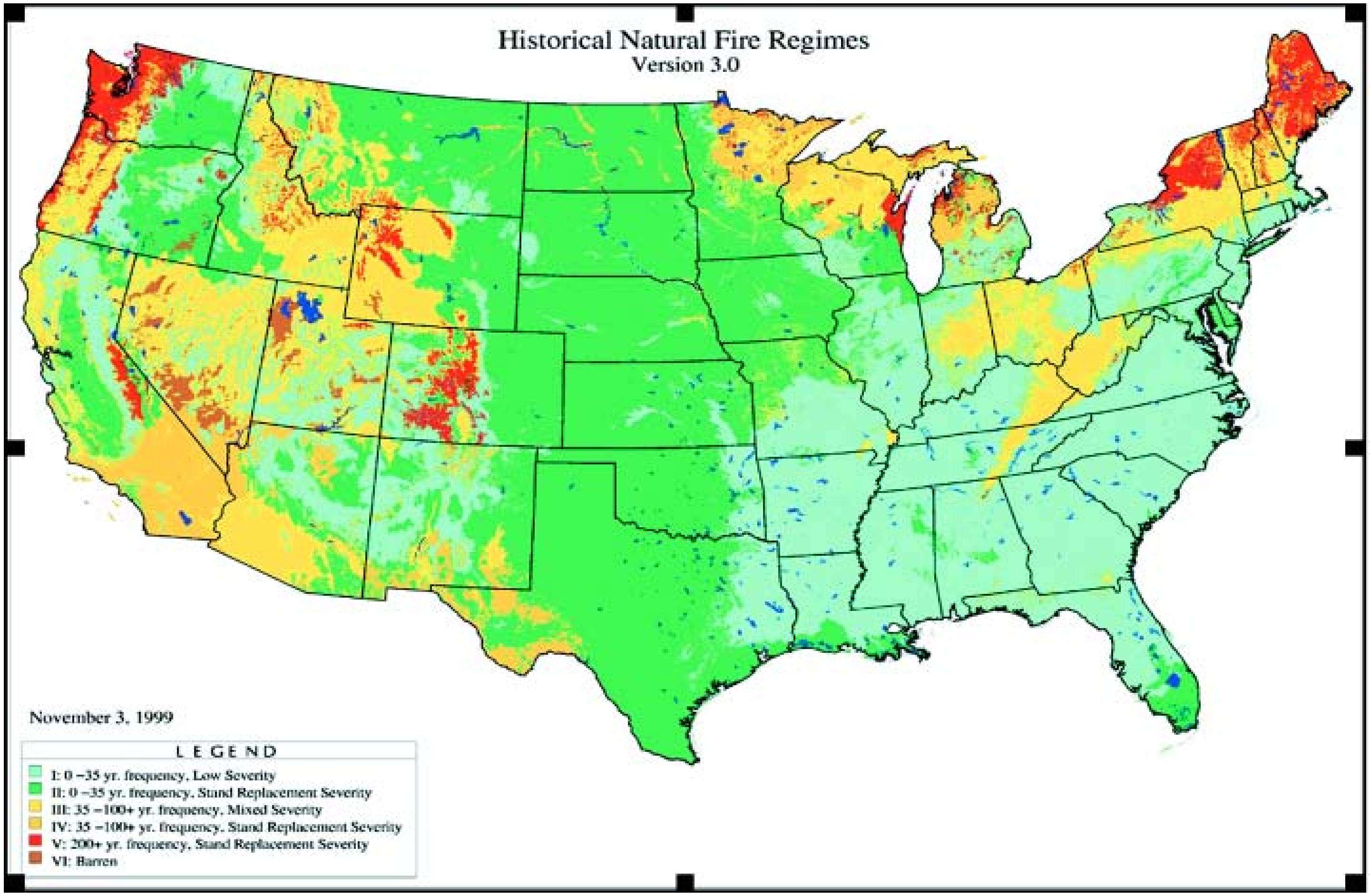

Figure 2. Historical natural fire regimes across the continental US. (Frost 1998)

2.3. Current Distribution

Shortleaf pine is found in 85 forest-type groups. According to Forest Inventory and Analysis, of the approximately 241 million acres of timberland in the shortleaf pine range, shortleaf pine and shortleaf pine-oak forest types occupy more than 7.4 million acres (Moser et al. 2006). While there are other “forest type” groups (e.g., loblolly pine, white oak/red oak/hickory, loblolly pine/hardwood, post oak/blackjack oak), these two encompass 60% of the residual trees. Approximately 64% of this acreage is in large-diameter stands (sawtimber), 26% is in medium-diameter stands (poletimber), and 10% is in small-diameter stands (seedling-sapling). Arkansas, Oklahoma, Mississippi, Alabama, and Georgia have the greatest number of trees, with about 1.9 billion shortleaf pine trees in the states that comprise its entire range (Moser et al. 2006).

2.4. Reproduction

According to Mattoon (1915), of the commercially important pines in the United States, few reproduce as vigorously as shortleaf. Shortleaf is a monoecious species, often producing seeds at age 20 (Fowells 1965). Reproduction by means of natural seeding is successful and heavy, because of the frequent and full seed crops, the lightness and short germinating period of the seed, and the high resistance of the seedlings to unfavorable conditions of temporary shade and drought (Mattoon 1915). The seeds are very small, varying usually from 50,000 to 70,000 per pound. They persist on trees for periods of about four years on vigorous shoots and seven to eight years on suppressed portions of the crown (Mattoon 1915). Shortleaf seeds have relatively large wings that allow them to be transported by the wind, often traveling distances two to five times the height of the tree.

2.5. Wildlife Benefits

Throughout the stages of stand development, shortleaf pine provides habitat for a number of wildlife species, and young sapling stands up to about 6.5 feet prior to canopy closure provide some cover for small mammals, including eastern cotton-tailed rabbit (*Sylvilagus floridan*) and northern bobwhite (*Colinus virginianus*) (Masters 1991a,b; Masters et al. 1997). According to Masters et al. (1997), the useful life of these stands for whitetail deer (*Odocoileus virginianus*) can be extended when prescribed fire is part of the management plan and if it is introduced early and at least on a 3 -year late-dormant cycle. Prescribed burning, on a three-year rotation in young shortleaf sapling stands, ensures that small mammals, bobwhite, and a number of different species of songbirds will continue to use the stands as they develop (Masters et al. 1997). In addition to providing cover, shortleaf pine offers several other wildlife benefits, including the production of seeds which are often consumed by birds and small mammals (Lawson 1990). Also, older trees that are infected with red heart rot (*Phellinus pini*) are used for nesting sites by red-cockaded woodpeckers (Lawson 1990; Masters et al. 1998; Cram et al. 2002).

2.6. **Littleleaf Disease: A Threat to Restoration**

While southern pine beetles (*Dendroctonus frontalis)* and other insects can cause great loss to shortleaf pine forests, littleleaf disease (*Phytophtora cinnamoni)* is its greatest threat. Littleleaf is a disease affecting mainly shortleaf pine on approximately 15 million acres across the South and Southeast (See Figure 3). It occurs from Virginia to Mississippi, with a northward extension into Tennessee. It is believed to pose extensive problems for management in Mississippi, Georgia, Alabama, South Carolina, North Carolina, Virginia, and Tennessee (Fowells 1965).

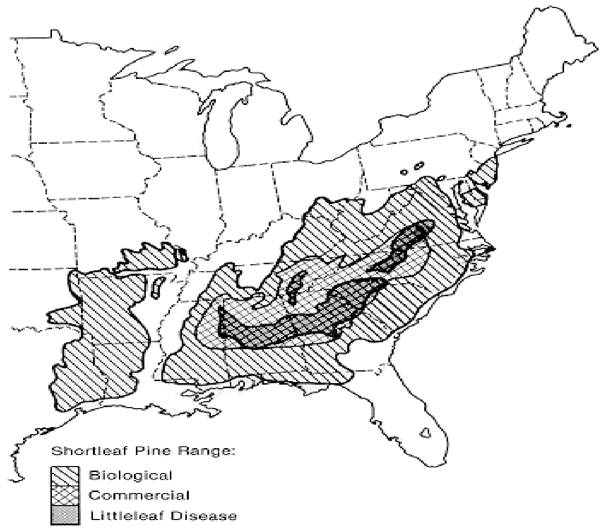

Figure 3. Known distribution of littleleaf disease

Littleleaf disease was first recognized in 1934 in Alabama (Walker and Wiant 1966; Tainter 1986). Reports of unhealthy shortleaf pine stands triggered investigations by the Division of Forestry Pathology, US Department of Agriculture (Boggess and Newman 1947). This condition was labeled as “a distinct disease of unknown origin”, and was found in practically every county (See Figure 4) located in the Piedmont, Upper Coastal regions, Coosa Valley, and along the southern fringe of the Appalachian Mountains (Boggess and Newman 1947).

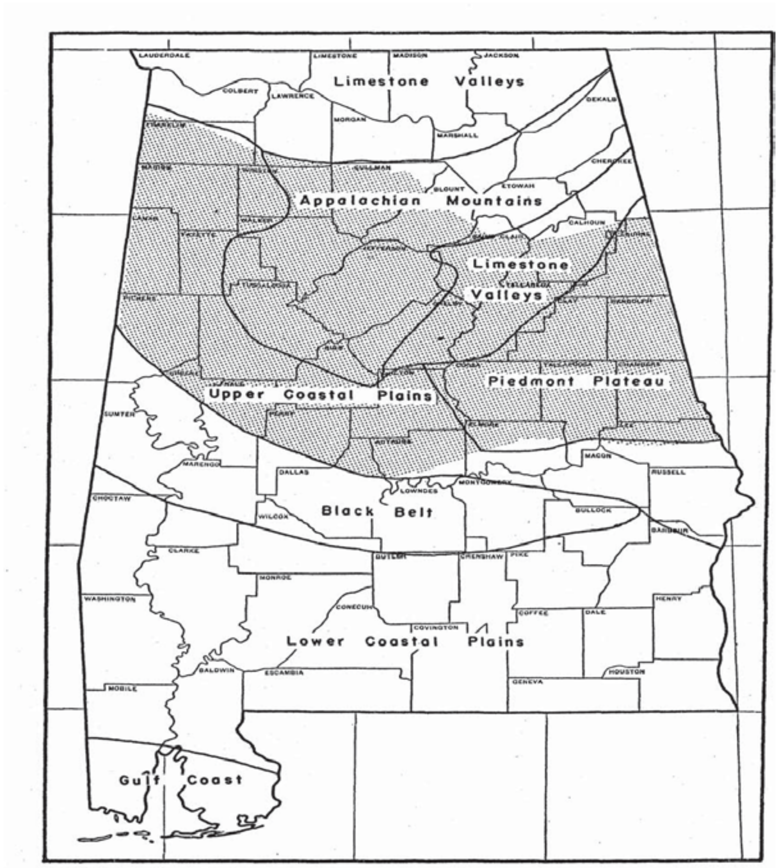

Figure 4. Distribution of littleleaf disease of pine in Alabama in relation to major soil regions (USDA Cir. 716)

Infestation is most prevalent on Piedmont, upper Coastal Plain, and associated mountain soils and it has been associated with old-field natural stands and plantations that were previously in intense cultivation for agriculture. Littleleaf has not been found west of the Mississippi River (Campbell and Copeland 1954). It is caused by a combination of heavy soils, radical fluctuations in soil moisture content for extended periods of time, and *Phytophthora cinnamomi*'s attack on feeding roots (Fowells 1965).

Extensive investigations have shown that littleleaf symptoms arise as the result of a nitrogen deficiency in the tree. This nitrogen deficiency is associated with the dying of new root tips and fine roots. There are several factors to which this can be attributed.

The water mold *Phytophthora cinnamomi* is probably the primary agent responsible for the dying, although soil factors such as poor aeration, low fertility (primarily nitrogen), and periodic moisture stress, are also damaging to the fine roots. *Phytophthora cinnamomi* produces motile swarm spores, under conditions of abundant moisture, which move throughout the soil and infect susceptible root tissue. This impedes the tree's ability to uptake nutrients, primarily nitrogen, and littleleaf disease symptoms develop (Hepting 1961). The symptoms include shorter needles and reduced yellow foliage, with trees typically dying within 3-10 years. This condition occurs in trees as young as 20 years old but most commonly occurs in trees 30-50 years old (Campbell et al. 1953).

2.7. Agroforestry Management Style

Agroforestry is a management style that combines agricultural and forestry technologies to create more diverse, productive and sustainable land-use systems. These management practices focus on satisfying economic, environmental and social objectives held by landowners (Merwin 1997; Rietveld and Francis 2000; Rule *et al*. 2000). Management systems that emphasize maximum diversity in contrast to simple crop yield (Olsen *et al*. 2000), and consider tree management as an integral part of overall farm strategy (Vandemeer *et al.* 1998; Rietveld and Francis 2000) are recognized alternatives to conventional agriculture in the US.

Agroforestry practices which integrate tree, crop, and animal components as part of an intensive land management approach that focuses on sustainable resource use and production are emerging as viable land-use systems, across the US (Rocheleau 1999, Lassoie and Buck 2000). These practices may include alley cropping, forest farming, windbreaks, riparian buffers, and silvopasture (USDA 2008). Alley cropping involves growing a long-term tree crop simultaneously with an agricultural crop (i.e. soybeans, forage grasses) (Williams et al. 1997). Forest farming incorporates the cultivation of high-value speciality crops like ginseng, decorative ferns, mushrooms, or other non-timber forest products (NTFP) under a protective, modified forest canopy (Chamberlain and Hammett 2002; Teal and Buck 2002). Garrett and Buck (1997) define windbreaks as linearly configured plantings of trees and shrubs that are designed for reducing wind velocity or snow accumulation. Riparian forest buffers are streamside growths of shrubs, trees, and grass, which are natural or have been re-established (Williams et al. 1997). These buffers decrease waterway pollution from adjacent land, reduce erosion, and protect aquatic environments. Silvopasture is a management option that combines the growth of trees with forage and livestock production (Nowak and Blount 2002; Workman et al. 2002). The trees are managed for quality timber production and at the same time they provide the benefits of shade and shelter for livestock as well as providing an open area for forage production.

