A literature review of management practices to support increased biodiversity in intensively managed loblolly pine plantations

Final Technical Report to the National Commission on Science for Sustainable Forestry (NCSSF)

July 31, 2005

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The National Commission on Science for Sustainable Forestry (NCSSF) sponsored the research described in this report. The National Council on Science and the Environment (NCSE) conducts the NCSSF program with support from the Doris Duke Charitable Foundation, the David and Lucile Packard Foundation, the Surdna Foundation, and the National Forest Foundation.

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I. Introduction

When European settlers first arrived in North America, it is estimated that the South had 200 million acres in pine, mixed oak, and other forest systems. Pine savannahs and open woodlands containing longleaf (*Pinus palustris*), loblolly (*P. taeda*), shortleaf (*P. echinata*), slash (*P. elliottii*) and pond (*P. serotina*) pine dominated. Of these species, it is estimated that longleaf pine ecosystems may have covered over 60 million acres[1] (Bragg 2002, Wahlenberg 1946). Longleaf pine stands were often characterized by a single species overstory, a sparse mid-story/shrub layer, and a well-developed and species-rich ground layer. Frequent, low intensity fires, natural or anthropogenic in origin, were the primary disturbance regime (Noss 1988, Van Lear et al. 2004). These stands were also known for the diversity of wildlife, particularly game species, they harbored. Trees in these stands were often very large (*Table 1*) and ranged as old as 600 plus years. Today, there are only about 3 million acres of longleaf pine forest, of which only 12,000 are regarded as old-growth (Bragg 2002). These old growth stands are now recognized for the habitat that they provide for dozens of threatened species (Bragg 2002, Noss 1988).

Table 1. Heights and diameters of old growth pines in the south and southeast (Bragg 2002).

Species	Height (feet)	Diameter at breast height (inches)
Loblolly pine	145 -180	39 - 65
Longleaf pine	85 - 130	27 - 45
Shortleaf pine	85 - 140	35 - 50

Nearly 90% of the forestland in the South today is in private ownership (Wicker 2002), and much of it is comprised of dense plantations of fast-growing loblolly pine. The management intensity of these plantations has been increasing in recent decades (Siry 2002). At the same time, private landowners are facing an increasing demand to provide for broad, non-timber values such as biodiversity on these lands, which can lead to conflict over forest management practices.

Forest plantations have long been negatively characterized as biological “deserts” in which concern for wildlife is limited to key game species (Margolin 1970). While it is true that today’s dense loblolly pine plantations are different from the natural, open pine stands that were historically prevalent throughout the South, these intensively managed forests can still contribute to biodiversity on the landscape (Wigley et al. 2000). This contribution may fall short relative to natural forests, but it may compare favorably to other competing land uses such as agriculture or urbanization (Moore and Allen 1999).

At any rate, because of their prevalence in the region, intensively managed plantations have a significant potential impact on the level of biodiversity. Stand-level management changes can be made that can readily support increased biodiversity in these plantations. Even minor changes

[1] Estimates vary from a low of 30 to a high of 92 million acres. If one uses the low estimate, then today’s acrage of longleaf pine is only 10% of the original and of that only a very small fraction is in “old-growth.” Therefore, there is value in discussing mechanisms to increase old-growth structures in these remaining forests in the South.

can significantly improve biodiversity values (Hartley 2002, Johnson et al. 1975). Some of these changes may be complimentary with timber production and economic goals; others may involve some costs and trade-offs (Allen et al. 1996, Buongiorno et al. 2004, Hunter 1990). In this paper we review the literature to identify a spectrum of practices that support increased biodiversity in intensively managed loblolly pine plantations.

II. Management practices to support increased biodiversity

Biodiversity has several definitions, the simplest being a variety of life. Many definitions further specify that the definition includes all types of organisms as well as genotypes and even ecological processes and their inter-relationships (Hunter 1990, Oliver 1992, Reid and Miller 1989).[1] There is no single forest type or structure that maximizes biodiversity. Different species have different habitat requirements such that structures that support some species may not support others (Dickson and Wigley 2001). Even individual species require habitat diversity (Johnson et al. 1975). Thus the overall key to supporting a variety and abundance of species is to provide a diversity of structure and vegetation (Allen et al. 1996, Harris et al. 1979, Marion et al. 1986, Sharitz et al. 1992). This includes both within stand diversity and between stand diversity (Marion and Harris 1982, Thill 1990).

