To the Graduate Council:

I am submitting herewith a thesis written by Amy Louise Morgan entitled “The Status of Table Mountain Pine (*Pinus pungens*) Stands on the Cherokee National Forest, Tennessee.” I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

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The Status of Table Mountain Pine (*Pinus pungens*) Stands on the Cherokee National Forest, Tennessee.

A Thesis
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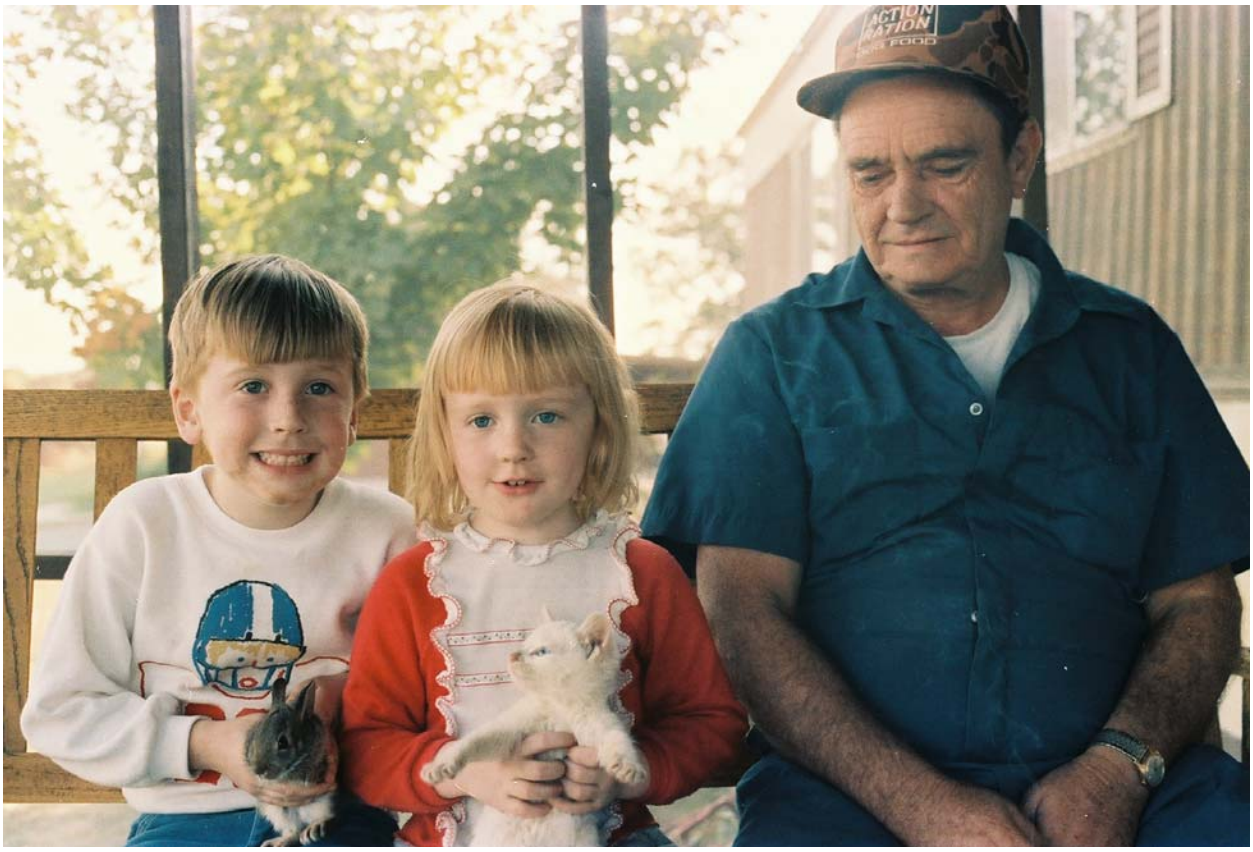
Dedication



This thesis is dedicated to my grandfather, JR Morgan (1928-2000). I was very fortunate to have a grandfather that not only understood and appreciated nature, but also took the time to teach me that same appreciation. Some of my earliest memories are of sitting with him and his hunting buddies around the campfire while fox hunting, going raccoon hunting, fishing, listening to the night and just leisurely walks in the woods with the hounds. His influence was greater than words can describe and I am forever grateful.

Abstract

Table Mountain pine (*Pinus pungens* Lamb.)(TMP) is a threatened species, endemic to the southern Appalachian Mountains. The status of TMP following the southern pine beetle (*Dendroctonus frontalis* Zimmerman) outbreak of 1999–2001 is unknown. This study focuses on stands of the Cherokee National Forest (CNF) in eastern Tennessee that had a TMP component in the 1994 Continuous Inventory of Stand Condition (CISC) data. This project has two parts: an inventory of the 1994 stands as well as a case study of cost comparison of release treatments for a young overstocked stand. The objective of the inventory was to visit the TMP stands designated in the 1994 CISC data on the CNF to determine whether these stands still contain a significant component of TMP and to document the present stand condition and successional status. The objective of the case study was to produce a cost analysis/comparison of releasing young TMP that are in the stem exclusion stage of stand development by several silvicultural methods: strip thinning, crop tree release, and prescribed burning.

TMP is declining across the CNF with less that 900 acres dominated by the species. TMP was a major component on more than 7400 acres from the 1994 data, but many have also succeeded to hardwoods because of the absence of fire and SPB infestations. Management actions should be taken to maintain the health of remaining TMP stands on the CNF. Re-introduction of a controlled burning regime to create seedbed conditions favorable to TMP regeneration and to control hardwoods in existing stands is suggested. If TMP is to remain in Southern Appalachian ecosystems, more direct, cost-effective, and positive management approaches are necessary.

Initial cost effectiveness of release treatments were analyzed. Regardless of treatment, costs ranged from $18 to $45 per acre. In this study, prescribed burning, generally considered

more cost effective than mechanical treatments, was most expensive because of the small tract size and the labor involved to monitor the burn. The crop tree release treatment had the least cost because small trees were cut and cost of equipment is minimal.

Table of Contents

List of Tables

Title **Page**

List of Figures

Title **Page**

Chapter 1. Literature Review

1.1 Introduction

Table Mountain pine (*Pinus pungens* Lamb.) (TMP) is a shade intolerant, fire-adapted species, endemic to the southern Appalachian Mountains. The acreage of TMP has declined because of fire exclusion policies (Waldrop and others, 2006). Fire reduces litter and duff thickness, which is favorable for TMP seed germination, controls or sets back competing species, and provides the heat required for the serotinous cones of TMP to open.

According to the 1994 CISC (Continuous Inventory of Stand Conditions) data, the Cherokee National Forest (CNF) contained approximately 6,500 acres of TMP across 202 stands, excluding wilderness areas. The stands were coded pure TMP or TMP/Hardwood mixes. After the 1999–2001 southern pine beetle (*Dendroctonus frontalis* Zimmerman) outbreak, there was concern about the amount of TMP remaining in the National Forest, the age distribution, and health status.

1.2 Brief Overview of Table Mountain pine

TMP was discovered sometime before 1794 near Tablerock Mountain in Burke County, North Carolina by Andre Michaux (Zobel, 1969). Aylmer Bourke Lambert described, named and classified TMP from a collection taken in the “Blue Mountains” of Virginia in 1803 (Zobel, 1969; Sanders, 1992).

The distribution of TMP is from the Appalachians in central Pennsylvania, south to the mountains in northeast Georgia, with small populations east of the Appalachian Mountain chain (Zobel, 1969) (Figure 1). TMP is one of the four hard, or yellow pines of this region.

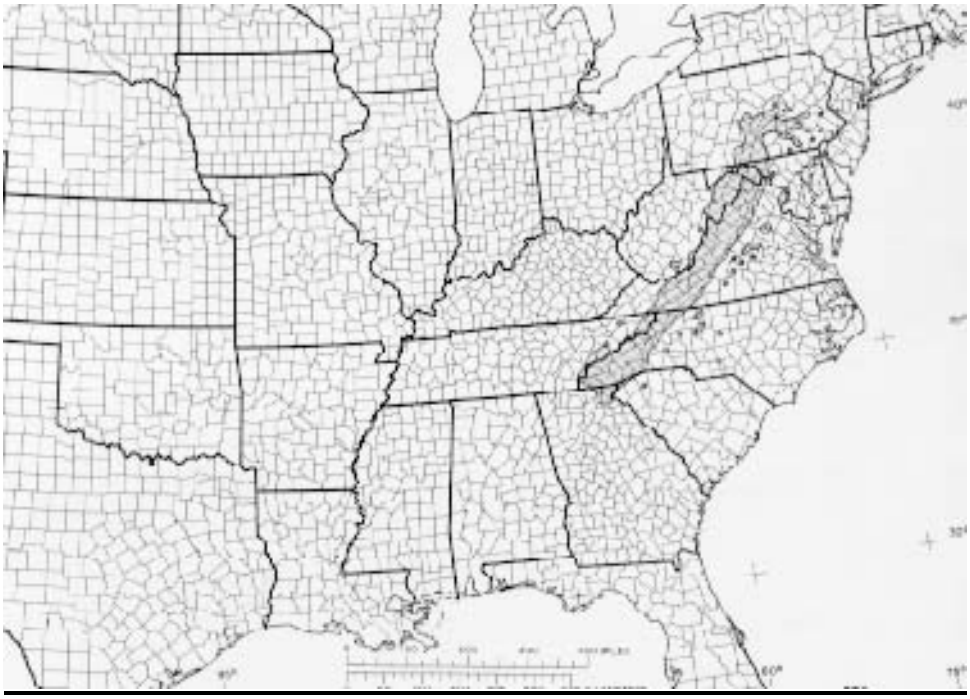


Figure 1. Species distribution of Table Mountain pine *(Pinus pungens*) in the United States (USDA http://www.na.fs.fed.us/pubs/silvics_manual/volume_1/pinus/pungens.htm, 2008).

The other yellow pines are *Pinus rigida* Mill., *P. echinata* Mill., and *P. virginiana* Mill.. According to Zobel (1969), TMP is the rarest of the four yellow pines. These stands typically are located on dry, rocky, southwest-facing slopes and ridges, on the warmest and driest sites, and at elevations between 1650 and 4500 feet (Hardin and others, 2001). Isolated stands of TMP occur east of the mountains at elevations below 1000 feet in Virginia, North Carolina, and Pennsylvania (Zobel 1969). Common soil series for TMP are Ramsey, DeKalb, Ashe and Porter (Zobel, 1969). These soils are rocky, acidic, shallow, well-drained, and often infertile soils with low productivity.

Mature TMP trees are generally small, reaching a diameter of 12 to 24 inches at 4.5 feet (d.b.h) and 20 to 40 feet in height (Hardin and others, 2001). The largest recorded TMP was 34.3 inches d.b.h and the tallest was 95 feet (Zobel, 1969). Generally, most TMP have poor form and many large limbs. The large branch stubs provide pathways for fungi into the trunk, thus diminishing their commercial value. Several decades of fungus–free growth are required to produce sound wood (Zobel, 1969).

TMP in a frequent fire environment is able to produce "self-maintaining, nonsuccessional, populations on dry, steep sites" (Williams and Johnson, 1990). By analyzing the age distributions of TMP, Williams and Johnson (1990) tested the hypothesis that "populations of *P. pungens* in dry pine-oak forests are maintained in the absence of fire." The results indicated that the populations were "either not self-maintaining or that recruitment may be episodic." Low recruitment of pines can be related to poor seedling survival due to drought, seedbed conditions, predation, or inadequate amount of seed fall. The research also suggested that reproduction from seed of suppressed trees is often unsuccessful. However, on exposed ridge tops with low stocking of pine canopies, Williams and Johnson (1990) postulate that TMP

may produce self-maintaining populations. Ice storms may be a pathway to create canopy gaps that aid TMP regeneration, but ice storm events are rather infrequent.

1.3 Seed and Cones

TMP is the only pine of the southern Appalachian Mountains with serotinous cones. The cones are typically 2 to 4 inches long, sessile and form in whorls of 2 to 7 (McIntyre, 1929). A minimum temperature of 90 ˚F must be reached for the cones to open (McIntyre, 1929). Seeds are approximately ¼-inch long with wings of about 1-inch and are triangular in shape. The average weight of each seed is 13.8 mg (Zobel, 1969). The seed of TMP is much larger than other *Pinus* species associates which may lead to a regeneration advantage in drier areas, allowing the seed to perpetuate and establish more quickly under favorable environmental conditions (Zobel, 1969).

1.4 Reproductive Cycle

The reproductive cycle of TMP begins with five immature female strobili whorled around a branch (Gibson and Hamrick, 1991). Once pollinated, the strobili swell. One to three cones become dominant and the other cones are aborted during the second year of growth. Because TMP is serotinous, many years of seed may be contained on a single tree, potentially increasing genetic diversity, depending upon the success of pollination.

Zobel (1969) found that TMP releases pollen earlier than the other yellow pines. The early growth and reproductive activity may be an advantage for TMP. “Transpiration and soil moisture stress are most likely low,” while there is “minimum competition for water, light and nutrients” (Zobel, 1969). However, earlier growth also makes TMP more susceptible to frost

damage that may occur late in the season. Other drawbacks may include pollen inviability if freezing occurs during meiosis, or male and female strobili may become out of sync as a result of different response rates to temperatures (Zobel, 1969).

Gibson and Hamrick (1991) reveals that TMP is "predominantly outcrossed." The study also concluded that the mating was not solely random based upon pollen allele frequencies contained in whorls as well as cones within whorls. Compared to other conifers, TMP maintains a high level of genetic diversity on the population level as well as diversity greater than normal for species with a similar life history. In an early seed and cone study by McIntyre (1929), no seeds were produced in the lower third of any cone sampled. McIntyre states that there is "no relation between length or weight of cone and number or viability of seeds produced."

1.5 Seed Availability and Viability

Gray and others (2002) studied TMP seed availability and viability in relation to tree age, cone age, and season on sites from three national forests: Cherokee (TN), Chattahoochee (GA) and Sumter (SC). No relationship was found among tree age class, cone age, and season for seed availability. However, the average number of seeds per cone decreased with increasing tree age. Individual TMP trees become reproductively mature around age 7 (Gibson and Hamrick, 1991). Gray and others (2002) concluded that trees in the 5 to 10 year age class were reproductively mature, but only contained 8.8 percent viable seeds. Cones contained more total seed in the fall and winter months as a result of the cones ripening in the fall.

Cones 4 to 5 years of age produced more viable seed than cones 2 to 3 years of age (Gray and others, 2002). These results led to the conclusion that if younger stands are burned too frequently, they may result in poor regeneration as a result of the low seed viability. However,

fire is needed periodically to control the hardwoods that may regenerate as well. Gray and others (2002) suggested that "although cones ripen in autumn of the second season, seed viability may not peak until winter." McIntyre (1929) concluded that TMP seeds may remain viable for 9 years or greater while in the cone. In comparison, Gray and others (2002) agreed that seeds remain viable for some time, but eventually reach a point of rapid decline where they may fail to germinate.

1.6 Seedbed, Duff Depth, and Light Requirements

Intact leaf litter and surface soils were collected in Virginia at Brush Mountain to conduct a controlled greenhouse study on the presence and type of leaf litter and the effects of soil moisture on the establishment of TMP (Williams and others, 1990). The study only used seed from cones 2–3 years in age because, at that time, seed viability was thought to decrease with increasing cone age. However, according to Gray and others (2002), seeds from cones 2 to 3 years old contain about 27 percent viable seed. Seed germination in no litter was less than germination in TMP and pitch pine needle litter or chestnut oak (*Quercus montana* L.) and scarlet oak (*Quercus coccinea* Münchh.) leaf litter. Mean soil moisture in the pine needle litter was 23.7 percent, oak litter 25.2 percent, and no litter 9 percent (Williams and others, 1990). Under oak litter, TMP seedling emergence was reduced compared to pine or no litter. The seedling roots in the oak litter had difficulty penetrating the litter and reaching the soil. When soil moisture was lower, the germinant remained in the litter isolated from the soil and death soon followed. When the seeds did reach the soil, they would clump together in weaker litter surfaces where roots could penetrate to the soil. Seeds in the pine litter were more evenly

dispersed. Of the germinants that did reach the soil in the pine and oak litter, there were no differences in the growth of the seedlings (Williams and others, 1990).

Waldrop and others (1999) studied duff depth and shade levels in established TMP stands that regenerated as a result of fire. A second study was conducted in a greenhouse to provide a greater range of controlled conditions. The greenhouse study had percent shade treatments of 0, 30, 63, and 85 percent shade and duff depths of 0, 2, and 4 inches. TMP germination in the greenhouse study was greatest on bare soil or in the 2-inch duff layer, but over the 90-day study period, survival was significantly better on bare soil and the 4-inch duff layer than the 2-inch duff layer (Waldrop and others, 1999). The 2-inch duff layer had a significantly higher stem density of 9.9 stems per pot. The greenhouse study indicated that germination rates were significantly greater when the percent of shade was greater than 30 percent (i.e. 30, 63, or 85 percent shade) than those under no shade, with the best germination rates occurring at the 63 percent shade treatment (Waldrop and others, 1999). After 90 days, the pots under 30 percent shade exhibited a 71.3 percent survival rate, significantly greater than the other shade levels, and contained a density of 10.2 stems per pot.

The field study shade treatments were no light (full shade) reaching the forest floor, 1 to 30 percent (high shade) of the floor receiving light, 31 to 60 percent (medium shade) of the floor receiving light, and 61 to 100 percent (low shade) of the floor receiving light with duff layers of 0.5 to 1.5 inches, 1.6 to 3.0 inches, and greater than 3.0 inches. The field portion of the study yielded similar results with the medium shade category (40–69 percent shade) containing 6,665.2 stems per acre (Waldrop and others, 1999). The 2-inch duff layer had a significantly higher stem density with 5152.8 stems per acre. Stem density was greater in 2-inch duff except for the no shade treatment. The lack of duff in full sun allowed the moisture in the soil to decrease and

become depleted quicker and thus, many seedlings died. Comparatively, no duff under 30 percent shade allowed for fewer seeds to germinate, once again reinforcing the importance of duff presence, the mulching effect of the duff, and soil moisture retention. The field portion did not reveal a significant difference in stem densities across duff depths in a shade category. The low and medium shade categories produced more stems than the high shade plots. The optimum combination for seedling height growth was in 2 inch or 4 inch duff depth under 30 percent or no shade (Waldrop and others, 1999). From this information, the high-intensity crown fires that were once thought to be the most beneficial for the species may not actually be needed. The overstory does not need to be completely removed for regeneration to occur successfully as a lower intensity fire may be adequate for regeneration of TMP.

Mohr and others (2002) conducted a similar greenhouse study at Clemson University. The shade levels tested were 0, 38 (low), 52 (medium) and 98 percent (high) shade and 0-, 2-, and 4-inch duff depths. Results from this TMP study were: (1) soil moisture was greatest under high shade with 4-inch duff, (2) no significant difference was found in percent germination under different shade levels or different duff depths, (3) seedlings grown under low and medium shade were significantly taller than those grown under no (zero) and high shade, and (4) 2- or 4-inch duff depth under medium shade was the best treatment because it provided adequate light and retained adequate soil moisture (Mohr and others, 2002). These results are similar to the results of Waldrop and others (1999) and agree with the suggestion that lower fire intensities will successfully regenerate Table Mountain pine.

1.7 The History of Changes in Fire Policies

Fire was a key component in many ecosystems found in the southern Appalachian Mountains and the adjacent areas. These fires were caused by lightning as well as humans. Lightning–ignited fires 10 to 20 thousand years ago forced communities and certain species to adapt to fire (Komarek, 1974). As the glaciers began to melt following the most recent ice episode, species began moving northward. By the beginning of the Holocene, 10,000 years ago, "present woody plants distributions were largely in place" (Buckner, 1989). Native Americans increased the frequency of fire with the practice of intentional burning to assist in creating browse for wildlife and game and to increase the abundance of fruits, grains, berries, and legumes (Buckner, 1989, 1994, 1995). Euro-Americans quickly learned to use fire to assist in hunting by flushing out or driving wildlife. They also learned that frequent low intensity fires made the forest underbrush less dense and more manageable. Fire was also used after logging to reduce the slash to improve grazing opportunities

In the early 1900s, the first research on prescribed burning was conducted by H.H. Chapman of Yale University (Van Lear and Waldrop, 1991). Beginning in the early 1920s, fire exclusion policies were put in place and the forests began to change drastically. On July 7, 1924, the Clarke-McNary Act gave the Secretary of Agriculture and state officials more power over fire protection and included provisions pertaining to insurance underwriting requirements (Shepard, 1937). In 1935, The Forest Service adopted the "10 AM Policy" whereby all human-caused fires would be extinguished by 10 a.m. (USDA-FS, 2007). The Cooperative Forest Fire Prevention Program was developed in 1944 by the USDA Forest Service. Albert Staehle produced the first Smokey Bear poster on August 9, 1944, thus beginning the Smokey Bear Campaign (Smokey Bear Official Website, 2008). In 1963, the Leopold Report was published

"which recommended greater use of management strategies that maintained biotic relationships within national parks, including occasional applications of prescribed burns" (Davis, 2001). However, the public was still leery and not supportive of fire as a management tool.

In 1964, the National Wilderness System was created and wildland fire was managed differently in remote areas (Stephens and Ruth, 2005). This made advances for both the National Park Service and The Forest Service (USFS) by changing the "philosophy of wildland fire use in remote areas" (Stephens and Ruth, 2005). The USFS even began using "prescribed natural fire" in the late 1960s on the Selway-Bitterroot and Gila National Forests. However, few other forests followed their example. The policy of the Park Service recognized the natural role of fire and started the "first prescribed natural fire program in Sequoia-Kings Canyon National Parks" in 1968 (Stephens and Ruth, 2005). As the years passed, managers increasingly began to accept prescribed burning as a vegetation management tool with increased acreage being burned on state and federal land.

The 1970s had many devastating fire seasons which led to increased pressure on fire agencies to increase their training and make the training more standardized. The National Wildfire Coordinating Group (NWCG) was created in 1976 and was composed of many land managers from various federal and state agencies. One of their first tasks was the adoption of the National Interagency Incident Management System (NIIMS) which provided a common incident command system. In 1971, The Forest Service put in place the 10-Acre Policy whereby all fires would be contained within 10 acres. The Forest Service began encouraging prescribed fire in 1977. Table 1 shows more recent advances in fire policy including the early 1990s until 2003.

Table 1. United States Fire Policy Advances, 1990–2003.

Year	Policy Advance
Early 1990s	Land managers were using mechanical treatments and/or prescribed fire as a tool to reduce fuels and understory trees in an attempt to reduce the risk of intense crown fires.
1995	The Federal Wildland Fire Management Policy and Policy Review were developed by a task group of various federal land management agencies. The 1995 Report was the first comprehensive statement about wildland fire policy coordinated between the USDA and the Department of the Interior (USDA-FS, 2007).
April 1998	The Interim Air Quality Policy on Wildland and Prescribed Fire was issued by the EPA to mitigate the impacts of air pollutant emissions.
2001	The Federal Wildland Fire Management Policy was revised in order to focus on the reduction of hazardous fuels. This was a direct result of the 2000 Wildfire season (Stephens and Ruth, 2005).
2002	Healthy Forests Initiative (HFI) developed in order to address issues related to fuels-management implementation. The goal was to streamline the review processes by facilitating timely reviews, amend rules for appeals, and provide prompt judicial review for any challenges (Stephens and Ruth, 2005).
2003	The Healthy Forests Restoration Act was similar to the HFI but also addressed old-growth forests by requiring proper management of not only the old-growth areas, but also areas with larger stems outside these areas at risk of wildfire. This act also encouraged monitoring and evaluation of communities in order to determine risk (Stephens and Ruth, 2005).
2003	The Interagency Strategy for the Implementation of Federal Wildland Fire Management Policy was developed in order to create common terminology, directives, guidelines and manuals for all the agencies involved (The Interagency Strategy for the Implementation of Federal Wildland Fire Management Policy, 2003).

1.8 The Effects of Fire on Table Mountain pine

Zobel (1969) stated that "Signs of fire were almost ubiquitous in stands of Table Mountain pine." Serotinous cones, black seeds (characteristic of TMP compared to other pine species), shade intolerance, and exposed mineral soils for seedbeds are all indications of high-intensity fire regimes typical of TMP stands (Brose and Waldrop, 2006). Many stands contain trees of one or two age classes with the younger trees growing in dense thickets and when present, a few older trees surviving on higher points or on moist depressions, where fire intensity was possibly reduced. These older trees probably provided a seed source in addition to the cones from dead, burned trees that opened and dispensed seed after the fire (Zobel, 1969). DeWeese (2007) reported that a majority of the fires that occur in TMP stands are during the dormant season and early in the growing season. She also found fires that occurred very early in the growing season contained more pine regeneration and contributed to controlling hardwood sprouting and regeneration (DeWeese, 2007).

TMP forest type acreage has been decreasing as a result of fire exclusion policies (Williams and others, 1990). Not only has fire exclusion reduced the diversity of vegetation in the southern Appalachian Mountains, but it has possibly threatened the existence of certain communities and species (Waldrop and Brose 1999). Armbrister (2002) conducted a study that focused on fire frequencies in the Great Smoky Mountain National Park (GSMNP). The fire frequency before the park was established was approximately 7 years, whereas fire frequency in some areas after park establishment, was 45 years. Armbrister (2002) suggested that with the recent southern pine beetle infestation, fire intensities may increase as a result of increased fuels from the snags and woody debris. He also stated that the "Maximum Hazard Interval for Table

Mountain pine stands in the GSMNP indicates that the probability that burning will occur in the next ten years is extremely high." The lack of fire in TMP stands leads to stagnation of younger stands, increasing risk for southern pine beetle and TMP cone worm outbreaks (*Dioryctria yatesi* Mutuura and Munroe) as well as an increase in butt and root rot (*Phaeolus scheweinitzii* (Fr.) Pat.) and heart rot (*Phellinus pini* (Thore:Fr.) Ames) (Harnett and Krofta, 1989; USDA Forest Service, 1990; Gray 2001; DeWeese, 2007).

1.8.1. Question of Fire Intensity

Much discussion and debate have occurred concerning the fire intensity required to regenerate TMP. Zobel (1969) suggested that severe fire was needed on sites with a "well-developed shrub layer." TMP regeneration only persisted in areas where the overstory and much of the undergrowth was removed and mineral soil exposed (Zobel, 1969). Turrill (1998) also suggested that stand replacing fires are required for regeneration. TMP does not regenerate following prescribed fires of lower intensities that create canopy gaps or reduced the amount of litter (Turrill 1998). Hemel (2004) indicated that lower intensity fires create gaps for shade intermediates which out-compete the TMP reproduction thus allowing the stand to transition from pine to hardwoods. Sanders (1992) concurred that lower intensity fires do not regenerate TMP as well, but may be useful for reducing hardwood competitors. Sanders (1992) stated that "crown fires best create the conditions required for successful regeneration of Table Mountain (sic) pine."

After a 1981 fire in a TMP stand that was regenerated from a fire in 1941 at Horsehitch Gap on the Nolichucky/Unaka district of the Cherokee National Forest, TMP regeneration "was densest along the edge of the 1941 stand, but was faster growing away from the edge where full sunlight was available" (Sanders, 1992). In an accompanying study at Greystone Mountain, a 20-

year-old stand was burned exposing mineral soil. Only one third of the stems in the stand contained TMP cones, regeneration was “almost non-existent after one growing season,” but a few seedlings did appear in the following three growing seasons (Sanders, 1992). The young stand at Greystone Mountain apparently had not produced enough seed to adequately regenerate the site.

Others have suggested more frequent, low intensity fires are able to create adequate seedbed conditions for regeneration of TMP (Van Lear 2000, Waldrop and Brose, 1999). Fires of a medium-high intensity provided adequate overstory mortality, thus creating adequate sunlight for seedlings to germinate and develop (Waldrop and Brose, 1999). Waldrop and others (2003) conducted research on three separate burn units to determine the effects of fire intensity on the basal area of pine and hardwoods as well as the number of hardwood sprouts and pine seedlings. “High- and medium-high- intensity fires were the only ones of sufficient intensity to kill enough of the overstory to achieve conditions of stand replacement” (Waldrop and others, 2003). The low- and medium-low intensities did not reduce the overstory enough to allow adequate light for seedling survival. Two of the three study sites showed that burns of low intensities were adequate for opening the cones and releasing the seed. The third site had poor regeneration, but that may be a result of low seed viability. Waldrop and others (2003) reported that in each of the three treatment blocks, the heat generated in the prescribed fire was great enough to open the cones, reduce the duff, and create canopy gaps, but none were successful in replacing the older TMP stand with new TMP regeneration. Although the medium-high intensity fires created regeneration and had greater overstory mortality than the other intensities, these fires did not control competition adequately due to hardwood and shrub sprouting. They also suggested “that ridge top pine stands were created by lower-intensity fires than once were thought necessary, and

that such fires would aid in community restoration" (Waldrop and others, 2003). Fire intensity must be adequate to reduce hardwood and shrub sprouts, but may not need to be a fire of stand replacing intensities.

A dendrochronology study by Brose and Waldrop (2006) investigated the age structure and recruitment dates of TMP stands at nine locations in the southern Appalachian Mountains to determine if fire was associated with the recruitment dates. Surface fires assisted with the continuous regeneration of these stands, but other disturbances such as drought, hurricanes, ice storms, thunderstorms and insect outbreaks also played a role. Each of these non-fire disturbances created canopy gaps of various sizes which assisted in TMP recruitment.

A prescribed fire of various intensities was conducted on the Tallulah District of the Chattahoochee National Forest in Georgia in 1997 and was measured at the end of the growing season in 1997, 1998, 1999 and 2002 to reevaluate mortality, regeneration and competition (Waldrop and others, 2006). The results indicated that the overstory was killed in each fire intensity class, but mortality was not immediate. TMP regeneration was abundant in each fire intensity treatment six years after the fire.

Randles and others (2002) suggested that a mixture of fire intensities occurred before the fire exclusion policies were enacted. They studied the frequencies of low intensity fires and the effects on vegetation structure and composition, fuel loading, and regeneration of TMP and pitch pine. Five treatments were implemented: Areas burned 1, 2, 3, and 4 times since 1988 on a three- to four- year interval as well as unburned control areas. Each fire was conducted during the dormant season between January and March. The results showed that areas of the 4-fire treatments had significantly higher species richness. The results may be somewhat skewed because the 4-fire stands had slightly higher fire intensities. The 2-, 3-, and 4-fire treatments all

had reduced understory densities compared to the control blocks. The 4-fire treatments did contain a lower vegetation density than that of the 1-fire treatments suggesting that “multiple burns are more effective in reducing understory density than single burns” (Randles and others, 2002). Pine regeneration was significantly higher in the 4-fire treatments than the other treatments. Overall, “multiple understory burns in table mountain/pitch pine stands create a more open forest with less cover of shrubs and saplings than unburned forests” (Randles and others, 2002). Welch and others (2000) found an increase in pine regeneration after fires but the lack of overstory gaps and adequate light may hinder their survival, growth, and development. Welch and others (2000) stated that “prescribed fires to restore table mountain (sic) pine and pitch pine forests must open the understory, as well as the overstory.” DeWeese (2007) suggested that wildfires of low severity/intensity occur frequently in TMP stands, and moderate intensity fires were fairly uncommon yet could produce new cohorts.