2.8. Environmental and Ecological Benefits of Agroforestry

Agroforestry has the potential to provide several environmental and ecological benefits. These include, but are not limited to, an enhanced biodiversity, nutrient recycling, erosion control, and carbon (C) sequestration (Nyakatawa et al. 2010; Garrett and McGraw 2000). Trees themselves are not a guarantee of good erosion control. Rather, it is the manner in which they are distributed and their structure and condition that determine the degree of erosion control (Bregman 1993). These features directly influence the cover, barrier, and soil containment capabilities of trees. The cover function is primarily considered for the control of surface and gully erosion. Cover function of trees can be classified as either litter cover or canopy cover. Litter cover guards against splash erosion and intercepts sediment from the surface water, while the canopies intercept rainfall, lessening the detachment force. Trees configured in rows or strips along the contour can act as barriers against soil loss. This effect is strongly influenced by the distance between the planted trees and the amount of litter that is on site. These barriers are important for controlling gully and surface erosion, and they also contribute to the prevention of mass movement through soil reinforcement (Bregman 1993).

In a study of a five-year-old *Acacia auriculiformis* plantation in Java, the effects of tree canopy, undergrowth, and litter were compared. In this study, litter alone reduced erosion by 95% as compared with bare soil (Young 1984). Conversely, in a natural forest, measured erosion remained at under 1t/ha/yr when both trees and undergrowth were artificially removed but with litter retained. It rose to 26t/ha/yr with undergrowth and litter removed and the tree canopy retained. In terms of erosion control, the primary role of the tree canopy in an agroforestry system is to provide a sufficient supply of leafy material, through direct litter fall or pruning, to maintain a surface cover. The soil litter cover, if maintained throughout periods of erosive rains, can often reduce erosion to within acceptable levels, even without additional measures of the runoff-barrier type (Young 1984).

If the barrier approach is needed to supplement other measures to control erosion within acceptable levels, agroforestry can contribute to this directly through the use of grass strips or hedgerows to serve as partly permeable barriers. Trees can contribute indirectly to erosion control by stabilizing earth structures and making productive use of the land they occupy, through the formation of impermeable barriers. These barriers serve to check runoff either by diversion or by slowing it to the point that increased infiltration occurs (Young 1984).

The mechanical support provided by tree roots (i.e. anchoring, arching, and mechanical reinforcement) is vitally important to the process of mass movement reduction. Trees reinforce soil stability on steep slopes by regulating the moisture content and the piezometric levels (Bregman 1993). The erosion control value of agroforestry systems is directly related to their protective functions. Trees, interplanted crops, animals, and soil conditions are especially important components, relative to influencing the protective functions of agroforestry systems (Bregman 1993). The vegetative components of the system affect erosion by their cover, barrier, and soil enforcement functions. In order to provide maximum protective value, interplanted crops should be selected based on the structure and density of the plants and root properties (Bregman 1993). A good surface cover is important to minimize soil erosion, and a number of options can be utilized to achieve the desired results (increase of plant density, sequential cropping, and intercropping). Interplanted crops in strips or rows on the contour can act as effective barriers, and a plant density sufficient to increase the litter accumulation between the plants is needed to ensure maximum effectiveness (Bregman 1993). In addition to the role that vegetation plays, some of the other components also indirectly affect erosion (increasing soil organic matter, nitrogen fixation, nutrient retrieval), although these effects are quite complex and are related to those features which have direct effects.

Animals in an agroforestry system can influence the condition of the vegetation and soil to a significant degree, and this in turn can cause deterioration that could result in surface erosion, gully erosion, and mass movement increase (Bregman 1993). Controlling the grazing load and distribution, avoiding continuous grazing through rotational paddocks, and controlled burning are management options which can help deal with vegetation deterioration (Bregman 1993).

Trees are an important component of an agroforestry system, because they reduce runoff, soil erosion, nutrient loss from watersheds, and improve infiltration. Studies conducted on pastured watersheds have shown that establishment of buffers at the field edge improves soil physical properties; because on the soil surface tree roots, fallen branches, and accumulated litter material reduces water flow velocity (Udawatta et al. 2010).

During a five-year study conducted in northern Missouri, grazed treatment with agroforestry buffers lost only 51% of the sediment that was lost on the control treatment. The control treatment without buffers lost 36% more soil than the average for the agroforestry and grass buffer treatments (Udawatta et al. 2010). Permanent vegetation, including the trees and undisturbed grass in the buffer areas of the treatments, may have utilized more water, thus runoff and erosion losses were less (Udawatta et al. 2010). Upland buffers, as a protective measure, can help reduce soil erosion and nutrient losses from pastured land and also reduce non-point source pollution, which results in improved water quality. Other agroforestry practices such as windbreaks, shelter breaks, and alley cropping produce a number of environmentally friendly attributes which reduce surface runoff, reduce wind velocity and thereby limit wind erosion, improve utilization of nutrients, and reduce the quantity of particulate matter in the air.

Soil erodobility is initially an innate property of the soil, but changes can be made to the rate at which erosion occurs by implementing management practices that elicit a desired response of the soil to the management practice. The primary cause of erosion is changes in soil organic matter, together with their effects on soil structure and permeability (Young 1984). Based on this evidence, agroforestry systems have the potential to be effective in erosion control through providing an increased supply of organic matter to the ground surface.

According to Young (1984), the aims of erosion control should be reassessed to place more emphasis on productivity decline as opposed to simply a loss of soil volume. Erosion of organic matter, with a consequent decline in soil physical properties and loss of nutrients, results in a significant decline in production long before erosion has proceeded to an advanced stage. Agroforestry practices have the capacity to supply organic matter and recycle nutrients needed to alleviate some of the losses that have occurred through erosion. Restoration of lost organic material, through implementation of agroforestry practices, can positively impact soil physical properties, soil nutrient levels, and ultimately soil productivity.

In his research on agroforestry systems to control erosion on tropical steeplands, Lal (1989) states that although additional research is needed from long-term field experiments, relative to selection of appropriate tree species, spacing and rotational sequencing, and various management practices, agroforestry systems have the potential to provide sustainable management alternatives for intensive use of tropical steeplands for food crop production. Usefulness of agroforestry systems in erosion control and in stabilizing steeplands has been demonstrated in Java, Philippines, Kenya, Sumatra, and Nigeria. Several different types of agroforestry systems have been used in tropical steepland management, including rotational agroforestry intercropping systems and discrete woodlots. Alley cropping and shelterbelts are examples of the intercropping systems (Lal 1989).

All of these approaches utilize the integration of annual crops, animals, and trees to decrease runoff and soil erosion by one or all of the following mechanisms: reducing runoff velocity, decreasing the runoff amount, minimizing raindrop impact and sheet erosion, and curtailing sediment transport in overland flow (Lal 1989). During the past decade, there has been an accumulation of evidence that supports the ecosystem services and environmental benefits offered by implementation of agroforestry systems. Among other things, these benefits can also positively impact the conservation of biological diversity by preventing degradation and loss of surrounding habitat (Jose 2009). Although the value of a particular agroforestry system is largely determined by the site, and given the fact that additional research needs to be conducted relative to choice of tree species, spatial and rotational sequences, and inter-species interaction, presently available research indicates that agroforestry systems can be very useful in erosion control for a variety of soils and at varying elevations.

CHAPTER 3

Soil suitability for shortleaf pine (*Pinus echinata* Mill.) on Redstone Arsenal

3.1. Introduction

Redstone Arsenal (RSA) in Madison County, Alabama, encompasses approximately 38,100 acres, and is comprised of a diverse landscape, which includes numerous soil types. It had its beginning in 1942, during World War II. The facility was originally called the Redstone Ordnance Plant and was constructed to supplement manufacturing and production at the nation's only chemical manufacturing plant, located at Edgewood Arsenal, Maryland. The name of the Redstone Ordnance Plant was changed to Redstone Arsenal in 1943. The term “Redstone”, according to Cagle (1961), was chosen because of the presence of red rocks and the soil coloration in this section of northern Alabama. In 1949, the neighboring Huntsville Arsenal was combined with Redstone Arsenal.

Redstone Arsenal has long been committed to sustainable land management practices. Of those, forest management in general and southern pine management in particular have been a focus for both wildlife habitat enhancement and revenue generation. Across north Alabama, loblolly pine (*Pinus taeda*) has long been favored by landowners for its rapid early growth and market value. However, as forest health concerns about the decline in loblolly pine grow, private landowners look for alternative pine species for their forests. One that is of increasing interest is shortleaf pine (*Pinus echinata* Mill).

Shortleaf pine has the widest range of any southern pine, is found in 22 states, and is most tolerant of a variety of sites (See Figure 5). It grows best with a surface soil over nine inches deep, underlain by friable subsoil (Coile 1952a). The best sites for shortleaf are the fine sandy loams or silt loams which provide for good internal drainage. In general, shortleaf pine growth is limited on soils with high calcium content or a high pH (>7.0) and sandy soils with excessive internal drainage (Coile 1952b). Shortleaf pine primarily occupies soils that are classed in the order Ultisols and the suborder Udults (USDA 1975). Soils belonging to this suborder are typically moist and somewhat low in organic matter, and they are formed in humid climates that have either short or few dry periods throughout the year. The two large soil groups, Paleudults and Hapludults, comprise the soils predominantly occupied by shortleaf pine. Paleudults are characterized by a thick horizon of clay accumulation with an absence of a significant accumulation of weatherable materials. In contrast, Hapludults may have either a somewhat thin clay subsurface horizon or one characterized by a significant quantity of weatherable material, or both (USDA 1975). Shortleaf pine may occupy soils in other orders, and although they do not constitute a major portion of its range, shortleaf's adaptability to a wide variety of site and soil conditions accounts for its wide distribution.

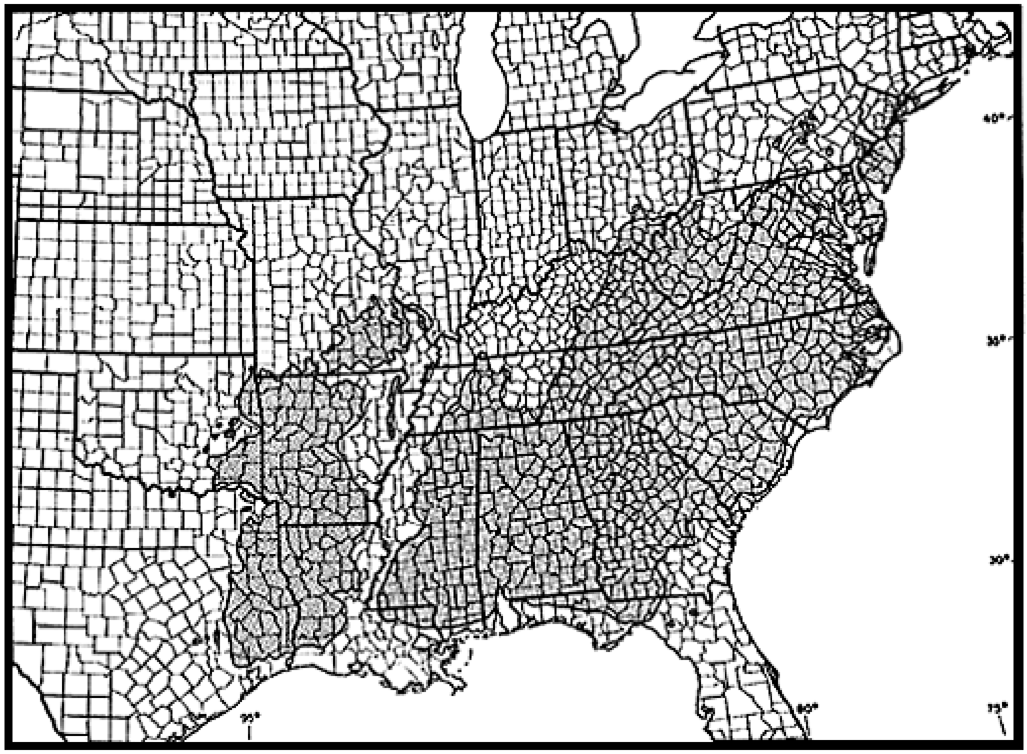

Figure 5. Shortleaf's native range map (Little 1971)

Sargent's publication in 1884 notes that shortleaf was a dominant part of Alabama's landscape, representing 2.3 billion board feet of commercial quality products. However, shortleaf pine forests in Alabama and across the region have decreased rapidly. Despite many qualities that make it an excellent choice for sawtimber and other forest products, landowners and land managers have dismissed shortleaf pine as a viable component of management options due to the prevalence of littleleaf disease (*Phytophtora cinnamoni*) and the rapid initial growth of loblolly (*Pinus taeda*). Of the 30.4 million total acres of pines planted in the 1990's, less than 485,000 acres were planted in shortleaf compared to 21.3 million of loblolly (South and Buckner 2003).