An important way to increase within-stand structural diversity is to maintain a lower overstory density. A more open canopy allows a diverse understory to develop, which provides forage and habitat for wildlife. Even plantations established with intensive site preparation are often very diverse in the early years as long as the canopy is open, but as the canopy closes this diversity rapidly decreases (Baker and Hunter 2002). Once the canopy closes, the stand moves into the stem exclusion stage that shades out the understory vegetation and subsequently lacks wildlife (Oliver and Larson 1990). Minimizing this stage can allow a stand to support more biodiversity over a given rotation. Maintaining an open canopy with a productive understory also makes plantations more similar to the diverse, natural pine communities that existed historically in this region (Bragg 2002, Noss 1988, Van Lear et al. 2004).

One way to maintain lower stand density for biodiversity is by planting at a lower density. A wider spacing, such as 12 feet, delays canopy closure, extending the more diverse early-successional stages (Dickson 1982, Johnson et al. 1975, Melchiors 1991). In addition to delaying canopy closure, a wider spacing between rows can also allow disking or mowing to help maintain a productive understory (Allen et al. 1996). A wider planting spacing may be undesirable, though, because of the resulting decreased wood quality. In this case a closer spacing followed by thinning may be a more desirable approach (Van Lear et al. 2004).

[1] "Biodiversity is defined by the UN as the variability among living organisms from all sources including terrestrial, marine, and other aquatic systems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems. The Global Biodiversity Strategy (WRL, IUCN, and UNEP 1992) espouses a shorter definition where biodiversity is the totality of genes, species and ecosystems in a region." (Patel-Weynand 2002)

Perhaps the most important way to establish and maintain an open, diverse structure is by thinning. Thinning has been found to benefit numerous individual wildlife species such as deer (Blair 1960, Halls 1973, Hurst and Warren 1980), quail (Dougherty 2004), small mammals (Mengak and Guynn 2003), turkeys (Mississippi State University Extension Service 2004), nuthatches (Wilson and Watts 1999), and other birds (Turner et al. 2002). Thinning early and often is widely recognized as an important component of an overall strategy to increase biodiversity (Hunter 1990, Marion et al. 1986). This minimizes the time in the stem exclusion stage and can maintain and further develop an open, diverse structure throughout the rotation. In addition to stimulating the herbaceous understory by allowing light to reach the forest floor (Harrington and Edwards 1999, Schultz 1997), thinning also facilitates additional understory management such as disking or burning (Johnson et al. 1975), and it increases the understory response to such treatments (Melchiors 1991, Tucker et al. 1998).

Van Lear et al. (2004) suggest that a commercial thinning be done by the time a plantation reaches age 15. Hurst and Warren (1980) suggest that it be done as early as age 12 if no pre-commercial thinning was done. The recommended frequency of thinning to maintain an open stand structure is usually around five years (Blair and Enghardt 1976, Conroy et al. 1982, Halls 1973, Hunter 1990, Schultz 1997). Maintaining an open stand structure requires heavier thinning than for timber production, with a target of 50-70 ft^2/acre of residual basal area (Blair and Enghardt 1976, Halls 1973, Van Lear et al. 2004). A residual basal area of 80 ft^2/acre is usually considered a minimum for timber production and economic return (Siry 2002, Siry et al. 2001).

A potential problem with thinning to open up the pine overstory is that it can allow understory hardwoods to develop into a dense midstory. Hardwoods produce heavy shade that inhibits understory vegetation (Blair and Enghardt 1976, Dickson and Wigley 2001, Schultz 1997, Tappe et al. 1993). Thinning can also increase vines and shrubs, which further shade out the herbaceous layer (Harrington and Edwards 1999). Thus, without controlling hardwoods and other woody vegetation, thinning can ultimately result in a less productive and less diverse understory (Blair and Feduccia 1977, Hunter 1990). A hardwood midstory can add vertical stratification and benefit some midstory-associated birds (Dickson 1982, Melchiors 1991, Turner et al. 2002). However, a hardwood midstory is generally undesirable for most wildlife, including deer, small mammals, and other birds (Dickson 1982, Lohr et al. 2002, Melchiors 1991, Wilson and Watts 1999).