“Both ectomycorrhizae and vesicular-arbuscular mycorrhizae may be necessary for survival of table mountain (sic) pine seedlings, but their respective roles in table mountain (sic) pine regeneration and their responses to high-intensity fires have not been considered” (Waldrop and others, 2003). Ellis and others (2002) collected seedlings that were 1 and 2 years old after the Tallulah fire to quantify the root biomass as well as ectomycorrhizal root tips. No significant differences were found among average stem lengths, total length, root length, or the average number of root tips that contained mycorrhizae between one and two year seedlings (Ellis and others, 2002). The research provided some evidence that mycorrhizae develop during the first growing season after fire and continue into the second growth season. Seedling growth following the second growing season after the fire at medium-low and medium-high fire

intensities had twice as many mycorrhizal root tips than seedlings from sites burned at higher intensities (Waldrop and others, 2003).

1.9 The Effect of Southern Pine Beetle and Ice Storms on TMP

Lafon and Kutac (2003) examined the effects of ice, southern pine beetle (SPB), and fire on TMP in the Little Walker Mountain area of Bland County, Virginia. The study area was composed of three TMP stands that were affected by SPB in 2001 and 2002 and had two major ice storms in 1994. A wildfire occurred in May 2001 in one stand. Ice storms in the unburned stands reduced the basal area by 23.0 percent with 39.6 percent of the pines killed. SPB killed 15.0 percent of the pines that survived the ice storms. Lafon and Kutac (2003) suggested that ice storms and SPB do not promote TMP regeneration and greatly reduce the number of TMP compared to hardwoods. The burned stand had a greater mortality of hardwoods and a greater number of regenerating pine seedlings. Lafon and Kutac (2003) advised that areas affected by SPB or ice damage should be burned to increase the amount of TMP regeneration.

1.10 Summary of Literature Review

Past and present fire policy has reduced the ability of managers to conduct prescribed fire in TMP stands. Because weather plays a large role in how fire behaves, fewer days are available that meet all the conditions (relative humidity, wind speed, ceiling for smoke in the atmosphere) for controlled burning and have the desired intensity and outcome. The accumulation of fuels also makes it more difficult to ensure that the fire will stay under control and maintain the desired intensity. Based on these factors, TMP is suffering from the lack of fire, especially for regeneration, including the stand establishing fires as well as repeated low intensity fires.

Researchers are finding that to regenerate TMP, the fires do not have to be the intense, stand-replacing fires, but those of medium intensities may create adequate canopy gaps and overstory mortality (Van Lear, 2000; Waldrop and Brose, 1999, Waldrop and others, 2003, Waldrop and others, 2006). Repeated lower intensity fires to maintain an open understory as well as reduce competition and fuel loading is also beneficial (Randles and others, 2002). Gibson and Hamrick (1991) found that TMP individuals become reproductively mature around 7 years, but Gray and others (2002) found that older trees contain a greater percentage of viable seed. If regeneration of TMP is an objective of a prescribed fire, the average stand age and seed viability should be known. To germinate TMP seed, duff and litter depth must be shallow enough for the seed to reach mineral soil, germinate, and develop. Waldrop and others (1999) found that "the optimum combination for seedling height growth was in 2-inch or 4-inch duff depth under 30 percent or no shade" and the 2-inch duff layer contained the greatest stem density.

In summary, regenerating TMP is critical because acreage is dwindling. The literature indicates that TMP may be regenerated by both high intensity, stand replacement fires or by frequent, low to medium intensity fires that affect vegetation structure and the amount of leaf/needle litter. Single, lower intensity fires at wide time intervals do not appear to promote the regeneration of TMP. Other factors that may contribute to or deter TMP regeneration success are litter depth, southern pine beetle, and ice storms. Although many studies have been conducted on the regeneration of TMP, there is still much to learn and questions to answer. Do frequent low intensity fires leave enough duff on the ground to favor regeneration or does it create conditions similar to bare soil? Are treatments that are typically used in hardwood stands options for release or management of TMP stands? With the many different landscapes that TMP inhabits and the various mixtures with hardwoods, the best combination of fire and mechanical treatments must

be determined in order to perpetuate TMP in a mixed forest setting. The knowledge of how to regenerate TMP should be expanded to ensure the successful regeneration and development of this endemic species over a wide range of vegetational settings and histories.

Chapter 2. Objectives and Justification

2.1 Objectives

Following the 1999–2001 SPB outbreak, managers of the Cherokee National Forest were concerned about the impact of SPB on TMP stands across the forest. The Forest Service wanted the state of each stand to be determined. The University of Tennessee was interested in learning more about potential release treatments in overstocked TMP stands. Thus, the project arose with two well–defined objectives; the inventory and the case study of release treatments.

2.1.1. Inventory

The objective of the inventory was to visit each of the TMP stands designated in the 1994 CISC data on the Cherokee National Forest to determine whether these stands still contain a significant component of TMP and to document the present stand condition and successional status. This information can be used to understand the status of TMP on the CNF so managers can make informed decisions in managing the species. It was thought that the number of TMP had greatly declined after the SPB outbreak.

2.1.2. Horsehitch Gap Case Study

The objective of the case study was to produce a cost analysis/comparison of releasing young TMP that are in the stem exclusion stage of stand development by several silvicultural methods: strip thinning, crop tree release, and prescribed burning. Several TMP stands in the CNF originated from stand replacement fires. Many of these stands are overstocked (6,400 stems per acre averaging 1.6 inches d.b.h after 27 years) with small crowns and poor vigor. These stands are in danger of stagnating and perhaps eventually succumbing before they reach optimal seed-bearing conditions. Actions should be taken soon to prevent the further decline of this

endemic species from the Cherokee National Forest. The long term goal is to promote the development of TMP stands, to evaluate the response to release to hasten tree development to produce seed, and to slow the conversion of TMP forest types to upland hardwood species. The economic analysis will provide land managers with information on the cost-effectiveness of the various release treatments in TMP.

Horsehitch Gap was chosen for a case study of release treatments because of its accessibility, known history, overstocked stand conditions at a young age (27 years), composition (a majority of TMP stems (greater than 75 percent),) and the size and continuity of the stand. Most TMP stands on the Cherokee National Forest are not in the younger age classes and are not of sufficient size to implement a series of release treatments.

2.2 Justification

TMP is listed as one of the rare communities in the southern Appalachian Mountains by the Southern Appalachian Man and the Biosphere (SAMAB) project (1996). The Forest Health Monitoring (FHM) (USDA-FS 2000; USDA-FS 2003) project has reported that insect outbreaks such as the southern pine beetle (SPB) have a significant impact on *Pinus* spp. within the southern region. Many TMP stands probably have been affected by repeated SPB outbreaks. The impacts of the recent (1999–2001) SPB outbreak have not been quantified for the Cherokee National Forest (CNF). According to the CNF's 1994 Continuous Inventory of Stand Condition (CISC) data, more than 5000 acres were classified as TMP stands and 2400 acres were designated as TMP/hardwoods stands. The amount of TMP after the SPB outbreak is thought to be substantially less. According to Forest Inventory and Analysis (FIA) data, in 1989 the East

Tennessee FIA unit contained 3.2 million TMP individuals, but by 1999 the number had increased to approximately 4.5 million (Miles and Hansen, 2008). After the SPB outbreak, the inventory of 2006 recorded the number to be approximately 2.8 million in the East Tennessee unit (Miles and Hansen, 2008). It appears that many of the TMP stands affected by SPB are slowly converting to hardwoods. The results of this study will offer information concerning the current status of TMP on the Cherokee National Forest and may help spur future conservation efforts to promote this endemic species.

Chapter 3. Study Areas

3.1 Inventory

The TMP stands on the Cherokee National Forest were inventoried. The 1994 CISC data indicated that the Tellico/Hiwassee District contained 8 stands (1 in Wilderness Area) (Figure 2), the Nolichucky/Unaka contained 112 stands (47 in wilderness areas) and 82 (13 in wilderness areas) were on the Watauga District (Appendix A, Table A1) (Figure 3). The stands in wilderness areas were not inventoried for many reasons. Management personnel on the CNF decided that wilderness areas would not be sampled as part of the project because (1) wilderness areas, by statute, are protected from manipulation of vegetation, (2) their accessibility, and (3) to reduce project costs. Thus, a total of 202 stands were sampled.

3.2 Horsehitch Gap

The 30-acre TMP stand at Horsehitch Gap is in the southern portion of Greene County, Tennessee on the Nolichucky/Unaka District of the Cherokee National Forest. The study area is on Short Mountain, part of the Unaka Mountains located on the northeastern end of the mountain between Woolsey Gap and Horsehitch Gap (36˚ 2’ 15” N, 82˚ 46’ 30” W), on the Davy Crockett Lake, TENN-N.C. quadrangle map. The study area is stand 54 of compartment 208 in the Cherokee National Forest (Figure 4). This stand was proposed as the Horsehitch Gap Research Natural Area in 1976, but is still pending approval. The stand is located on a southerly aspect and is bounded at the base of the mountain by Back Creek.

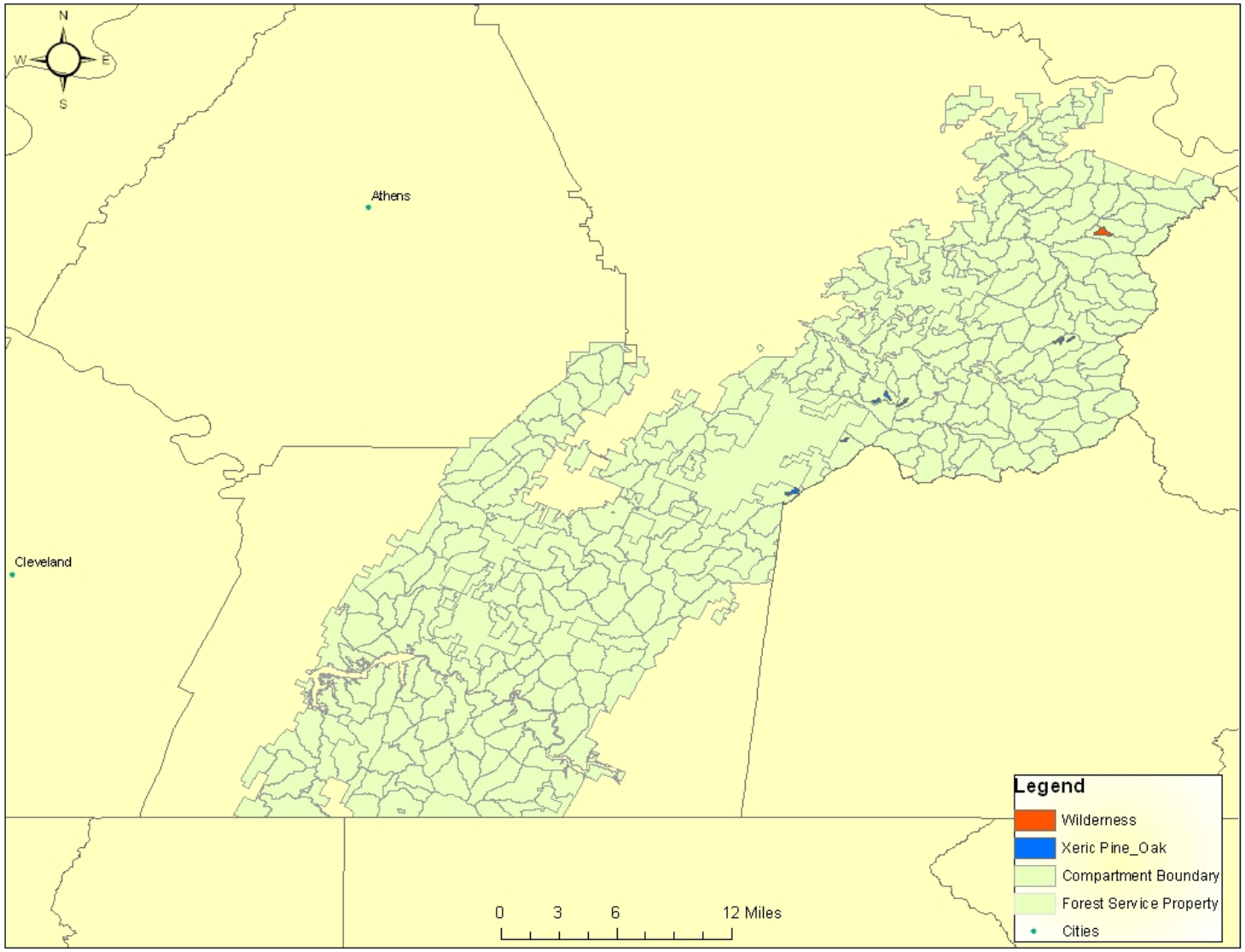


Figure 2. Southern districts stand types containing Table Mountain pine. Cherokee National Forest, 1994.

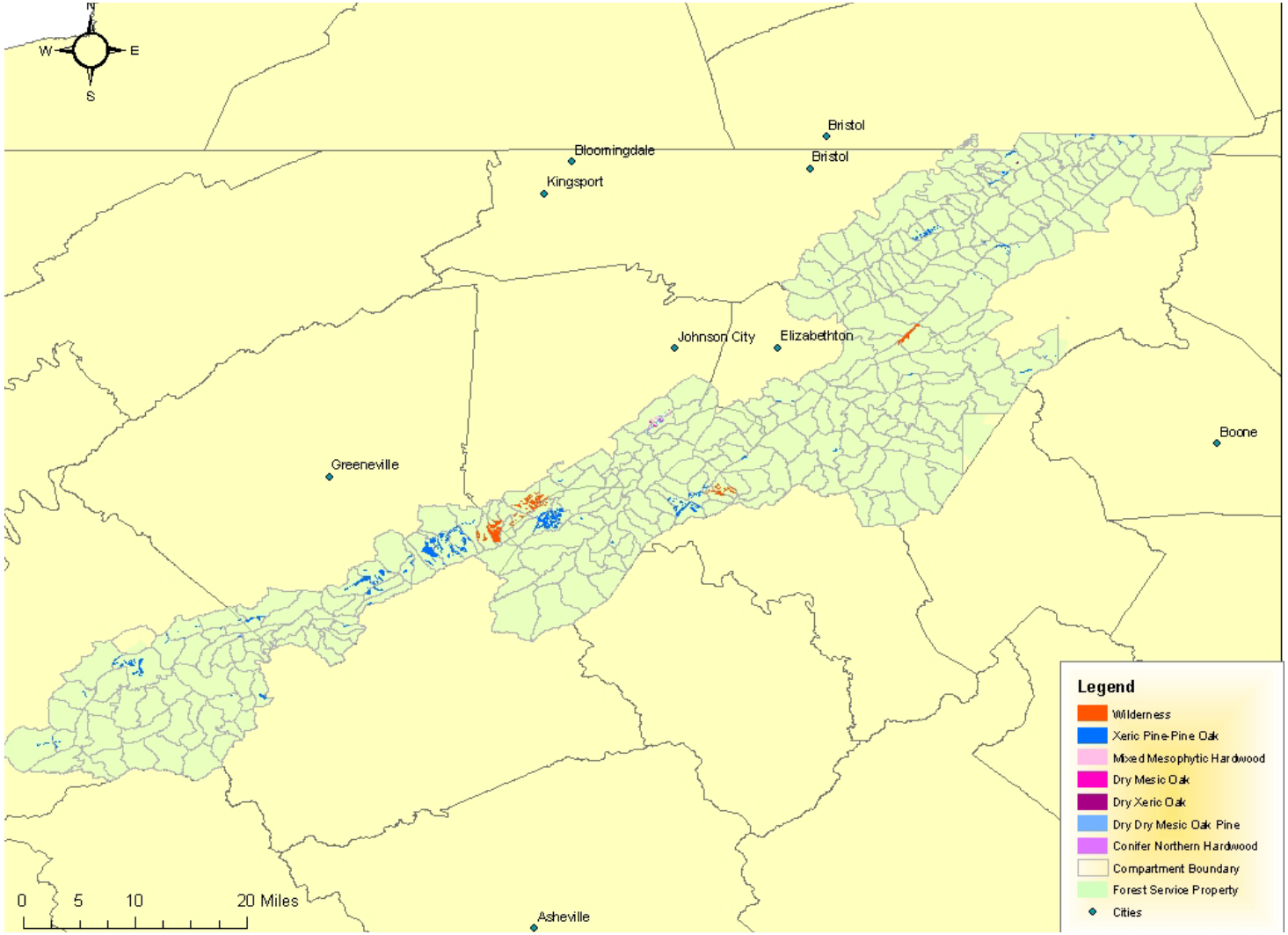


Figure 3. Northern districts stand types containing Table Mountain pine. Cherokee National Forest, 1994.

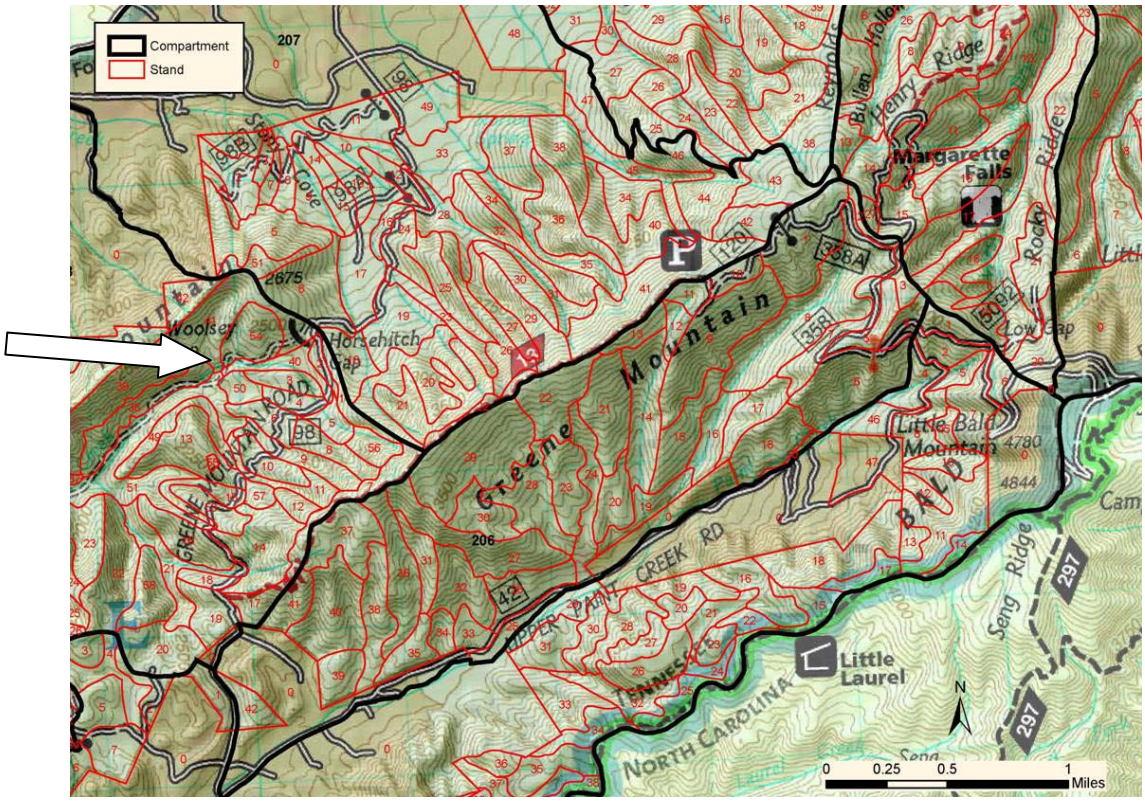


Figure 4. Horsehitch Gap Research Area compartment and stand map. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2007. Arrow is pointing to Stand 54 of Compartment 208.

The predominant soils of the study area are Ramsey stony loams of the very steep phase (United States Department of Agriculture Natural Resource Conservation Service, Soil Survey Division 2001). The geology of the site is the Ocoee Supergroup and Unicoi formations. The elevation of the area ranges from 2,080 feet to 2,740 feet with an average of 2,400 feet. The site is located in the Nolichucky/Unaka Watershed which encompasses 1,772.8 mi^2 (Environmental Statistics Group, 2003).

The University of Tennessee Research and Education Center (36˚ 06' N, 82˚ 51' W) at Greeneville operates the nearest National Weather Service weather station approximately 10 miles northwest of the study area. The weather station is located at an elevation of 1,320 feet and the study area is at an elevation of 2,400 feet. Thus, some differences in mean annual weather statistics are expected between the weather station and the study site. The annual mean temperature at the Greeneville weather station is 53.6 ˚F with the annual daily maximum of 68.5 ˚F and minimum of 38.6 ˚F (U.S. Department of Commerce, 2004). The annual precipitation is 44.28 inches with a mean monthly amount of 3.69 inches. The greatest amount of precipitation typically occurs during May, June, and July while the lowest amount occurs typically during September, October, and November. Snowfall probably occurs more often at Horsehitch Gap than at the Research Center which recorded an annual snowfall of 7.2 inches.

The Horsehitch Gap area was approved for purchase May 17, 1930 by means of the Weeks Law and acquired April 14, 1932 for $4 per acre (USDA-FS, 1974). The ownership is known dating back to 1841 when Samuel Snapp was granted the land from the State of Tennessee. According to an interview of Mr. Ed Tweed conducted for the Establishment Report (USDA-FS, 1974), the area probably burned around 1911.

Horsehitch Gap burned completely in April 1941 as a result of a brush pile fire on Paint Creek. The fire consumed approximately 2,965 acres (Sanders, 1992). Mr. Tweed recalled that the fire had resulted in almost 100 percent mortality. White pines (*Pinus strobus* L.) were planted in 1952 along the trail adjacent to Back Creek at the base of the mountain in 1952. The white pine was underplanted below the upper slopes where TMP had already been established.

The FS/CNF proposed to make the Horsehitch Gap area a Research Natural Area in 1976, but it was never formally approved. At this time, the CNF recognized that TMP was an endemic species that was declining in acreage in the southern Appalachian Mountains and particularly in the CNF and wanted to "provide a benchmark for evaluating the possible beneficial or harmful impacts of forest management activities on similar sites in the Southern Appalachians" (USDA-FS, 1974). If for nothing else, The Forest Service/or CNF recognized the genetic diversity of the area and the need to preserve the seed source.

In 1981, a portion of this area burned once again in a stand replacing fire, thus creating two distinct stands: the 1941 cohort stand and the 1981 cohort stand. The 1981 fire burned a total of approximately 1976 acres (Sanders, 1992). After the 1981 fire, The Forest Service/CNF planted Virginia pine on 38 acres. However, this planting was not successful and Virginia pine only comprises a small percentage of the composition of the stand (Sanders, 1992). In 2000, the SPB outbreak killed most of the TMP in the 1941 cohort and portions of the 1981 cohort. Sanders (1982) reported that the 1981 stand was beginning to show signs that it was approaching a stagnant condition in 1992, when the stand was only 11 years old. In 2001, approximately 25 acres within the 1981 cohort were killed when a fire occurred in the stand.

In preparation for this project, plots were measured to determine the current stocking of the area. Temporary plots, one 1/200th acre plot per acre, were placed across the proposed study

area. The stand contained an average of 6,400 stems per acre with an average diameter of 1.6 inches creating a basal area of 103 ft^2/ac. This degree of overstocking decreases the health of the stand because of the limited resources available to each tree (growing space, moisture, and nutrients) and increased risk of disease outbreaks and devastating fire. Canopy trees in this stand contained an average of 8 cones. These stems should be thinned to promote conditions for increased diameter growth and cone production. Hopefully, thinning will lead to a healthier, more productive stand for the future.

Chapter 4. Methods

4.1 Forest Inventory

The inventory of TMP stands on the Cherokee National Forest was conducted between May 2006 and January 2007. Verification plots on the Northern districts were installed between February and May 2008.

The methods on the Tellico/Hiwassee District were to hike to points in the stands to determine species composition. Plots were located with computer generated random points in each stand. A 20 basal area factor prism was used with prism points per four acres in each stand. Diameter and height were recorded for each tree in the prism plot. If they had abundant cones, that was noted as well. Other information recorded was southern pine beetle damage (snags or fallen), evidence of fire, and the occurrence of rhododendron (*Rhododendron* spp.) and mountain laurel (*Kalmia latifolia* L.). These data provided a basis to create stand type descriptions to classify stands on the Northern Districts of the CNF (Appendix A, Table A2).

The inventory on the Northern Districts (Nolichucky/Unaka and Watauga) was completed by a combination of hiking to stands, drive–by surveys, and aerial photography for stands that could not be accessed safely on the ground. The aerial photography was taken April 2001.

4.2 Stand Type Descriptions

Stand type descriptions were created using data from the Tellico district. These stand types were hardwood, hardwood/TMP, TMP/ hardwood, and pure Table Mountain pine. Stands

where TMP comprised less than 10 percent of the stand composition were designated as the hardwood type. Stands in which TMP constituted at least 80 percent of the stems were designated as the pure TMP stand type. TMP/Hardwood and hardwood/TMP stand types differed based on the percentage of TMP in the stand. The TMP/Hardwood stands contained a minimum of 50 percent TMP, but no more than 79 percent. The Hardwood/TMP stands were dominated by hardwoods and contained at least 10 percent TMP, but no more than 49 percent. These stand descriptions were verified by collecting data from three stands in each stand type. In each of the four stand types, three stands were chosen based on location and ease of access. After the stands were located, three 1/10th acre plots were installed along a north to south transect with one plot every 100 feet. In these plots, all trees greater than 1-inch in diameter were tallied by diameter class. Seedlings were also counted across the plots.

4.3 Horsehitch Gap Treatments

A 30-acre overstocked TMP stand at Horsehitch Gap was selected to implement and investigate various release treatments. The stand was overstocked, easily accessible by road, had an existing trail at the base of the stand, and had a known recent fire history. The release treatments were a prescribed burn, strip thin, crop tree release, as well as a control. The stand boundary was entered in ArcMap and treatment blocks of similar size and topography were formulated (Figure 5). The stand boundaries and treatment blocks were established and temporary vegetation plots were taken to determine whether species composition was similar for each treatment block. Release treatments were approved for this project by the USFS using the National Environmental Policy Act (NEPA) process. Once the project was approved, the

Figure 5. Treatment blocks and plot locations at Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2007.

boundaries were painted using tree marking paint. Permanent plots were marked with metal tags that were nailed to the tree at plot center using aluminum nails. The tags were marked with three columns of numbers. The hundreds column represented the treatment blocks (1= burn, 2= strip, 3= control, 4= crop tree). The other two columns represented the tree number within each treatment block. The plot size of 1/200th acre was chosen because the stand is consistent and the trees are relatively the same size. Diameter, height, number of cones and duff/litter depth (only five duff measurements were taken in the crop tree) were recorded on each permanent plot. Duff and litter were measured at 6.7 feet east and west of plot center.

4.3.1. Prescribed Burn Treatment

The prescribed burn treatment block was 7.3 acres and located on the upper portion of the southern facing slope (Figure 6). In this block, 16 1/200th acre permanent plots were installed along transects. Permanent plots 1 through 5 were placed along a transect that began 75 feet from a 6.1 inch diameter chestnut oak along the southwestern side of the trail. The reference tree of the starting point was marked with yellow paint and yellow flagging. The transect was on a bearing of 260° and the plots were placed 175 feet apart. From plot 5, plots 6, 7 and 8 were placed 100 feet apart on a transect with a bearing of 0°, forming an "L" shape with the other transect. Plots 9 and 10 were placed east of plots 7 and 8. Plots 11 thru 16 were placed on a transect running west to east beginning 50 feet south plot 5. A tree at the center point of each permanent plot was marked with a three column aluminum tag with the number 1 in the hundreds column and the plot number in the ones/tens column (i.e. 103, 110).

In addition to the measurements taken in the prescribed burn block, 12" thermocouple attached to a Hobo® data logger were provided by the USDA Forest Service Southern Research

Figure 6. Prescribed burn plot locations at Horsehitch Gap, Nolichucky/Unaka District, Cherokee Nationals Forest, Greeneville, 2007.

Station in Clemson, South Carolina. They were placed in the ground to measure temperature on a fixed time interval during the prescribed burn. The probes were placed about 2 feet south of plot center for each plot and three plots also had probes 2 feet north of plot center. Ceramic fire tiles were also used for each plot (Figure 7). These file tiles were 4 inch squares with strips of paint on the back. These strips were a single brush stroke of paints with melting points ranging from 175 ˚F and 1800 ˚F placed in ascending order. Four tiles were placed for each plot: above and below the center tree and east and west about 7 feet from the center tree. Plot tree 104 was omitted because the plot could not be located when probes were being placed before the burn. The probes and tiles were placed the morning of the prescribed burn.

The prescribed burn occurred on April 22, 2008. The backing fire was ignited at 13:15 at the top of the burn block with drip torches. At the time of lighting, the temperature was 70 ˚F, a relative humidity of 53 percent with winds 2–4 miles per hour out of the North (Appendix C, Table C1).

All permanent plots were revisited on May 22, 2008. Each crop tree was remarked and retagged as needed. Duff/litter measurements were recorded because there was still a mat of duff that was not burned on all plots. Because crowning did occur, the state of the crowns were noticed and recorded as “green,” “brown with green tips,” “brown,” or “no crown remaining.” A record of the burn is included as Appendix C for future re-measurements.

Figure 7. Thermocouple probe and fire tile locations at Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2007.

4.3.2. Strip Thin Treatment

The strip thin treatment block was 4.4 acres in size and located on the westerly side of the stand (Figure 8). Four temporary 1/200th acre plots were installed pre-treatment in this block for comparison to the other sites. Four strips were installed down the southern facing slope. The first strip was placed 32 feet east of the western boundary and was on a bearing of 0^{o}. The strip was 8 feet wide. The strips were approximately 32 feet apart. Forty-eight permanent measurement plots adjacent to the thinned strips were installed in January 2008. Thirty-two plots were installed on the edge of the strips and 16 plots in the center of the strips of trees.

