COST EFFECTIVENESS OF THREE DIFFERENT RELEASE TREATMENTS OF TABLE MOUNTAIN PINE IN A SEVERELY OVERSTOCKED AND PURE STAND

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Abstract—Table Mountain pine (*Pinus pungens* Lamb.) (TMP) is a threatened species, endemic to the Southern Appalachian Mountains. This study focuses on the release of TMP stems in an overstocked and pure TMP stand on the Cherokee National Forest in eastern Tennessee. 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. Initial cost effectiveness of release treatments was 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 was minimal.

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). TMP stands often originate from stand replacement fires which lead to severely overstocked conditions without silvicultural treatment or other disturbances including a fire regime. On the Cherokee National Forest (CNF), several TMP stands have developed under these conditions. The stands are overstocked (averaging 5,600 stems per acre, 1.6 inches d.b.h. after 27 years for the stand sampled in this study) with small crowns and poor vigor. These stands are in danger of stagnating and perhaps eventually succumbing before they reach optimal seed-bearing conditions. These unhealthy, overstocked stand conditions also make the stand more vulnerable to southern pine beetle (*Dendroctonus frontalis*) (SPB) infestations.

OBJECTIVES

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. The associated economic analysis will provide land managers with baseline information on the cost effectiveness of the various release treatments in TMP.

STUDY AREA

The study was conducted in a 30-acre TMP stand at Horsehitch Gap in the southern portion of Greene County, TN, on the Nolichucky/Unaka District of the CNF. 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, TN-NC quadrangle map.

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). 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 1,976 acres (Sanders 1992). In 2000, an 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.

METHODS

A 30-acre overstocked TMP stand at Horsehitch Gap was selected to implement and investigate various release treatments. The stand was selected because of its overstocked condition, was 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 an uncut control. A small plot size of one two-hundredth of an acre was chosen for the inventory because the stand was fairly uniform and consistent with many small diameter trees of relatively the same size (1 to 3 inches d.b.h.). Diameter, height, and number of cones for each tree on the permanent plot were recorded.

The prescribed burn treatment block was 7.3 acres and was located on the upper portion of the southern facing slope. In this block, 16 one two-hundredth-acre permanent plots were installed along transects. The prescribed burn occurred on April 22, 2008. The backing fire was ignited at 1:15 at the top of the burn block with drip torches.

The strip-thin treatment block was 4.4 acres in size and located on the westerly side of the stand. Four strips were installed downhill on the southern facing slope on November 27, 2007. The first strip was placed 32 feet east of the western boundary and was on a bearing of zero degrees. 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.

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The control treatment block was 3.5 acres in size and was located between the strip-thin and the crop-tree release blocks. Eight permanent plots were installed in January 2008.

The crop-tree release treatment block was 4.8 acres and was located on the eastern side of the stand. The spacing for the crop trees was approximately 45 by 45 feet, or 20 crop trees per acre. The crop trees were selected along a transect at approximately 45-foot intervals by identifying the largest diameter tree with the best overall form with a full, dominant, and symmetrical crown. The diameters (inches) and heights (feet) of each crop tree were measured. The trees were released using a crown-touching method. The diameters and heights of the cut trees were recorded. The trees were released on November 27, 2007.

Horsehitch Gap data were compiled with basal area, trees per acre, importance values of each species, and mean diameters and heights determined for each treatment. Importance values were used to compare uniformity of TMP (basal area and density) between treatment units in the stand. Analysis of variance (ANOVA) was 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 ranked values.

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 [http://www.deere.com/en_US/cfd/construction/deere_const/media/non_current_pdfs/noncurrent_dozers/DKA450H0209.pdf (Date accessed: August 2008)]. 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 also followed Brinker and others (2002). No tax costs were calculated for in-woods equipment because this equipment is not usually subject to tax collection (Brinker and others 2002). Ratings for fuel usage per hour were obtained from John Deere [http://www.deere.com/en_US/cfd/construction/deere_const/media/non_current_pdfs/noncurrent_dozers/DKA450H0209.pdf (Date accessed: August 2008)]. Off-highway diesel costs were obtained by using the U.S. Department of Energy (2008a) 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).