While a dense midstory is undesirable, some hardwoods are necessary for supporting biodiversity. Mature hardwoods such as oaks provide hard mast that is important for many wildlife species (Dickson 1982, Dickson and Wigley 2001, Johnson 1987, Johnson et al. 1975). Maintaining a desirable component of hardwoods can improve wildlife habitat (Tappe et al. 1993). When controlling hardwoods, individual fruit or mast producing trees can be selectively retained (Blair 1967, Blair and Feduccia 1977). Maintaining whole areas of hardwoods is also important. An interspersion of hardwood and pine forest types provides good wildlife habitat (Shultz 1997). Hardwoods should especially be maintained in sensitive areas such as bottomlands and drainages (Halls 1973, Johnson et al. 1975). Hardwood maintenance should generally stay focused on hardwood sites (Johnson 1987).

In historic, natural pine stands, frequent low-intensity fires helped to control hardwoods and maintain an open stand structure with a productive and diverse understory (Noss 1988, Van Lear et al. 2004). Frequent low-intensity fires tend to favor growth of herbaceous vegetation by suppressing hardwoods and other woody vegetation (Reed et al. 1994). Prescribed burning can be used in conjunction with thinning in intensively managed plantations to achieve desired conditions that support increased biodiversity. Many of the plants and animals associated with southern pine communities are adapted to or even dependent on fire, and wildlife mortality from fire is generally very low (Landers 1987, Means and Campbell 1981, Moorman 2002). Regular burning improves habitat for many species, including deer (Dickson 1982, Halls 1973, Hurst et al. 1980, Marion et al. 1986), quail (Dougherty 2004), turkey (Marion et al. 1986, Mississippi State University Extension Service 2004), amphibians and reptiles (Means and Campbell 1981), and Bachman's sparrow (Tucker et al. 1998).   To help provide for a broad suite of species in the short and long term, areas should not be burned evenly, but rather patches of unburned areas should be left to provide for nesting and cover (Landers 1987, Moorman 2002).

Prescribed burning is recommended when the dominant pine trees are 15 feet tall (Halls 1973, Moorman 2002). Recommended burning intervals range from 3-6 years (Blair and Enghardt 1976, Blair and Feduccia 1977, Halls 1973, Mississippi State Extension Service 2004, Schultz 1997). Marion et al. (1986) suggest 3-5 years to allow enough time for browse and cover to develop, as well as enough fuel to carry the next fire. Historically, longleaf pine communities in Florida burned naturally every 2-5 years (Noss 1988). Prescribed burning should not be overdone, or the cumulative impacts could become negative in the long term (Melchiors 1991). For example, if burning is done too frequently, such as annually, it can eliminate hardwoods altogether, (Dickson 1982, Grano 1970, Schultz 1997). Complete loss of the hardwood component would have a negative impact on biodiversity.

Many authors recommend burning in winter (Allen et al. 1986, Blair and Feduccia 1977, Halls 1973, Mississippi State Extension Service 2004, Schultz 1997). However, Robbins and Myers (1992) note that varying both the season and the frequency of burning avoids favoring only one suite of species. Adding this element of variability can increase overall stand diversity. Coordinating burning with thinning is also important. Thinning increases the effectiveness of prescribed burning for wildlife (Hurst and Warren 1982, Melchiors 1991, Tucker et al. 1998). Burning before thinning can make thinning easier (Hurst et al. 1980), and it avoids the problem of the fire burning too intensely in the slash from the thinned trees (Van Lear et al. 2004).

An alternative to prescribed burning for the control of nonpine woody vegetation is to use herbicides (Dickson and Wigley 2001, Harrington and Edwards 1999). Herbicides can be less costly than burning and may be especially desirable where burning opportunities are limited (Wigley et al. 2002). Normal applications of herbicides are generally not directly toxic to wildlife (McComb and Hurst 1987). Herbicides may have a longer residual effect on understory diversity than prescribed burning or mechanical vegetation control (Hunter 1990). Nonetheless, vegetation seems to recover quickly within 1-3 years (Keyser et al. 2003, Reed et al. 2004). A longer term study found no significant impact on floristic diversity 11 years after herbicide treatment (Miller et al. 1999).