Littleleaf disease is caused by a combination of heavy soils, radical fluctuations in soil moisture content for extended periods of time, and *Phytophthora cinnamomi*'s attack on feeding roots (Fowells 1965). Extensive investigations have shown that littleleaf symptoms arise as the result of a nitrogen deficiency in the tree (Hepting 1961). This nitrogen deficiency is associated with the dying of new root tips and fine roots. There are several factors to which this can be attributed. The water mold *Phytophthora cinnamomi* is probably the primary agent responsible, although soil factors, such as poor aeration, low fertility (primarily nitrogen), and periodic moisture stress, are also damaging to the fine roots. *Phytophthora cinnamomi* produces motile swarm spores, under conditions of abundant moisture, that move throughout the soil infecting susceptible root tissue. This impedes the tree's ability to uptake nutrients, primarily nitrogen, and littleleaf develops (Hepting 1961).

Soil characteristics (fertility/make-up) constitute significant elements for the timber production planning process. To date, little to no soils work has been conducted in Alabama for shortleaf pine. Studies have been conducted for shortleaf, from research dealing with shortleaf pine – bluestem ecosystem restoration (Huebschmann 2000) to dynamics and development of shortleaf stands in East Tennessee (Cassidy 2004). Huebschmann's (2000) research focuses on an economic analysis designed to predict the amount of timber harvest volume and revenue the Ouachita National Forest may sacrifice by implementing a shortleaf pine-bluestem grass (or pine-bluestem) management system as opposed to traditional, even-aged management. During the 100-year simulation stage, the pine-bluestem scenario produced 26% less sawlog volume than other practices within the restoration area. The simulation results for this area also yielded a reduced timber sale revenue (-51%) in present-value terms, but due to the small area that the pine-bluestem section encompasses, forest-wide revenue was reduced by only 2-5%.

Huebschmann explains that these losses can be offset due to the predicted increase in red-cockaded woodpecker (*Picoides borealis)* habitat. Shortleaf pine-bluestem grass restoration efforts were predicted to support 400 breeding pairs, equivalent to an implicit value of $1,700 per year (present-value terms) for each woodpecker.

Cassidy's (2004) research focuses on the shortleaf pine resources in the "Ridge and Valley regions of Tennessee". Cassidy explains that what once was a thriving species (in pure and mixed stands) is in peril of being eradicated. By conducting stem analysis, Cassidy determined that there were two separate cohorts present in the research areas, the younger of the two being from the mid-1930s. Due to management changes (fire suppression and limited harvesting) in the 1950's, regeneration conditions are lacking, and he notes that there has been no regeneration since the early 1970's. Cassidy suggests that perpetuation of the species can be attained through several management practices. These include plantation establishment, underplanting, and natural regeneration through gap promotion. However, these studies were conducted on areas outside the State.

Despite limitations on the body of currently available research for shortleaf pine in Alabama, there is an increasing interest in the species across the state. To that end, this study seeks to address some of the misconceptions relating to shortleaf pine restoration by means of the following objectives: 1) Determine which soils on RSA are either optimal or suitable for shortleaf pine management, and 2) map those areas using a process that can be utilized by land managers and landowners to determine shortleaf pine management areas in other regions of Alabama. Historically, shortleaf flourished over a significant portion of Alabama and the results presented here should provide information for landowners that will assist them in making an informed choice regarding successful restoration of this species on their property.

3.2. Methods

For this current study, 43 identified soil types, (19 soil series and 27 soil map units), were analyzed for their suitability as optimal shortleaf pine sites (Clendenon 1996). Optimal soils are those soils that are the most favorable or desirable for generating the best results possible (i.e., growth, survivability, and minimal probability for littleleaf infestation). Through utilization of a Natural Resource Conservation Service (NRCS) soil survey and RSA's geographic information system (GIS), soils were classified as suitable, optimal, or not-suitable, based in part on information contained in the publication entitled Considerations for Forest Management on Alabama Soils (USDA NRCS 1993). A shortleaf pine suitability map was generated, based on those soil types which were least likely to contribute to the development of littleleaf disease. Wetlands were eliminated and the finalized product was created with the expectation that this process can be utilized to generate suitability maps for other areas of the state.

By utilizing historical accounts, soils information, and range maps for shortleaf pine and littleleaf disease, a soil suitability map for shortleaf on RSA was created. Table 1 displays the criteria used to generate the map and can likely be expanded to produce a suitability map for other areas of the state, thus providing information for landowners that will assist them in making an informed choice regarding introduction of this species on their property.

Table 1 – Criteria for soil evaluation relating to optimal shortleaf production on RSA, 2012

	Suitable for optimal shortleaf pine production	Not suitable for optimal shortleaf pine production
Soils	Within the Paleudults and Hapludults soil groups (See Table 3)	All other soil types
Range	Within the range illustrated on Little's (1971) map	Outside of the range depicted on Little's (1971) map
Soil Characteristics	Sandy or silty loam with good internal drainage	High clay content with poor internal drainage

Study Area

Redstone Arsenal encompasses approximately 60 square miles (10 miles north to south and about 6 miles from east to west) and is centrally located between Birmingham, Alabama (95 miles north); Nashville, Tennessee (109 miles south); Memphis, Tennessee (212 miles southeast); and Atlanta, Georgia (175 miles northwest) (See Figure 6). Redstone Arsenal's timberlands are diverse with pine (both loblolly and shortleaf) covering 4,318 acres, hardwoods (both the red oak and white oak groups) covering approximately 6,601 acres, and mixed stands of eastern redcedar, hardwood, and pine covering 4,978 acres. RSA also has 765 acres of wetlands and 14,370 acres classified as non-forestland. Many of these "non-forested" areas were in agricultural cultivation prior to the Arsenal's establishment in 1941, with cotton, corn, hay, peanuts, livestock, and various fruits and vegetables being the primary agricultural products produced by the area's inhabitants. Subsequent to the Arsenal's establishment, these "non-forested" areas have been grazed or mowed extensively. RSA has an active forest management program, which provides an ideal location for shortleaf pine soil research.

Figure 6. Location of Redstone Arsenal near Huntsville, AL

3.3. Approach

Several considerations went into soil selection and classification. Soil types were analyzed based on utilization of historical accounts, soils information, and range maps for shortleaf pine and littleleaf disease. Shortleaf's physiological adaptations and documented site indices for specific soils were considered throughout the planning process. Historical soils information, listing those groups (including "suitable" and "optimal" soils) where shortleaf pine once occurred, was cross-referenced with the soil types present on RSA (USDA 1975; Clendenon 1996; USDA NRCS 1993) and ranked accordingly. Another consideration was littleleaf disease and the method by which the associated fungal spores move throughout the soil. Campbell and Copeland's (1954) numerical system of field rating sites for littleleaf hazard, based on soil characteristics, provided a useful tool for assessing RSA soils for potential littleleaf development. With this in mind, “not-suitable” soils were classified as such due to their hydric nature, permeability, and drainage class. Soils were categorized, based on their capacity for growing shortleaf, by relying heavily on the NRCS soil survey conducted for the Arsenal in 1996 (Clendenon 1996), USDA NRCS (1993), and RSA’s current operating system for Geographic Information System (ArcGIS 9.3.1 with 2010 imagery). The predominant soil types for RSA are: Decatur silty clay loam (DeB2) which encompasses approximately 6.4% of the land base, Emory silt loam (EnA) which encompasses approximately 5.6% of the land base, Ketona silt loam (KoA) which encompasses approximately 5.8% of the land base, Paleudults-Udarents complex (PuD) which encompasses approximately 5.1% of the land base, Locust silt loam (LoA) which encompasses approximately 4.1% of the land base, Waynesboro loam (WaB2) which encompasses approximately 6.3% of the land base, Locust silt loam (LoA) which encompasses approximately 4.1% of the land base, Ketona-Chenneby complex (KtA) which encompasses approximately 15.4% of the land base, Rock outcrop-Gladdice complex (RgE) which encompasses approximately 5.0% of the land base, and Urban land-Decatur-Emory complex (UdB) which encompasses approximately 13% of the land base.

3.4. Digital Inventory

The NRCS’s soil survey and information from these findings (http://datagateway.nrcs.usda.gov) were clipped to Redstone Arsenal’s boundaries. By utilizing documented historical perspectives, relating to range and “optimal” soil types for shortleaf, various soil types were notated and selected for inclusion on the suitability map (Table 1). Soil types were analyzed based on the properties of potential productivity (common trees), suitability for planting, site index for shortleaf, rooting restrictions, permeability, and drainage class (Table 2). Information from the (USDA NRCS 1993) and RSA's soil survey information were used to classify soils as either suitable or not suitable (Tables 3 and 4). A map depicting both "optimal" and "suitable" soil locations (Figure 8) was then generated, thus providing RSA land managers with a "working" map for future shortleaf planting locations.

Soil types deemed not suitable for shortleaf production were queried out within RSA's GIS database, leaving only optimal soils. In conjunction with this analysis, the wetland's data layer was selected and buffered (100 ft.) to ensure that the integrity of these areas remained intact, and also to provide for functionality during future harvest operations. Within the buffered areas, the clip tool was utilized to remove all of the suitable soils (Figures 7 and 8). These maps identify areas well suited for shortleaf management on RSA, and this process can potentially be utilized to generate suitability maps for other areas of Alabama.

Table 2 - Optimal soil types for shortleaf pine production on RSA (Clendenon 1996)

Soil Symbol	Soil Name	Suitability for Planting (hand/machine)	Site Index for Shortleaf	Rooting Restrictions	Permeability	Drainage Class
DeA	Decatur silt loam	Well suited	75	None	Moderate	Well
DeB2	Decatur silty clay loam	Well suited	75	None	Moderate	Well
DeB3	Decatur silty clay	Well suited	65	None	Moderate	Well
DeC2	Decatur silty clay loam	Well suited	75	None	Moderate	Well
DeC3	Decatur silty clay	Well/moderately suited (slope)	60	None	Moderate	Well
EtA	Etowah loam	Well suited	75	None	Moderate	Well
EtB2	Etowah loam	Well suited	75	None	Moderate	Well
EwB2	Etowah loam	Well suited	75	None	Moderate	Well
FIB2	Fullerton gravelly silt loam	Well suited	65	None	Moderate	Well
FIC2	Fullerton gravelly silt loam	Well/moderately suited	65	None	Moderate	Well
FID2	Fullerton gravelly silt loam	Well/poorly suited (slope)	65	None	Moderate	Well

Soil Symbol	Soil Name	Suitability for Planting (hand/machine)	Site Index for Shortleaf	Rooting Restrictions	Permeability	Drainage Class
MnB2	Minvale gravelly silt loam	Well/moderately suited	75	None	Moderate	Well
MnC2	Minvale gravelly silt loam	Moderately/moderately suited	75	None	Moderate	Well
MnD2	Minvale gravelly silt loam	Moderately/poorly suited (rock fragments and slope)	75	None	Moderate	Well
PeD3	Paleudults	Well/moderately suited (slope)	NA	None	Moderate	Well
PuD	Paleudults-Udarents	Well/moderately suited (slope)	NA	None	Moderate	Well
SoA	Swafford fine sandy loam	Well suited	NA	Fragipan* at a depth of 60-79”	Slow	Moderately well
UdB	Urban land-Decatur-Emory complex	Decatur – well suited Emory – well suited	65	None	Moderate	Well
WaB2	Waynesboro loam	Moderately/moderately suited	65	None	Moderate	Well

Soil Symbol	Soil Name	Suitability for Planting (hand/machine)	Site Index for Shortleaf	Rooting Restrictions	Permeability	Drainage Class
WaC2	Waynesboro loam	Moderately/moderately suited	65	None	Moderate	Well
WaC3	Waynesboro clay loam	Moderately suited (stickiness and slope)	60	None	Moderate	Well

*Fragipan – a loamy, brittle subsurface horizon

Table 3 – Suitable soil types for shortleaf pine production on RSA (Clendenon 1996; NRCS 1993)

Soil Symbol	Soil Name	Suitability for Planting (hand/machine)	Site Index for Shortleaf	Rooting Restrictions	Permeability	Drainage Class
CoB2	Colbert silty clay loam		60	40-72" Lithic Bedrock*	Very slow	Moderately well drained (MWD)
CoC2	Colbert silty clay loam		60	40-72" Lithic Bedrock	Very slow	(MWD)
CsD	Colbert gravelly loam		60	40-72" Lithic Bedrock	Very slow	(MWD)
HaB2	Hartselle loam		60	20-40" Lithic Bedrock	Moderate	Well
HeE	Hector-Rock outcrop complex		65	10-20" Lithic Bedrock	Moderately rapid	Well
LcA	Locust loam		70	18-36" Fragipan**	Slow	(MWD)
LcB2	Locust silt loam		70	18-36" Fragipan	Slow	(MWD)
LoA	Etowah loam		85	18-36" Fragipan	Slow	(MWD)

Soil Symbol	Soil Name	Suitability for Planting (hand/machine)	Site Index for Shortleaf	Rooting Restrictions	Permeability	Drainage Class
LoB2	Fullerton gravelly silt loam		65	18-36" Fragipan	Slow	(MWD)
WoA	Wolftever silt loam		80	None	Moderately slow	(MWD)

*Lithic Bedrock - solid rock that underlies the soil

**Fragipan - a loamy, brittle subsurface horizon

Table 4 – Soil types classified as not suitable for shortleaf pine production on RSA (Clendenon 1996; NRCS 1993)

Soil Symbol	Soil Name	Suitability for Planting (hand/machine)	Site Index for Shortleaf	Rooting Restrictions	Permeability	Drainage Class
ChA	Chenneby silty clay loam		NA	None	Moderate	Somewhat poorly drained (SPD)
EgA	Egam silt loam		NA	None	Moderately slow	(MWD)
EmA	Emory silt loam		NA	None	Moderate	Well drained
HoA	Hollywood silty clay		NA	48-96” Lithic Bedrock*	Very slow	(MWD)
KeA	Ketona silt loam		NA	None	Very slow or slow	Poorly drained
KrA	Ketona-Chenneby complex		NA	None	Very slow or slow	Poorly drained
KtA	Ketona-Chenneby complex		NA	None	Very slow or slow	Poorly drained
Pt	Pits-Dumps complex	Disturbed areas utilized as borrow pits and waste disposal sites	NA	NA	NA	NA

Soil Symbol	Soil Name	Suitability for Planting (hand/machine)	Site Index for Shortleaf	Rooting Restrictions	Permeability	Drainage Class
RgE	Rock outcrop-Gladdice complex		NA	20-30” Lithic Bedrock	Moderately slow	Well drained
SeA	Staser loam		NA	None	Moderate	Well drained
TuA	Tupelo-Ketona complex		NA	None	Slow	(SPD)
W	Water	Areas inundated with water for the entire year	NA	NA	NA	NA

*Lithic Bedrock - solid rock that underlies the soil

3.5. Results

When the analysis and maps were completed, the field calculator was used to determine the exact number of soil types suitable for shortleaf and also to calculate the exact acreage that these soil types encompass. Based on these calculations, 21 of the 43 soil types present on Redstone Arsenal were determined to be “optimal” for shortleaf production, and these soil types are prevalent on 10,754 acres (28% of land base). After further evaluation, 10 additional soil types (4,132 acres) were determined to be “suitable” for shortleaf production, meaning that 14,886 acres (39% of land base) on RSA can be considered for future planting sites. Soils that did not possess the desired characteristics for shortleaf were eliminated (Tables 2, 3, and 4) from inclusion on the suitability map.