Stihl MS 361 [http://www.stihlusa.com/chainsaws/MS361.html (Date accessed: August 2008)] chainsaws were used to cut trees in the crop-tree release treatment. The 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. However, the number of trees cut was recorded. Purchase prices of chainsaws were obtained from Stihl's recommended price online [http://www.stihlusa.com/chainsaws/MS361.html (Date accessed: August 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.

RESULTS

Inventory

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 1). 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 1). Thus, importance value of TMP was fairly homogenous within treatment units of the stand.

Prescribed Burn Treatment Block—The trees in the prescribed burn block inventory (n = 16 plots) had a mean diameter of 1.9 inches and a mean height of 14.9 feet (table 2). This block contained 5,388 trees per acre with a basal area of 127.5 square feet per acre. The mean diameter of the permanent plot trees (n = 16) was 2.77 inches. TMP composed 86 percent of the treatment block, followed by 5 percent chestnut oak (*Quercus prinus* L.) (table 3). The mean importance value for TMP was 164.30, 34.14 for hardwoods, and 1.56 for the other pines (*Pinus* spp.) (table 1).

Strip-Thin Treatment Block—The mean diameter of trees in the strip-thin treatment block inventory (n = 16 plots) was 1.6 inches with a mean height of 17.7 feet (table 2). The block contained 4,242 trees per acre with a basal area of 75.7 square feet per acre. The mean diameter of the permanent plot trees (n = 48) was 2.56 inches. TMP composed 90 percent of the treatment block, followed by scarlet oak (*Q. coccinea* Münchh.) at 5 percent (table 3). The mean importance value for TMP was 173.87, 24.89 for hardwoods, and 1.25 for other pines (table 1).

Control Treatment Block—The mean diameter of trees in the control block inventory (n = 8 plots) was 1.8 inches with a mean height of 21.3 feet (table 2). The block contained 5,200 trees per acre with a basal area of 110.2 square feet per acre and had a mean permanent plot tree diameter of 3.23 (n = 8). TMP composed 70 percent of the treatment block, followed by scarlet oak at 13 percent (table 3). The mean importance value for TMP was 174.66, for hardwood 24.83, and other pines 0.51 (table 1).

Table 1—Importance values for Horsehitch Gap treatment blocks from inventory plots, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, TN, January 2007

		TMP		Hardwood		Pine	
Treatment	N	Mean[a]	SD	Mean[a]	SD	Mean[a]	SD
Prescribed burn	16	164.30	57.19	34.14	54.85	1.56	3.77
Strip-thin	16	173.87	29.16	24.89	29.75	1.25	2.82
Control	8	174.66	22.94	24.83	23.13	0.51	1.43
Crop tree	5	165.98	32.66	33.38	33.33	0.65	1.44
P-value		0.9179		0.9374		0.9231	
F-value		0.17		0.14		0.16	

TMP = Table Mountain pine; SD = standard deviation.

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

Table 2—Data for Horsehitch Gap treatment blocks, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, TN, January 2007

Measurement	Crop tree	Strip-thin	Prescribed burn	Control
Mean d.b.h. (inches)	1.3	1.6	1.9	1.8
Mean basal area (square feet per acre)	79.4	75.7	127.5	110.2
Mean trees per acre	7,720	4,242	5,388	5,200
Number of plot trees	73	48	16	8
Mean height (feet) of plot trees	13.4	17.7	14.9	21.3
Mean number of cones per plot tree	8.7	5.0	5.3	6.1
Mean diameter (inches) of plot trees	2.83	2.56	2.77	3.23

Table 3—Species composition for Horsehitch Gap treatment blocks, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, TN, January 2007