4.3.3. Control Treatment

The control treatment block was 3.5 acres in size and was located between the strip thin and the crop tree release blocks (Figure 9). This block contained a drain that caused a slight difference in species composition, containing an increased number of hardwoods compared to the other three blocks. Thus, this block was designated as the control. The block contained four permanent plots opportunistically located such that the drain has little influence on species composition. Eight permanent plots were installed in January 2008 with plots 301–305 along a transect across the slope with 75 feet between each plot. Plot 306 was located 75 feet down slope from plot 301. Plots 307 and 308 were on an east transect from plot 306, each plot being 75 feet apart.

4.3.4. Crop Tree Treatment

The crop tree release treatment block was 4.8 acres and was located on the eastern side of the stand (Figure 10). The spacing for the crop trees was approximately 45 feet by 45 feet, or 20 crop trees per acre. The crop trees were selected by identifying the largest diameter tree with the

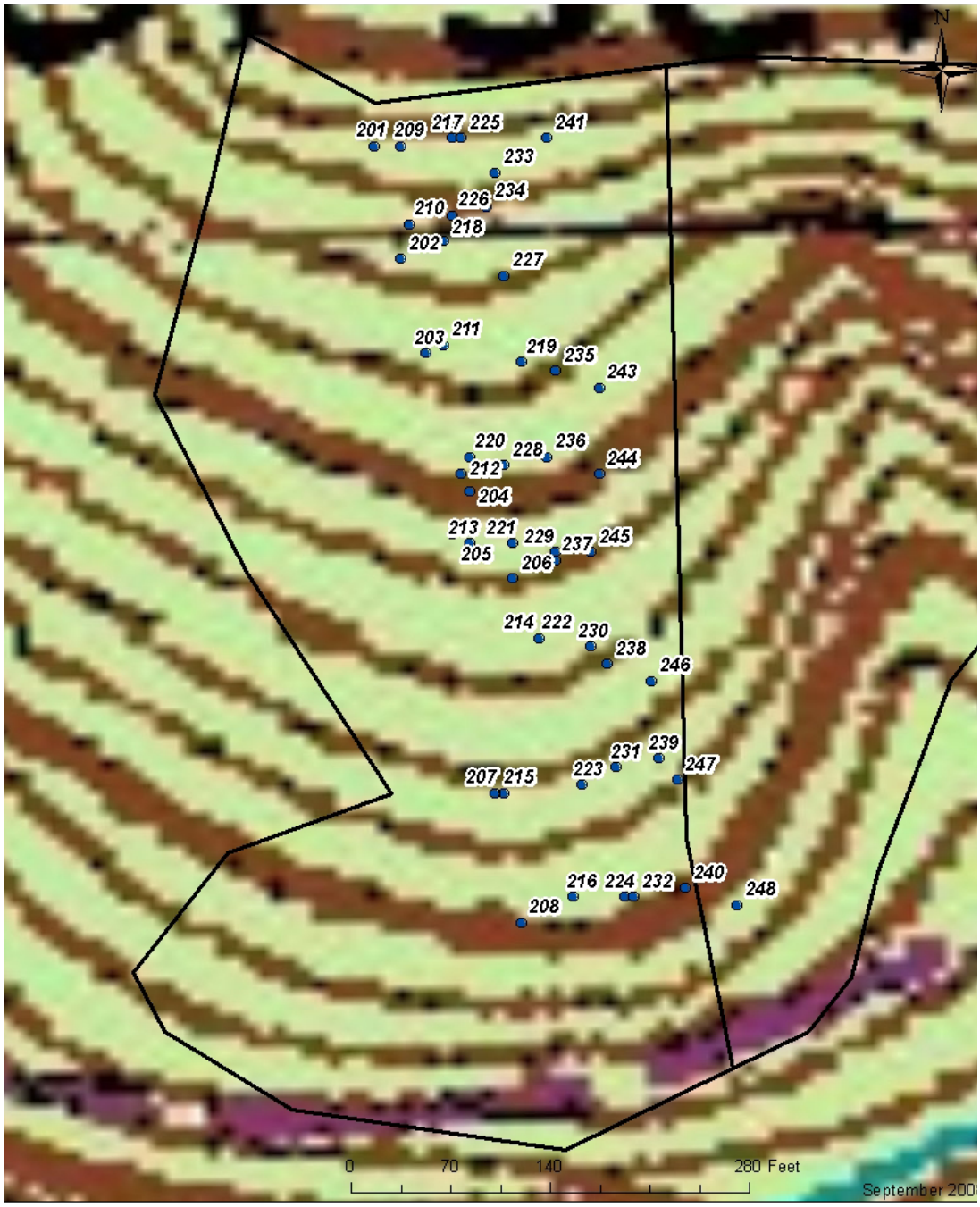


Figure 8. Strip thin plot locations at Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2007.

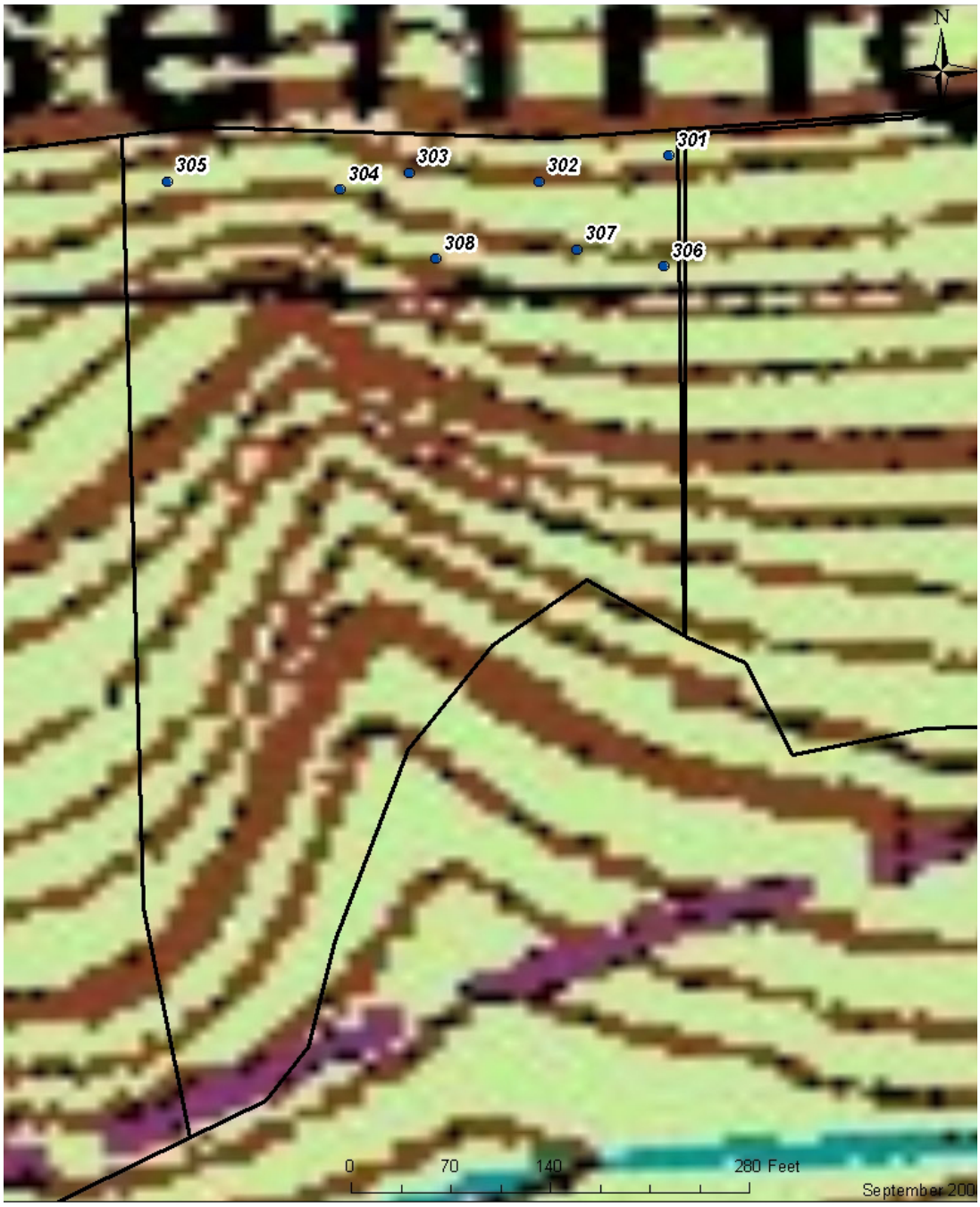


Figure 9. Control plot locations at Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2007.

best overall form with a full, dominant, and symmetrical crown. The crop trees were marked by nailing metal tags to the tree with aluminum nails. The crop trees were also painted and flagged in florescent pink. The diameters (inches) and heights (feet) of each crop tree were measured. The trees were released using a crown touching method. The adjacent trees to be cut were flagged with blue flagging. The diameters and heights of the cut trees were recorded. The trees were released on November 27, 2007.

The data were compiled using Microsoft Excel. For each plot, average diameter, average height, basal area (BA) per plot and acre, and trees per acre were determined. Species composition was also recorded per plot. These data were compiled and means calculated by treatment.

4.4 Data Analysis of Inventory Data

The plot data from the Northern districts, 36 verification plots, were organized in Microsoft Excel. Basal area per acre, trees per acre, importance values, and means for diameter, height, and basal area were determined. Importance values were calculated using the methods of Curtis and McIntosh (1951) by determining relative density and relative dominance. ANOVAs were analyzed using the importance value of a species (TMP) or species group (hardwood, all pines, or other pines) as the dependent variable and treatments or stand types as the independent variable (SAS Institute, 2003). Least Significant Difference (LSD) was used as the method for comparing treatment group means after the ANOVA null hypothesis of equal means has been rejected (F-Test). The level of significance for LSD was set at $P < 0.05$.

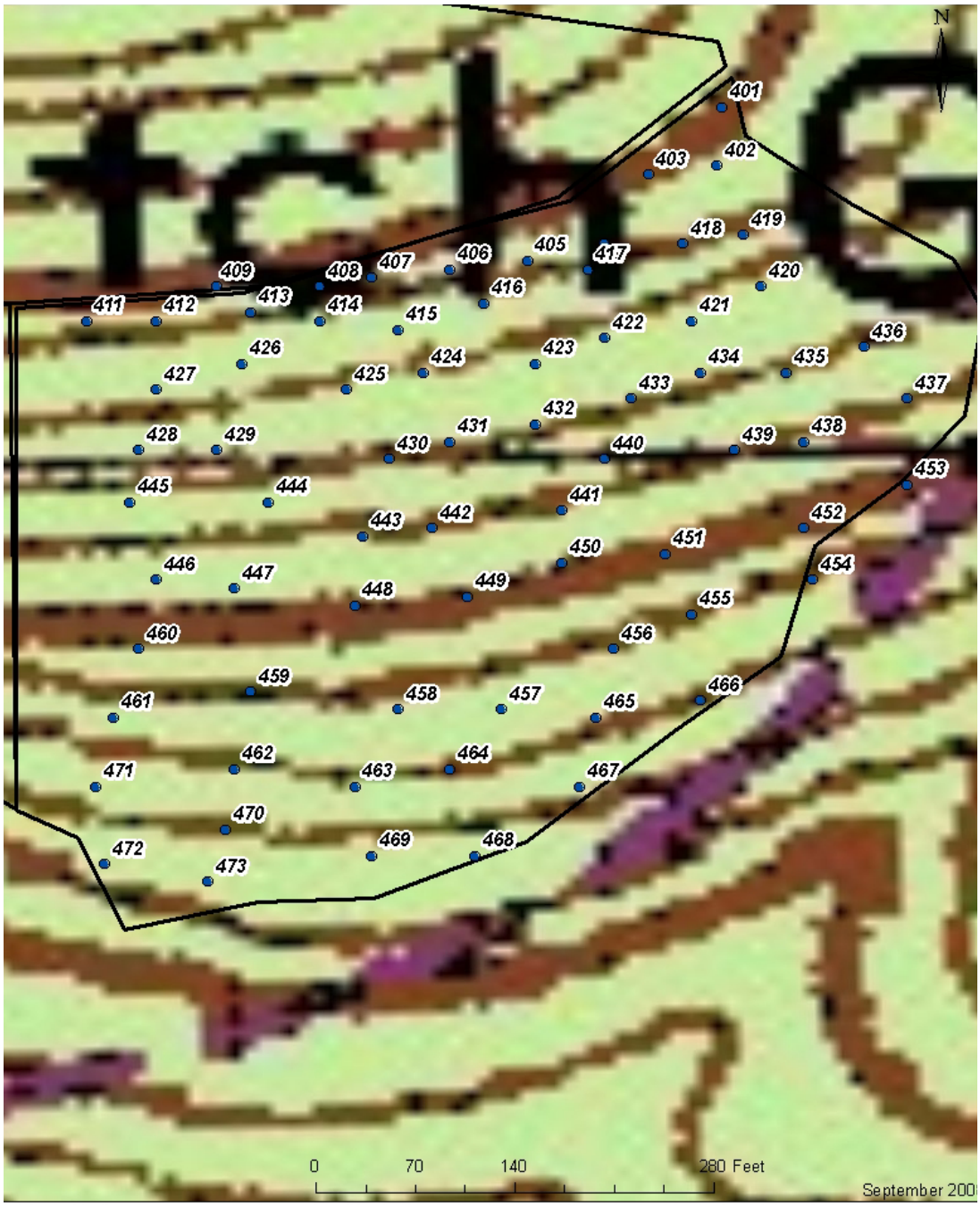


Figure 10. Crop tree plot locations at Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2007.

The TMP importance value failed to meet the equal variance assumption, so the data were transformed with the natural log, after which both the variance and normality assumptions were met. The tests used were the Levene Test for Equality of Variance and the Shapiro-Wilk Test for Normality. The hardwood importance values also failed to meet the equal variance assumptions, so the natural log was taken. The natural log transformation did not correct the variance issue so a rank transformation was used. The ANOVA was analyzed using rank values. The pine importance value was also used with the natural log.

Horsehitch Gap data were compiled with basal area, tree per acre, importance values of each species, and mean diameters and heights determined. ANOVAs were analyzed using the importance values (TMP and hardwood) as the dependent variable and treatments as the independent variables. All of the species importance values failed to meet the equal variance assumptions, thus the data were transformed using the natural log. This did not correct the variance issue so a rank transformation was used. The ANOVA was analyzed using the ranks values.

4.5 Cost Analysis

The cost analysis of the treatments at Horsehitch Gap was completed using methods of Miyata (1980) and Brinker and others (2002). Miyata (1980) outlines the methods for calculating operating costs. Brinker and others (2002) developed a worksheet that contains these formulas in a user-friendly layout.

At Horsehitch Gap, the strips were installed using a John Deere 450H LT dozer on November 27, 2007. The time to install each strip was recorded. Purchase prices were obtained

from local dealers. Percentages for fringe benefits followed Christman (2002). The life estimate, salvage value, utilization rate, repair and maintenance, interest rate, and lubrication costs were obtained from Brinker and others (2002). The tax rate for this study followed the same logic as Brinker and others (2002) because "in-woods equipment is not usually subject to tax collection," thus no costs were calculated for this portion of the equation. Ratings for fuel usage per hour were obtained from John Deere (2008). Off-highway diesel costs were obtained by using the Department of Energy 2008 rate for on-highway diesel and subtracting the state and federal taxes (University of Tennessee, 2007). Wage rates were obtained from the U.S. Department of Labor (2007). Scheduled machine hours followed the methods of Miyata (1980).

The cut trees around the crop trees were cut using Stihl MS361 chainsaws. This treatment was implemented by two sawyers. The time to walk between plots was recorded for each plot. Time to cut each competing tree on a plot was not recorded because tree size was relatively homogenous, averaging 1 to 3 inches in diameter. Purchase prices were obtained from Stihl's recommended price online (Stihl website, 2008). The variables used for the chainsaw calculations were from the same sources as those used for the dozer. Hauling rates for personnel and for the dozer to be transported to the worksite were not calculated as part of the hourly rates or the cost analysis.

Chapter 5. Inventory Results and Discussion

5.1 Results

The inventory of the stands classified as TMP or TMP/Hardwood in the 1994 CISC data revealed that only 1 of the 129 stands still dominated by TMP in the overstory (Table 2). Only 15 of the 73 stands considered to be TMP with a hardwood component in 1994 contained more than 50 percent TMP in the overstory (Table 2). Ninety-four stands that became hardwood/TMP stands and 92 stands converted to hardwood (Table 2). Less than 900 acres that are greater than 50 percent TMP remain of the more than 5,000 that existed, according to the 1994 data (Table 3). Twenty-four stands had been affected by the SPB and burned (Table 4). Two additional stands which had burned were not affected by the SPB. Table A1 in Appendix A contains the classification by individual stands. Detailed stand types descriptions are available in Table A2 of Appendix A.

The one TMP stand was young and contained an average of 6,280 trees per acre with an average diameter of 1.6 inches and a mean basal area of 100.7 ft^2/ac (Table 5). The importance value for TMP was 173.9 and 23.8 for hardwoods (Table 6). The main component of this community was TMP, but it also contained upland oaks and blackgum (*Nyssa sylvatica* Marsh.) in minor amounts.

TMP/Hardwood stands had an average basal area of 29.7 ft^2/ac and an average diameter of 10.8 inches (Table 5). The mean density was 651 stems per acre. The importance value of TMP was 120.5 and 68.0 for hardwoods (Table 6). TMP comprised about 70 percent of the stand, followed by blackgum and blackjack oak (*Quercus marilandica* Münchh.) at 14 percent and 10 percent, respectively (Figure 11).

Table 2. Comparison of the number of TMP stand types on the Cherokee National Forest, 1994 and 2007

Stand Type	1994	2007
TMP	129	1
TMP/ Hardwood	73	15
Hardwood/ TMP	-	94
Hardwood	-	92

Table 3. Acreage of stand types sampled on the Cherokee National Forest, 2007.

Stand Type	1994	2007
TMP	5047.5	30.3
TMP/Hardwood	2409.4	802
Hardwood/TMP	-	4087.4
Hardwood	-	2537.2

Table 4. Percentage of stand types sampled with evidence of fire or southern pine beetle on the Cherokee National Forest, 2007.

Stand Type	Fire	Southern Pine Beetle
TMP	100%	100%
TMP/Hardwood	26.7%	100%
Hardwood/TMP	11.7%	84.0%
Hardwood	10.9%	65.2%

Table 5. Comparison of stand data by stand type on the Cherokee National Forest, 2007.

Stand Type	Basal Area (ft^2/ac)	Trees/Acre	DBH
TMP	100.7	6280	1.6”
TMP/Hardwood	29.7	651	10.8”
Hardwood/TMP	28.7	543	10.3”
Hardwood	59.7	264	13.9”

Table 6. Importance values of stand types sampled on the Cherokee National Forest, 2007.

Stand Type	TMP	Hardwood	Other Pine
TMP	173.916	23.761	2.160
TMP/Hardwood	120.540	68.039	11.420
Hardwood/TMP	37.809	157.852	4.338
Hardwood	3.282	187.387	9.330

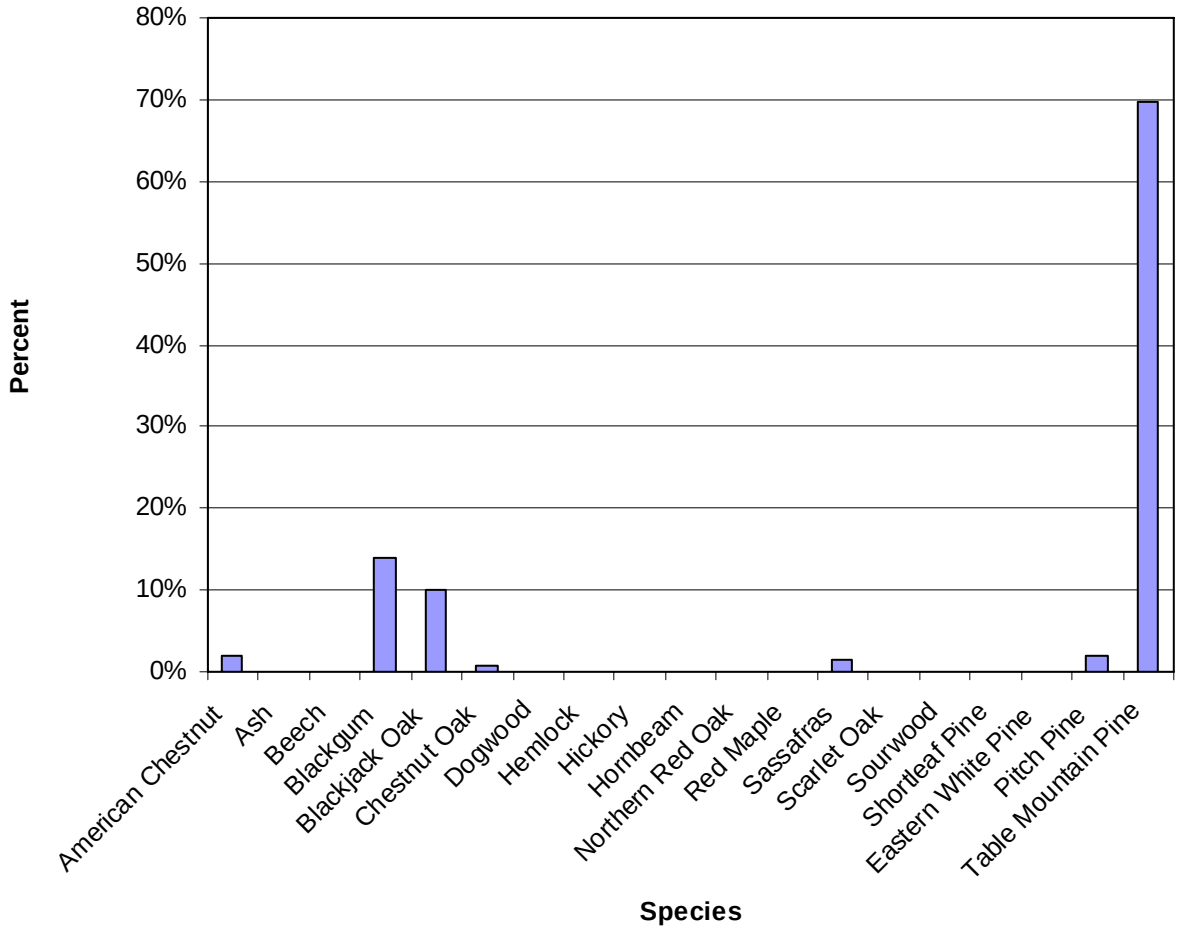


Figure 11. Species composition of TMP/hardwood stands on the Cherokee National Forest, 2007.

The Hardwood/TMP stands had an average basal area of 28.7 ft^2/ac, an average diameter of 10.3 inches, and a mean density of 543 trees per acre (Table 5). The importance value for TMP was 37.8 and 157.9 for hardwoods. Chestnut oak was the most abundant species, making up about 40 percent of all stems. TMP made up about 19 percent, followed by scarlet oak, red maple *(Acer rubrum* L.*),* and blackgum at 16, 11, and 7 percents, respectively (Figure 12).

The Hardwood stands contained an average basal area of 59.7 ft^2/ac, mean diameter of 13.9 inches, and mean density of 264 stems per acre (Table 5). The importance value for TMP was 3.3 and the value for hardwoods was 187.4 (Table 6). This community type was dominated by chestnut oak at approximately 35 percent, red maple at 17 percent and blackgum at 13 percent. Other species that comprised at least 5 percent of the composition included sourwood (*Oxydendrum arboretum* L.), pitch pine, northern red oak (*Quercus rubra* L.), and hickories (*Carya* spp) (Figure 13).

The statistical analysis of the four forest communities revealed that no statistical difference of importance values between the TMP and TMP/Hardwood, but a statistically significant difference was found between values for Hardwood/TMP and Hardwood stands (Table 7, Figure 14). No statistical difference was found between values for TMP/Hardwood and Hardwood/TMP stands. The TMP importance value in the Hardwood type was significantly different from all other types (Table 7, Figure 14). Post ANOVA mean separation comparing hardwood importance values indicated no statistically significant differences between the Hardwood and Hardwood/TMP stand types. Similarly, the TMP and TMP/Hardwood stand types had no statistically significant differences for hardwood importance values. However, the two hardwood-dominated forest types were significantly different from the two pine-dominated forest types (Table 8, Figure 15). ANOVAs were completed using the importance value of the

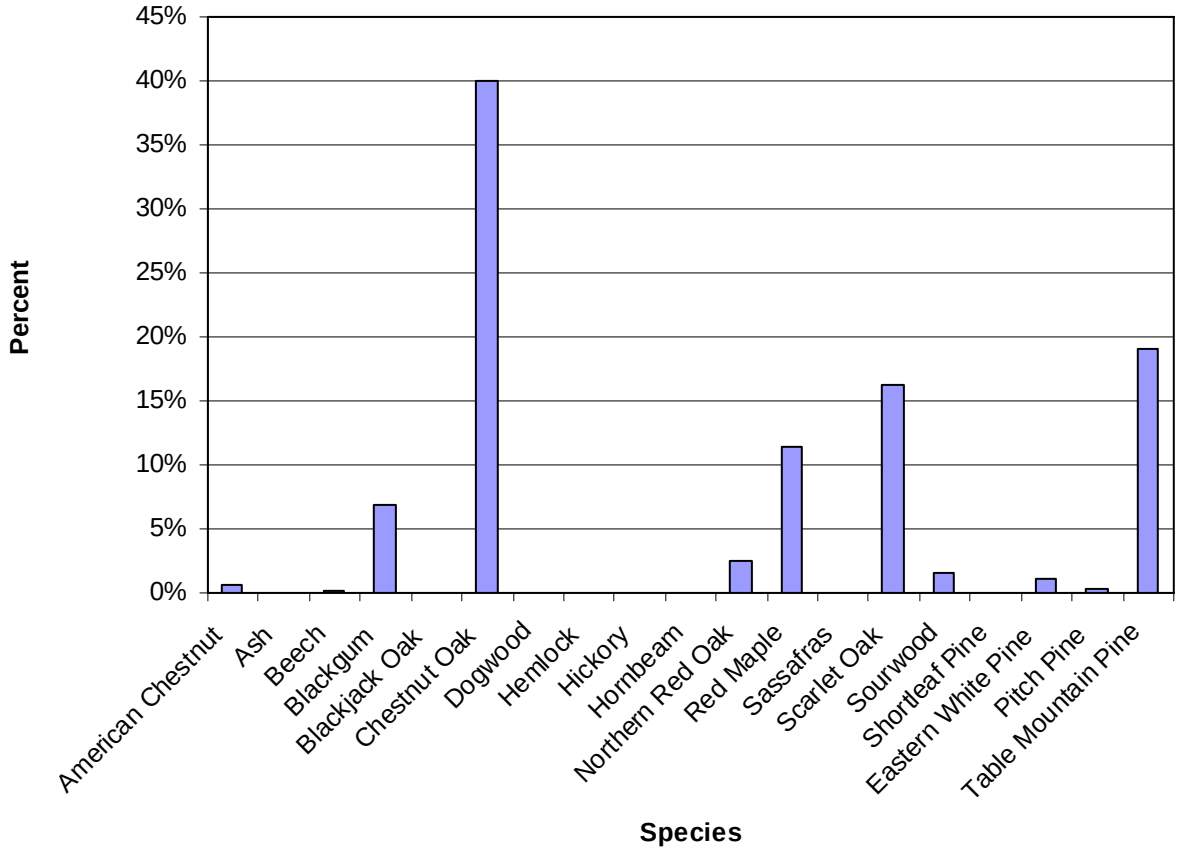


Figure 12. Species composition of Hardwood/TMP stands on the Cherokee National Forest, 2007.

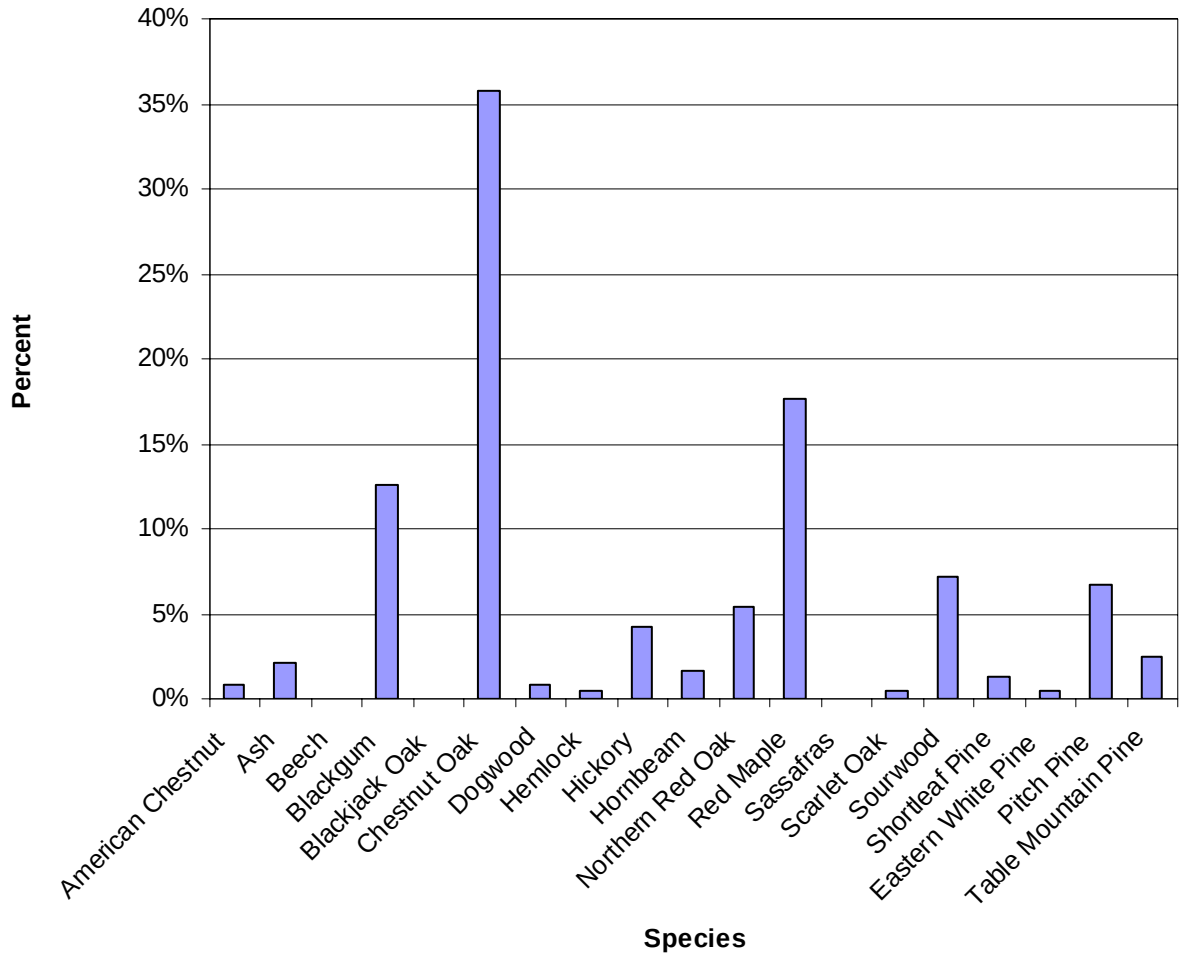


Figure 13. Species composition of Hardwood stands on the Cherokee National Forest, 2007.