Figure 7 depicts the locations of soils on RSA that are optimally suitable for shortleaf production. Decatur silty clay loam is the most prevalent soil type, appearing on 2,302 acres and comprising 6% of the total land base. These optimal soils are primarily located in the west, north-central (excluding the mountainous region) and northwest sectors of RSA. The Paleudults-Udarents complex soil type is least prevalent, covering some 9 acres.

Figure 8 depicts those soils designated as optimal (notated in red) and suitable (notated in purple) for shortleaf production. Of the suitable soils, the Etowah loam soil type is most prevalent, covering 1,590 acres or approximately 4% of the RSA land base. The greatest concentration of suitable soils is found in the south-central region. The Hartselle loam soil type is least prevalent, covering 132 acres.

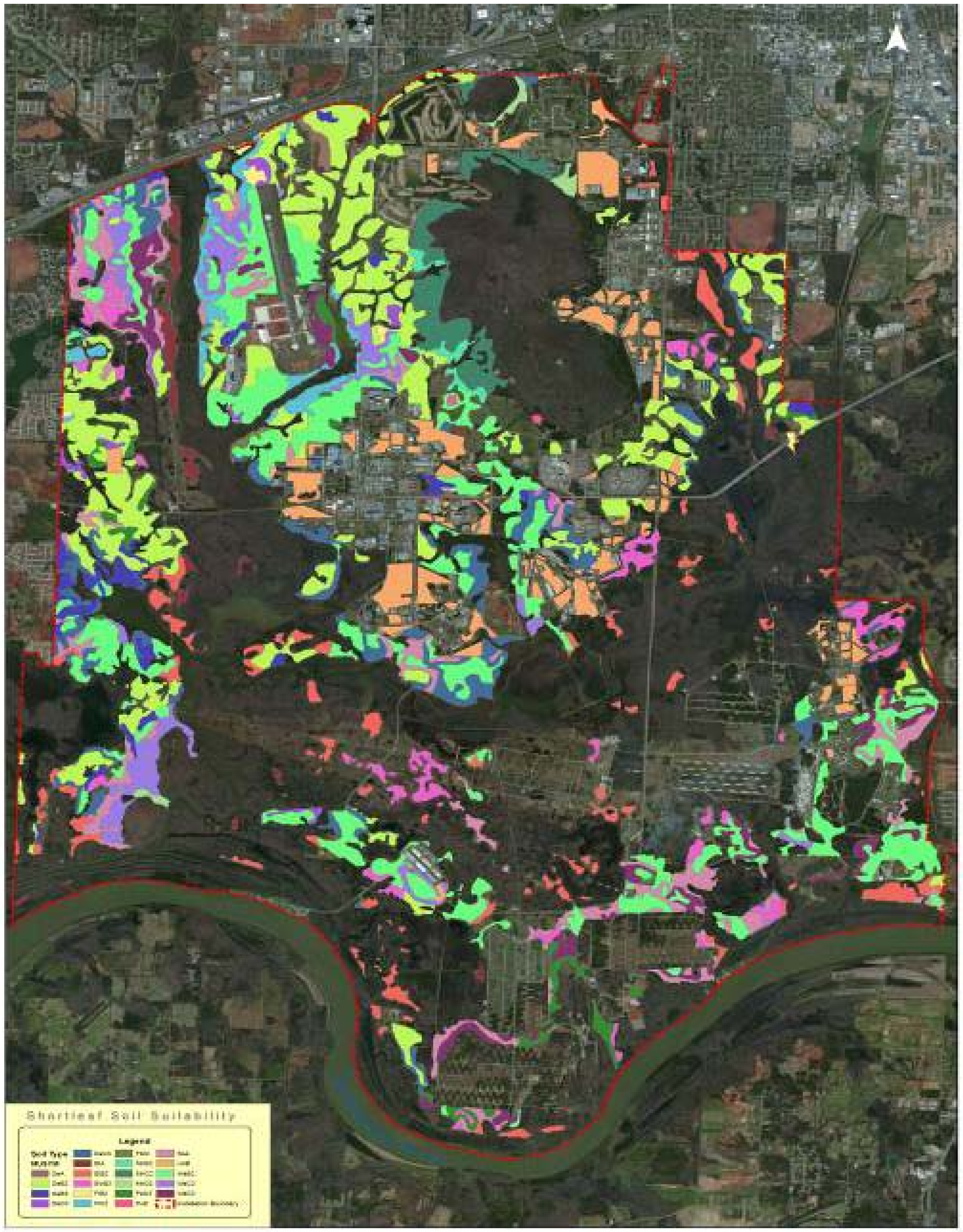

Figure 7. Redstone soils suited for optimal shortleaf production, 2012

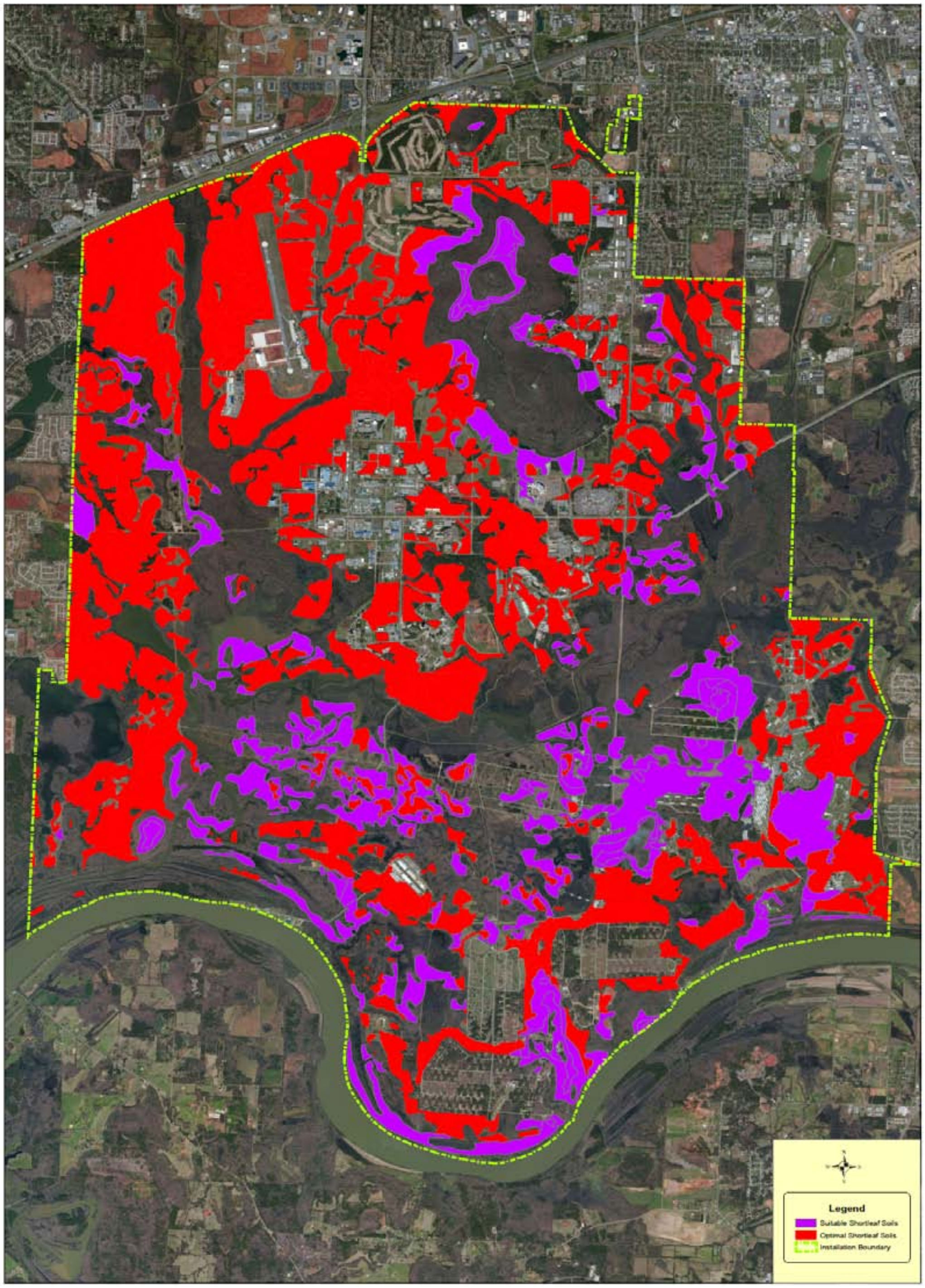

Figure 8. Redstone soils determined to be suitable for shortleaf pine production, 2012

3.6. Discussion

Based on the data acquired thus far, it appears that the shortleaf restoration effort implemented on RSA can constitute a workable system. This approach has the potential for being mutually beneficial to a number of stakeholders (RSA, other government entities, research universities, landowners, etc.), because of Redstone Arsenal's commitment to promoting best management strategies that enhance resource sustainability and provide for research continuity. This project is designed to be ongoing and will provide additional information that will contribute to minimizing the existing "gap" related to shortleaf soils research for this area. Clearly, additional soils work is needed, including further data collection and analysis as it relates to shortleaf restoration on RSA.

After careful consideration of a number of factors, it was determined that this research, dealing with suitable shortleaf soils, could provide useful data since there is a recognized need for such. Additionally, the research will provide for a better understanding of littleleaf disease and improve the ability to identify those factors that can minimize the potential for its occurrence. As previously mentioned, littleleaf occurs within certain soil types and under certain conditions. This current study demonstrates that landowners and land managers may have more options than previously believed. They should carefully examine soils on their land and no longer dismiss shortleaf pine as a viable component of management options due to this disease. Shortleaf, just as other southern pine species should be planted on a site-specific basis. The dissemination of usable information, relating to this research project, will aid in this process. The soil suitability information outlined in this chapter can perhaps be expanded to produce suitability maps for other areas of Alabama. Soil suitability is a significant criterion for determining the viability of incorporating shortleaf pine into RSA's management system. With access to information generated by this project, landowners will have a valuable tool that can help enable them to make an educated and informed decision regarding whether or not establishment/propagation of this species would be right for their property.

CHAPTER 4

Development of a silvopasture system on Redstone Arsenal: 2 year results

4.1. Introduction

Agroforestry is a management style that combines agricultural and forestry technologies to create more diverse, productive and sustainable land-use systems. These management practices focus on satisfying economic, environmental and social objectives held by landowners (Rietveld Merwin 1997; Rietveld and Francis 2000; Rule et al. 2000). Management systems that emphasize maximum diversity in contrast to simple crop yield (Olsen et al. 2000) and consider tree management as an integral part of overall farm strategy (Vandemeer and Francis 2000) are recognized alternatives to conventional agriculture in the US. Farm enterprises that lack diversity often make the operation more susceptible to environmental and economic changes. Therefore, agroforestry, which can provide a viable alternative for income production, has the potential to provide greater permanence and a more balanced income stream for small farm operators in Alabama and across the Southeast. Many economic cost-benefit studies have shown that agroforestry management techniques (i.e. alley cropping, forest farming, silvopasture) can produce a higher rate of return than conventional forestry and agricultural operations (Kurtz 2000; Garrett and McGraw. 2000; Clason 1995; Brandle et al. 1992b). Also, products from these techniques are often described as non-revenue generating, providing yields such as “public goods” or environmental services (Workman et al. 2003).

Although agroforestry is not widely practiced in the US, a number of studies have documented the opportunities for increased adoption and the challenges that exist for its expansion across North America (Williams et al. 1997; AFTA 2000; Garrett and McGraw 2000) and the southeastern US (Mercer and Miller 1997; Workman et al. 2003). The National Association of Resource Conservation and Development Councils (NARC and DC) recently noted the great need for more research and education in agroforestry management, specifically in the South and Southeast (NARC and DC 2000).