Species	Crop tree	Strip-thin	Prescribed burn	Control
	---------- *percent* ----------			
Table Mountain pine	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

Crop-tree Treatment Block—The crop-tree treatment block inventory (*n* = 5 plots) contained trees with a mean diameter of 1.3 inches and a mean height of 13.4 feet (table 2). The block contained 7,720 trees per acre with a basal area of 79.4 square feet per acre and a mean permanent plot tree diameter of 2.83 inches (*n* = 73). The crop tree block was composed of 86 percent TMP and 8 percent blackjack oak (*Q. marilandica* Münchh.) (table 3). The mean importance value for TMP was 165.98, 33.38 for hardwood, and 0.65 for other pines (table 1).

Cost Comparison of Treatments

Prescribed Burn Treatment Block—The prescribed burn costs were greatly skewed because the fire burned an additional 15 acres. According to the fire management officer (FMO) for the Nolichucky/Unaka district of the CNF, the average cost of a prescribed burn is about $45.00 per acre.[2] This usually represents large burn units >200 acres. The cost per acre is generally more with smaller tract size. The prescribed burn at Horsehitch Gap was $815.37 per acre (table 4). This cost included the dozer and operator, chainsaws, 29 Forest Service employees including the Hotshots and type 2 firefighters, and 2 helicopters with pilots and copilots and fuel.

Table 4—Total costs for prescribed burn at Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, TN, April 2008

Category	Cost
	dollars
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

Strip-Thin Treatment Block—Table 5 provides the hourly costs associated with the use of the dozer in the strip-thin treatment. According to John Deere [http://www.deere.com/en_US/cfd/construction/deere_const/media/non_current_pdfs/noncurrent_dozers/DKA450H0209.pdf (Date accessed: August 2008)], the purchase price of the dozer was $95,000. At an insurance rate of 1.0 percent, the fixed costs were estimated to be $1.90 per hour (table 5). The operating costs totaled $41.64 per hour with fuel costs at $2.986 per gallon

Table 5—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, TN, April 2008

Category	Value
Insurance	1.0 percent
Fuel	2.0 gallons per hour
Oil and lubricants	0.74 gallons per hour
Labor	$15.62 per hour
Fringe benefits	30 percent
Scheduled operating time	2,000 hours
Utilization	25 percent
Productive time	500 hours
Fixed costs	
Taxes	N/A
Insurance	$950.00 per year
Total fixed costs	$950.00 per year
	$1.90 per hour
Operating costs	
Maintenance and repair	$30.40 per hour
Fuel and lubrication	$11.24 per hour
Total operating costs	$41.64 per hour
Labor costs	
Wages	$15.62 per hour
Fringe benefits	$4.69 per hour
Total labor costs	$20.31 per hour
Total hourly costs	$63.85 per hour

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

[2] Personal communication. 2008. Greg Salansky, District Fire Management Officer, Cherokee National Forest, 4900 Asheville Highway SR70, Greeneville, TN 37743.

and oil and lubricants set at 36.8 percent of the fuel costs (table 5). Labor and benefits were calculated to be $20.31 per hour (U.S. Department of Labor 2007). Thus, total estimated cost was $63.85 per hour. Transportation costs for hauling the dozer from the work center location to the fieldsite was $1.52 per mile according to the CNF and was not included when calculating the hourly rate. On average, each strip was about 500 feet long and took about 40 minutes each to install. Thus, the installation of the four strips on the treatment unit cost an average of $38.70 per acre.