Table 7. Importance values of TMP by stand type on the Cherokee National Forest, 2007.

Stand Type	Importance Value[1]	Standard Error[1]	Significance[2]
Hardwood	0.226	0.4174	C
Hardwood/TMP	8.005	2.2535	B
TMP/Hardwood	50.309	5.6348	AB
TMP	173.497	10.4603	A

[1]- Value was back transformed to show means.

[2]- Means followed by the same letter are not different (df=3,32) by LSD at $p<0.05$. ($F=12.46$; $p<0.0001$).

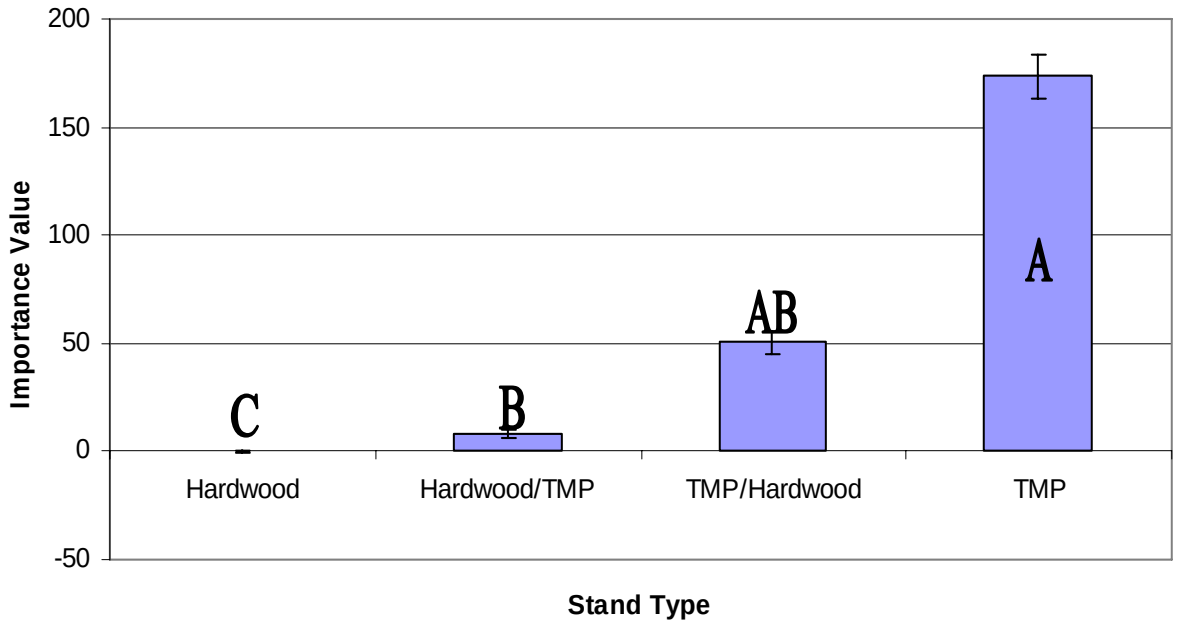


Figure 14. Importance value of TMP by stand type on the Cherokee National Forest, 2007. Different letters indicate a significant difference among stand types (df=3,32) by LSD at $p<0.05$. ($F=12.46$; $p<0.0001$).

Table 8. Importance value of hardwoods by stand type on the Cherokee National Forest, 2007.

Forest Type	Importance Value[1]	Standard Dev.[1]	Significance[2]
Hardwood	187.39	16.81	A
Hardwood/TMP	157.85	50.26	A
TMP/Hardwood	68.04	62.82	B
TMP	23.76	12.8	B

[1]- Value was obtained using the Means Procedure due to the use of ranks.

[2]- Means followed by the same letter are not different (df=3,32) by LSD at $p<0.05$. ($F=19.50$; $p<0.0001$).

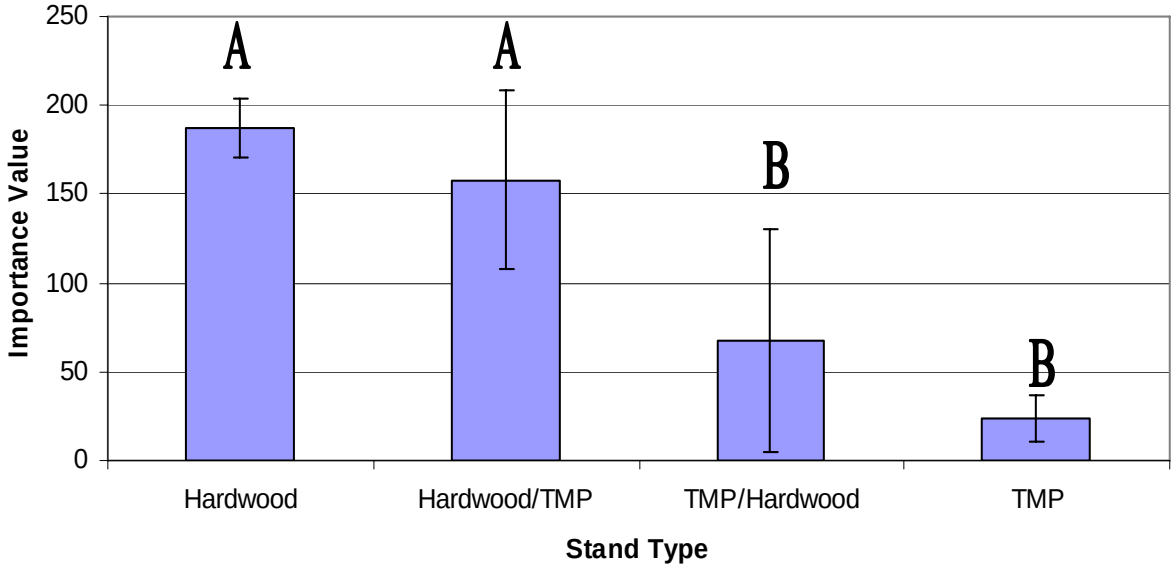


Figure 15. Importance value of hardwoods by stand type on the Cherokee National Forest, 2007. Different letters indicate a significant difference among stand types (df=3,32) by LSD at $p<0.05$. ($F=19.50$; $p<0.0001$).

other pines found in the stands. The importance value of the other pines showed no statistically significant difference across all forest types (Table 9, Figure 16). Because other pines in the stands were minimal, the TMP and other pines were added together to obtain a figure for all pines. The importance value of all pines had no statistically significant difference between the TMP and TMP/Hardwood (Table 10, Figure 17). No significant difference was found between the TMP/Hardwood and Hardwood/TMP and no difference was observed between Hardwood/TMP and Hardwoods for all pine importance values.

5.2 Discussion

The data suggest a great reduction in the number of stands classified by the 1994 CISC data as TMP stands. The reduction in TMP stands may be due to any combination of SPB infestation, the lack of fire, or even errors in the 1994 data. The number of stands, as well as acreage of TMP, has declined drastically as shown by Tables 2 and 3. In 1994, more than 5000 acres classified as TMP stands and 2400 acres as TMP and hardwoods mixed stands. Now, less than 900 acres are dominated by TMP (Table 3).

The amount of TMP in each stand classified in the 1994 CISC data is difficult to determine, whether TMP composed a major or minor component of the species composition. Without fire to suppress and control the competing hardwoods, many of the stands were converting to hardwood or hardwood pine mixed stands prior to the 2007 survey. The gaps created when the pines died were promptly filled by hardwoods, unless a burn had created conditions for TMP regeneration. In the absence of fire, it is difficult for the TMP to compete with the hardwoods. Without fire, the seedbed is not conducive to pine regeneration as the litter

Table 9. Importance value of other pines by stand type on the Cherokee National Forest, 2007.

Forest Type	Importance Value[1]	Standard Error[1]	Significance[2]
Hardwood	1.02617	0.90911	A
Hardwood/TMP	0.05482	0.28372	A
TMP/Hardwood	0.96923	0.88473	A
TMP	0.2399	0.47185	A

[1]- Value was back transformed to show means.
[2-] Means followed by the same letter are not different (df=3,32) by LSD at p<0.05.(F=1.62; p=0.2039).

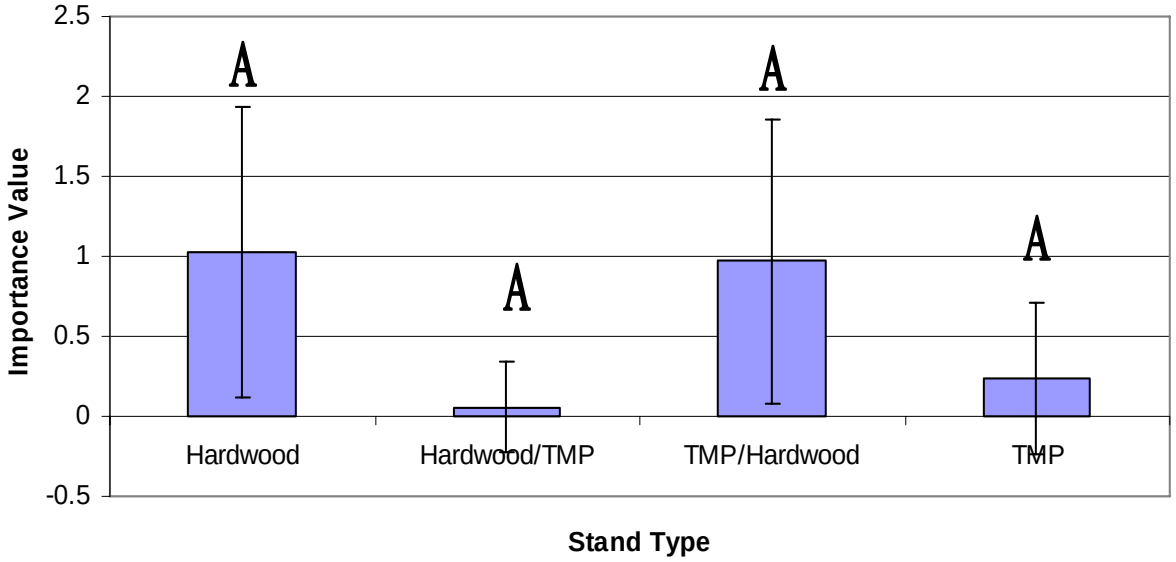


Figure 16. Importance value of other pines by stand type on the Cherokee National Forest, 2007. Different letters indicate a significant difference among stand types (df=3,32) by LSD at p<0.05. (F=1.62; p=0.2039).

Table 10. Importance value of all pines by stand type on the Cherokee National Forest, 2007.

Forest Type	Importance Value[1]	Standard Error[1]	Significance[2]
Hardwood	1.208	0.9556	C
Hardwood/TMP	8.312	2.4636	BC
TMP/Hardwood	58.831	6.5373	AB
TMP	175.644	11.2925	A

[1]- Value was back transformed to show means.
[2]- Means followed by the same letter are not different (df=3,32) by LSD at $p<0.05$. ($F=6.55$; $p=0.0014$).

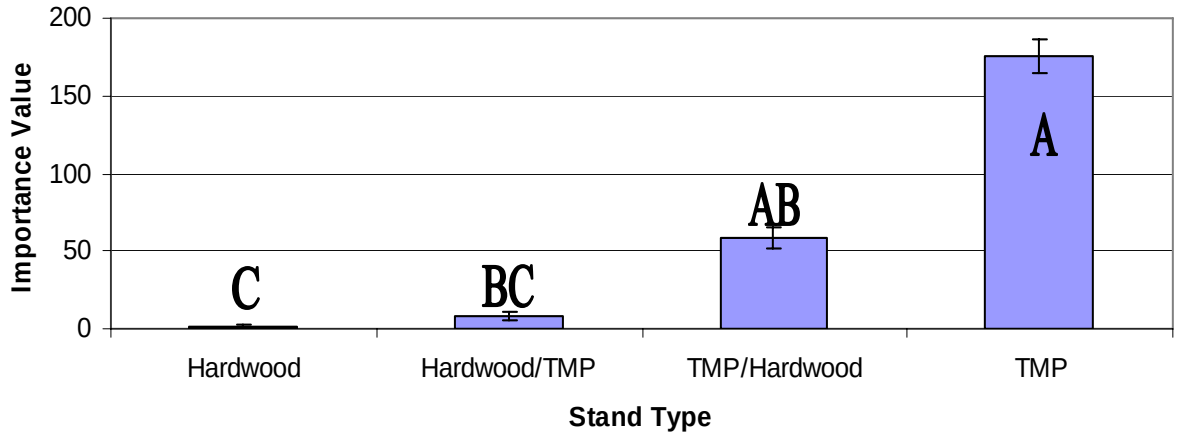


Figure 17. Importance value of all pines by stand type on the Cherokee National Forest, 2007. Different letters indicate a significant difference among stand types (df=3,32) by LSD at $p<0.05$. ($F=6.55$; $p=0.0014$).

and duff may be impenetrable. Hardwoods may be hindered directly by fire or damage such as fire scars that may lead to butt rot.

As shown in Figures 11-13, species dominant presently in the Hardwood, Hardwood/TMP and TMP/Hardwood stand types were chestnut oak, scarlet oak, blackjack oak, blackgum and red maple. Many of the Hardwood and Hardwood/TMP stand types appear to be younger, because the number of stems in the smaller diameter classes is substantially larger than the number in larger classes with the average being in the 10- to 11-inch range in the TMP/Hardwood and Hardwood/TMP stand types (Table 5). The Hardwood stand types had a slightly higher average diameter at 13.9 inches. TMP had a higher importance value in the TMP stands and TMP/Hardwood stands, 174 and 121 respectively, but very little importance in the Hardwood and Hardwood/TMP stands, 3 and 38 respectively. This was exactly opposite for hardwood importance. The importance value of hardwood in TMP and TMP/Hardwood was minimal, 24 and 68 respectively, 157 out of a possible 200 for Hardwood/TMP and 187 for the Hardwood stands (Table 6).

Table 2 illustrates that many of these stands had a very large hardwood component. Mixed stands are unstable and always in a state of transition. Without continued disturbances to create favorable regeneration conditions for pine, the hardwood becomes more prominent with increasing age. Many hardwoods also live longer than pines. As pines die, gaps are created and hardwoods quickly occupy the free space in the absence of pine regeneration.

As shown in Table 4, most of the sampled stands had been affected by SPB and very few had evidence of fire. All of the TMP/Hardwood stands had evidence of SPB and 27 percent had evidence of fire. Whether fire was pre–or post–SPB is unknown, but many of these stands had pine regeneration. Eighty-four percent of the stands in the Hardwood/TMP type had evidence of

SPB, but only 12 percent had evidence of fire (Table 4). The increase of fuels from down woody material as well as snags may have also increased fire intensities. Even after the SPB outbreak, fire could have opened the many residual cones and produced proper seedbeds for regeneration. Again, without fire to create proper seedbed conditions, these gaps are filled by hardwoods as they are adapted to the deeper litter and duff depths. With the overstory of pines devastated from the SPB, a mixed stand will very quickly transform to hardwoods by releasing hardwoods present in the midstories and understories.

While sampling the Tellico/Hiwassee district stands, areas with abundant cones were noted. It appears that many of these trees were individuals that survived the SPB and were older, mature trees, with ages ranging from 50 to 100 years old. These individuals were generally in the mixed stands or were single TMP stems in hardwood stands. By burning in these stands with mixed hardwoods and pines, single trees may be able to maintain pockets of TMP with adequate fire regimes. Occasionally, younger stems that held a dominant position in the crown canopy did contain abundant numbers of cones. In the areas where the TMP overstory had been killed by the SPB, many of the down tops still contained many unopened cones that could potentially be released if fire occurred in the area.

One question that arises is the accuracy of the 1994 data. Was every stand in every compartment sampled in order to produce these data or were some of the stands still based on community types from an earlier date? In speaking with several CNF district employees, it appears that some stands had not been visited since the 1970s. From the 1994 CISC data, the TMP stands are classified as being either greater than or less than 20 years of age with 196 stands being greater than 20 years. Based on field observations, these stands were much older and very susceptible to SPB. Even if all the stands classified as greater than 20 years were only

20 years old in 1994, they were at least 30 years old at the time of sampling for this project which supports the hypothesis that many were susceptible to SPB. Fire Management Officer (FMO) Greg Salansky (2008) said he was aware of stands that contained small pockets of TMP that may not have even been included in the 1994 CISC data. Many of these stands were interpreted in drive-bys or by aerial photography because of steep slopes and inaccessibility that prevented the collection of ground data.

The CNF burns approximately 20,000 acres annually by means of prescribed burning (USDA-FS, 2008). Between January and September 2008, more than 25,000 acres in the CNF had been prescribed burned (personal communication, Mike Bot, 2008). The districts are making advances in their TMP management by increasing the occurrence of fire in stands that have a TMP component (personal communication with FMO Greg Salansky, 2008). By attempting to put more fire on the ground, the chances of regenerating TMP increase. Many of the TMP/Hardwood stands in the Greene Mountain and Rocky Top areas have an impressive amount of TMP regeneration and great potential for maintaining TMP in the system with prescribed burning. These areas have very steep rocky slopes and much of the area has mountain laurel and/or rhododendron. Management of TMP requires a fire regime to maintain the species and discourage other species.

Although this study focused solely on the Cherokee National Forest, TMP is also located on private lands. The general public could be made more aware of this species and its threatened state. With added support from the public, prescribed burning may become more frequent and be able to cover a greater number of the stands containing TMP. With the public more aware of the species and the conditions across East Tennessee and the southern Appalachian Mountains, more pro-active management can be placed on maintaining and restoring healthy populations of TMP.

Chapter 6. Horsehitch Gap Case Study Results and Discussion

6.1 Results

ANOVAs were conducted to compare importance values of TMP, hardwoods, and other pines in each treatment block. The analysis showed no statistically significant difference among treatment blocks (Table 11, Figure 18). The mean TMP importance value for the prescribed burn block was 164.30, 173.87 for the strip thin, 174.66 for the control, and 165.98 for the crop tree block, indicating no difference among treatments (Table 11).

6.1.1. Prescribed Burn Treatment Block

The trees in the prescribed burn block had a mean diameter of 1.9 inches and a mean height of 14.9 feet (Table 12). This block contained 5388 trees per acre with a basal area of 127.5 ft^2/ac. The mean diameter of the permanent plot trees was 2.77 inches. TMP made up 86 percent of the treatment block, followed by 5 percent chestnut oak (Table 13) (Figure 19). The mean importance value for TMP was 164.30, 34.14 for hardwoods, and 1.56 for the other pines (Table 11).

6.1.2. Strip Thin Treatment Block

The mean diameter of trees in the strip thin treatment block was 1.6 inches with a mean height of 17.7 feet (Table 12). The block contained 4242 trees per acre with a basal area of 75.7 ft^2/ac. The mean diameter of the permanent plot trees was 2.56 inches. TMP made up 90 percent of the treatment block, followed by scarlet oak at 5 percent (Table 13) (Figure 20). The mean importance value for TMP was 173.87, 24.89 for hardwoods and 1.25 for other pines (Table 11).

Table 11. Importance values for Horsehitch Gap treatment blocks. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, January 2007.

Treatment	N	TMP Mean[1]	TMP (Std Dev)	Hardwood Mean[1]	Hardwood (Std Dev)	Pine Mean[1]	Pine (Std Dev)	Significance[2]
		164.30	(57.19)	34.14	(54.85)	1.56	(3.77)	A
Burn	16							
Strip Thin	16	173.87	(29.16)	24.89	(29.75)	1.25	(2.82)	A
Control	8	174.66	(22.94)	24.83	(23.13)	0.51	(1.43)	A
Crop	5	165.98	(32.66)	33.38	(33.33)	0.65	(1.44)	A
P value		0.9179		0.9374		0.9231		
F value		0.17		0.14		0.16		

[1]- Value was obtained using the Means Procedure due to the use of ranks.
[2]- Means followed by the same letter are not different (df=3,41) by LSD at $p<0.05$.

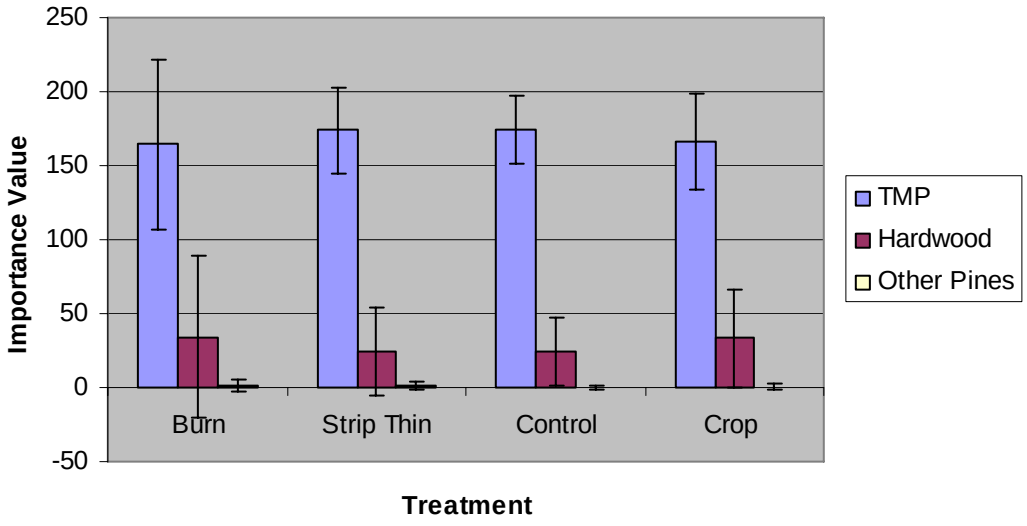


Figure 18. Importance values for Horsehitch Gap treatment blocks. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, January 2007. Values were obtained using the Means Procedure due to the use of ranks (TMP P=0.9179; Hardwood P=0.9374; other pine P=0.9231).

Table 12. Plot data for Horsehitch Gap treatment blocks. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, January 2007.

Measurement	Crop Tree	Strip Thin	P. Burn	Control
Mean D.B.H. (in.)	1.3	1.6	1.9	1.8
Mean Basal Area (ft^2/ac)	79.4	75.7	127.5	110.2
Mean Trees/Acre	7720	4242	5388	5200
Average Height (ft.)/Plot tree	13.4	17.7	14.9	21.3
Average number of cones/Plot tree	8.7	5.0	5.3	6.1
Mean diameter of plot tree (in.)/Plot tree	2.83	2.56	2.77	3.23

Table 13. Species composition for Horsehitch Gap treatment blocks. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, January 2007.

Species	Crop Tree	Strip	P. Burn	Control
	----------*Percent*----------			
TMP	86.01	90.70	86.08	69.52
Blackjack Oak	8.29	0.78	1.39	0.00
Chestnut Oak	1.55	2.54	5.34	3.14
Blackgum	3.63	0.10	1.86	11.00
Shortleaf Pine	0.52	0.00	0.93	0.00
Scarlet Oak	0.00	4.89	4.41	13.20
Hickory	0.00	0.10	0.00	0.00
Pitch Pine	0.00	0.88	0.00	3.14

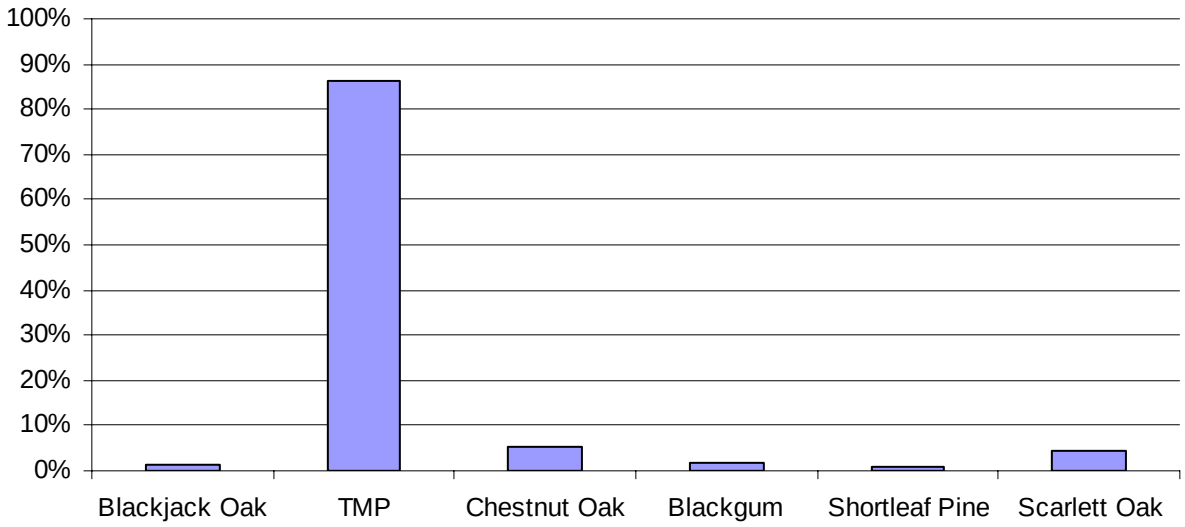


Figure 19. Species composition of prescribed burn treatment block at Horsehitch Gap. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2007.

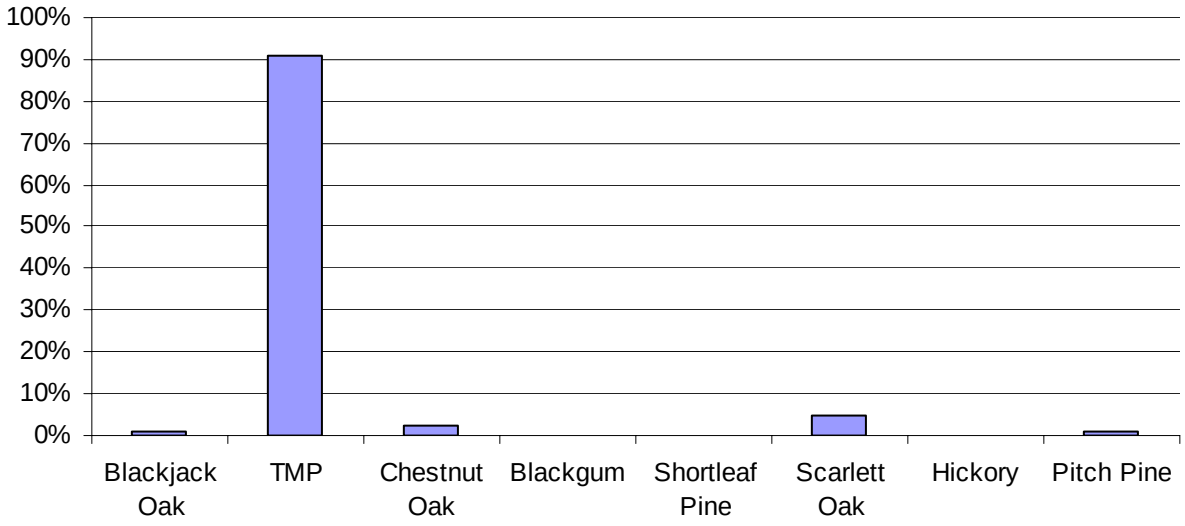


Figure 20. Species composition of the strip thin treatment block at Horsehitch Gap. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2007.

6.1.3. Control Treatment Block

The mean diameter of trees in the control block was 1.8 inches with a mean height of 21.3 feet (Table 12). The block contained 5200 trees per acre with a basal area of 110.2 ft^2/ac and had a mean permanent plot tree diameter of 3.23. TMP made up 70 percent of the treatment block, followed by scarlet oak at 13 percent. (Table 13) (Figure 21). The mean importance value for TMP was 174.66, for hardwood 24.83, and other pines 0.51 (Table 11).

6.1.4. Crop Tree Treatment Block

The crop tree treatment block contained trees with a mean diameter of 1.3 inches at and a mean height of 13.4 feet (Table 12). The block contained 7720 trees per acre with a basal area of 79.4 ft^2/ac. The crop tree block was made up of 86 percent TMP and 8 percent blackjack oak (Table 13) (Figure 22). The mean diameter of the 73 crop trees was 2.8 inches and mean height was 19.7 feet (Table 14). The mean diameter of the cut trees was 1.5 inches with a mean height of 14.6 feet. On average, 6.4 trees were cut per crop tree (Table 14). The mean importance value for TMP was 165.98, 33.38 for hardwood, and 0.65 for other pines (Table 11).

6.2 Cost Comparison of Treatments

6.2.1. Prescribed Burn Treatment Block

The prescribed burn costs were greatly skewed because the fire burned an additional 15 acres. According to the FMO for the Nolichucky/Unaka district of the CNF, the average cost of a prescribed burn is about $45.00/acre. This usually represents large burn units greater than 200 acres. The cost per acre is generally more with smaller tract size. The prescribed burn at Horsehitch Gap was $815.37/acre (Table 15). This cost included the dozer and operator, chainsaws, 29 FS employees including the hotshots and Type 2 firefighters, and 2 helicopters with pilots and copilots and fuel.

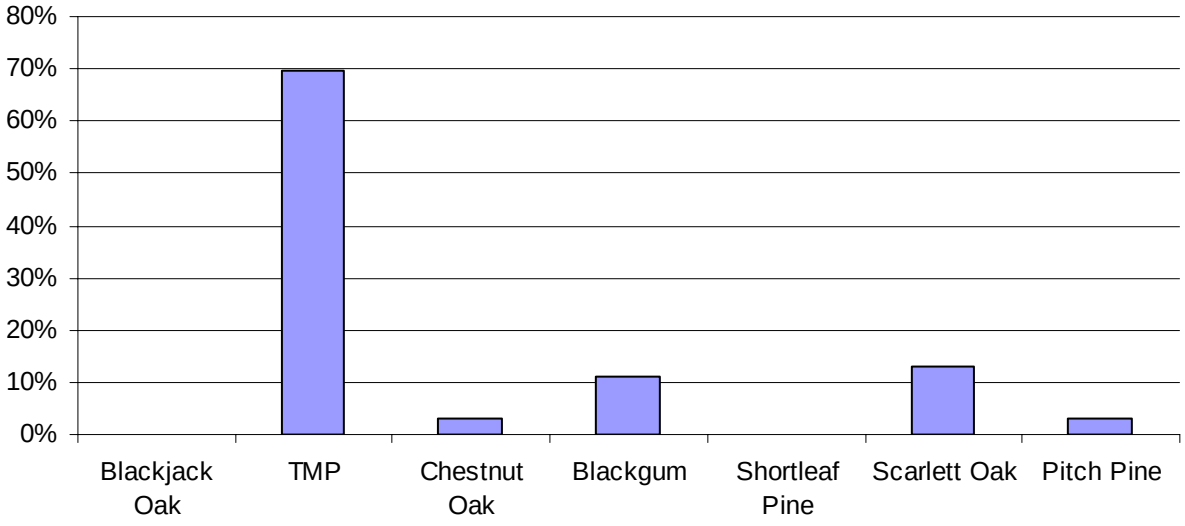


Figure 21. Species composition of control treatment block at Horsehitch Gap. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2007.