4.1.1. **Silvopasture: An Agroforestry Practice**

Silvopasture is an agroforestry practice that is specifically designed and managed for the production of trees, tree products, forage and livestock as a single integrated system (Clason and Sharrow 2000). This management approach combines timber and pastures to produce high-value sawlogs, and provides forage, shelter, and shade for livestock (Klopfenstein et al. 1997). A silvopasture system increases biodiversity and protects water quality by acting as a buffer for agricultural practices such as fertilizer and herbicide application. Trees provide a deep rooting system that captures excess nutrients that have leached below the rooting zone of the agronomic crops. These nutrients are then recycled and placed back into the system through root turnover and litterfall, thus enhancing the nutrient use efficiency of the system (Allen et al. 2004).

4.1.2. Landowner Objectives

With approximately 20 million acres of non-forest cropland in the South classified as marginal, multiple land use practices combining trees and grazing offer a viable option for landowners to use this land in a manner that will enhance cash flow during the protracted time associated with conventional forest production. A careful analysis of agroforestry components including trees, livestock, and pasture, to determine where concentration of these components should occur, can maximize returns. Demand projections for forest products call for a 40% increase by year 2030. Such trends suggest that silvopasture holds strong potential as an opportunity to increase profit for private, non-industrial landowners (Dangerfield and Harwell 1990) and to satisfy important economic, environmental, and social objectives.

4.1.3. Agroforestry in the US

Despite its numerous benefits, agroforestry is not widely practiced in the US. Various studies have documented the opportunities for increasing the adoption of agroforestry and the challenges that exist for its expansion across North America (Williams et al. 1997; AFTA 2000; Garrett and McGraw 2000) and the southeastern US (Mercer and Miller 1997; Workman et al. 2003). According to Zinkhan and Mercer (1997), constraints for the introduction of agroforestry, as noted by many natural resource professionals in the southern US, include: a lack of technical knowledge and management savvy on the part of farmers for these practices, incongruity between multiple outputs, high establishment and management costs, and the harmful effects of livestock on tree seedlings and soil productivity. Buck (1995) states that other possible obstacles for the adoption of an agroforestry management style are: farmers who are inexperienced with economic planning for amount and timing of inputs and outputs, deficiency of institutional and policy support (finances and incentives), or unsuitable "technology packages." Some of these "packages" are considered unsuitable, because they often do not deal with farmers' goals in a cost-effective manner (Schultz et al. 1995; Merwin 1997). Consequently, many private landowners, foresters, and other land managers in the US fail to view agroforestry as a viable and sustainable land management practice (Williams et al. 1997; Lassoie and Buck 2000). As previously mentioned, the National Association of Resource Conservation and Development Councils (NARC and DC) recently noted the great need for more research and education in agroforestry, specifically in the South and Southeast (NARC and DC 2000).

4.1.4. Agroforestry in the South

Numerous research studies have focused on the suitability of southern pine species, mainly loblolly (*Pinus taeda*) and slash (*Pinus elliottii*), in agroforestry systems (Grado and Husak 2004). Several of these studies were conducted in the Southeast (Karki and Goodman 2010), analyzing everything from implementation of pine-based silvopastures in southern grasslands (Brauer et al. 2009) to the comparison of soil nitrate leaching in silvopasture versus open pasture and pine plantations (Bambo et al. 2009). Both of these studies deal exclusively with loblolly pine and in states other than Alabama. According to a study conducted by Clary (1979) on 13-to 16-year old rotationally burned slash pine plantations, grazing did not affect total herbage production, although heavy grazing did reduce tree basal area. In another study, designed to evaluate the degree of injury to slash pine by cattle eating the needles, Lewis (1980a, b, and c) determined that for 6-, 18-, and 30-month-old plants, survival was excellent except when 100% of the needles were removed 6 months after planting. Reductions in rate of height growth were noted in the most severe cases of defoliation, but even so, the greatest accumulated height loss was less than 1 meter over the 6-year period.

4.1.5. Agroforestry Research on Shortleaf pine

Currently, there is a limited amount of research information relating to shortleaf pine in agroforestry systems. Studies have been conducted for shortleaf, from research dealing with shortleaf pine – bluestem ecosystem restoration (Huebschmann 2000) to dynamics and development of shortleaf stands in East Tennessee (Cassidy 2004). Huebschmann's (2000) research focuses on an economic analysis designed to predict the amount of timber harvest volume and revenue the Ouachita National Forest may sacrifice by implementing a shortleaf pine-bluestem grass (or pine-bluestem) management system as opposed to traditional, even-aged management. During the 100-year simulation stage, the pine-bluestem scenario produced 26% less sawlog volume than other practices within the restoration area. The simulation results for this area also yielded reduced timber sale revenue (-51%) in present-value terms, but due to the small area that the pine-bluestem section encompassed, forest-wide revenue was reduced by only 2-5%. Huebschmann (2000) explains that these losses can be offset due to the predicted increase in red-cockaded woodpecker (*Picoides borealis)* habitat. Shortleaf pine-bluestem grass restoration efforts were predicted to support 400 breeding pairs, equivalent to an implicit value of $1,700 per year (present-value terms) for each woodpecker.

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Because of the limited scope of these and other studies, there is a noticeable "gap" in the body of research dealing with both agroforestry (more specifically silvopasture) and shortleaf pine. We propose to close this void through the following objectives: 1) Determine which soils on Redstone Arsenal (RSA) are suitable for silvopasture establishment, and 2) analyze the early survival of shortleaf in silvopasture systems on RSA. This research will not only add to the scientific body of knowledge, but also will provide non-industrial private forest landowners (NIPF) with information on an often under-utilized land management system.

Study Area

Redstone Arsenal encompasses approximately 60 square miles (10 miles north to south and about 6 miles from east to west) and is centrally located between Birmingham, Alabama (95 miles north); Nashville, Tennessee (109 miles south); Memphis, Tennessee (212 miles southeast); and Atlanta, Georgia (175 miles northwest) (See Figure 6). Redstone Arsenal's timberlands are diverse with pine (both loblolly and shortleaf) covering 4,318 acres, hardwoods (both the red oak and white oak groups) covering approximately 6,601 acres, and mixed stands of eastern redcedar, hardwood, and pine covering 4,978 acres. RSA also has 765 acres of wetlands and 14,370 acres classified as non-forestland. Many of these "non-forested" areas were in agricultural cultivation prior to the Arsenal's establishment in 1941, with cotton, corn, hay, peanuts, livestock, and various fruits and vegetables being the primary agricultural products produced by the area’s inhabitants. Subsequent to the Arsenal’s establishment, these “non-forested” areas have been grazed or mowed extensively.

4.2. Methods

4.2.1. Suitability Maps

In conjunction with the planting, agroforestry suitability maps were created. These maps identified other areas across the Arsenal that are well-suited for both agroforestry and the incorporation of shortleaf pine in a silvopastoral system. This information will provide RSA land managers with a layer inside their current operating system for Geographic Information System (ArcGIS 9.3.1 with 2010 imagery), which lists areas suited for implementing one or both of these practices in the future. These maps were generated by means similar to those used for shortleaf pine suitability (See Chapter 3). Since RSA has active wildlife management and agricultural lease programs, agroforestry “suitable” soils were determined with these practices in mind. Soil types were eliminated based on land use, potential for wildlife habitat elements, and land capability classification. Slopes greater than 10% were also eliminated due to potential problems with machine accessibility and maneuverability (See Tables 5 and 6). Wetlands were also eliminated. The finalized maps (shortleaf and agroforestry) were then overlaid, to produce a map that designates areas suited for both, with hopes that this process can be utilized to generate suitability maps for other areas of the state. This finished product will provide interested landowners and land managers with site-specific information that accurately identifies locations suited for these practices. To determine soil suitability for shortleaf agroforestry, the selection function was utilized in order to identify all of the shortleaf soils that were also suitable for agroforestry. The “select by location tool” was then utilized, and the spatial selection method used was comprised of features that contain the source layer feature. In determining overall soil suitability, the target layer was agroforestry, and the source layer was the soils suitable for shortleaf.

Table 5 – Criteria for agroforestry soil evaluation on RSA, 2012

	Suitable for agroforestry on RSA	Not suitable for agroforestry management on RSA
Wildlife habitat elements	Good to Fair potential for production (See Table 4)	Poor potential for production (See Table 4)
Slope	<10%	>10%
Land capability classification	Prime farmland	Not prime farmland

Table 6 - Soil types suitable for agroforestry production on RSA (Clendenon 1996)

Soil Symbol	Soil Name	Land Use	Wildlife Habitat Elements (grasses/legumes, grain/seed crops, and wild herbaceous plants)	Land Capability Classification (Prime Farmland)	Slope
DeA	Decatur silt loam	Hayland and pastureland	Good potential	Yes	0-2%
DeB2	Decatur silty loam	Hayland and pastureland	Good potential	Yes	2-6%
EgA	Egam silt loam	Woodland	Good potential	Yes	0-2%
EmA	Emory silt loam	Hayland and pastureland	Good potential	Yes	0-2%
EtA	Etowah loam	Hayland and pastureland	Fair, fair, and good potential	Yes	0-2%
EtB2	Etowah loam	Hayland and pastureland	Fair, fair, and good potential	Yes	2-6%
EwB2	Etowah loam	Hayland and pastureland	Fair, fair, and good potential	Yes	2-6%
HaB2	Hartselle loam	Woodland	Good potential	Yes	2-8%
HoA	Hollywood silty clay	Hayland and pastureland	Fair potential	Yes	0-2%
LcA LcB2	Locust loam	Hayland and pastureland	Fair, good, and good potential	Yes	0-3%
	Locust silt loam	Hayland and pastureland	Fair, good, and good potential	Yes	2-6%

Soil Symbol	Soil Name	Land Use	Wildlife Habitat Elements (grasses/legumes, grain/seed crops, and wild herbaceous plants)	Land Capability Classification (Prime Farmland)	Slope
LoA	Locust silt loam	Hayland and pastureland	Fair, good, and good potential	Yes	0-2%
LoB2	Locust silt loam	Hayland and pastureland	Fair, good, and good potential	Yes	2-6%
MnB2	Minvale gravelly silt loam	Woodland, hayland, and pastureland	Good potential	Yes	2-6%
SeA	Staser loam	Woodland	Fair potential	Yes	0-3%
SoA	Swafford fine sandy loam	Hayland and pastureland	Fair, good, and good potential	Yes	0-3%
WaB2	Waynesboro loam	Hayland and pastureland	Good potential	Yes	2-6%
WoA	Wolftever silt loam	Woodland	Good potential	Yes	0-4%

4.2.2. Shortleaf pine silvopasture establishment

Shortleaf (1st generation bare root seedlings from the Tennessee Department of Agriculture Nursery) and loblolly pine (2nd generation bare root Super Tree seedlings from Arbor-Gen) stands were machine planted on 120 acres of inactive agricultural leases in the spring of 2010 (February – March). The areas were site prepped with a prescribed burn prior to planting. All treatments were randomly assigned, and approximately 60 acres was divided into 9 agroforestry blocks, 5 in loblolly and 4 in shortleaf. The agroforestry blocks utilize a double-row configuration. These double rows are planted at a 6' x 8' spacing (350 trees per acre (TPA)), while leaving a 40-foot "alley" between them. This provides for ample sunlight to reach both the understory vegetation and seedlings throughout the day and allows for continued hay harvest within the alleyways. The remaining 60 acres was divided into 9 conventional blocks, 5 in loblolly and 4 in shortleaf. These blocks were planted in traditional plantations of 600 TPA (9' x 8' spacing). Blocks average in size from 6-9 acres, and were oriented in an east-west direction (Figure 9). Upon completion, quality audits were performed to ensure that the desired stocking requirements were met.

4.2.3. Herbaceous Weed Treatment

Due to the high grass groundcover component in the research blocks, herbaceous weed treatments were applied in an attempt to control competition. An early rotation release spray was applied during May 2010. Six-ounces of Oust-Extra (Dupont) per acre was applied (via 4-foot band application), ensuring that a 90% kill rate was attained. The sprayer volume was calibrated to10 gal/ac. In addition, the lanes between the planted rows (both agroforestry and conventional) were mowed one time during the first growing season. This was done in an attempt to provide extended weed control for the newly planted seedlings. During the second growing season, mowing was conducted solely within the agroforestry areas. The alleyways were mowed and raked for hay production, thus providing an alternate means for revenue production and ensuring some degree of competition control.

4.2.4. Planting Evaluation (Year 1)

After the first growing season (2010), research blocks were evaluated for survival and total growth rates. The blocks were transected in an east-west orientation, with a grid of 3 chains between lines (198 ft), and 2.5 chains between the plots (165 ft). One-fifth acre (52.7 ft. radius) plots were tabulated and the number of plots was based on block size, ensuring that at least 20% of each block was analyzed.

Evaluations were made from the northeast corner of each block, south, then west, utilizing handheld GPS units to navigate to the first plot center. Once plot centers were designated, a PVC pipe was placed there to indicate such, and I then placed pin flags with the appropriate plot number (according to numeric order) in the pipe. A tape was pulled from plot center due north 52.7 ft, placing a ribbon on the first live or dead seedling encountered. This seedling, as well as the others within each plot, was measured for diameter at ground level and new growth. These measurements were made with digital calipers for diameter growth, and meter sticks for total height. The measurements were recorded initially in millimeters (diameter growth) and centimeters (height). The first seedling was identified as "seedling 1” on the tally sheets, noting its measurements accordingly. From “seedling 1” I worked clockwise, notating each seedling that fell within the designated plot radius and assigning it a number based on tape orientation. In total, there were 16 blocks and 120 (1/5 acre) plots, which provided a 20% sample of the 120 acres. Microsoft Excel spreadsheets containing the data were created and tabulated based on species and planting configuration (TPA). In order to ensure that the designated plot centers and "seedling 1's" could be located for future data collection; each was marked with a handheld GPS unit. The appropriate plot radius (52.7 ft.) was also added to provide reference points depicting where the seedlings classified as "1" were located (Figure 10) within the plots. This ensured that there was no overlap in the data collected.

