SPECIES DIVERSITY IN PLANTED PINE AND NATURAL HARDWOODS 24 YEARS AFTER SHEARING AND CHIPPING ON THE CUMBERLAND PLATEAU, TN

Karen Kuers[1]

Abstract--Plant species richness in 24 year-old planted loblolly pine (*Pinus taeda L.),* eastern white pine (*Pinus strobus* L.), yellow-poplar (*Liriodendron tulipifera* L.), naturally regenerated hardwoods, and mature hardwoods was compared using the North Carolina Vegetation Survey protocol. Comparisons were made in plots established after shearing and on-site chipping of a low quality hardwood stand on the Cumberland Plateau near Sewanee, TN in 1976. In 3 of the 6 plots representing each species, stems over 1.3 meters tall were injected with herbicide during the winter after harvest. Six years after planting, half of each eastern white pine plot was cleaned by manually or chemically removing only those trees essential to release the overtopped white pines. Three additional plots were installed in 2000 in the surrounding mature forest. Data collected in 2000 included species presence and cover class for a log10 series of nested square subquadrats (0.01, 0.1, 1.0, 10, and 100 square meters) within a 900 square meter quadrat for each of the 0.4 hectare plots. A total of 159 plant species (excluding grasses) were encountered within the twenty-seven 900 square meter plots. Sixty-three were found in all 5 stand types. Thirty-nine were found in only one stand type, with the largest number (10) found in loblolly pine and yellow-poplar. Plant species richness beneath the loblolly pine was not significantly different from planted yellow-poplar, natural regeneration, or the surrounding older hardwood forest. Eastern white pine, however, exhibited reduced plant richness relative to the other stand types. The effects of tree injection on plant richness varied with stand type and plant form. While woody plant species declined slightly in all plot types, herbaceous species tended to decline in pine plots and increase in the hardwood plots. The effects of successive competition treatments on plant species richness in eastern white pine were cumulative (average 4.5 species per treatment).

INTRODUCTION

Many assumptions and beliefs exist regarding the effects of pine conversion on the biodiversity of our native hardwood forests. The public is concerned that replacing hardwoods with planted pine or using silvicultural practices such as competition control will reduce plant species diversity. While various studies have been initiated to address the effects of silvicultural practices on the floral diversity of harvested hardwood stands (Baker and Hodges 1998, Hammond and others 1998, McMinn 1998, Wender and others 1999) fewer studies have addressed understory composition of planted pine (e.g., Krochmal and Kologiski 1974), and none are available that compare the understory of planted pine to that of similar age hardwood stands on the Cumberland Plateau in Tennessee.

In the 1970's the Sewanee Silviculture Lab of the USDA Forest Service Southern Research Station initiated a series of studies to address land management opportunities for private landowners with cut-over, degraded hardwood stands. One such study (McGee 1980), investigated the potential of clear-felling by in-woods chipping, followed by planting one of two species of pine (loblolly and eastern white), yellow-poplar, or allowing natural regeneration. In addition to providing valuable tree growth information, this study (now 24 years-old), provided an excellent opportunity to compare the floral diversity under different planted species to that of natural hardwood regeneration. Since two different levels of tree removal were used, harvest to a 10 centimeter dbh and harvest to 10 centimeters with the injection of the smaller residual stems, it was also possible to test the effect of woody competition control on plant species richness.

The objectives of the research reported here were to determine the effects of 1) planting pine, planting yellow-poplar or natural hardwood regeneration and 2) control of woody competition at harvest on the plant richness (non-woody and woody vascular plants) of a low-quality hardwood stand on the Cumberland Plateau near Sewanee, TN.

STUDY AREA

The 15 hectare (37-acre) study area, is located on the Cumberland Plateau near Sewanee, TN (35°12'30"N and 85°55'W). It is typical of Landtype 1 (Undulating Sandstone Uplands) (Smalley 1982). The moderately deep to deep soils developed in loamy residuum from sandstone and some shale. Sandstone outcrops in places. The soils are classified as fine-loamy, siliceous, mesic Typic Hapludults. Elevation ranges from 579 to 594 meters. Annual precipitation, averaging 140 centimeters, is well distributed; September and October are the driest months.

The area was harvested in 1976 by shearing and chipping (McGee 1980). Prior to harvest, the stand consisted primarily of culls and low quality hardwood stems. The dominant

[1]Associate Professor of Forestry, Department of Forestry and Geology, The University of the South, Sewanee, TN, 37383

Citation for *proceedings:* Outcalt, Kenneth W., ed. 2002. Proceedings of the eleventh biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-48. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 622 p.

overstory species were white oak (*Quercus alba* L.) and scarlet oak (*Quercus coccinea* Muenchh.). Site index estimates ranged from 17 to 23 meters for oak, but accurate estimates were difficult to obtain because there were few suitable overstory trees (McGee 1980). The harvest removed 1200 tons of green chips and a total of 30 tie logs or sawlogs from the entire 15 hectare area. All stems = 10 centimeters dbh were removed from the site during the shearing, leaving 125 to 1480 stems per hectare (mostly 5 - 8 centimeters dbh).