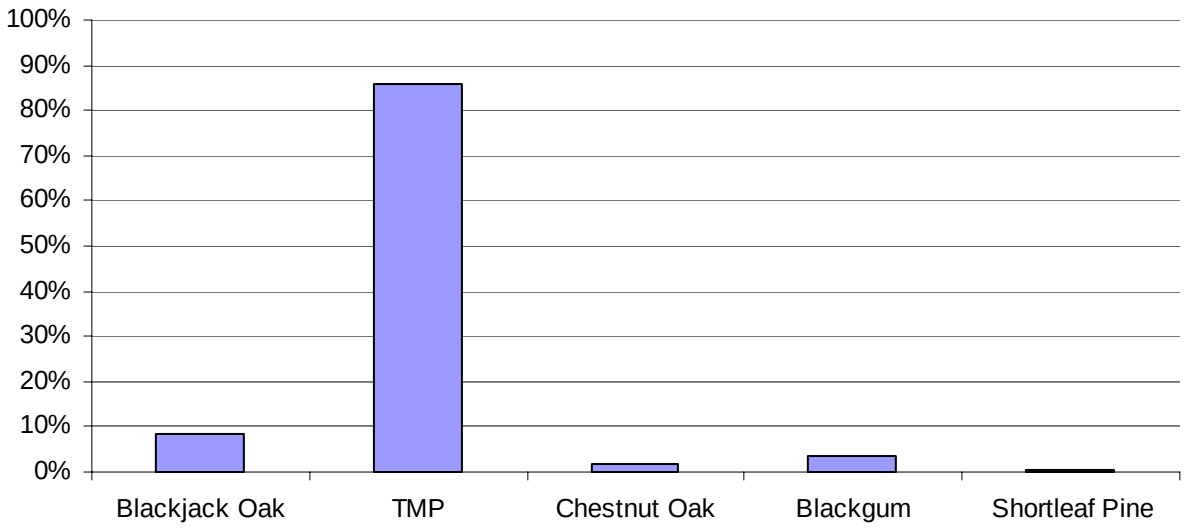


Figure 22. Species composition of the crop tree treatment block at Horsehitch Gap. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2007.

Table 14. Crop tree and cut tree data collected at Horsehitch Gap. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, November 2007.

	Crop Trees	Cut Trees
Average D.B.H. (in.)	2.8	1.5
Standard Deviation	1.327	0.684
Standard Error	0.155	0.032
95% Confidence Interval	0.431	0.088
Average Height (ft.)	19.7	14.6
Standard Deviation	4.039	4.398
Standard Error	0.473	0.205
95% Confidence Interval	1.312	0.569
Average number of cut trees per crop tree	-	6.4
Standard Deviation	-	2.694
Standard Error	-	0.315
95% Confidence Interval	-	0.875

Table 15. Total costs for prescribed burn at Horsehitch Gap. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, April 2008.

Category	Cost ($)
Labor-	8,157.97
Fleet-	
Dozer Transport	90.60
Dozer	208.35
Type 2 Helicopter	6,000.00
Type 3 Helicopter	4,190.00
Truck	6.50
Total Fleet	10,495.45
Other Costs-	
Fuel	75.00
Saw Supplies	25.00
Total Other	100.00
Total Cost-	**18,753.42**
Total Cost per Acre-	**815.37**

6.2.2. Strip Thin Treatment Block

Table 16 provides the hourly costs associated with the use of the dozer in the strip thin treatment. According to John Deere (2008), the purchase price of the dozer was $95,000.00. At an insurance rate of 1.0%, the fixed costs were estimated to be e $1.90/hr because no taxes were used in the estimate (Table 16). The operating costs totaled $41.64/hr with fuel costs at $2.986/gal and oil and lubricants set at 36.8% of the fuel costs (Table 16). Labor and benefits were calculated to be $20.31/hour (U.S. Department of Labor, 2007). This leads to a total cost of $63.85/hour. Transportation costs for the dozer are $1.52/ mile according to The Forest Service. This cost was the cost per mile for hauling the dozer from the work center location to the work site in the field. This cost was not included when calculating the hourly rate, but was made available as a reference.

On average, each strip was about 500 feet long and took about 40 minutes each to install. Thus, the installation of the three strips cost an average of $38.70.

6.2.3.Crop Tree Treatment Block

Table 17 shows a breakdown of hourly chainsaw costs associated with releasing crop trees. According to Stihl (Stihl website, 2008), the purchase price of the MS361 was $600.00. At an insurance rate of 4.0%, the fixed costs are $0.024/hr because no taxes were used in the estimate (Table 17). The operating costs totaled $4.58/hr with fuel costs at $3.097/gal and oil and lubricants set at 36.8% of the fuel costs (Department of Energy, 2008) (Table 17). Labor and benefits were calculated to be $21.26/hour according to the U.S. Department of Labor. This leads to a total cost of $25.87/hour. Transportation costs for the saw were $0.485/mile according to the Internal Revenue Service for 2007 (U.S. Department of the Treasury Internal Revenue Service, 2006).

Table 16. Total costs for hourly productive time; estimation of hourly owning and operating costs of the John Deere 450H LT Dozer. Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, April 2008.

Category	Value
Insurance	1.0%
Fuel	2.0 gal/hr
Oil and Lubricants	0.74 gal/hr
Labor	$15.62/hr
Fringe Benefits	30%
Scheduled Operating Time	2000 hr
Utilization	25%
Productive Time	500 hr
Fixed Costs-	
Taxes	n/a
Insurance	$950.00/yr
Total Fixed Costs	$950.00/yr
	$1.90/hour
Operating Costs-	
Maintenance and Repair	$30.40/hr
Fuel and Lubrication	$11.24/hr
Total Operating Costs	$41.64/hr
Labor Costs-	
Wages	$15.62/hr
Fringe Benefits	$4.69/hr
Total Labor Costs	$20.31/hr
Total Hourly Costs-	**$63.85/hr**

Haul rates of the dozer to and from the site location was not calculated in the hourly rate for the dozer. Estimated cost is $1.52/mile.

Table 17. Total costs for hourly productive time; estimation of hourly owning an operating costs of the Stihl 361 Chainsaw. Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2008.

Category	Value
Insurance	4.0%
Fuel	0.22/hp/hr
Oil and Lubricants	36.8%
Labor	$16.35/hr
Fringe Benefits	30%
Scheduled Operating Time	2000 hr
Utilization	50%
Productive Time	1000 hr
Fixed Costs-	
Taxes	n/a
Insurance	$24.00/yr
Total Fixed Costs	$24.00/yr
	$0.024/hour
Operating Costs-	
Maintenance and Repair	$0.48/hr
Fuel and Lubrication	$4.10/hr
Total Operating Costs	$4.58/hr
Labor Costs-	
Wages	$16.35/hr
Fringe Benefits	$ 4.91/hr
Total Labor Costs	$21.26/hr
Total Hourly Costs-	**$25.87/hr**

Haul rates of the chainsaw and personnel to and from the site location were not calculated in the hourly rate for the chainsaw. Estimated cost is $0.485/mile.

Table 18. Comparison of treatment costs at Horsehitch Gap. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2008.

Treatment	Cost ($)/acre
Prescribed Burn	
Actual-	815.37
Average-	45.00
Strip Thin	38.70
Crop Tree	17.52

The average number of trees cut per crop tree was 6.4. At each crop tree, the sawyers spent about 2 minutes to remove the "cut" trees and an average of 41 seconds to walk between crop trees. Thus, the total time was 3.25 hours to release 73 crop trees.

Table 18 is a comparison of costs by treatment. The prescribed burn cost $815.37. Based on the forest average for prescribed burning, the average cost is $45.00 per acre. The strip thin was $38.70 per acre. The crop tree was $17.52 per acre.

6.3 Discussion of Horsehitch Gap Case Study

The case study at Horsehitch Gap focused on the cost of installing each TMP release treatment. Although baseline tree measurements were tallied and calculated for each treatment, the subsequent tree response to the treatments will take several years and are beyond the scope of this thesis. As previously mentioned, there were no significant differences in the importance values for TMP hardwoods or the other pines among treatment blocks (Table 11). Pines other than TMP were minimal across the stand having a mean importance value ranging from 0.51 to 1.56 in the various treatment blocks (Table 11).

The TMP stand at Horsehitch Gap was in the stem exclusion stage and was severely overstocked and stressed by intense competition for growing space. Mean diameters ranged from 1.3 to 3.2 inches for the permanent plot trees with 5600 stems per acre after 27 years (Table 12). The current poor growing condition of the stand poses many questions for future management and perpetuation of TMP. These questions include response to release, cone production and crown response, regeneration, fuel management, and succession.

How this overstocked TMP stand will respond to release treatments is unknown. The data from the release treatments will not be available for several years. How much time is needed for a response is also unknown as these trees are in a stressed condition. A delayed growth response may occur as resources are reallocated. However, there could be little to no response due to the degree of stress the trees have been under. Ideally, the crop trees will significantly increase in diameter and height, thus providing a growth advantage over other stems.

The mean number of cones on crop trees ranged from 5.0 in the strip thin to 8.7 in the crop tree treatment (Table 12). Hopefully, the release treatments will provide adequate resources to increase cone production. If the chosen trees do develop a growth and size advantage over the other stems, an increase of cone production is anticipated providing a seed source for the future. Differing release treatments may result in differing amounts of cone production. The crop tree treatment released the crown from all sides by removing trees whose crown touched that of the crop tree. The strip thin treatment released only one side of the crown of the trees along the strips. In this block, 32 permanent trees were along the strips and 16 were within the remaining strips of trees. It is doubtful that those within the strips of trees will have the same results as those with any amount of crown release on the edge of the strips. The crowns should increase in

size and fullness after release, thus increasing the vigor and cone production potential of the trees.

The objective of the prescribed burn was to release stems by thinning the stand, not to regenerate the stand. A slow, backing fire would be of a lower intensity that would kill some trees, but allow others to survive. However, after the flanking fire joined the backing fire, the intensity began to increase in some areas. The fire did range greatly across the stand in intensity from surface to crown and surface burning. Cones did open and seedbed conditions were created such that some TMP regeneration or possibly a new cohort may result. However, the purpose of burning was to simulate a precommercial thinning, not to create regeneration. The fire intensity needed to provide the desired mortality is unknown at this time because of the mosaic of intensities encountered. Remeasurement of permanent plots within the burn treatment during the 2009 growing season will provide some data on the survival and mortality of TMP. The desired mortality for this stand was set in the burn plan by the FMO at 60 percent. A mortality of 60 percent would free resources and growing space for the remaining trees.

Another issue that arose with this young, overstocked TMP stand was the abundance of vertical fuels. These vertical fuels played a role in the fire escaping the fire line. A very narrow window of opportunity exists for prescribed burning in TMP stands because of the rough and steep terrain. Fuel moisture, wind speed, and wind direction are factors that limit prescribed burning in these stands. The assumption with using prescribed burning as a release treatment is that some trees will succumb while other trees will survive. However, burning conditions to provide this assumption are unknown. Most studies of burning in TMP focus on regeneration rather than thinning, and as previously discussed, debate still occurs about which intensity is needed to provide conditions for regeneration. To determine which intensity is needed for

desired amounts of mortality, fire intensity studies should be implemented in similar stands of TMP. By monitoring fire intensities and mortality in these overstocked stands, the fire intensity that best achieves the optimal amount of mortality while providing release of other trees in overstocked conditions may be determined.

As a result of the crown fire, strips across the stand had no remaining crowns. One month after the burn, an abundance of oaks had sprouted. If a significant number of stems died in these strips, will hardwoods fill in the gap or did enough viable seed fall to create a new cohort in this area? Mixed stands are transitional in this area and if these gaps are filled with hardwoods, will the stand progress to hardwood domination over time? Based on the recent fire history of this stand, with fires occurring once every 30 to 40 years, the fire frequency and interval may not control hardwood encroachment.

The costs associated with prescribed burning were greater than the mechanical treatments used in this study (Table 18). Typically, the costs for prescribed burning decrease on a per acre basis as the area burned increases. A few considerations that increase the costs of prescribed burning in this study area are the installation of fire lines, adequate labor to monitor the prescribed burn, and the steep and rocky terrain.

The initial costs show that crop tree release had the least costs of all the release treatments at $17.52/acre. Equipment costs were minimal (Table 18). This cost would probably increase as average tree size increased. The trees in this study were very small and many could be removed in a matter of minutes (Table 14). The primary cost associated with this treatment was labor. The strip thin was $38.70/acre with operating and labor costs. The cost of diesel, including off-road diesel, is continuing to rise, so the operating costs will probably increase. With the average cost of prescribed burning at $45.00 per acre, the majority of the costs would

be related to labor. However, in this case, equipment costs were a major contributor considering two helicopters and a dozer were used during the prescribed fire treatment.

The response of TMP to these release treatments will not be known for several years. This study provides an estimate of initial costs of the release treatments with the crop tree release being the least initial cost and prescribed burning being the most. Cost figures will vary depending on size of treatment area as well as how many trees are released in the crop tree release treatments. Strip treatment costs will also vary depending on the number and size of strips. In this study, strips were 8 feet wide with 32 feet between strips. Larger (or smaller) strips and area left between strips can vary depending on management or operation objectives, thus adding to or decreasing treatment costs. Future measurements or studies may provide more information on the tree response to the release treatments installed in this study. Hopefully, these treatments are viable options for the release of TMP stands to encourage future growth, survival, and cone production.

Chapter 7. Conclusion and Recommendations for the Future

Forest inventory data of TMP stands in this study indicate that the number of stands dominated by TMP on the CNF is declining because of a combination of factors that includes the absence of fire and past southern pine beetle infestations. The absence of fire is providing little control over hardwood encroachment, causing stands to convert to more hardwood–dominated stands. The urgency of this situation is expanding and must be addressed if TMP is to be perpetuated on the forest and healthy stands maintained.

Prescribed burning has been thought to be the most effective tool for managing these stands. This project investigates the cost effectiveness of other mechanical treatments that have proven successful as potential release methods. This study implemented several release treatments for future growth considerations. The permanent plots in this study should be re-measured periodically to determine growth response from each treatment. The initial cost of the release treatments should be valuable in determining the future cost-efficiency based on growth response rate. In typical situations where land managers are able to use prescribed fire across numerous acres, the cost of $45.00 per acre is acceptable. The crop tree release treatment was very labor intensive, but with a cost of $17.52 per acre, appears to be another viable option with small diameter stems. The strip thin treatment may be more difficult in some areas due to the terrain and possible safety issues. After reassessing tree growth following these treatments, more information can be evaluated concerning the best treatment for the investment. Although the wood products value of TMP is limited due to inaccessibility and terrain, this unusual, endemic species provides many ecosystem and diversity aspects to forests in the region.

Many of these stands have a very strong hardwood component and pose new questions for further investigation. Without prescribed use of fire to control hardwoods and to create seedbed conditions for successful TMP regeneration, will these areas continue to transition to a hardwood composition? What was the historical overstory composition of natural TMP stands? Were they pure TMP or a mosaic mixed with hardwoods? What are possible ways to manage against devastating SPB events in areas containing TMP? If prescribed burning is used as a thinning method, what is the desired intensity and projected mortality for overstocked stands to achieve optimal release response? These questions are beyond the scope of this study, but can possibly be addressed in future studies. However, a plethora of TMP research is available and ongoing that attempt to respond to these questions (Waldrop and Brose, 1999; Van Lear, 2000; Armbrister, 2002; Mohr and others, 2002; Randles and others, 2002; Waldrop and other, 2006; DeWeese, 2007). More research is needed to fully understand the natural development of TMP and management concerns to create favorable environmental conditions for the species.

TMP is an endemic species in the southern Appalachian Mountains and a species of concern. An active management program that includes the use of fire is necessary to maintaining healthy communities of TMP. Management actions should be taken to ensure the regeneration of the species and to promote stand development of TMP trees to maturity. This study provides information on the costs of implementing various release treatments to encourage further growth and development of the species.

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Appendices

Appendix A. Stand Descriptions

Table A 1. 1994 CISC data and 2007 field collected data. Cherokee National Forest, 2007.

District	Stand	1994	2006	Acres	BK	Fire	Age
Watauga	16027	south yel pine	Hdwd_TMP	10	yes	no	20+
Watauga	17028	xericpine_hdwd	Hdwd_TMP	113.6	no	no	20+
Watauga	17034	xericpine_hdwd	Hdwd_TMP	17.5	no	no	20+
Watauga	17035	xericpine_hdwd	Hdwd_TMP	9.5	yes	no	20+
Watauga	17040	xericpine_hdwd	Hdwd	20.3	no	no	20+
Watauga	19005	xericpine_hdwd	Hdwd	19	no	no	20+
Watauga	19015	south yel pine	Hdwd_TMP	8.7	yes	no	20+
Watauga	23002	xericpine_hdwd	Wilderness	296.3	nonsample	nonsample	20+
Watauga	24013	xericpine_hdwd	Wilderness	25.9	nonsample	nonsample	20+
Watauga	32016	xericpine_hdwd	Hdwd	31.9	no	no	20+
Watauga	40036	xericpine_hdwd	Hdwd	17	no	no	20+
Watauga	40039	xericpine_hdwd	Hdwd	48.9	no	no	20+
Watauga	41030	xericpine_hdwd	Hdwd	10.7	no	no	20+
Watauga	41043	xericpine_hdwd	Hdwd	9.2	no	no	20+
Watauga	42014	xericpine_hdwd	Hdwd	55	no	no	20+
Watauga	43012	xericpine_hdwd	Hdwd	32	no	no	20+
Watauga	55013	xericpine_hdwd	Hdwd	10.6	yes	no	20+
Watauga	87014	xericpine_hdwd	Hdwd	17.9	no	no	20+
Watauga	87017	xericpine_hdwd	Hdwd	17.1	no	regen	20+
Watauga	87025	xericpine_hdwd	Hdwd	31.5	no	no	20+
Watauga	91003	xericpine_hdwd	Hdwd	63.9	yes	regen	20+
Watauga	91004	south yel pine	Hdwd	19.5	yes	no	20+
Watauga	91018	xericpine_hdwd	Hdwd_TMP	13.1	yes	fire	20+
Watauga	93018	south yel pine	Hdwd	20.3	yes	fire	20+
Watauga	93024	south yel pine	Hdwd	33	yes	fire	20+
Watauga	94017	south yel pine	Hdwd_TMP	7.3	yes	no	20+
Watauga	95011	south yel pine	Hdwd_TMP	61.6	yes	no	20+
Watauga	95012	south yel pine	Hdwd_TMP	10.4	yes	no	20+
Watauga	103028	xericpine_hdwd	Hdwd_TMP	17.2	yes	no	20+
Watauga	103030	xericpine_hdwd	Hdwd_TMP	22.7	yes	no	20+
Watauga	103032	xericpine_hdwd	Hdwd_TMP	91.9	yes	no	20+
Watauga	103034	xericpine_hdwd	Hdwd_TMP	23.1	yes	no	20+
Watauga	104023	xericpine_hdwd	Hdwd_TMP	10.5	yes	no	20+
Watauga	104026	xericpine_hdwd	Hdwd_TMP	60.5	yes	no	20+
Watauga	104030	xericpine_hdwd	Hdwd_TMP	62.7	yes	no	20+
Watauga	111014	xericpine_hdwd	Hdwd_TMP	14.4	yes	no	20+
Nolichucky/Unaka	197014	south yel pine	Hdwd_TMP	77.7	yes	no	20+
Nolichucky/Unaka	198001	south yel pine	Hdwd_TMP	32.4	yes	no	20+
Nolichucky/Unaka	198004	south yel pine	Hdwd	21.3	yes	no	20+

District	Stand	1994	2006	Acres	BK	Fire	Age
Nolichucky/Unaka	198008	south yel pine	Hdwd_TMP	70.1	yes	no	20+
Nolichucky/Unaka	198012	xericpine_hdwd	Hdwd	45.1	yes	no	20+
Nolichucky/Unaka	198016	south yel pine	Hdwd	20	yes	no	20+
Nolichucky/Unaka	198019	south yel pine	Hdwd	46.8	yes	no	20+
Nolichucky/Unaka	198020	xericpine_hdwd	Hdwd	49.2	yes	no	20+
Nolichucky/Unaka	198034	xericpine_hdwd	Hdwd	24.2	yes	no	20+
Nolichucky/Unaka	198039	south yel pine	Hdwd	87.5	yes	no	20+
Nolichucky/Unaka	198057	south yel pine	Hdwd_TMP	17.1	yes	no	20+
Nolichucky/Unaka	198059	south yel pine	Hdwd	2.5	yes	no	20+
Nolichucky/Unaka	200005	south yel pine	Hdwd_TMP	17.5	yes	no	20+
Nolichucky/Unaka	200006	xericpine_hdwd	TMP_Hdwd	31.6	yes	no	20+
Nolichucky/Unaka	200008	xericpine_hdwd	Hdwd	9.1	yes	no	20+
Watauga	200009	south yel pine	Hdwd	7.8	yes	no	20+
Nolichucky/Unaka	200012	south yel pine	Hdwd	39.6	yes	no	20+
Nolichucky/Unaka	200017	south yel pine	Hdwd	13.9	yes	no	20+
Nolichucky/Unaka	200019	south yel pine	Hdwd	40.6	yes	no	20+
Nolichucky/Unaka	200020	xericpine_hdwd	Hdwd	44.5	no	no	20+
Nolichucky/Unaka	200034	xericpine_hdwd	Hdwd	42.8	yes	no	20+
Nolichucky/Unaka	200047	south yel pine	Hdwd	5	yes	no	20+
Nolichucky/Unaka	200051	xericpine_hdwd	Hdwd	18.3	yes	no	20+
Nolichucky/Unaka	200053	south yel pine	Hdwd_TMP	134.7	yes	no	20+
Nolichucky/Unaka	200056	xericpine_hdwd	Hdwd	30.2	yes	no	20+
Nolichucky/Unaka	200058	south yel pine	Hdwd_TMP	101.2	no	no	20+
Nolichucky/Unaka	200062	south yel pine	Hdwd_TMP	48.8	no	no	20+
Nolichucky/Unaka	200063	xericpine_hdwd	Hdwd	19.9	yes	no	20+
Nolichucky/Unaka	200064	south yel pine	Hdwd	17.4	yes	no	20+
Nolichucky/Unaka	200066	xericpine_hdwd	Hdwd	16	yes	no	20+
Nolichucky/Unaka	200071	south yel pine	Hdwd	15.7	yes	no	20+
Nolichucky/Unaka	201009	south yel pine	Hdwd	38.1	yes	no	20+
Nolichucky/Unaka	201010	xericpine_hdwd	Hdwd_TMP	12.4	yes	no	20+
Nolichucky/Unaka	201022	xericpine_hdwd	Hdwd_TMP	19.5	yes	no	20+
Nolichucky/Unaka	201029	xericpine_hdwd	Hdwd	19.4	no	no	20+
Nolichucky/Unaka	201030	xericpine_hdwd	Hdwd	45.4	yes	no	20+
Nolichucky/Unaka	201031	south yel pine	Hdwd	54.5	no	fire	20+
Nolichucky/Unaka	201033	xericpine_hdwd	TMP_Hdwd	133.8	yes	no	20+
Nolichucky/Unaka	201034	south yel pine	Hdwd_TMP	45.8	yes	fire	20+
Nolichucky/Unaka	201035	south yel pine	Hdwd_TMP	46.1	no	no	20+
Nolichucky/Unaka	201038	south yel pine	Hdwd_TMP	73	yes	no	20+
Nolichucky/Unaka	201039	xericpine_hdwd	Hdwd	34.6	yes	no	20+
Watauga	201044	xericpine_hdwd	Hdwd	16.8	yes	no	20+
Nolichucky/Unaka	201045	south yel pine	Hdwd_TMP	26.2	yes	no	20+
Nolichucky/Unaka	201047	south yel pine	Hdwd_TMP	32.1	yes	no	20+
Nolichucky/Unaka	201048	south yel pine	Hdwd_TMP	21.8	yes	no	20+
Nolichucky/Unaka	201052	south yel pine	Hdwd_TMP	17.5	yes	no	20+
Nolichucky/Unaka	203002	south yel pine	Hdwd	29.4	yes	no	20+
Nolichucky/Unaka	203011	xericpine_hdwd	Hdwd	35.8	yes	no	20+

District	Stand	1994	2006	Acres	BK	Fire	Age
Nolichucky/Unaka	203023	xericpine_hdwd	Hdwd_TMP	46.5	yes	no	20+
Nolichucky/Unaka	205039	south yel pine	Hdwd_TMP	24.6	no	no	10-20
Nolichucky/Unaka	206027	south yel pine	Hdwd_TMP	60.1	no	no	20+
Nolichucky/Unaka	206040	xericpine_hdwd	Hdwd	56.6	no	no	20+
Nolichucky/Unaka	206041	xericpine_hdwd	Hdwd	19.8	no	no	10-20
Nolichucky/Unaka	207001	south yel pine	Hdwd	12.5	no	no	20+
Nolichucky/Unaka	207006	south yel pine	Hdwd_TMP	52.9	yes	no	20+
Nolichucky/Unaka	207021	south yel pine	Hdwd_TMP	46.9	yes	no	20+
Nolichucky/Unaka	207025	south yel pine	Hdwd	30	yes	no	20+
Nolichucky/Unaka	207029	xericpine_hdwd	Hdwd_TMP	35.2	yes	no	20+
Nolichucky/Unaka	207036	south yel pine	Hdwd	45.2	yes	no	20+
Nolichucky/Unaka	207037	xericpine_hdwd	Hdwd_TMP	35	yes	fire	20+
Nolichucky/Unaka	207038	south yel pine	Hdwd_TMP	34.8	yes	no	20+
Nolichucky/Unaka	207046	south yel pine	Hdwd_TMP	22.7	yes	no	20+
Nolichucky/Unaka	207051	south yel pine	Hdwd	14.2	no	no	20+
Nolichucky/Unaka	208001	south yel pine	Hdwd_TMP	13.9	yes	no	20+
Nolichucky/Unaka	208012	xericpine_hdwd	Hdwd_TMP	9.5	yes	no	20+
Nolichucky/Unaka	208035	south yel pine	Hdwd	42.7	yes	no	20+
Nolichucky/Unaka	208038	xericpine_hdwd	Hdwd_TMP	36.3	yes	no	10-20
Nolichucky/Unaka	208039	south yel pine	TMP_Hdwd	74.8	yes	no	10-20
Nolichucky/Unaka	208041	south yel pine	Hdwd_TMP	59.4	yes	no	10-20
Nolichucky/Unaka	208054	south yel pine	TMP	30.3	yes	no	10-20
Nolichucky/Unaka	221025	south yel pine	Hdwd	64.9	no	no	20+
Nolichucky/Unaka	221029	south yel pine	Hdwd	76.9	no	no	20+
Nolichucky/Unaka	222035	south yel pine	Hdwd_TMP	13.7	no	no	20+
Nolichucky/Unaka	224004	south yel pine	Hdwd	14.4	no	no	20+
Nolichucky/Unaka	225003	south yel pine	Hdwd_TMP	15.5	no	no	20+
Watauga	226002	south yel pine	Hdwd	14.3	yes	no	20+
Nolichucky/Unaka	226014	south yel pine	Hdwd_TMP	8	yes	no	20+
Nolichucky/Unaka	230005	south yel pine	TMP_Hdwd	14.4	yes	no	20+
Nolichucky/Unaka	230014	south yel pine	Hdwd_TMP	8.9	yes	no	20+
Nolichucky/Unaka	230016	south yel pine	Hdwd	22.1	yes	no	20+
Nolichucky/Unaka	230072	xericpine_hdwd	Hdwd_TMP	16.2	no	no	20+
Nolichucky/Unaka	232027	xericpine_hdwd	Hdwd_TMP	91	yes	no	20+
Nolichucky/Unaka	235001	xericpine_hdwd	TMP_Hdwd	53.9	yes	no	20+
Nolichucky/Unaka	235005	south yel pine	TMP_Hdwd	43.2	yes	no	20+
Nolichucky/Unaka	235009	south yel pine	TMP_Hdwd	7.6	yes	no	20+
Nolichucky/Unaka	235010	xericpine_hdwd	TMP_Hdwd	28	yes	no	20+
Nolichucky/Unaka	235012	south yel pine	Hdwd_TMP	110	no	no	20+
Nolichucky/Unaka	235017	south yel pine	Hdwd	17.2	no	no	20+
Nolichucky/Unaka	235021	south yel pine	TMP_Hdwd	154.8	yes	no	20+