4.2.5. Replanting and Comparison of Growth and Survival (Year 2)

Year 1 survival numbers, for all of the research blocks (both conventional and agroforestry) planted in shortleaf pine, fell below the desired stocking rates. In contrast, only one of the loblolly blocks was unacceptable. Per the scope-of-work for the planting contract, the contractor was required to ensure a 90% survival and stocking rate one-year post planting (barring any acts of God). Blocks with fewer than 90% of the desired stocking requirements were re-planted (hand-planted with ho-dads) in the spring of 2011 (January – February). The shortleaf seedlings were obtained from the Tennessee Department of Agriculture Nursery, ensuring similar genetic stock. The variation in planting technique was required to minimize the damage to the residual seedlings, while also allowing for an evaluation of planting methods and how this affects growth and survival rates between species. Following replanting, data on seedling survival were collected by means similar to Year 1, but due to the variation in growing seasons between species, diameter variations were excluded from the stand dynamic comparisons. However, total height (in foot increments) and survival were still noted.

Fewer plots were evaluated (65 total) for Year 2 than Year 1 based on worker availability and allotted time. Every second plot was tallied, and this provided an 11% sample of the 120 acres included in research. After collecting data for Year 2, Year 1-growth rates were converted to feet for the sake of consistency, and transferred into Microsoft Excel for compilation. Data were tabulated based on species, configuration (TPA), and planting technique.

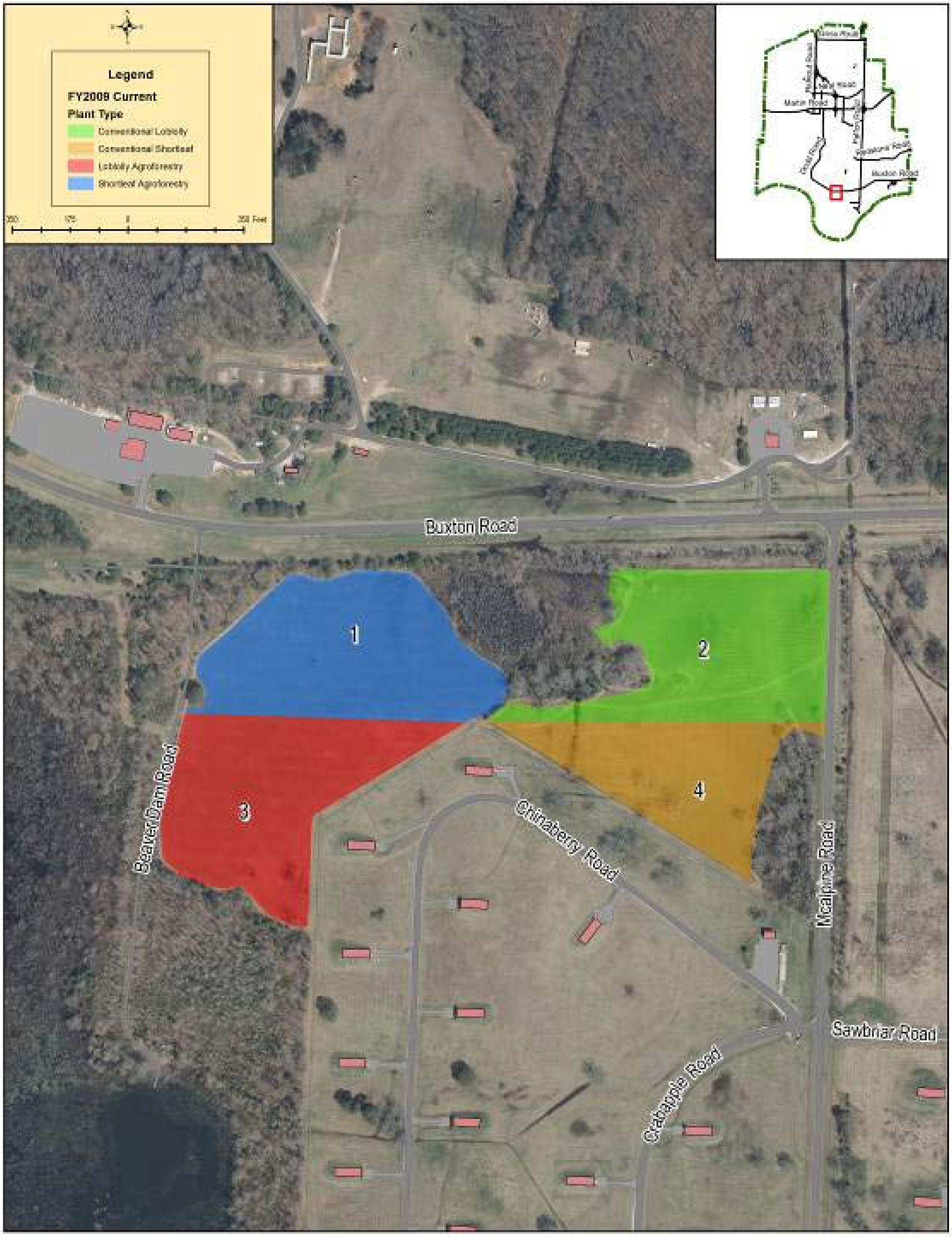

Figure 9. Block Orientation within Research areas on RSA

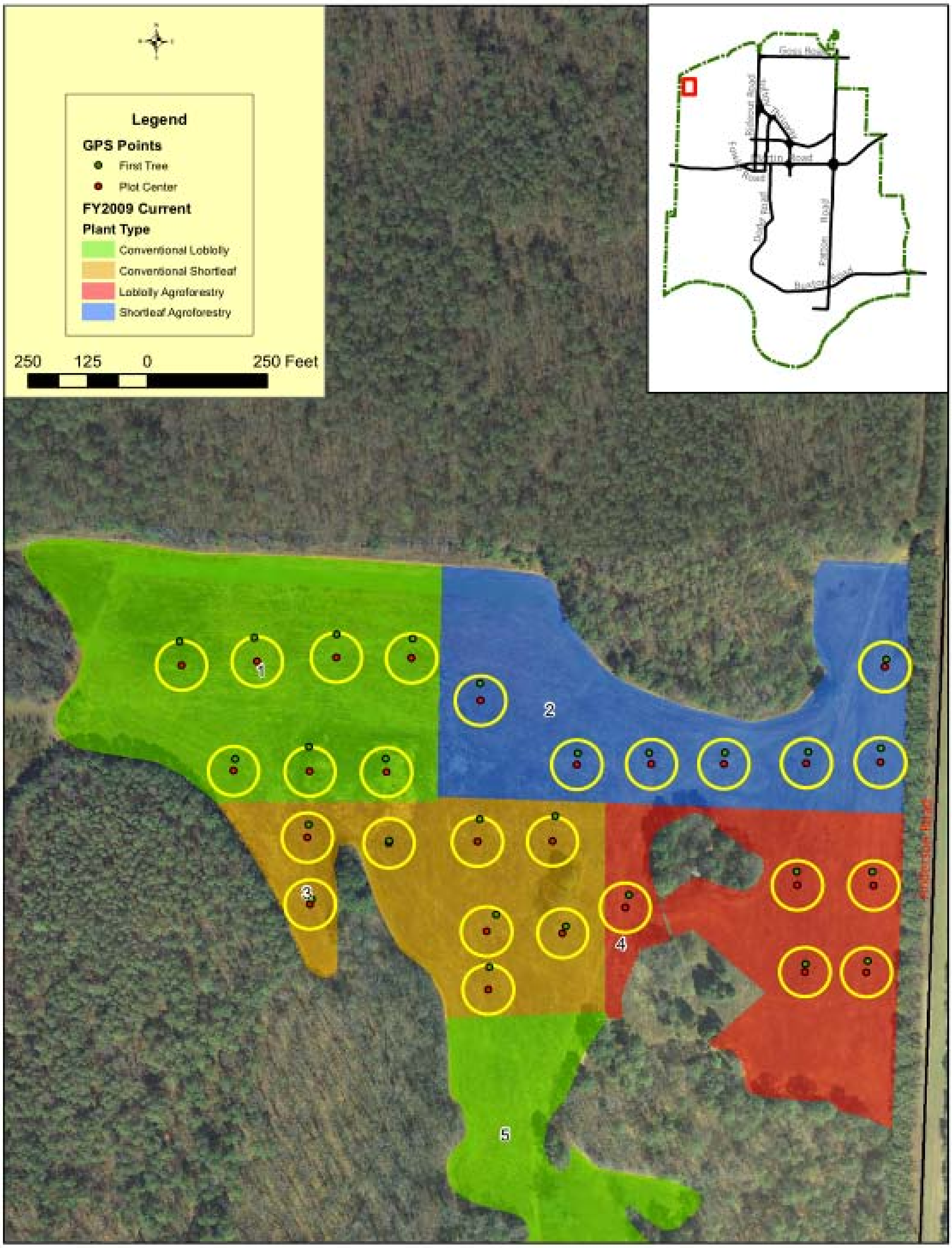

Figure 10. Designated Plot Centers and Seedlings within Research Blocks on RSA

4.3. Results

Stand dynamics results for both species and configurations (Year 1 and Year 2) are shown in Table 7. First-year survival (Figure 13) ranged from 86.40% (loblolly agroforestry) to 44.04% (shortleaf conventional). There was little difference in growth rates during Year 1 for loblolly in conventional vs. agroforestry sets (Figure 14). Also, there was little difference in growth rates during Year 1 for shortleaf in conventional vs. agroforestry sets (Figure 15). During Year 2, loblolly exhibited a slightly better growth rate in the agroforestry set compared to the conventional set (Figure 17). In addition, there was a slight improvement in survival rate for the agroforestry set, registering 100% compared to 99.32% in the conventional set. During Year 2, shortleaf showed a better growth rate in the agroforestry set compared to the conventional set (Figure 18). Survival rates were comparable in both types of sets. Both loblolly and shortleaf fared better, in terms of growth rates, in the agroforestry set during Year 2 (Figure 16).

Competing vegetation varied across the research blocks from grasses to forbs for Years 1 and 2. Table 8 lists the predominant competing vegetation in the plots for both years. Although there were only minimal differences in height growth rates between configurations, survival and stocking rates were drastically different from Year 1 to Year 2 for both species. This may be attributed to a lack of visibility in regards to spotting/documenting dead seedlings.

In regards to suitable soils, 18 of the 43 soil types present were determined to be suitable for agroforestry, and this area encompassed 12,082 acres (32% of land base). Figure 11 depicts the locations of RSA soils best suited for agroforestry. Decatur silty loam is the most prevalent soil type, appearing on 2,429 acres and representing approximately 6% of the total land base. A concentration of agroforestry suitable soil types appears in the north-central, northwest, and southern sectors of RSA. The Hollywood silty clay soil type is the least prevalent, covering about 45 acres. Fifteen of the 43 soil types present are suitable for both practices, encompassing 6,817 acres (18% of land base). Figure 12 depicts the locations of RSA soils best suited for shortleaf agroforestry. Decatur silty clay loam is the most prevalent soil type, appearing on 2,302 acres and representing approximately 6% of the total land base. A concentration of agroforestry suitable soil types appears in the north-central, west, and southern sectors of RSA. The Fullerton gravelly silt loam soil type is the least prevalent, covering about 4 acres.

Figure 11. Redstone soils suited for an agroforestry management style, 2012

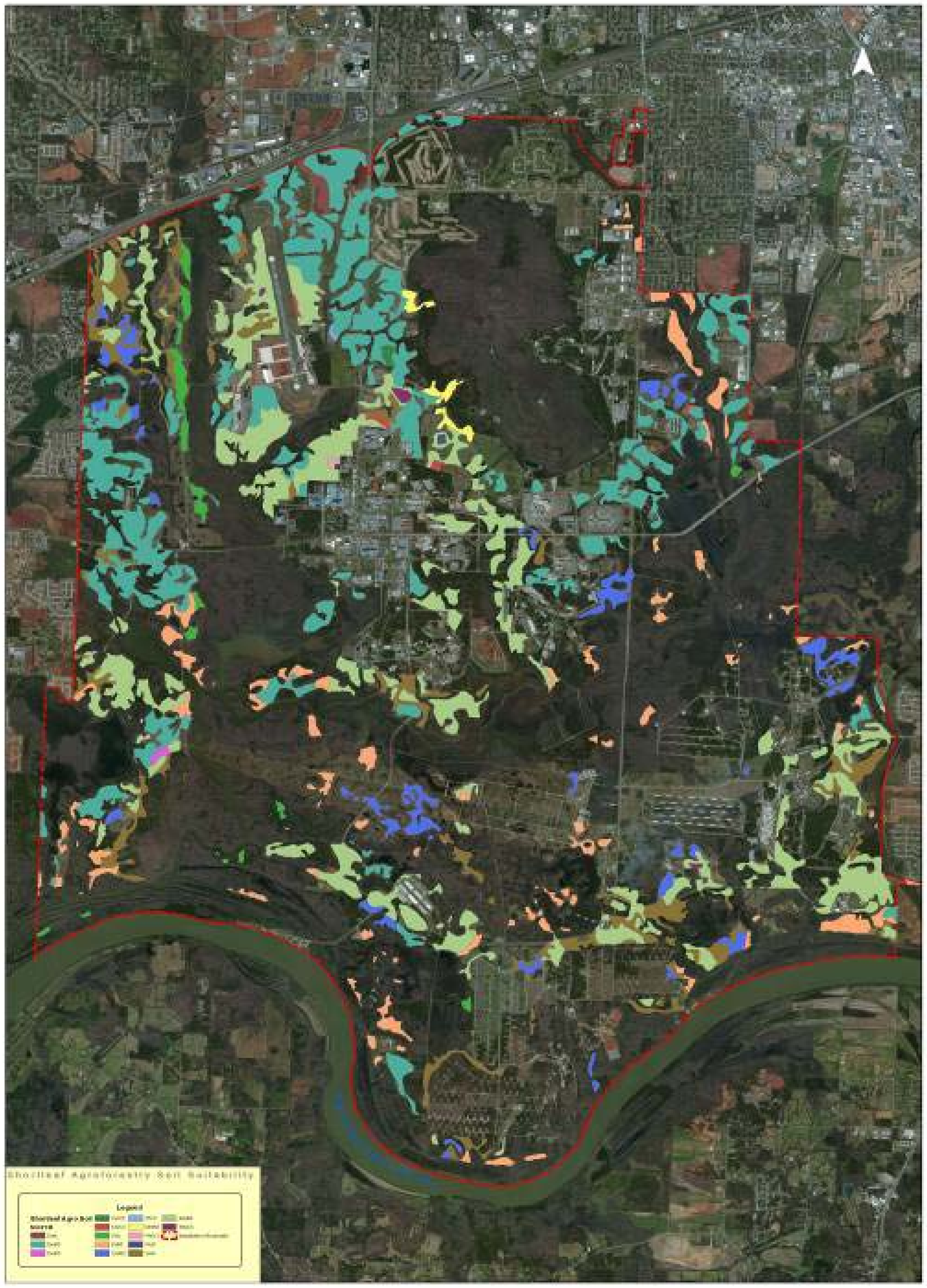

Figure 12. Redstone soils suitable for both shortleaf and agroforestry management practices, 2012