After harvest, twenty-four 0.4 hectare (1 -acre) plots were established and six plots were randomly selected for each of the following treatments: planting 1 .0 loblolly pine (LP), planting 2.0 eastern white pine (EWP), planting 1 .0 yellow-poplar (YP), and natural regeneration (NAT). Trees were planted at a 2.4 x 3 meter spacing. In three plots of each treatment, stems over 1.37 meters tall were injected (INJ) with herbicide during the winter after harvest. A square 0.1 hectare measurement subplot was established in the center of each plot. Six years after planting, half of each EWP plot was cleaned by manually or chemically removing only those trees necessary to release the overtopped white pines. The early growth and development of the trees have been reported in a series of publications (Hepp 1989, McGee 1980, McGee 1982, McGee 1986), the most recent of which was a report on a subset of the treatments after the fifteenth growing season (Dethero 1992).

METHODS

In the summer of 2000, a 900 square meter plot (30 meters x 30 meters) was established within the central measurement plot in each of the original 24 experimental plots. Three additional 0.4 hectare plots were established in regions of the adjacent forest that were not harvested in 1976 (UNCUT) to allow comparison of the diversity in the clear-cut plots to that of mature forest. A 900 square meter measurement plot was established in each.

A modification of the North Carolina Vegetation Survey protocol (Peet and others 1998) was used to compare the total plant diversity of the treatments. Each 900 square meter quadrat was subdivided into nine 10 x IO square meter modules. Two series of smaller subplots (0.01 , 0.1, 1 .0, and IO square meters) were nested within opposite corners of four of the nine 100 square meter modules.

The presence and cover class of each plant species were recorded for all nine 100 square meter modules within each treatment plot. In four of the modules, species presence was recorded within the two nested series of subplots. Thus for each species/treatment combination there were 3 replications of the 900 square meter plots, 27 of the 100 square meter subsamples (9 per plot) and 24 subsamples (8 per plot) for each of the smaller areas sampled (10, 1, 0.1, and 0.01 square meters).

In the fall of 2000, dbh, height class, and crown class for all stems = 1.3 meters tall (living and dead) were recorded by 100 square meter module for each of the twenty-seven 900 square meter measurement plots (only the basal area information will be included in this report).

Similarity of plant communities was investigated using the Czekanowsky Coefficient of Similarity (Czekanowski 1913). The Czekanowsky Coefficient includes both qualitative (presence/absence) and quantitative (abundance) data. The value used for species abundance was the number of 100 square meter plots in which a species was found rather than the actual number of stems. Coefficients range from 0 to 1, with 0 indicating no species in common, and 1 indicating the same number and same abundance present for each of the species.

Main effects (species; injection) and the interaction were tested at the a = 0.05 level using General Linear ANOVA models (SPSS). Duncan's Multiple Range Test was used to compare means when significant differences were detected.

RESULTS

A total of 159 plant species (excluding grasses) representing 119 genera and 24 families were encountered within the 27 900 square meter plots (table 1). These included 34 trees, 19 shrubs, 91 herbs, 9 vines, and 6 ferns. Sixty-three (40 percent) were found in all 5 plot types and 18 (11 percent) were found in all 27 of the measurement plots.

Thirty-nine (25 percent) of the identified species were found in only one plot type, the majority of which were herbs (25 species; table 2). The largest numbers of unique species (10) were found in LP and YP sites. The lowest numbers (6) were found in both UNCUT and NAT sites. Differences in numbers of unique species were due primarily to differences in numbers of herbs.

The Similarity Coefficient (Czenakowski 1913) based upon all plants in all 6 plots for each plot type indicated that the LP, YP, and NAT plots were more similar to each other than they were to the EWP plots (table 3). While coefficients averaged 0.84 among the non-EWP plots, the average similarity of EWP to the non-EWP plots was only 0.71. The coefficients for herbaceous species (0.66 average) were significantly lower than those for woody plants (0.84 average; p < .0001).

Table I-Comparison of species richness (number of species) by plant form across twenty-seven 900 square meter plots (3 mature mixed-oak forest, and 6 each of 24 year-old loblolly pine, eastern white pine, yellow-poplar and natural regeneration)

	All Forms	Trees	Shrubs	Herbs	Vines	Ferns
Totals[a]	159	34	19	91	9	6
Common[b]	63	21	8	27	6	1
Ubiquitous[c]	18	8	4	4	2	0
Unique[d]	39	6	5	25	2	1

[a]Total number of species fouind in the 27 study plots
[b]Number of species that were fuound in all 5 plot types
[c]Number of species that were fuound in all 27 plots
[d]Number of species that were fuound in only one plot type

Table 2-Number of unique[a] species by plant form in mature mixed-oak forest (UNCUT), and 24-year-old loblolly pine (LP), eastern white pine (EWP), yellow-poplar (YP) and natural regeneration (NAT)

	Plant Form					
	All Forms	Trees	Shrubs	Herbs	Vines	Ferns
Uncut	6	1	1	4	0	0
EWP	7	3	0	2	2	0
LP	10	1	1	8	0	0
NAT	6	1	1	3	0	1
YP	10	0	2	8	0	0

[a] Species found in only one plant type

Coefficients comparing INJ to NON-INJ plots of the same species were 0.75 (YP), 0.80 (EWP), 0.83 (NAT), and 0.85 (LP).