The intensity and methods of site preparation for controlling vegetation at the beginning of the rotation should also be considered when managing pine plantations for increased biodiversity. More intensive site preparation favors grass and forbs, while less intensive site preparation favors vines and woody vegetation (Johnson 1975, Locascio et al. 1990). More intensive site preparation also reduces the availability of fruit for wildlife (Hunter 1990, Stransky and Roese 1984). Thus, while intensive site preparation can benefit some game species like deer, less intensive site preparation is generally better for a diversity of wildlife (Marion and Harris 1982, Marion et al. 1986). Locascio et al. (1990) found that moderate intensity site preparation produced the greatest understory biomass, and moderate intensity treatments may be the most cost effective, especially for non-industrial landowners. In terms of site preparation methods, Locascio et al. (1991) observed that mechanical site preparation (shear, chop, disk, etc.) did not seem to diminish understory plant diversity. Mechanical methods may provide for greater understory diversity and food production compared to herbicides (Fredericksen et al. 1991, Keyser et al. 2003). Burning may also be a desirable option for stimulating stored seeds (Hunter 1990).

Other management activities like fertilization and pruning can also impact biodiversity. Use of fertilization in pine plantations has increased in recent decades, though it is mostly done on industry lands (Siry 2002). The impacts of fertilization on biodiversity are somewhat mixed. Fertilization can improve understory food production for wildlife, especially in stands that have been thinned (Hunter 1990, Hurst and Warren 1982, Melchiors 1991). Fertilization can also accelerate canopy closure, though, which can offset wildlife benefits (Dickson and Wigley 2001). Thus fertilization treatments should be done in conjunction with thinning to maximize wildlife benefits. Pruning can benefit biodiversity by increasing understory vegetation (Baker and Hunter 2002, Hurst and Warren 1982) as well as creating more horizontal openings.

Another way to support increased biodiversity in pine plantations is by retaining key structural features such as snags, coarse woody debris, and mature live trees. These elements add additional structural complexity that benefits a wide range of wildlife (Allen et al. 1996, Baker and Hunter 2002, Dickson and Wigley 2001, Lohr et al. 2002, Marion et al. 1986, Sharitz et al. 1992). Maintaining riparian buffers, or streamside management zones, can provide for some of these elements (Dickson and Wigley 2001, Thill 1990). Riparian buffers further contribute to biodiversity by providing for aquatic species and water quality (Baker and Hunter 2002) and by providing habitat connectivity (Dickson and Wigley 2001, Johnson 1987).

All of the management practices described above will be most effective if done in conjunction with longer rotations. Pulpwood rotations can be as short as 20 years (Biblis et al. 1998, Melchiors 1991). Short rotation management limits pine plantations to early successional structures and does not provide for species needing older seral stages (Johnson et al. 1975). Because of the dominance of short rotations, older seral stages are becoming rare in the region (Allen et al. 1996). Managing for longer rotations can increase diversity (Sharitz et al. 1992). Rotations of 40-100 years can provide for long-term wildlife forage as well as key habitat elements such as hardwood mast, snags, and cavities (Melchiors 1991).

Longer rotations can impact economic returns. Because future revenues are discounted, longer rotations must produce significantly more revenue to be economically competitive with shorter rotations. Dean and Chang (2002) found that economic performance decreased with increasing rotation length. In contrast, Biblis et al. (1998) noted that 50-year sawtimber rotations performed better economically than 20-year pulpwood rotations if the target rate of return was 7% or less. Ultimately it depends on the relative prices of pulpwood and sawtimber and the rate of return that is acceptable to the landowner.