4.4. Discussion

The inactive grazing/hay leases, on which both species were planted, had been cropped or in livestock production since the 1940's. In spite of no-till cropping, compaction, due to equipment or livestock, was expected. According to Wheeler et al. (2002) tillage, including subsoiling, drastically improves loblolly seedling survival and growth after 3 years. However, due to environmental concerns and a particular section's proximity to a Threatened and Endangered Species (T&E), only minimal ground disturbance was permitted. Planting for Year 1 was performed with a tree-planter mounted on a three-point hitch. This ensured that a small furrow was created, thus allowing for some ground fracture in which to plant the seedlings.

Research blocks were designed for a comparison of stand dynamics between species, allowing for an "apple to apple" evaluation. But, as previously mentioned, shortleaf seedlings were 1st generation bare root, and in contrast loblolly seedlings were 2nd generation bare root Super Tree from Arbor-Gen. This situation immediately introduced variability between the species. Genetically improved shortleaf pine seedlings are not as readily available as loblolly, and in this case, were difficult to locate based on locale (latitude and longitude).

Overall survival averages for Year 1 shortleaf stands (48.57%) were lower than those of loblolly (83.97%). This could be attributed to several factors, including seedling storage, planting, and machinery damage. The contractor acquired the shortleaf seedlings two weeks prior to planting, which required that they be stored properly. During a post-plant audit, a number of improperly planted seedlings were observed (i.e. J-rooting or improper depth). Due to the manner in which shortleaf seedlings were packaged, separating and inserting them in the planter was made extremely difficult, and this often resulted in improper planting. Also, in an effort to control competition, some seedlings were damaged by mowing equipment, due to the lack of visibility and row spacing.

In conjunction with tillage, herbaceous competition control is equally as important for survival rates of both species (Miller et al. 1995a, 1995b; Yeiser and Barnett 1991). As mentioned earlier, herbaceous weed release treatments were applied during the Year 1 growing season, thus eliminating many of the competing forbs/grasses. Also, as previously indicated, due to environmental concerns/constraints, only one release treatment was allowed within a particular section and for the sake of consistency among research blocks, only one release treatment was applied to all the areas included in research.

Year 2 stocking rates decreased for both species, while the survival rates increased. This could be attributed to problems with visibility in some research blocks, which perhaps prevented the data (number of dead seedlings) from being recorded correctly. There was no significant difference in survival among the different planting techniques. Shortleaf agroforestry sets yielded higher survival and stocking rates than those of conventional sets for Years 1 and 2, while also providing greater growth rates for Year 2 as well. These results again pose the question: How will shortleaf fare in an agroforestry set?

Kushla (2009) notes the need for continued research dealing with how shortleaf pine responds to intensive forest management (i.e. site-prep, release treatments, and fertilization). This study can contribute to a better understanding of some of these factors that relate to establishment of shortleaf pine in North Alabama.

Table 7. Stand dynamics results for Year 1 and Year 2 for both shortleaf and loblolly pine relative to the shortleaf agroforestry research on RSA, Alabama.

Year/Species	Configuration	Height (ft)	Survival (%)	Stocking (%)
Year 1 Loblolly	Conventional (600TPA)	.47	81.54	82.84
Year 2 Loblolly	Conventional	3.28	99.32	76.39
Year 1 Loblolly	Agroforestry (350TPA)	.45	86.40	79.04
Year 2 Loblolly	Agroforestry	3.37	100	66.56
Year 1 Shortleaf	Conventional	.44	44.04	41.74
Year 2 Shortleaf	Conventional	2.04	97.04	29.07
Year 1 Shortleaf	Agroforestry	.42	53.09	57.43
Year 2 Shortleaf	Agroforestry	2.21	95.61	37.25

Table 8. Predominant competing vegetation across research blocks as observed May, 2011.

Configuration	Most predominant competitors
Conventional (600 TPA)	Bermuda grass, Fescue grass
Agroforestry (350 TPA)	Bermuda grass, Fescue grass, Johnson grass

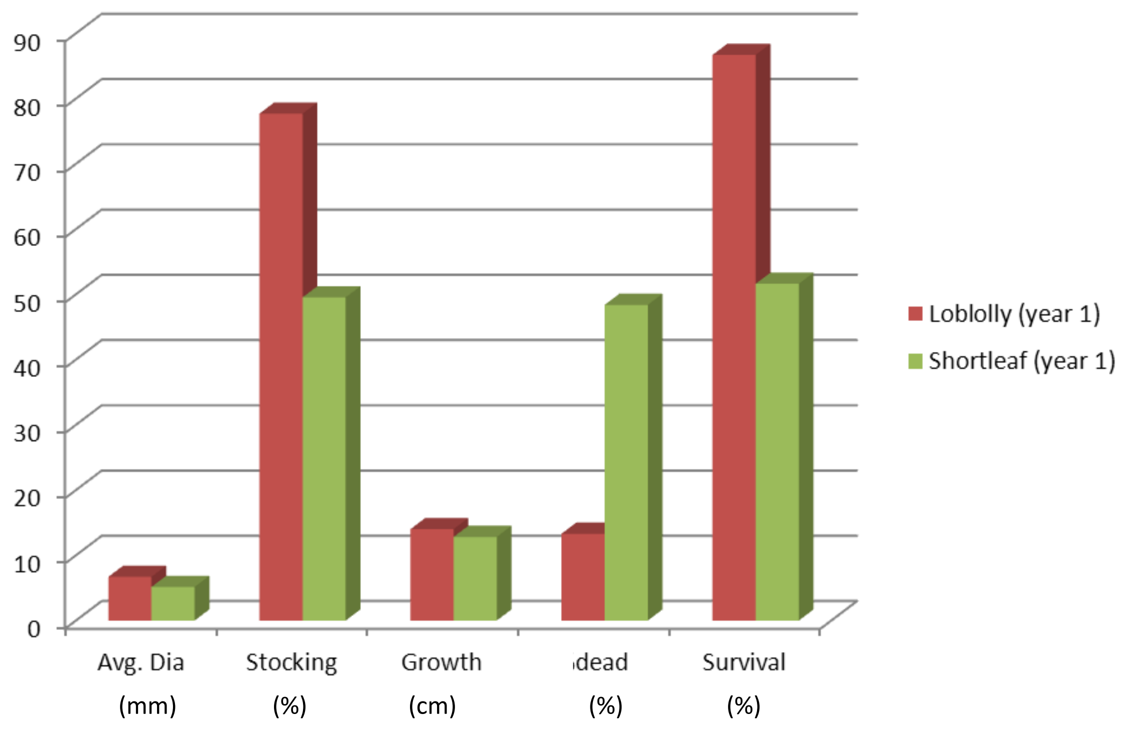

Figure 13. **Year 1 stand dynamic results for both shortleaf and loblolly pine relative to the shortleaf agroforestry research on RSA, Alabama. Data results (by species) were compiled and results, other than average diameter (mm) and growth (cm), are depicted as percentages.**

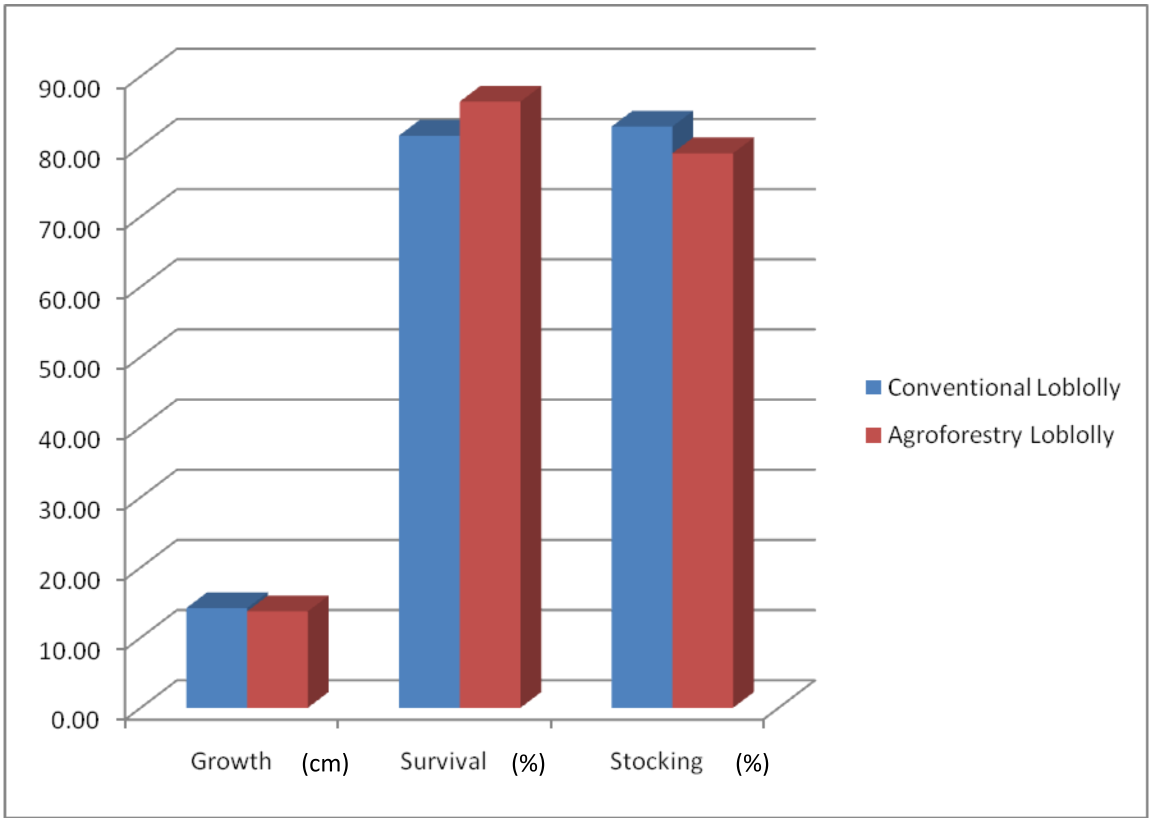

Figure 14. Year 1 comparison between loblolly pine planting configurations relative to the shortleaf agroforestry research on RSA, Alabama. Data results (by species and configuration) were compiled and results, other than average growth (cm), are depicted as percentages.

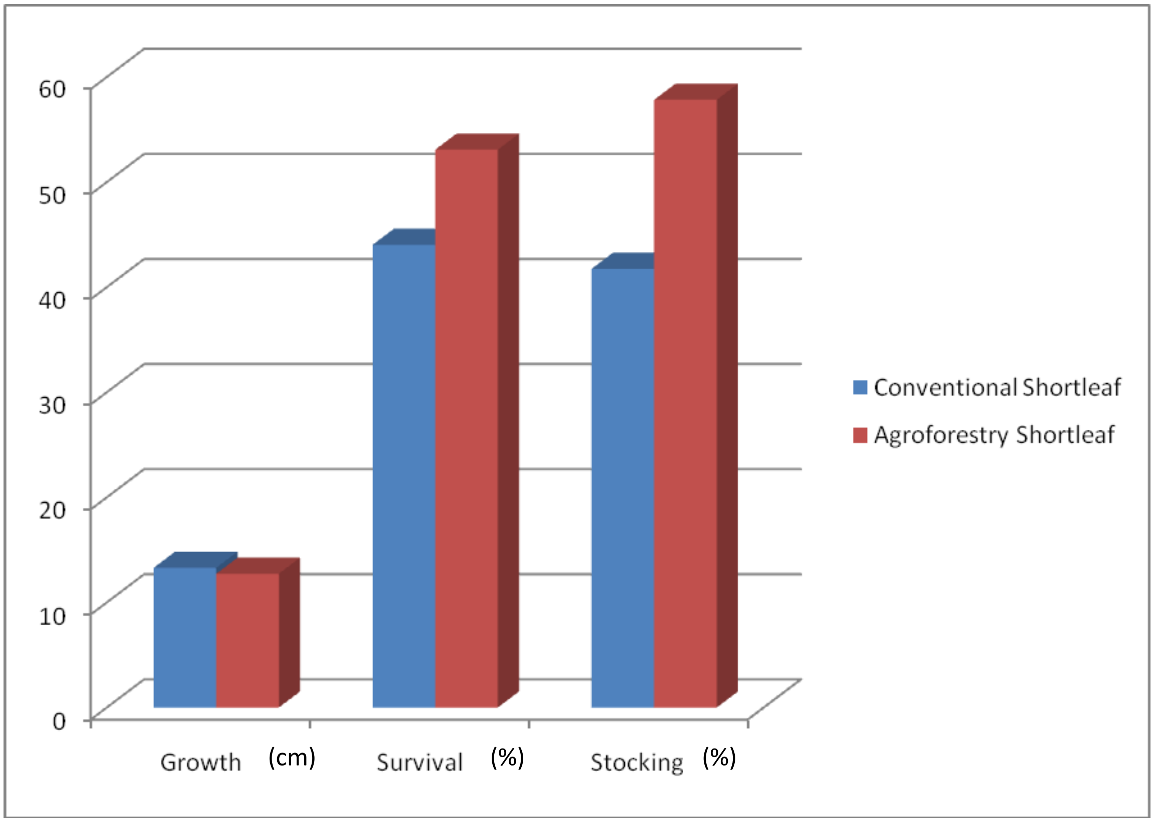

Figure 15. Year 1 comparison between shortleaf pine planting configurations relative to the shortleaf agroforestry research on RSA, Alabama. Data results (by species and configuration) were compiled and results, other than average growth (cm), are depicted as percentages.