District	Stand	1994	2006	Acres	BK	Fire	Age
Nolichucky/Unaka	235024	south yel pine	Hdwd_TMP	15.6	no	no	20+
Nolichucky/Unaka	235026	south yel pine	TMP_Hdwd	71.2	yes	no	20+
Nolichucky/Unaka	237005	xericpine_hdwd	Hdwd_TMP	13.9	no	no	20+
Nolichucky/Unaka	248011	south yel pine	Hdwd_TMP	36	yes	no	20+
Nolichucky/Unaka	259007	south yel pine	TMP_Hdwd	52.1	yes	no	20+
Nolichucky/Unaka	259009	south yel pine	TMP_Hdwd	43.6	yes	no	20+
Nolichucky/Unaka	260012	south yel pine	Hdwd_TMP	72.5	yes	no	20+
Nolichucky/Unaka	262011	south yel pine	Hdwd_TMP	26.2	yes	no	20+
Watauga	310024	xericpine_hdwd	Hdwd_TMP	9.7	yes	no	20+
Watauga	310033	south yel pine	Hdwd_TMP	25.3	yes	no	20+
Watauga	334005	xericpine_hdwd	Hdwd	13.4	no	no	20+
Watauga	334007	xericpine_hdwd	Hdwd	36.5	no	no	20+
Watauga	341004	south yel pine	Hdwd_TMP	41.9	yes	no	20+
Watauga	352008	south yel pine	Hdwd	18.1	yes	no	20+
Watauga	352010	south yel pine	Hdwd	26.8	yes	no	20+
Watauga	352014	south yel pine	Hdwd	33.9	yes	no	20+
Watauga	352019	south yel pine	Hdwd	17.9	yes	no	20+
Watauga	352022	south yel pine	Hdwd	14.6	yes	no	20+
Watauga	352025	south yel pine	Hdwd	13.6	yes	no	20+
Watauga	353004	south yel pine	Hdwd_TMP	15.4	yes	no	20+
Watauga	353005	south yel pine	Hdwd_TMP	18.1	yes	no	20+
Watauga	353008	south yel pine	Hdwd_TMP	21.1	yes	no	20+
Watauga	353010	south yel pine	Hdwd_TMP	22.2	yes	no	20+
Watauga	353012	south yel pine	Hdwd_TMP	22.3	yes	no	20+
Watauga	353014	south yel pine	Hdwd_TMP	35.9	yes	no	20+
Watauga	353016	south yel pine	Hdwd_TMP	22.9	yes	no	20+
Watauga	353017	south yel pine	Hdwd_TMP	21.2	yes	no	20+
Watauga	353018	south yel pine	Hdwd_TMP	31.5	yes	no	20+
Watauga	353022	south yel pine	Hdwd	9.7	yes	no	20+
Watauga	353023	south yel pine	Hdwd	10.8	yes	no	20+
Watauga	360007	south yel pine	Hdwd	46.4	yes	no	20+
Watauga	361012	south yel pine	Wilderness	25.7	nonsample	nonsample	20+
Watauga	361014	south yel pine	Wilderness	27.6	nonsample	nonsample	20+
Watauga	361017	south yel pine	Wilderness	12.1	nonsample	nonsample	20+
Watauga	361022	south yel pine	Wilderness	16.5	nonsample	nonsample	20+
Watauga	361024	south yel pine	Wilderness	73.1	nonsample	nonsample	20+
Watauga	361026	south yel pine	Wilderness	45.3	nonsample	nonsample	20+
Watauga	361027	south yel pine	Wilderness	10.5	nonsample	nonsample	20+
Watauga	361028	south yel pine	Wilderness	19.4	nonsample	nonsample	20+
Watauga	362008	south yel pine	Wilderness	23.6	nonsample	nonsample	20+
Watauga	362013	south yel pine	Wilderness	20.2	nonsample	nonsample	20+
Watauga	362017	south yel pine	Wilderness	62	nonsample	nonsample	20+
Watauga	364017	south yel pine	Hdwd_TMP	56.2	yes	no	20+
Watauga	364019	south yel pine	Hdwd_TMP	18.9	yes	no	20+
Watauga	364023	south yel pine	Hdwd	31.8	yes	no	20+
Watauga	364027	south yel pine	Hdwd	33.4	yes	no	20+

District	Stand	1994	2006	Acres	BK	Fire	Age
Watauga	364028	south yel pine	Hdwd	7.3	yes	no	20+
Watauga	372002	south yel pine	Hdwd_TMP	44.9	yes	no	20+
Watauga	372005	south yel pine	Hdwd	17.2	yes	no	20+
Watauga	372007	south yel pine	Hdwd	7.3	yes	no	20+
Watauga	372015	south yel pine	Hdwd	15.3	yes	no	20+
Watauga	372017	south yel pine	Hdwd	12.1	yes	no	20+
Watauga	372019	south yel pine	Hdwd_TMP	39	yes	no	20+
Watauga	372026	south yel pine	Hdwd	8.3	yes	no	20+
Watauga	372027	xericpine_hdwd	Hdwd_TMP	39.7	yes	no	20+
Watauga	374001	south yel pine	Hdwd_TMP	136.8	yes	no	20+
Watauga	374006	south yel pine	Hdwd_TMP	8.5	yes	no	20+
Watauga	374007	south yel pine	Hdwd_TMP	5.9	yes	no	20+
Watauga	374010	xericpine_hdwd	TMP_Hdwd	3.1	yes	no	20+
Watauga	374024	xericpine_hdwd	Hdwd_TMP	40.2	yes	no	20+
Watauga	374026	south yel pine	Hdwd_TMP	32.6	yes	no	20+
Watauga	374028	xericpine_hdwd	Hdwd_TMP	80.7	yes	no	20+
Watauga	374043	south yel pine	Hdwd	35.9	yes	no	20+
Nolichucky/Unaka	385017	south yel pine	Hdwd_TMP	34.4	yes	no	20+
Nolichucky/Unaka	386020	south yel pine	Wilderness	19.7	nonsample	nonsample	20+
Nolichucky/Unaka	386022	south yel pine	Wilderness	63.2	nonsample	nonsample	20+
Nolichucky/Unaka	386027	south yel pine	Wilderness	24.7	nonsample	nonsample	20+
Nolichucky/Unaka	387003	south yel pine	Wilderness	5.2	nonsample	nonsample	20+
Nolichucky/Unaka	387006	south yel pine	Wilderness	15.7	nonsample	nonsample	20+
Nolichucky/Unaka	387009	south yel pine	Wilderness	16.6	nonsample	nonsample	20+
Nolichucky/Unaka	387010	south yel pine	Wilderness	14.7	nonsample	nonsample	1-10
Nolichucky/Unaka	387012	south yel pine	Wilderness	41.5	nonsample	nonsample	20+
Nolichucky/Unaka	387016	south yel pine	Wilderness	19.3	nonsample	nonsample	20+
Nolichucky/Unaka	387019	south yel pine	Wilderness	21	nonsample	nonsample	20+
Nolichucky/Unaka	387021	south yel pine	Wilderness	31.1	nonsample	nonsample	20+
Nolichucky/Unaka	387025	south yel pine	Wilderness	27.2	nonsample	nonsample	20+
Nolichucky/Unaka	387026	south yel pine	Wilderness	42.7	nonsample	nonsample	20+
Nolichucky/Unaka	387027	south yel pine	Wilderness	42.3	nonsample	nonsample	20+
Nolichucky/Unaka	387030	south yel pine	Wilderness	17.1	nonsample	nonsample	20+
Nolichucky/Unaka	387034	south yel pine	Wilderness	41.4	nonsample	nonsample	20+
Nolichucky/Unaka	387036	south yel pine	Wilderness	72.8	nonsample	nonsample	20+
Nolichucky/Unaka	387040	south yel pine	Wilderness	14.2	nonsample	nonsample	20+
Nolichucky/Unaka	387044	south yel pine	Wilderness	48.6	nonsample	nonsample	20+
Nolichucky/Unaka	387049	south yel pine	Wilderness	15.3	nonsample	nonsample	20+
Nolichucky/Unaka	388001	south yel pine	Wilderness	53.1	nonsample	nonsample	20+
Nolichucky/Unaka	388012	south yel pine	Wilderness	21	nonsample	nonsample	20+
Nolichucky/Unaka	388015	south yel pine	Wilderness	63.4	nonsample	nonsample	20+
Nolichucky/Unaka	388023	south yel pine	Hdwd_TMP	49.2	yes	no	20+
Nolichucky/Unaka	388028	south yel pine	Wilderness	19	nonsample	nonsample	20+
Nolichucky/Unaka	389011	south yel pine	Hdwd_TMP	16.1	yes	no	20+
Nolichucky/Unaka	389012	south yel pine	Hdwd_TMP	70.3	yes	no	20+

District	Stand	1994	2006	Acres	BK	Fire	Age
Nolichucky/Unaka	389016	south yel pine	Hdwd	38.6	no	no	20+
Nolichucky/Unaka	389017	south yel pine	Hdwd_TMP	75	no	no	20+
Nolichucky/Unaka	389018	south yel pine	Hdwd_TMP	26.8	no	no	20+
Nolichucky/Unaka	389024	south yel pine	Hdwd_TMP	25.1	yes	no	20+
Nolichucky/Unaka	390013	south yel pine	Hdwd	18.4	no	no	20+
Watauga	392019	xericpine_hdwd	Hdwd	24.9	yes	no	20+
Nolichucky/Unaka	399002	south yel pine	TMP_Hdwd	53.6	yes	no	20+
Nolichucky/Unaka	399003	south yel pine	Hdwd_TMP	476.6	yes	no	20+
Nolichucky/Unaka	399009	south yel pine	Hdwd_TMP	143.7	yes	no	20+
Nolichucky/Unaka	399018	south yel pine	Hdwd_TMP	95.2	yes	no	20+
Nolichucky/Unaka	399019	south yel pine	Hdwd	34.8	no	no	20+
Nolichucky/Unaka	399020	south yel pine	Hdwd_TMP	23.7	yes	no	20+
Nolichucky/Unaka	399022	south yel pine	Hdwd	29.6	yes	no	20+
Nolichucky/Unaka	399023	south yel pine	Hdwd	14.4	yes	no	20+
Nolichucky/Unaka	401004	south yel pine	Wilderness	12.3	nonsample	nonsample	1-10
Nolichucky/Unaka	401006	south yel pine	Wilderness	15.1	nonsample	nonsample	1-10
Nolichucky/Unaka	401013	south yel pine	Wilderness	25.7	nonsample	nonsample	1-10
Nolichucky/Unaka	401018	south yel pine	Wilderness	17.9	nonsample	nonsample	10-20
Nolichucky/Unaka	401022	south yel pine	Wilderness	18.5	nonsample	nonsample	10-20
Nolichucky/Unaka	401024	south yel pine	Wilderness	15.8	nonsample	nonsample	10-20
Nolichucky/Unaka	402028	south yel pine	Wilderness	8.4	nonsample	nonsample	20+
Nolichucky/Unaka	402037	south yel pine	Wilderness	6.7	nonsample	nonsample	20+
Nolichucky/Unaka	404028	xericpine_hdwd	Wilderness	85	nonsample	nonsample	20+
Nolichucky/Unaka	404029	south yel pine	Wilderness	88.8	nonsample	nonsample	20+
Nolichucky/Unaka	404033	xericpine_hdwd	Wilderness	60.3	nonsample	nonsample	20+
Nolichucky/Unaka	404035	xericpine_hdwd	Wilderness	54.5	nonsample	nonsample	20+
Nolichucky/Unaka	404036	xericpine_hdwd	Wilderness	47.8	nonsample	nonsample	20+
Nolichucky/Unaka	404039	south yel pine	Wilderness	50.7	nonsample	nonsample	20+
Nolichucky/Unaka	404040	xericpine_hdwd	Wilderness	42.5	nonsample	nonsample	20+
Nolichucky/Unaka	404041	south yel pine	Wilderness	91.8	nonsample	nonsample	20+
Nolichucky/Unaka	404042	xericpine_hdwd	Wilderness	90.2	nonsample	nonsample	20+
Nolichucky/Unaka	404043	south yel pine	Wilderness	42.6	nonsample	nonsample	20+
Nolichucky/Unaka	404044	south yel pine	Wilderness	38.9	nonsample	nonsample	20+
Nolichucky/Unaka	404045	south yel pine	Wilderness	64.7	nonsample	nonsample	20+
Nolichucky/Unaka	404046	xericpine_hdwd	Wilderness	56.2	nonsample	nonsample	20+
Nolichucky/Unaka	405009	xericpine_hdwd	Wilderness	62.7	nonsample	nonsample	20+
Nolichucky/Unaka	405010	xericpine_hdwd	Wilderness	47.9	nonsample	nonsample	20+
Nolichucky/Unaka	405023	xericpine_hdwd	Wilderness	55.8	nonsample	nonsample	20+
Tellico	113_4	xericpine_oak	Hdwd_TMP	17	yes	no	41-50
Tellico	114_8	xericpine_oak	Hdwd	77	no	no	81-90

District	Stand	1994	2006	Acres	BK	Fire	Age
Tellico	29_11	xericpine_oak	Wilderness	113	no	no	71-80
Tellico	414_16	xericpine_oak	Hdwd	18	no	no	81-90
Tellico	414_18	xericpine_oak	Hdwd_TMP	13	yes	no	81-90
Tellico	414_4	xericpine_oak	Hdwd	15	no	no	81-90
Tellico	64_12	xericpine_oak	Hdwd_TMP	39	no	no	41-50
Tellico	64_8	xericpine_oak	Hdwd	27	no	no	41-50
Tellico	76_10	xericpine_oak	Hdwd	23	yes	no	71-80

Table A 2. Stand type descriptions for TMP on the Cherokee National Forest, 2007.		
Stand Classification	**Species**	**Description**
1	Hardwood	**Stage of Stand Development:** Understory Reinitiation Stage. Stand has succeeded to mixed hardwoods containing mainly upland oaks, blackgum, and red maple. **Recent History:** Remaining Table Mountain pines are snags that resulted from the pine beetle kill. **Overstory:** These stands are comprised of approximately 36 percent chestnut oak, 17 percent red maple, 13 percent blackgum as well as American chestnut sprouts, ash, dogwood, hemlock, hickory, Northern red oak, scarlet oak, and sourwood. These stands contain very few pines. Shortleaf, Eastern white and pitch pines are present, but TMP composes most of the pine component at 3 percent of the total composition. The lower portions of the slopes contain rhododendron and mountain laurel. Mean Basal Area: 59.65 ft^2/ac Mean TPA: 264 Mean D.B.H.: 13.9” Mean Height: 72.8’ **Regeneration:** Regeneration includes chestnut oak, red maple, blackgum, northern red oak, sassafras, eastern hophornbeam, and hickories. Few, if any, TMP seedlings are present.
2	Hardwood and Table Mountain pine*	**Stage of Stand Development:** Understory Reinitiation **Recent History:** Some TMP remaining after the SPB event with an estimated 50 percent or more of the TMP dead. **Overstory:** Stand contains mixed hardwoods containing mostly upland oaks, red maple and blackgum. These stands have a pine component consisting of Eastern white, pitch and Table Mountain pines. TMP is 19 percent of the species composition, 40 percent chestnut oak, 16 percent scarlet oak, 12 percent red maple and 7 percent blackgum. Other minor species such as American chestnut sprouts, beech, Northern red oak and sourwood are present. Mean Basal Area: 28.68 ft^2/ac Mean TPA: 543

		Mean D.B.H.: 10.32” Mean Height: 58.8’ **Regeneration:** The regeneration in these stands includes chestnut oak, eastern white pine, northern red oak, TMP, red maple, sassafras, as well as a few others. TMP regeneration is still very limited, but if fire had occurred in recent past, a greater number were present. However, the occurrence of fire was very minimal. *Stands contain less than 50 percent TMP
3	Table Mountain pine and Hardwood*	**Stage of Stand Development:** Understory Reinitiation **Recent History:** Greater number of TMP remaining after SPB event. Many snags and course woody debris are present in stand. Fire evidence was more frequent in this type and the burning has promoted conditions for regenerating TMP and set back the hardwood encroachment. **Overstory:** Stand contains mixed hardwoods containing mostly upland oaks, blackjack oak, and blackgum. These stands have a pine component consisting of pitch and Table Mountain pines. TMP comprised on average 70 percent of the stand, 14 percent blackgum and 10 percent blackjack oak. Rhododendron and mountain laurel were on the lower slopes as well. Mean Basal Area: 29.74 ft^2/ac Mean TPA: 651 Mean D.B.H.: 10.82” Mean Height: 63.0’ **Regeneration:** Regeneration includes TMP, red maple, chestnut oak, sassafras and some northern red oak. Regeneration of TMP was abundant in most of these stands. * Stands contain a minimum of 50 percent TMP.
4	TMP	**Stage of Stand Development:** Stand Initiation or Stem Exclusion Stage **Recent History:** Very few hardwoods were in this stand type. Most of the stands with an older overstory of pines are dead due to SPB or the stand is a younger cohort that resulted after earlier stand replacing fires and/or SPB events. Many of the south facing slopes that were once

		pine, are now covered in snags and down tops. These stands may have also burned very recently (blackened trees/ground still visible) to mineral soil. **Overstory:** Few, if any overstory hardwoods present. Where overstory trees are present, TMP makes up about 85% of the stand. Other species include chestnut oak, scarlet oak, blackgum and blackjack oak. Mean Basal Area: 100.65 ft^2/ac Mean TPA: 6280 Mean D.B.H.: 1.59” Mean Height: 15.3’ **Regeneration:** Regeneration includes TMP with a few upland oaks, blackgum and sassafras. TMP making up about 85 percent of the seedlings/saplings.

Appendix B. Figures from Inventory

Figures B1, B2, and B3 are the stands on the southern districts of the CNF that were delineated from the 1994 data containing TMP. Figure B1 displays the stand types containing TMP in 1994 and Figure B2 displays the 2007 reclassification of stand types that contained TMP in 1994.

Figure B4 is an overview map of the northern districts of the CNF from the 1994 data. Figures B5, B6, B7, B8 and B9 show the same 1994 data, but at a larger scale that better displays the stand types that contain TMP. Figure B10 is an overview map of the 2007 reclassification of stand types that contained TMP in 1994. Figures B11, B12, B13, B14, and B15 are the corresponding maps of the 2007 reclassification of stand types that contained TMP in 1994 and follow the same order from southwest to northeast.

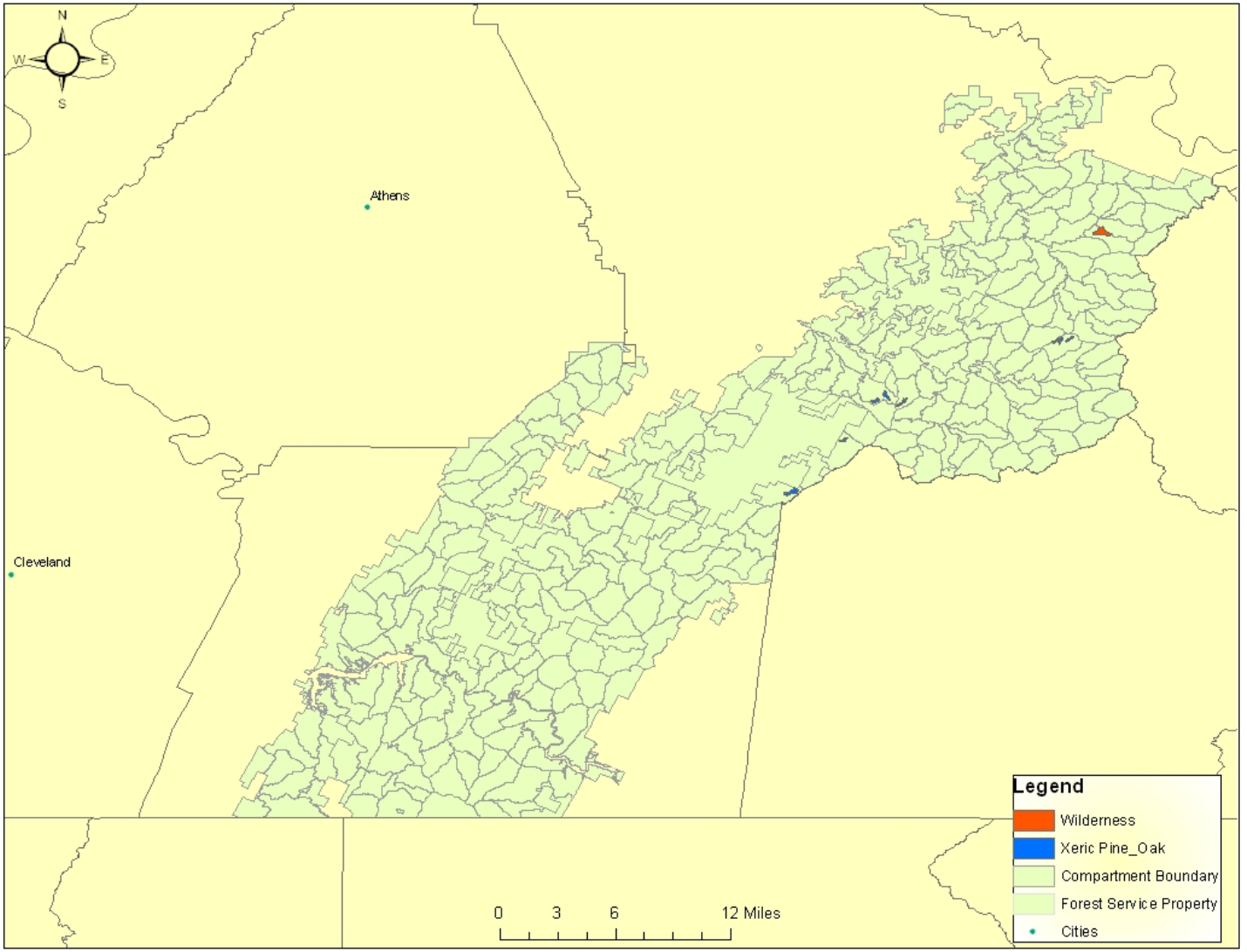

Figure B 1. Southern districts stand types containing Table Mountain pine. Cherokee National Forest, 1994 (1 of 2).

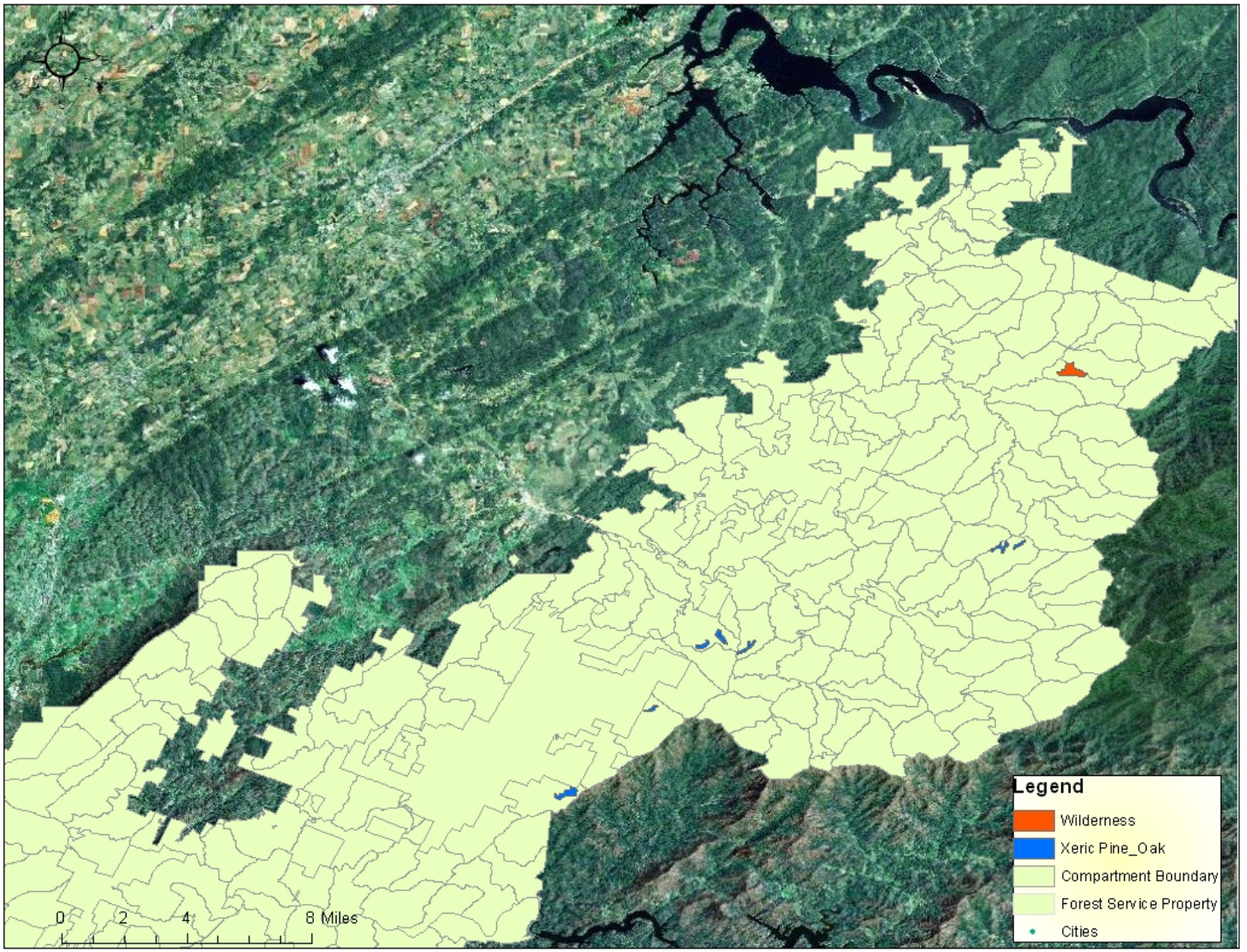

Figure B 2. Southern district stand types containing Table Mountain pine. Cherokee National Forest, 1994 (2 of 2).

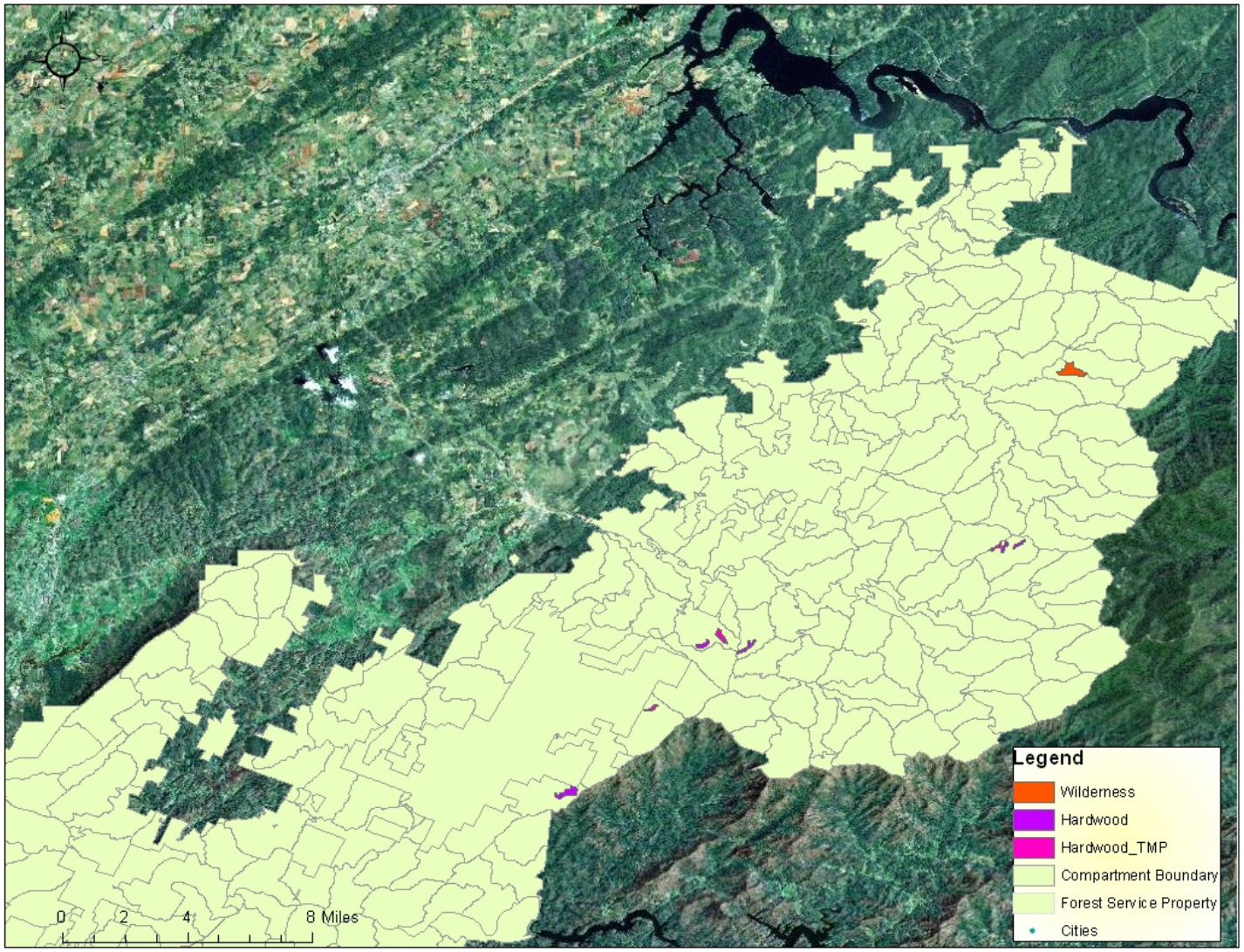

Figure B 3. Reclassification of southern districts stand types that contained Table Mountain pine in 1994. Cherokee National Forest, 2007.

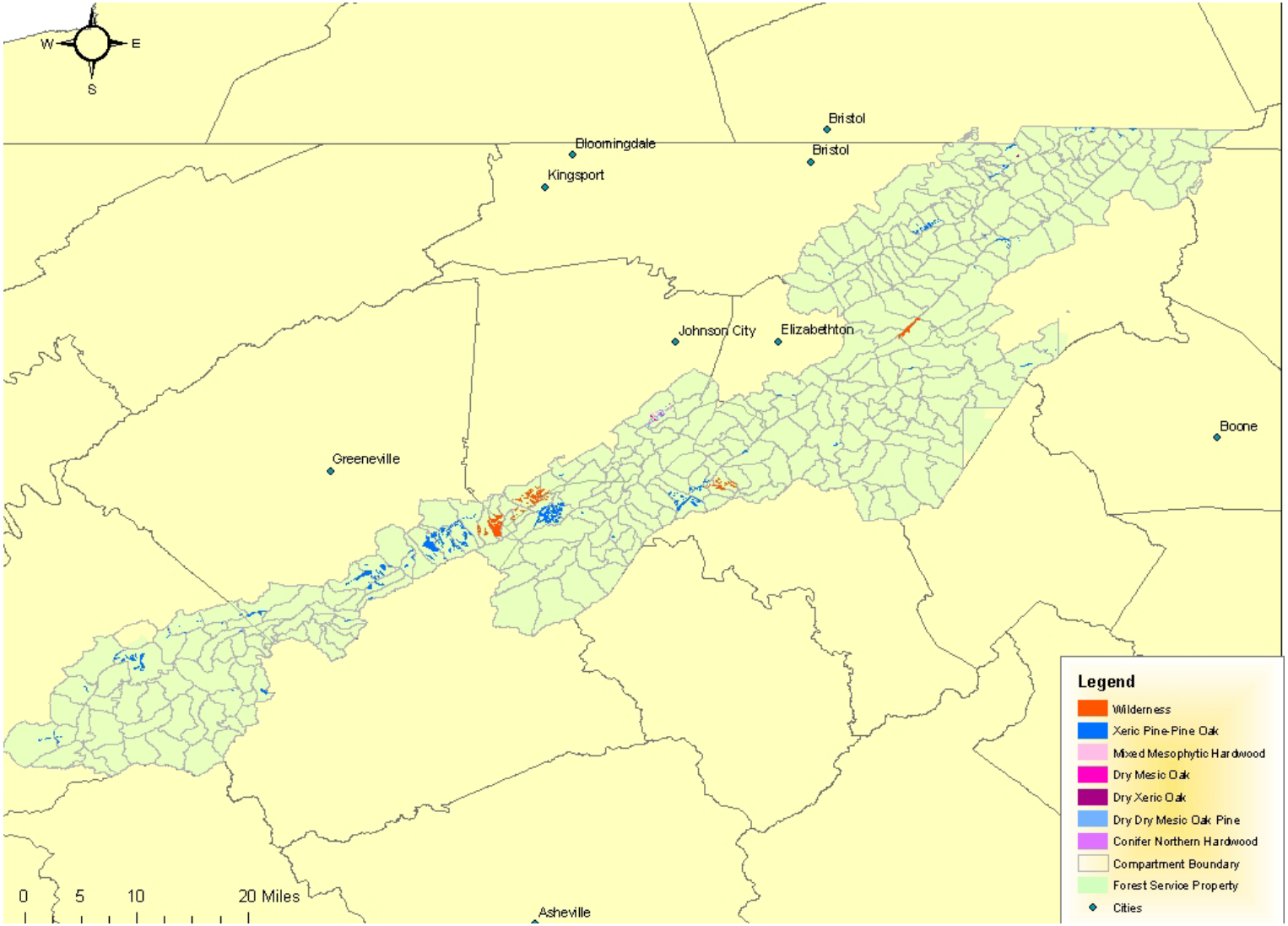

Figure B 4. Northern districts stand types containing Table Mountain pine. Cherokee National Forest, 1994 (1 of 6).