III. Other considerations

In looking at management practices to increase biodiversity in intensively managed loblolly pine plantations, some additional considerations should be made. The management practices described in this paper are geared towards increasing stand-level biodiversity. Ultimately, though, a landscape approach is needed. A variety of different stand structures and age classes should be present on the landscape to support the full range of biodiversity (Marion et al. 1986, Moore and Allen 1999, Oliver 1992). The size, shape, and spatial arrangement of these structures are also important (Johnson 1987). For landowners with large areas of contiguous holdings, a landscape management approach to providing for biodiversity may be feasible. When the landscape is broken up among different ownerships, landscape management requires coordination between different landowners with different needs and goals. The issues involved with such coordination are beyond the scope of this review. In any case, maintaining biodiversity at the landscape level depends on a collection of stand-level decisions. If individual landowners employ practices to increase stand level biodiversity, their practices are likely to support significantly increased biodiversity across the landscape.

Another important consideration when managing for biodiversity is land use history. Hedman et al. (2000) found that understory vegetation is driven more by previous land use than forest management practices within the past 35 years. Plantations established on old field sites do not have biological legacies such as seeds and rootstocks that are present in plantations established on cutover lands (Baker and Hunter 2002). Because of this, old field sites have low understory diversity regardless of management practices (Hedman et al. 2000, Marion and Harris 1982, Marion et al. 1986). On the other hand, old field sites have greater pine growth and yield and can produce more wood per area of land (Yin and Sedjo 2001). Thus, intensive timber management that maximizes wood production and economic return should be focused on old field sites where biodiversity is likely to be poor regardless of management practices. Likewise, practices to improve biodiversity should be targeted to cutover lands.

Finally, there should be economic considerations when examining ways to increase biodiversity. Intensively managed plantations are business enterprises for which landowners will expect some level of economic return. There are various costs associated with managing for increased biodiversity which create trade-offs between biodiversity and economic returns (Allen et al. 1996, Hunter 1990). If management practices are too costly, they are unlikely to be implemented on private lands. Management strategies that balance both biodiversity and economic objectives should be identified (Buongiorno et al. 2004).

One thing that may help offset the costs of managing for increased biodiversity is the potential for increased hunting lease revenue (McKee 1987, Melchiors 1991). Hunting leases can provide significant revenue, especially if there is quality wildlife habitat (Baker and Hunter 2002, Johnson 1995, Jones et al. 2001). Ownership size may limit these opportunities, though.

IV. Summary

There is concern about the maintenance of biodiversity in the intensively managed loblolly pine plantations that are increasingly prevalent in the southeastern United States. There are a number of stand-level management practices that can support increased biodiversity in these plantations. The overall key to providing for biodiversity is to provide structural diversity. An open stand structure with a diverse, productive grass-herb understory is more similar to the natural, fire-maintained pine communities that were historically present and can support a broad suite of plants and wildlife.

Maintaining an open canopy with a diverse understory can be achieved with heavy thinnings early and often in the rotation. This may allow a dense hardwood midstory to develop, though, which would shade out the understory and negate the benefits of thinning. Consequently, hardwood control will be necessary either by prescribed burning or with mid-rotation herbicide applications. Hardwoods should not be eliminated entirely. A mast producing component should be maintained to provide wildlife food and structural diversity.

Light to moderate site preparation is best for biodiversity, and mechanical methods may perform better in this respect than herbicides. Fertilization can benefit wildlife by increasing understory growth, but it should be done in conjunction with thinning to maximize benefits. Key structural features such as snags, coarse woody debris, and mature trees should be maintained, along with riparian buffers to protect aquatic areas and provide for habitat connectivity. Long rotations are necessary to provide a broader range of age classes, though the economic impacts may be a consideration.

Biodiversity is ultimately achieved at the landscape level, but stand-level changes can go a long way towards making improvements and can be implemented regardless of ownership pattern. Land use history is an important consideration, as old field sites are unlikely to support a diverse stand structure regardless of management practices. Economics should also be considered, as management practices to increase biodiversity need to be economically viable if they are to be successful on private lands. Opportunities for hunting lease revenue may offset some of the costs of managing for biodiversity.

Metric equivalents

When you know:	Multiply by:	To find:
Acres	0.4047	Hectares
Feet	0.3048	Meters
Inches	2.54	Centimeters
Square feet per acre (ft^2/acre)	0.229	Square meters per hectare

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