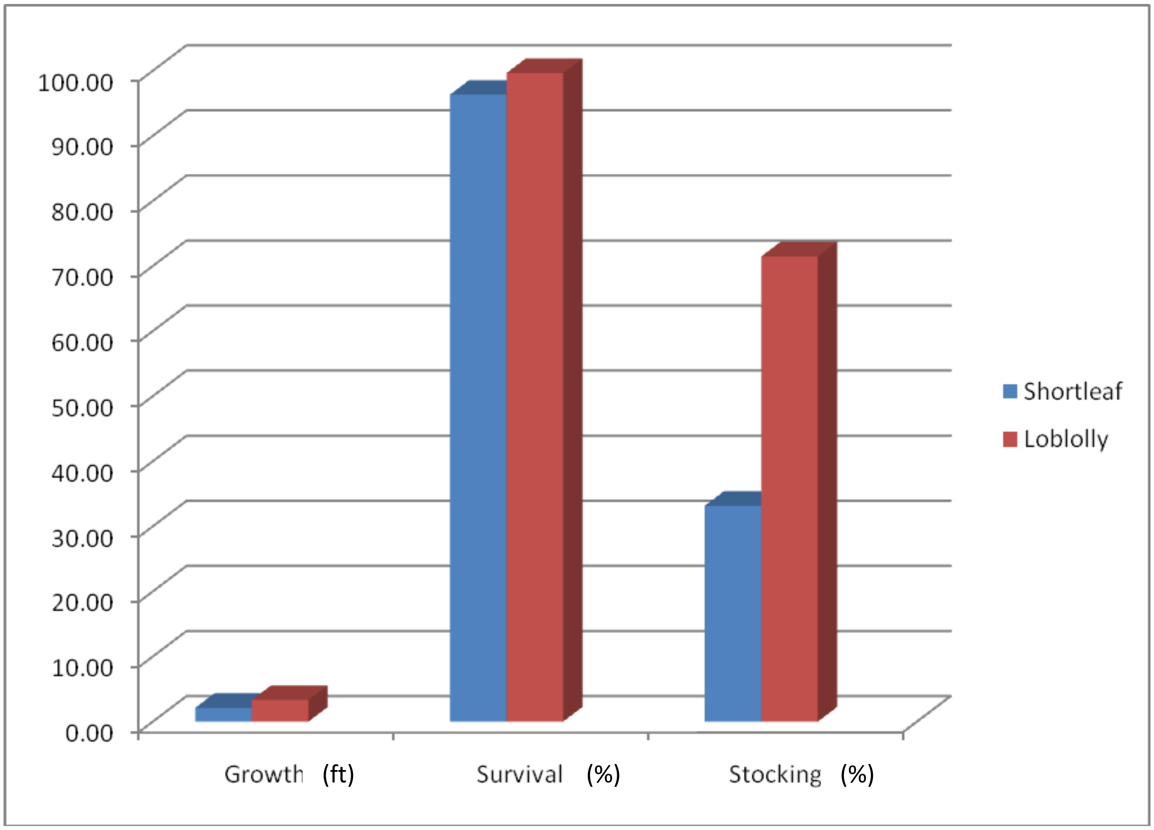

Figure 16. Year 2 stand dynamic results for both shortleaf and loblolly pine relative to the shortleaf agroforestry research on RSA, Alabama. Data results (by species) were compiled and results, other than average growth (ft), are depicted as percentages.

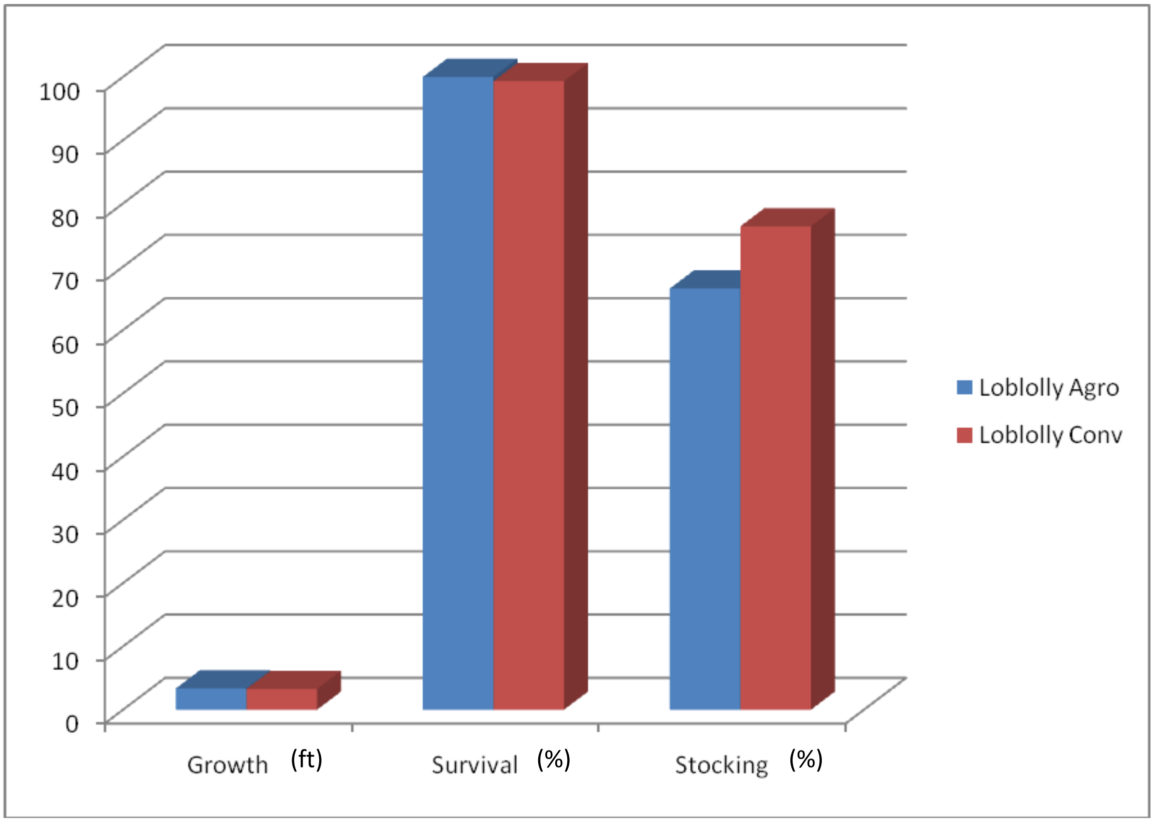

Figure 17. Year 2 comparison between loblolly pine planting configurations relative to the shortleaf agroforestry research on RSA, Alabama. Data results (by species and configuration) were compiled and results, other than average growth (ft), are depicted as percentages.

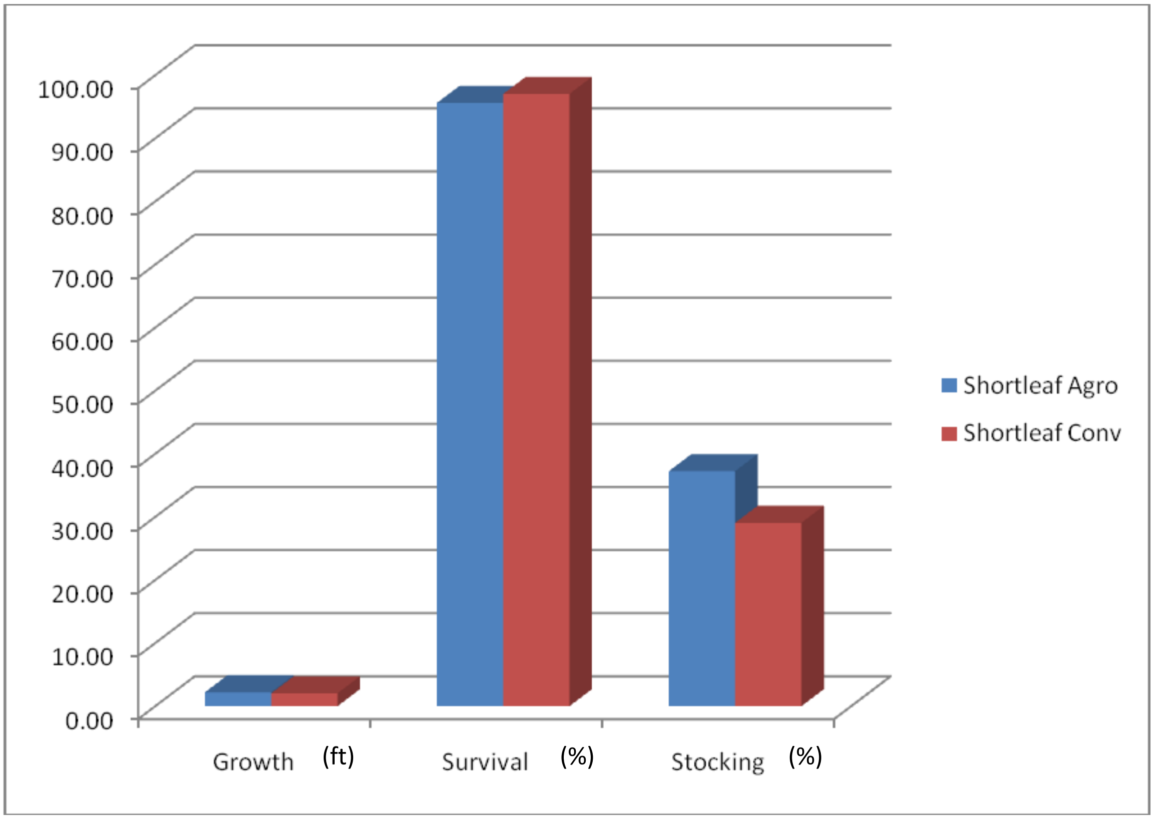

Figure 18. Year 2 comparison between shortleaf pine planting configurations relative to the shortleaf agroforestry research on RSA, Alabama. Data results (by species and configuration) were compiled and results, other than average growth (ft), are depicted as percentages.

CHAPTER 5

Conclusion

Shortleaf pine is an important part of the forest landscape across Alabama and numerous other states. On Redstone Arsenal alone, 14,886 acres (39% of land base) are suited for future planting/planning considerations. Through efforts similar to those utilized in this research, landowners and land managers across the State can perform similar types of soil analyses on their land holdings. Alabama landowners should no longer dismiss shortleaf pine as a viable component of management options due to concerns about littleleaf disease. Littleleaf occurs within certain soil types and under certain conditions. Careful analysis of the factors which influence littleleaf occurrence is essential, and pertinent information relating to identifying those factors is crucial in minimizing this problem. Shortleaf, just as other southern-yellow pines, is a site-specific species, and should be planted accordingly.

Redstone Arsenal provides a perfect location for this type of research, due to the government's willingness to allow data collection to continue for a protracted period of time. The research areas will serve as demonstration sites, providing NIPF landowners, land managers, and other government agencies with examples of applied techniques relating to implementation of silvopasture/shortleaf on their property. Information from this type of activity will be useful in ensuring that the public has a greater awareness of the potential benefits that can be derived, and the collected data will be used to develop outreach publications that outline the appropriate methods for interested landowners to implement these practices on their property.

One of the primary objectives of this ongoing research project is to assess the viability for promoting shortleaf regeneration on RSA by means of a silvicultural management approach. Although the RSA location is an ideal one, some factors may have influenced the overall outcome, through Year 2. Some modifications, relative to soil preparation and herbicide application, could have impacted the rate of growth and survival for first year seedlings in both agroforestry and conventional sets.

Because of environmental concerns, relative to minimizing ground disturbance in close proximity to an endangered species, the ground was not ripped prior to planting seedlings. Similar environmental issues and the desire to ensure consistency among research blocks precluded the application of an herbaceous weed treatment for Year 2. Omitting these practices could have potentially impacted seedling survival and growth rates.

Although shortleaf pine has an extensive range and is tolerant of a variety of soil conditions, silvicultural research with the species is limited. A number of scientists and managers believe it offers a viable choice for management, and since it had a historical presence in the RSA area this research project was motivated largely in response to these factors. Findings from this research undertaking will hopefully provide much needed information that can help fill an existing “gap” relative to shortleaf inclusion in a silvopastoral setting.

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