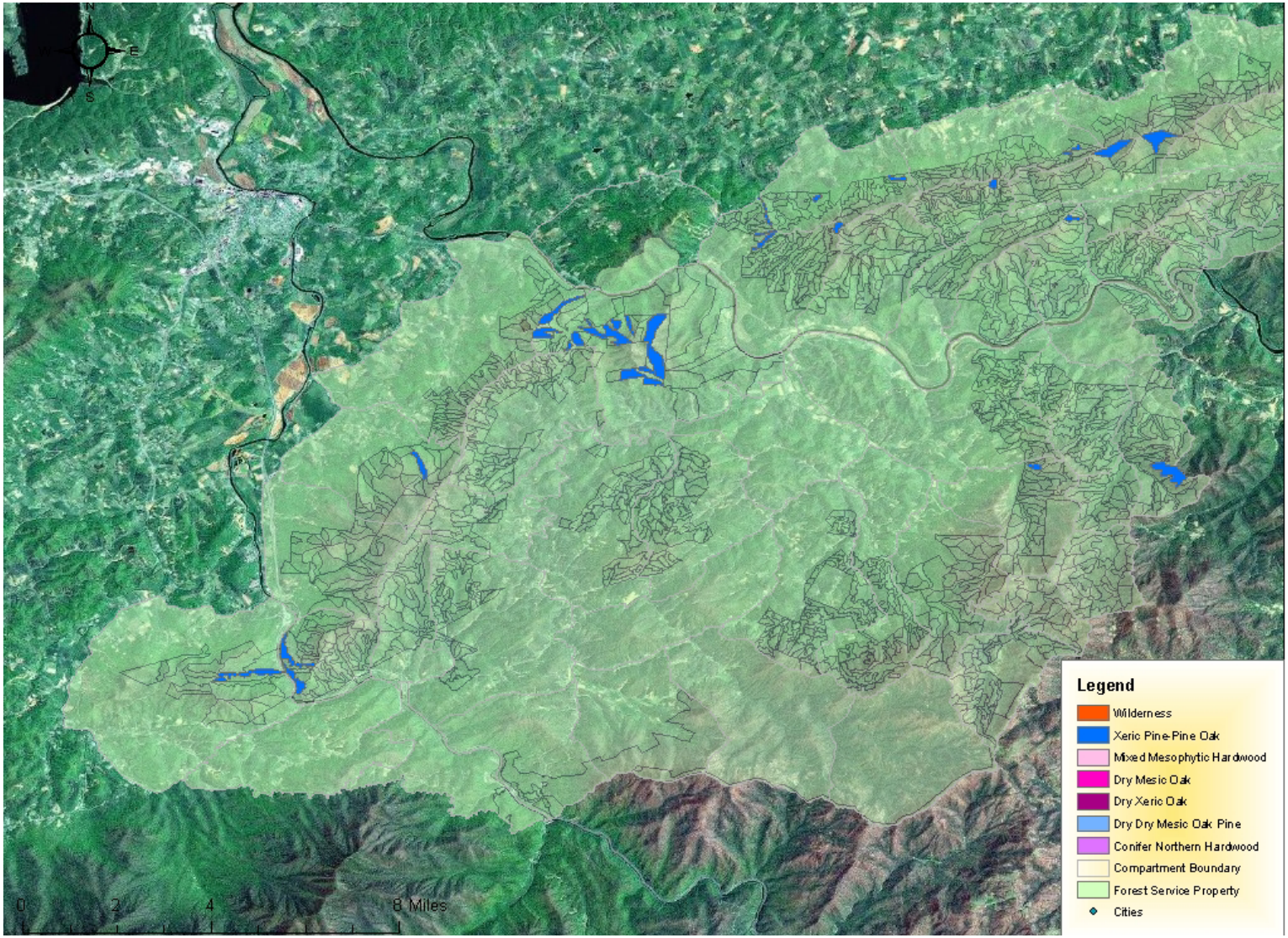

Figure B 5. Northern districts stand types containing Table Mountain pine. Cherokee National Forest, 1994 (2 of 6).

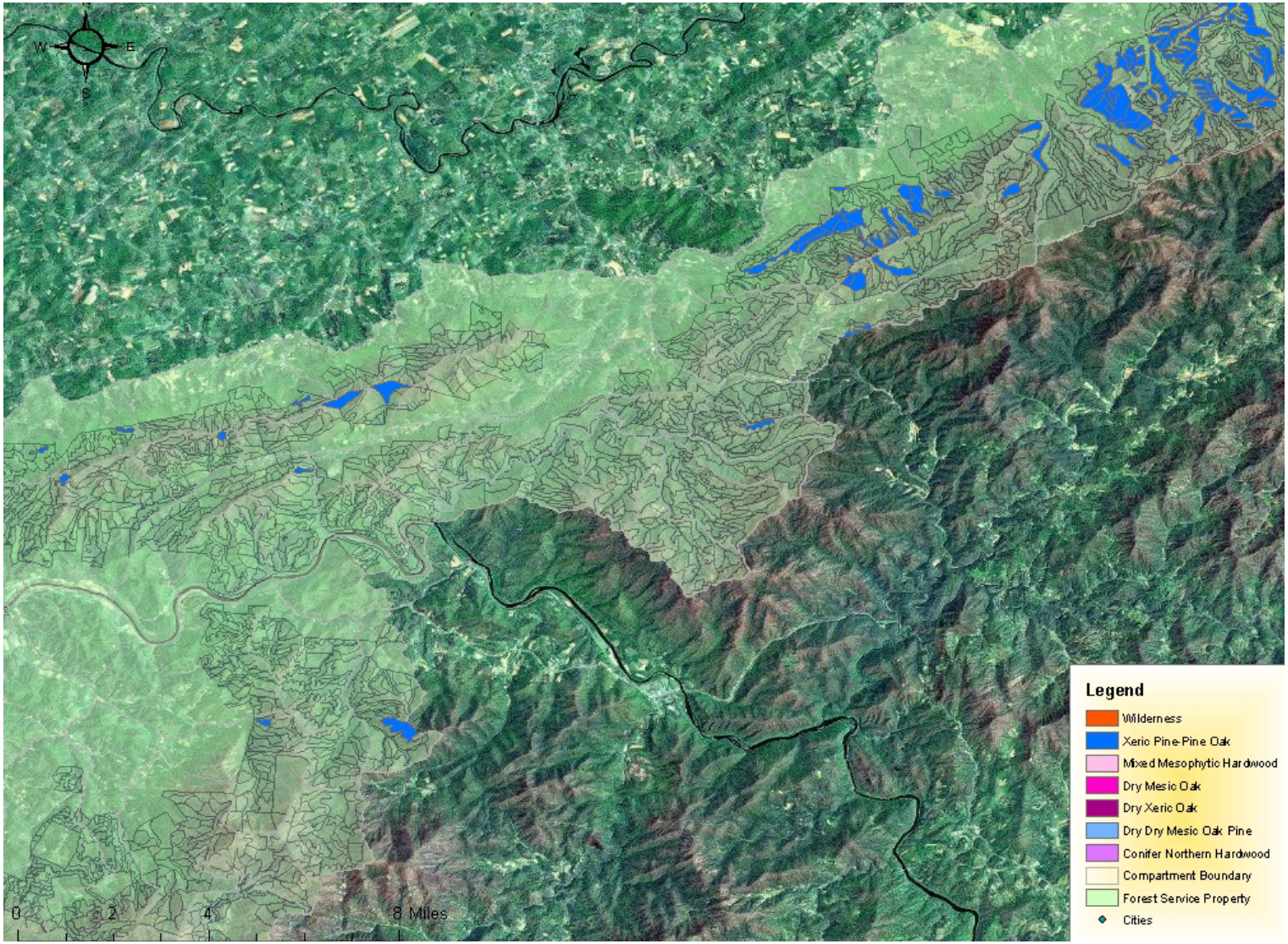

Figure B 6. Northern districts stand types containing Table Mountain pine. Cherokee National Forest, 1994 (3 of 6).

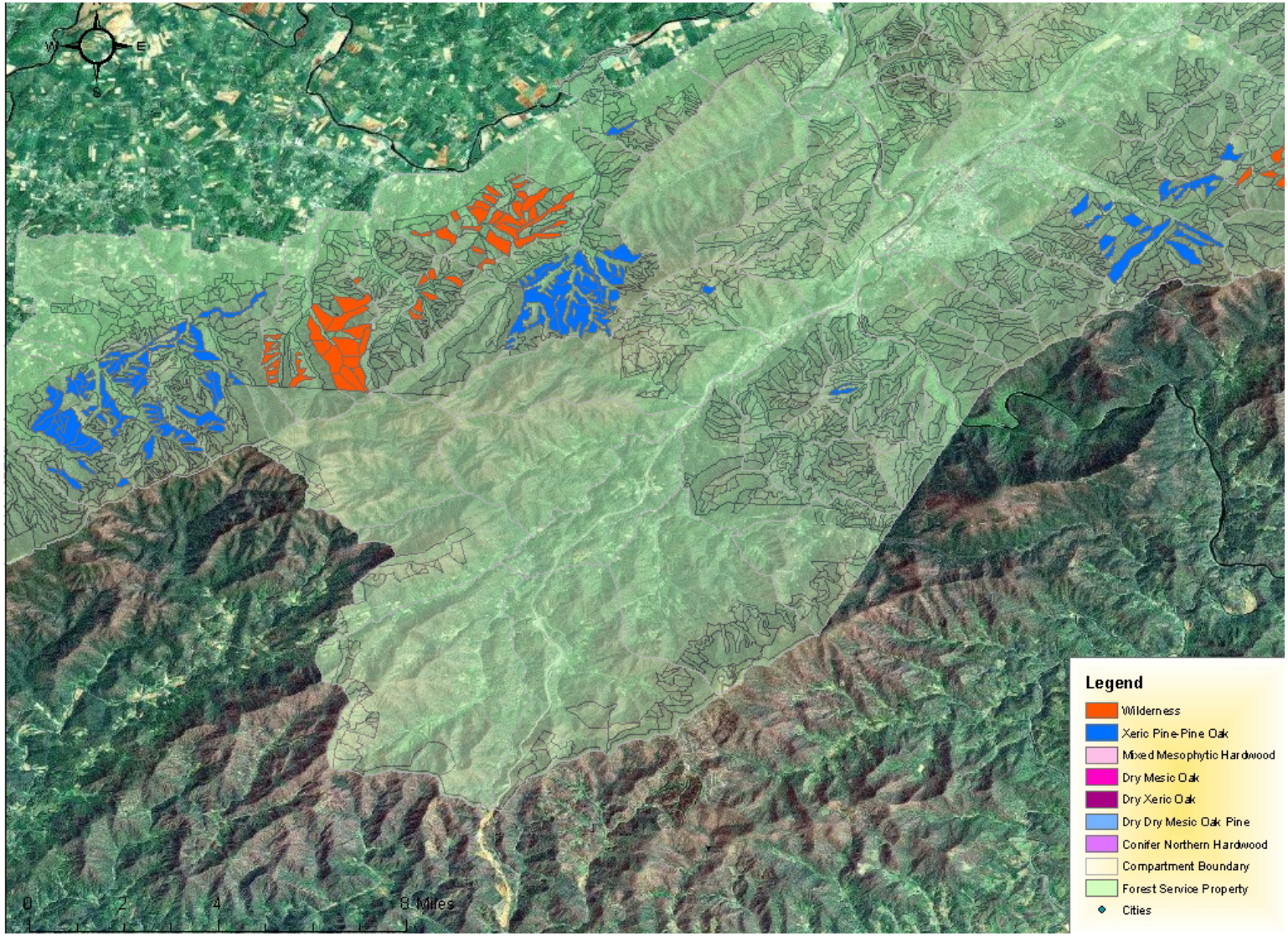

Figure B 7. Northern districts stand types containing Table Mountain pine. Cherokee National Forest, 1994 (4 of 6).

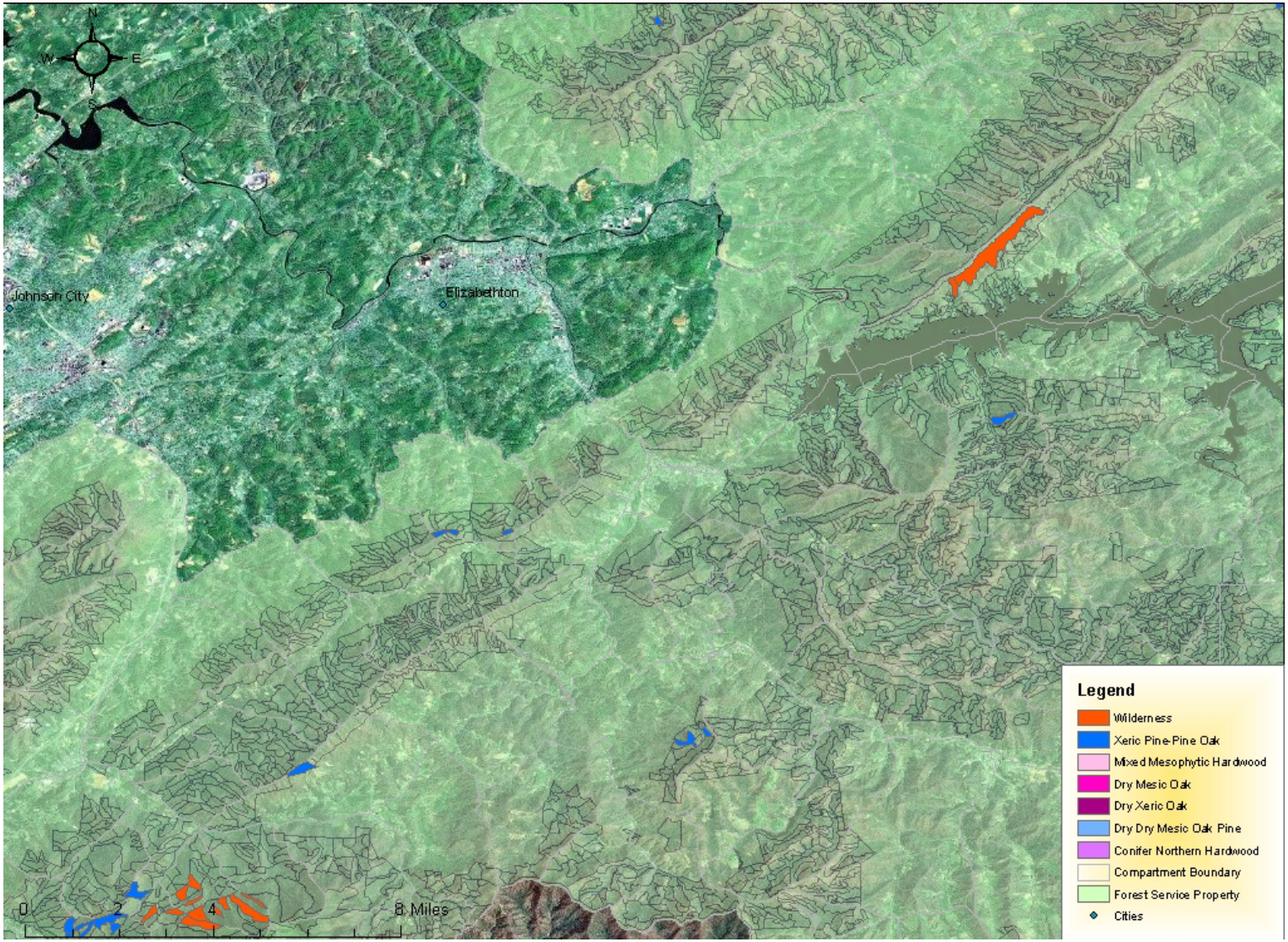

Figure B 8. Northern districts stand types containing Table Mountain pine. Cherokee National Forest, 1994 (5 of 6).

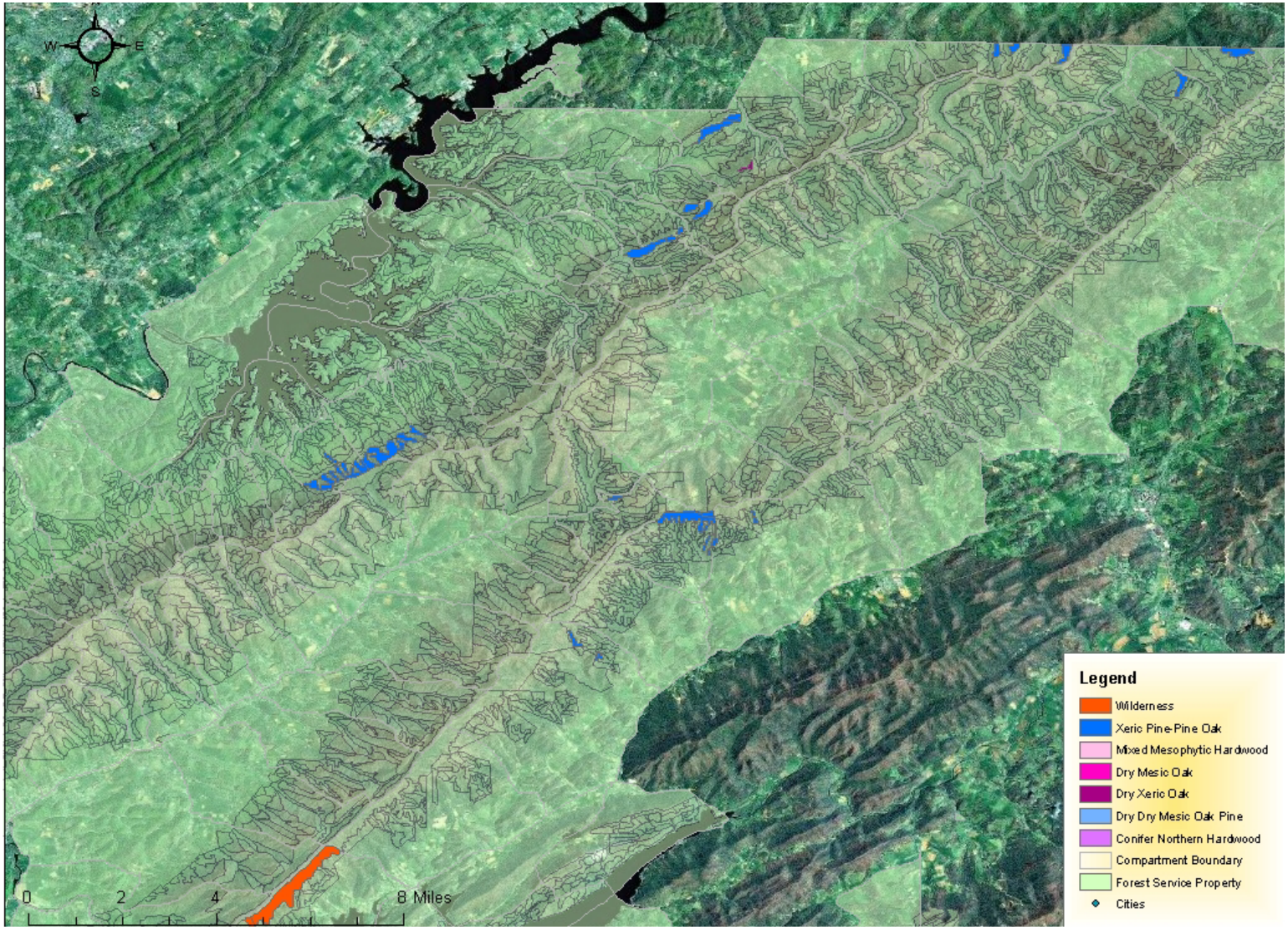

Figure B 9. Northern districts stand types containing Table Mountain pine. Cherokee National Forest, 1994 (6 of 6).

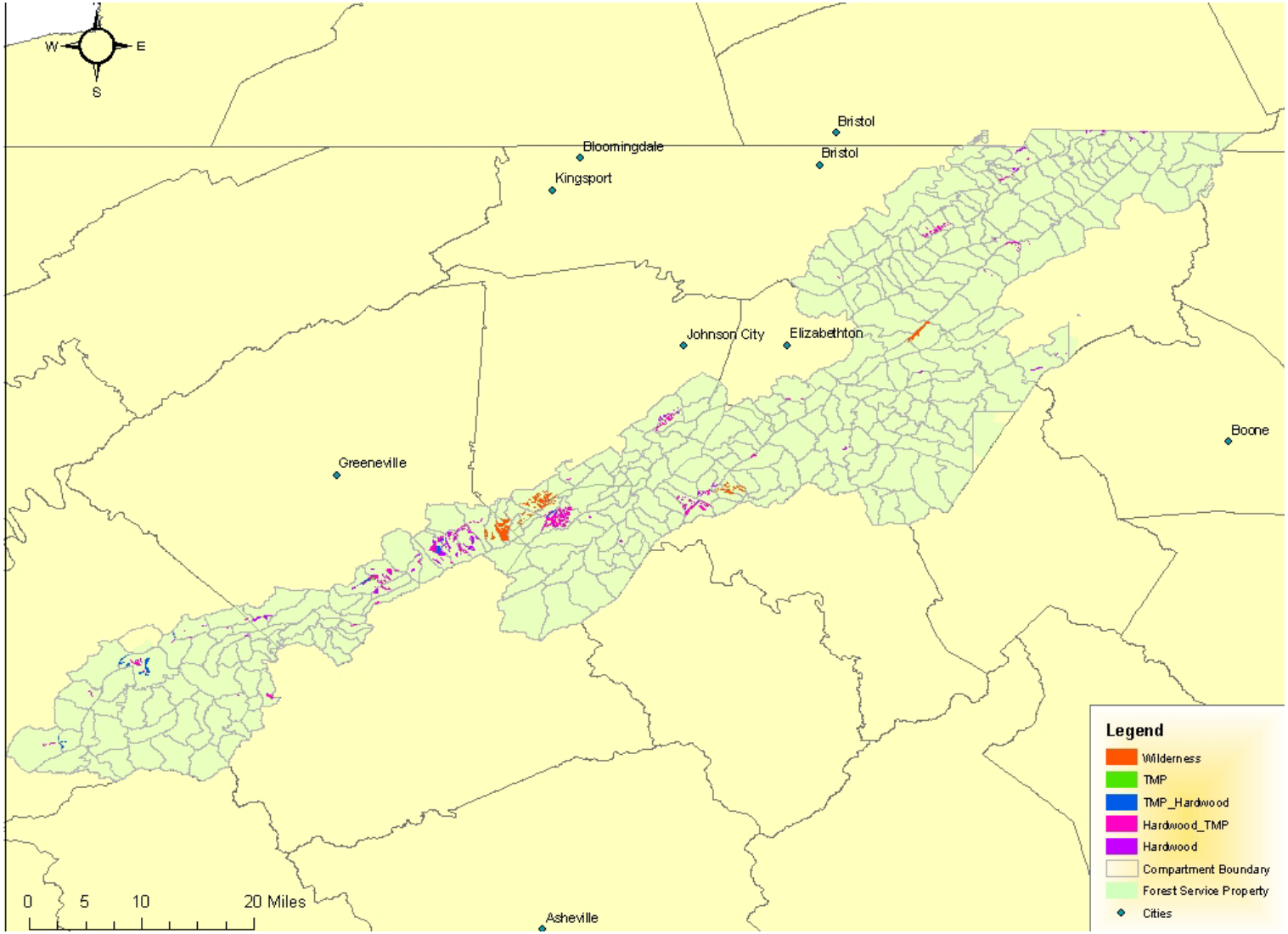

Figure B 10. Reclassification of northern districts stand types that contained Table Mountain pine in 1994. Cherokee National Forest, 2007 (1 of 6).

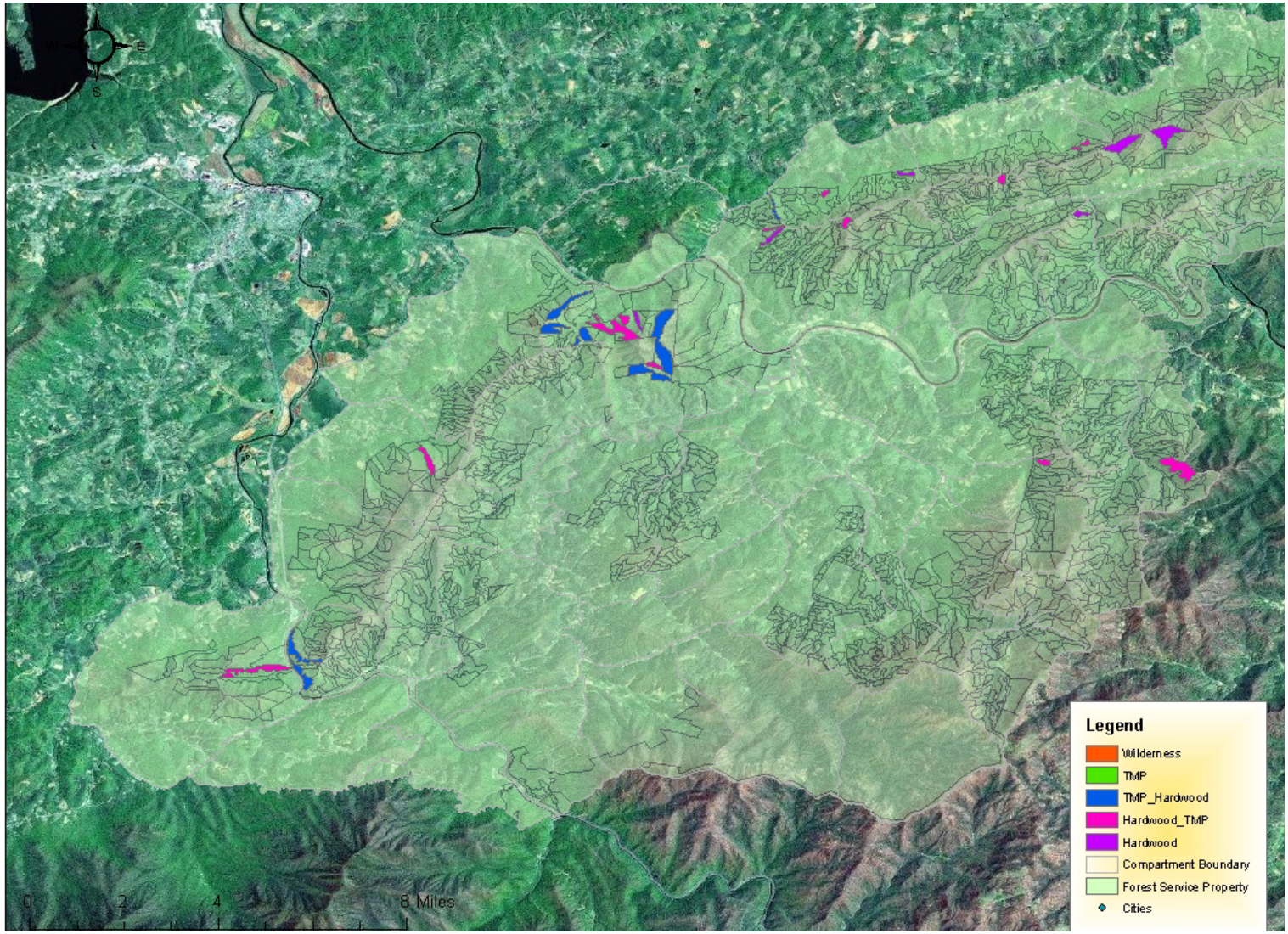

Figure B 11. Reclassification of northern districts stand types that contained Table Mountain pine in 1994. Cherokee National Forest, 2007 (2 of 6).