Crop-tree Treatment Block—Table 6 shows a breakdown of hourly chainsaw costs associated with releasing crop trees. According to Stihl [http://www.stihlusa.com/chainsaws/MS361.html (Date accessed: August 2008)], the purchase price of the MS 361 was $600. At an insurance rate of 4.0 percent, the fixed costs are $0.024 per hour (table 6). The operating costs totaled $4.58 per hour with fuel costs at $3.097 per gallon and oil and lubricants set at 36.8 percent of the fuel costs (U.S. Department of Energy 2008b) (table 6). Labor and benefits were calculated to be $21.26 per hour according to the U.S. Department of Labor. Thus, the total estimated cost was $25.87 per hour. Transportation costs for the saw were $0.485 per mile according to the Internal Revenue Service for 2007 (U.S. Department of the Treasury, Internal Revenue Service 2006).

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 7 is a comparison of costs by treatment. The prescribed burn cost $815.37 per acre. 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.

DISCUSSION

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 study. As previously mentioned, there were no significant differences in the importance values for TMP hardwoods or the other pines among treatment blocks. TMP was uniform across the stand by treatment units (table 1). Pines other than TMP were minimal having a mean importance value ranging from 0.51 to 1.56 in the various treatment blocks (table 1).

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 stem densities of 5,600 stems per acre after 27 years (table 2). The current poor-growing condition of the stand poses many questions for future management and perpetuation

Table 6—Total costs for hourly productive time, estimation of hourly owning and operating costs of the Stihl 361 chainsaw, Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, TN, 2008

Category	Value
Insurance	4.0 percent
Fuel	0.22 per horsepower per hour
Oil and lubricants	36.8 percent
Labor	$16.35 per hour
Fringe benefits	30 percent
Scheduled operating time	2,000 hours
Utilization	50 percent
Productive time	1,000 hours
Fixed costs	
Taxes	N/A
Insurance	$24.00 per year
Total fixed costs	$24.00 per year
	$0.024 per hour
Operating costs	
Maintenance and repair	$0.48 per hour
Fuel and lubrication	$4.10 per hour
Total operating costs	$4.58 per hour
Labor costs	
Wages	$16.35 per hour
Fringe benefits	$4.91per hour
Total labor costs	$21.26 per hour
Total hourly costs	$25.87 per hour

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 per mile.

Table 7—Comparison of treatment costs at Horsehitch Gap, Nolichucky/Unaka District, Cherokee National Forest, Greeneville, TN, 2008

Treatment	Cost
	dollars per acre
Prescribed burn	
Actual	815.37
Average	45.00
Strip-thin	38.70
Crop tree	17.52

of TMP. These questions include response to release, cone production, stand development, and fuel management.

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 encountered. Ideally, the crop trees will significantly increase in diameter and crown size, 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 2). Hopefully, the release treatments will provide additional resources to increase crown size and, thus, 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 greater 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 of trees along the edge of the strip 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 smaller diameter trees, but allow larger diameter trees to survive. Fire intensity was highly variable across the stand ranging from surface to crown 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 and in the future 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 when burning 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, steep terrain and the vertical fuels in stands that have not been previously burned. Fuel moisture, windspeed, 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. 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.

The costs associated with prescribed burning were greater than the mechanical treatments used in this study (table 7). 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 per acre. Equipment costs were minimal (table 7). 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. The primary cost associated with this treatment was labor. The strip-thin was $38.70 per 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.

CONCLUSION

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 in silvicultural operations. This study implemented several release treatments for future growth considerations. The permanent plots in this study should be remeasured 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 reasonable. The crop-tree release treatment was very labor intensive, but with a cost of $17.52 per acre, it appears to be another viable option with small-diameter stems. The strip-thin treatment may be more difficult to apply 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 markets, inaccessibility, and terrain, this unusual, endemic species provides many ecosystem and diversity aspects to forests in the region.

Many stand development questions about TMP are beyond the scope of this study, but can possibly be addressed in future studies. A plethora of TMP research is available and ongoing about the regeneration and stand dynamics of TMP (Armbrister 2002, DeWeese 2007, Mohr and others 2002, Randles and others 2002, Van Lear 2000, Waldrop and Brose 1999, Waldrop and others 2006). 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 in 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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