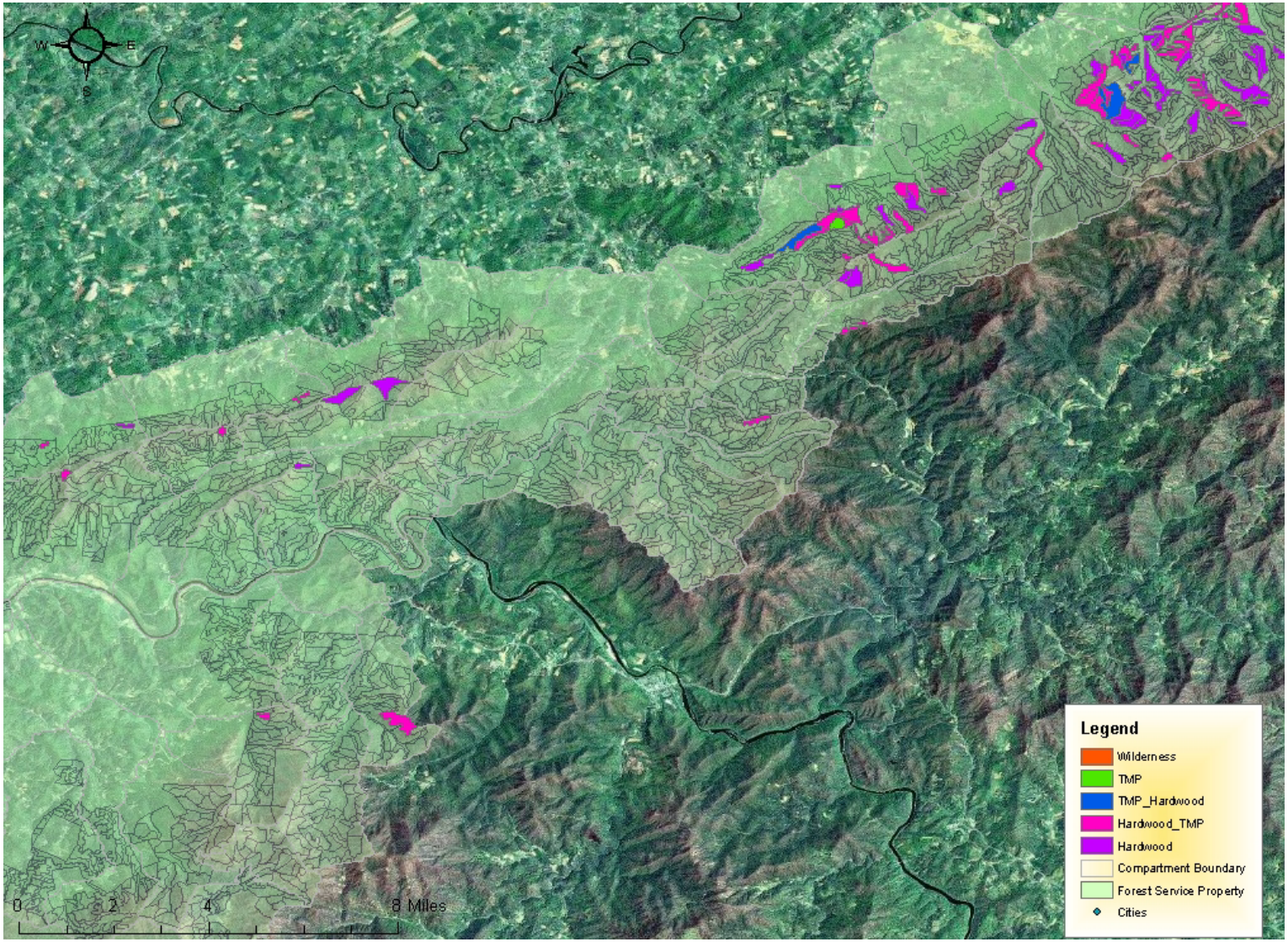

Figure B 12. Reclassification of northern districts stand types that contained Table Mountain pine in 1994. Cherokee National Forest, 2007 (3 of 6).

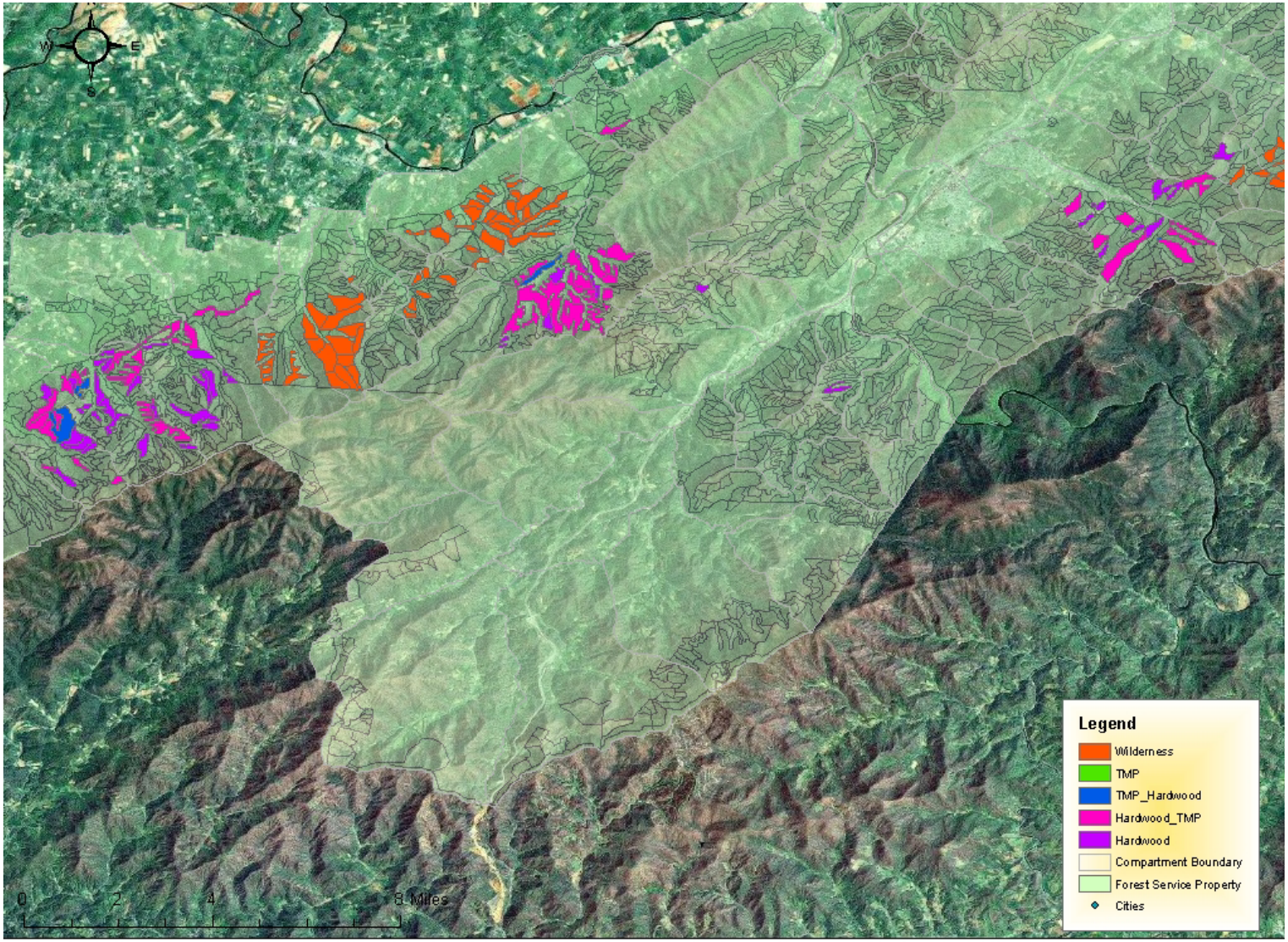

Figure B 13. Reclassification of northern districts stand types that contained Table Mountain pine in 1994. Cherokee National Forest, 2007 (4 of 6).

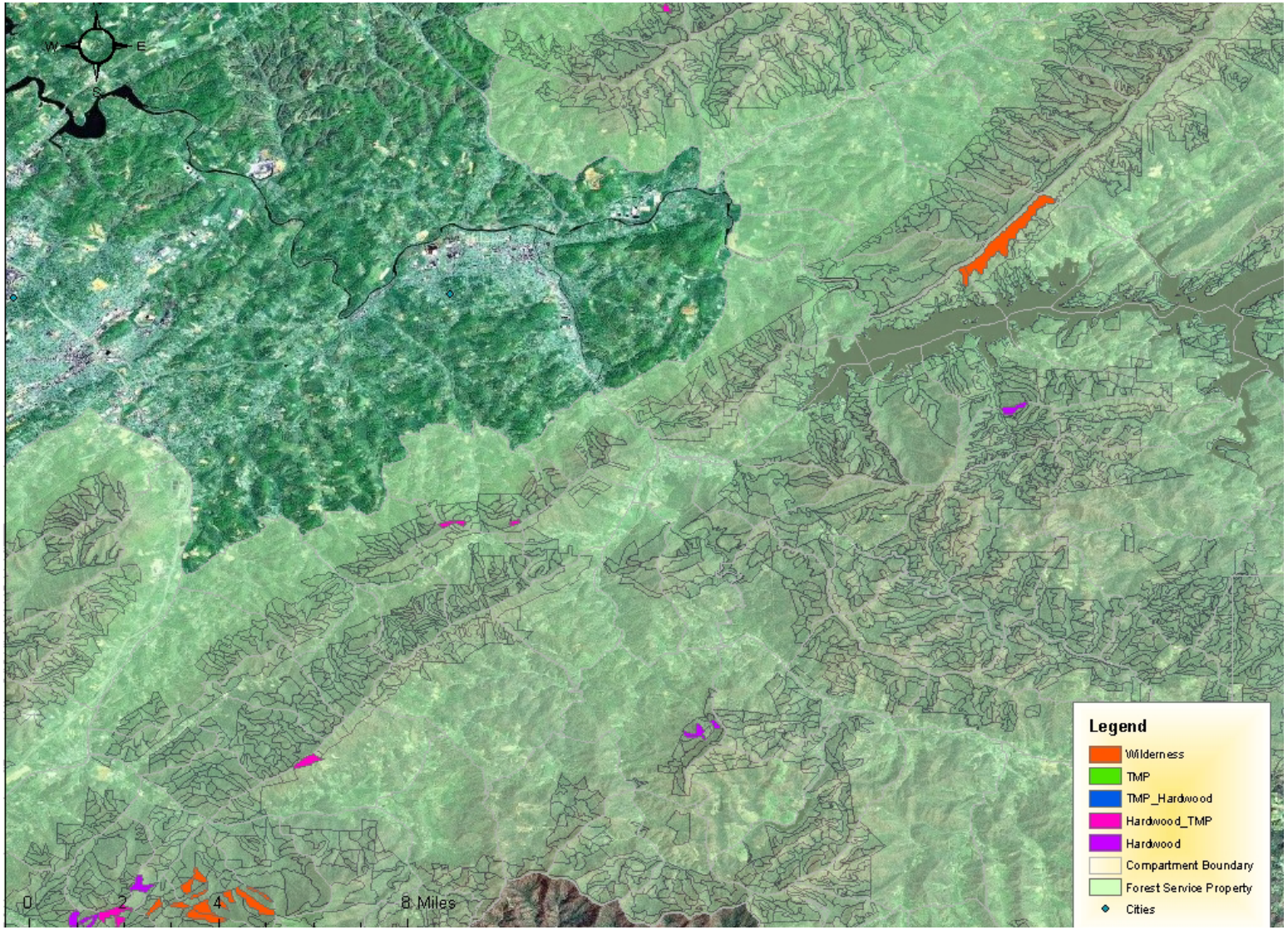

Figure B 14. Reclassification of northern districts stand types that contained Table Mountain pine in 1994. Cherokee National Forest, 2007 (5 of 6).

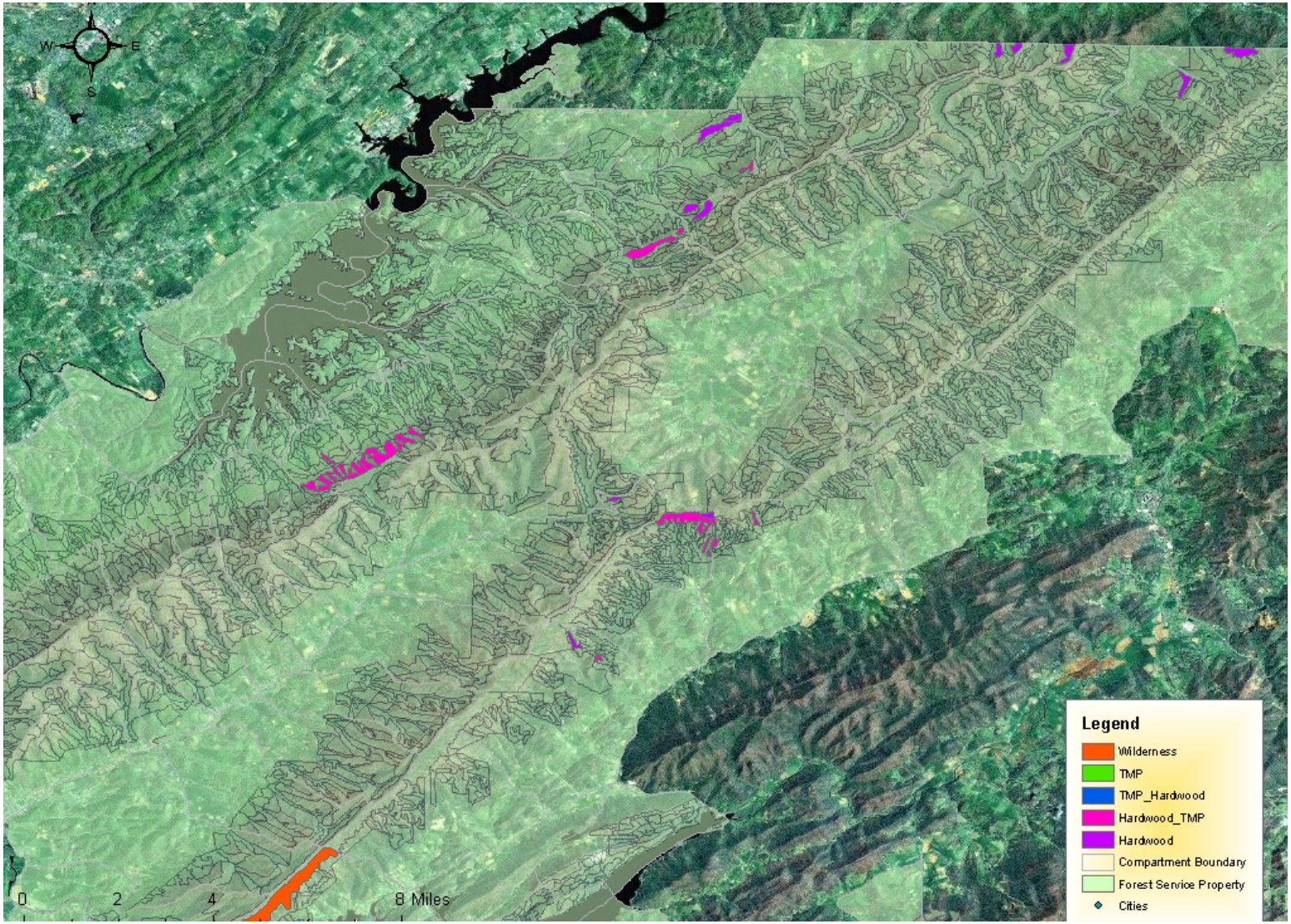

Figure B 15. Reclassification of northern districts stand types that contained Table Mountain pine in 1994. Cherokee National Forest, 2007 (6 of 6).

Appendix C. The Horsehitch Gap Prescribed Burn

The prescribed burn occurred on April 22, 2008. The initial fire crew consisted of 21 people including the Cherokee Hotshots, a few Redmond Smokejumpers on detail as well as Type 2 Firefighters from the Nolichucky/Unaka and Watauga districts of the CNF. The backing fire was ignited at 13:15 at the top of the burn block with drip torches. At the time of lighting, the temperature was 70˚ F, relative humidity was 53% with winds 2-4 miles per hour out of the North (Table C1).

The fire began as a backing fire from the top of the slope. Fire was also initiated on the east and west flanks. The winds in the area occasionally have an eddy effect due to the lay of the mountains and the channelization of the winds. The winds changed direction, the flank and the backing fire met, and the fire reached into the tree crowns and the winds pressed the crown fire downhill. The fire spotted over the line into the crop tree block and was not contained immediately. The dozer was used to push the first strip of the strip treatment block to mineral soil in order to contain the fire, i.e. a fire line. The trail at the bottom of the slope was used as the fire line for the bottom and another trail was used as the line on the eastern side. A backing fire was then lit from the west side of the strip block in order to burn out and prevent the fire from moving into the green area to the west, outside of the research area. With the assistance of two helicopters, the area burned out by the early morning hours on April 23. A Type 2 helicopter assisted with fire control for approximately 3 hours and a Type 3 helicopter for 3.3 hours. The Type 3 unit was on contract with the Cherokee NF and the Type 2 was available from a wildfire in North Carolina. Eight additional firefighters came to assist with the burn once the fire jumped

Table C 1. Weather data collected during Horsehitch Gap prescribed burn. Nolichucky/Unaka District, Cherokee National Forest, April 22, 2008.

Time	Temperature	Relative Humidity	Wind	Sky
11:45	61	65	2-4 N	PC
13:30	70	53	2-4 N	PC
14:30	74	42	3-5 NE with 8 Gusts	PC
15:30	77	44	2-5 N with 8 Gusts	Cumulus with build-up to NE
16:30	76	43	2-4 NE with 6 Gusts	PC
17:30	75	46	2-4 N	PC
18:30	71	56	1-2 N	MC
19:30	67	55	L/V	MC
20:30	65	54	L/V	C
21:30	62	52	3-4 SE with 7 Gusts	C
22:30	61	52	1-2 SE	C
12:30	70	58	L/V	PC

the line. The fire was contained by the evening, but was monitored throughout the following day and checked periodically for the next few days.

Table C1 is a record of the weather throughout the day of the burn. The information was collected by one of the Cherokee Hotshots during the burn. There was a drop in the relative humidity around 14:30 and 8 miles per hour (mph) gusts began. The gust continued at 8 mph until they were recorded at 6 mph at 16:30 (Table C1). It was during this time that the fire spotted into the crop tree block.

Table C2 shows the maximum temperatures recorded at permanent plots in the prescribed burn block. Probes and tiles were only placed in the burn to monitor air and ground temperature during the prescribed burn. Plot 104 was not located before the fire so no tiles or probes were placed on this site. Also, probes were placed three feet south of the permanent plot tree, but because a few extra probes were available, some plots had an additional probe placed three feet north of the plot tree. Many of the plots along the lower slope of the block had temperatures greater than 1100^{o}F. The crown fire occurred in the lower section of the prescribed burn block after starting on the eastern side (Figure C1). Figure C1 is a photo taken by the helicopter crew that assisted during a fly over the next day while checking for any firespots. The treatment blocks have been drawn over the photo to provide a reference while viewing. The black strips were where the crown fires occurred.

Litter depth was recorded in each treatment block before and after the burn. There were no significant differences in litter depth among treatment blocks before the burn (Figure C2). The mean litter depth before and after the burn for each treatment block is shown in Table C3. There were no significant differences among treatment blocks after the prescribed burn (Figure C3). The mean litter depth before the burn ranged from 2.70 to 3.0 inches in the various

Table C 2. Maximum temperatures in degrees Fahrenheit recorded using fire tiles and Hobo probes at the permanent prescribed burn plots at Horsehitch Gap. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, April 22, 2008.

Tree	Probe Bottom	Probe Top	Tile Top	Tile Bottom	Tile East	Tile West
101	no data	no data	300	300	300	300
102	187.5	329	300	300	300	300
103	1155	no data	1300	1300	1100	1100
104	no data	no data	no data	no data	no data	no data
105	648.5	1341.5	1300	1300	750	488
106	1376.5	no data	1450	1450	1500	1500
107	160.5	no data	175	175	200	200
108	889	no data	1450	1300	1450	850
109	666.5	no data	650	488	400	488
110	250	427	488	488	488	488
111	178.5	no data	488	488	488	200
112	1252.5	no data	1450	1450	1450	1800
113	312	no data	300	300	300	300
114	826.5	no data	1450	1450	1800	1800
115	1376.5	no data	1500	1500	1450	1450
116	1678	no data	1450	1500	1800	1800

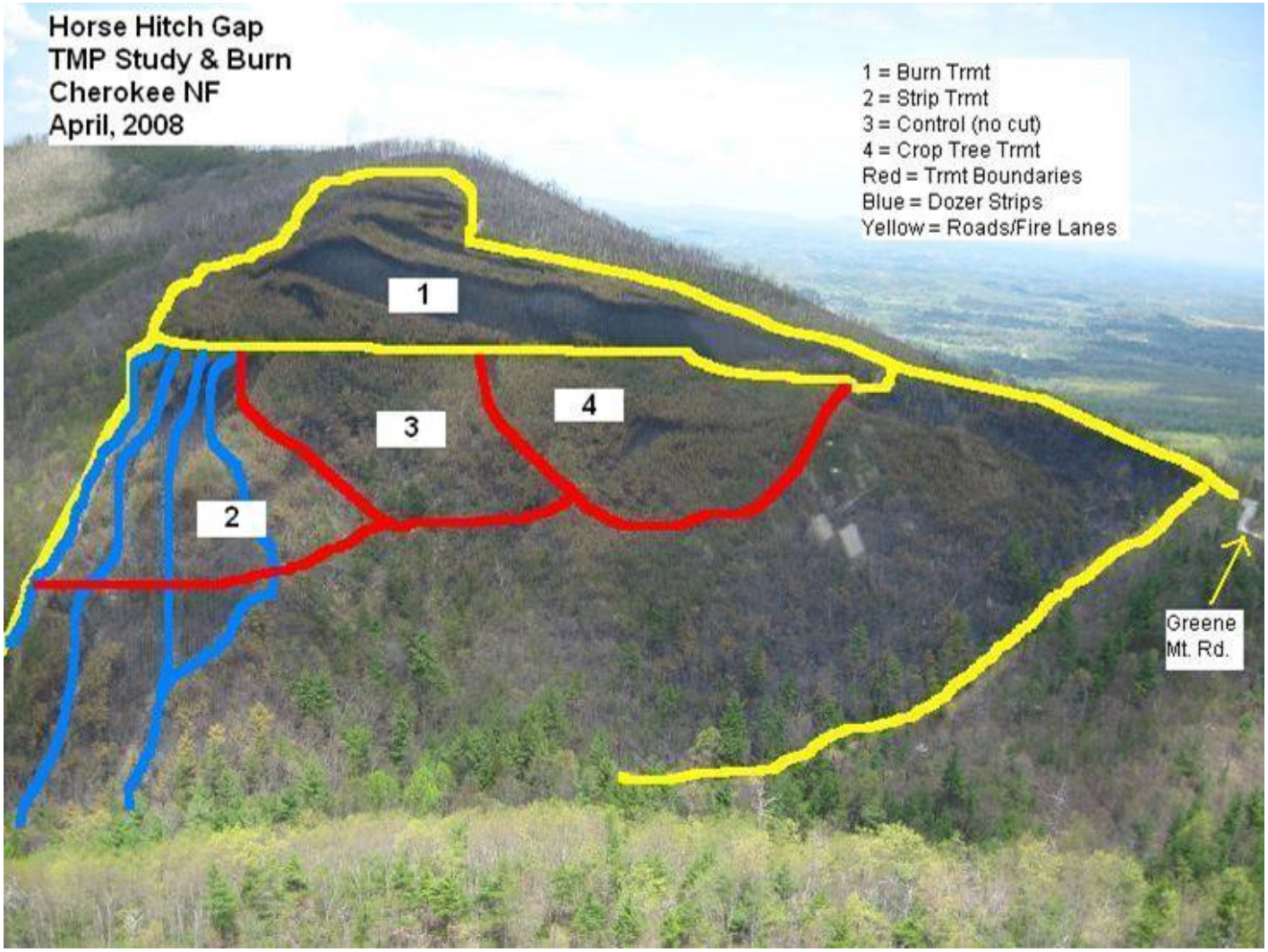

Figure C 1. Photo taken from helicopter on April 23,2008. Lines drawn on photo include treatment block boundaries, strips in the strip thin block, and preexisting trails. Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2008.

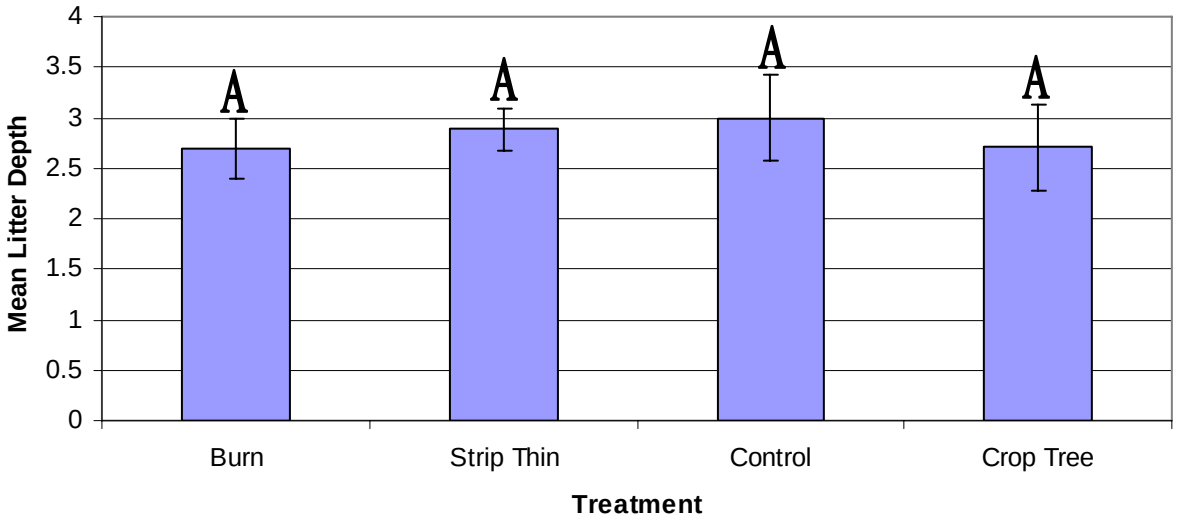

Figure C 2. Litter depth in inches before prescribed burn by treatment blocks. Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2007. Means followed by the same letter are not different (df=3,28) by LSD at p<0.05. (P=0.9166; F=0.17).

Table C 3. Comparison of litter depth in inches before and after the prescribed burn at Horsehitch Gap. Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2008.

Treatment	N	Depth Preburn[1]	Std Dev	Depth Posburn[1]	Std Dev	Significance[2]
Prescribed Burn	8	2.70	1.01	0.86	0.4	A
Strip Thin	16	2.88	0.6	0.96	0.71	A
Control	4	3.00	1.49	0.75	0.92	A
Crop Tree	4	2.7	0.66	1.25	0.54	A

1- Value was obtained using the Means Procedure due to the use of ANCOVA using depth preburn as a covariate.

2- Means followed by the same letter are not different by LSD at p<0.05. (P=0.8904; F=0.02).

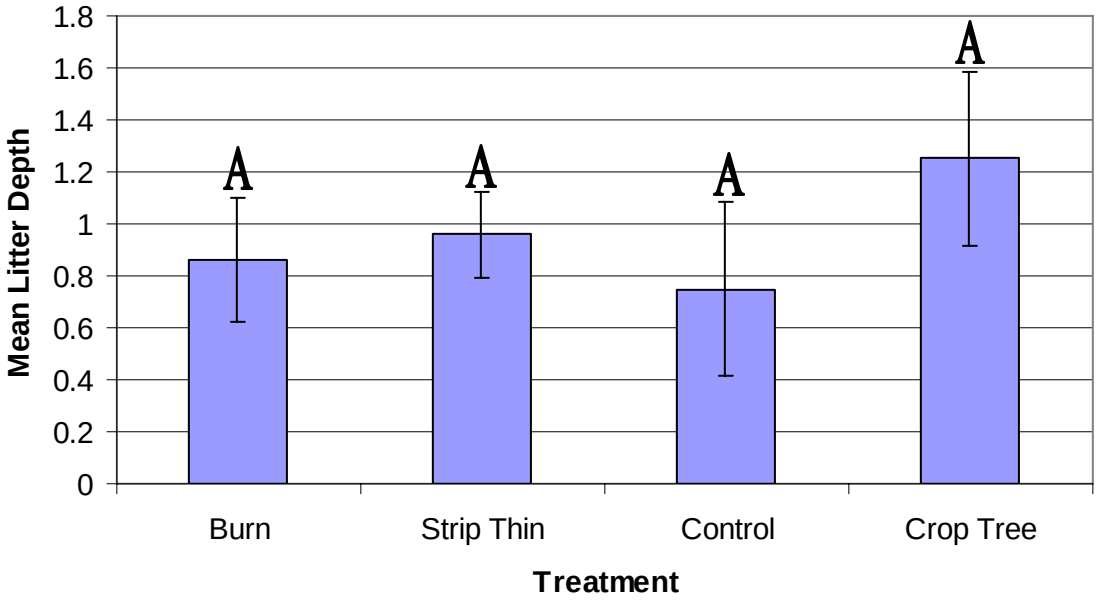

Figure C 3. Mean litter depth after prescribed burn by treatment blocks. Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2008. Means followed by the same letter are not different by LSD at p<0.05. (P=0.8904; F=0.02).

treatments and then 0.75 to 1.25 inches after the burn (Table C3). Fire occurred in each plot where litter depth was sampled, however, the fire intensity varied greatly across the research area.

Crown condition was recorded one month after the prescribed burn occurred (May, 2008). Crown condition was noted as green, brown with green tips, brown or no crown. Table C4 shows the number of permanent plot trees in each treatment that fall in each category. The prescribed burn contained 7 trees with a brown crown, 5 with no crown, 2 that were green and 2 that were brown with green tips. The strip thin contained 28 trees that were brown, 9 with no remaining crown, 8 that were brown with green and 3 that were green. All of the trees in the control block had a crown remaining. It contained 3 brown, 3 brown with green, and 2 that were green. The crop tree block only contained 1 with no crown, 17 brown, 26 brown with green, and 29 green. Across the entire research area, 15 plot trees had no remaining crown as a result of the crown fire (Table C4). A total of 55 trees had brown crowns. These were typically in areas where the fire intensity was greater but not where crown fires occurred. Crowns that were brown with green tips totaled 39 trees across the research area. Thirty-six plot trees had green crowns. The trees with green crowns were in areas where the fire intensities were lower. Trees with green crowns, brown crowns, and brown crowns with green tips should be re-evaluated in the spring or summer of 2009 to determine survival and any other impacts that resulted from the burn. This information is documented here to provide records and histories for others who conduct future research at this site or revisit the permanent plots installed in this study.

Table C 4. Crown condition after prescribed burn by treatment blocks. Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, 2008.

Crown Condition	P. Burn	Strip Thin	Control	Crop Tree	Total
Brown	7	28	3	17	55
Brown with green	2	8	3	26	39
Green	2	3	2	29	36
No crown remaining	5	9	0	1	15

Vita

Amy Morgan was born in East Ridge, TN on December 29, 1983. She was raised in Bradley County Tennessee and graduated from Bradley Central High School in May 2002. Amy also attended Cleveland State Community College where she obtained an Associate of Science in May 2002. Amy then attended the University of Tennessee, Knoxville where she earned a Bachelor of Science in Forest Resource Management with a minor in Wildlife in May 2006. While obtaining her BS, Amy worked for Dr. Wayne Clatterbuck's Forest Stand Dynamics Research Lab and Dr. Mark Fly's Human Dimensions Research Lab. Amy attended Graduate School at the University of Tennessee where she earned a Master of Science Degree in Forestry in December 2008. She also worked for the USDA Forest Service as a Forestry Technician for the Southern Research Station's Forest Inventory and Analysis unit while completing her B.S. and M.S. degrees.