Average plant richness per 900 square meters ranged from a low of 59 species in EWP to a high of 71.3 in LP (figure 1). Numbers in YP, UNCUT, and NAT were intermediate (61.7, 66.7, and 69.0 respectively).

The size of the area sampled had an impact on apparent effects of the treatments. For example, tree species richness averaged 20.2 per 900 square meters and was not affected by either species or injection. When based upon the smaller 100 square meter plots, however, tree species richness did differ among species, with richness in EWP lower than in the other species (11 .O versus 14.3 average).

Table 3-Comparison of plant community similarity between plots of 24 year-old lobololly pine (LP), eastern white pine (EWP), yellow-poplar (YP) and natural regeneration (NAT) using the Czekanowski Similarity Coefficient" (based upon six 900 square meter plots for each type)

	Czekanowski Coefficient			
Plot type	LP	EWP	YP	NAT
LP	-	.75	.82	.81
EWP	-	-	.70	.69
YP	-	-	-	.89
NAT	-	-	-	-

[a]The coefficient was calculated: $2 \sum \min(X_i, Y_i) / (\sum X_i + \sum Y_i)$ where X_i = # of 100 m² plots in which species i occurs in plot type X, Y_i = # of 100 m² plots in which species i occurs in plot type Y, and $(\min(X_i, Y_i))$ = the lesser # of 100 m² plots (type X or Y) in which species i occurs.

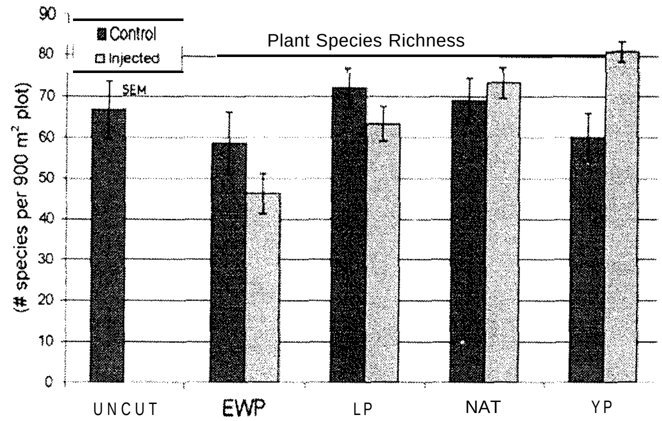

Figure 1 -Average total plant richness of injected and non-inject 900 square meter plots of mature mixed-oak forest (UNCUT), and 24 year-old loblolly pine (LP), easter white pine (EWP), yellow-poplar (YP) and natural regeneration (NAT).

The effects of tree injection on total plant richness varied with plot type (figure 1). While the within-species trend was for pine sites to exhibit decreased richness with INJ and hardwood sites increased richness, only in YP was the difference statistically significant. injection reduced the plant richness of the EWP(INJ) sites relative to all other treatments except EWP(NON-INJ) and YP(NON-INJ).

Woody species richness (shrubs + trees) was not significantly different in INJ and NON-INJ 900 square meter plots (figure 2), although there was a trend across all species for a reduction of approximately 3 species. While herbaceous species richness declined with INJ in pine plots by an average 8 species per 900 square meter plot, richness actually increased by an average of 8 species in the deciduous plots. (Only in YP was this difference significant at 0.05.)

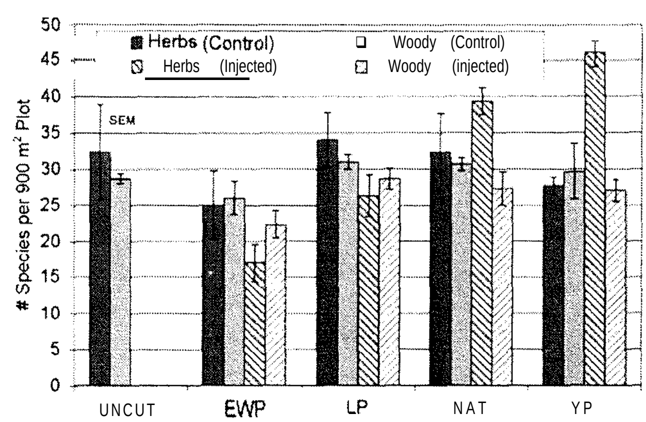

Figure 2-Average woody species richness (shrubs + trees) and herbaceous species richness (excluding grasses) of injected and non-injected 900 sq. meter plots of mature mixed-oak forest (UNCUT), and 24 year-old loblolly pine (LP), eastern white pine (EWP), yellow-poplar (YP) and natural regeneration (NAT).

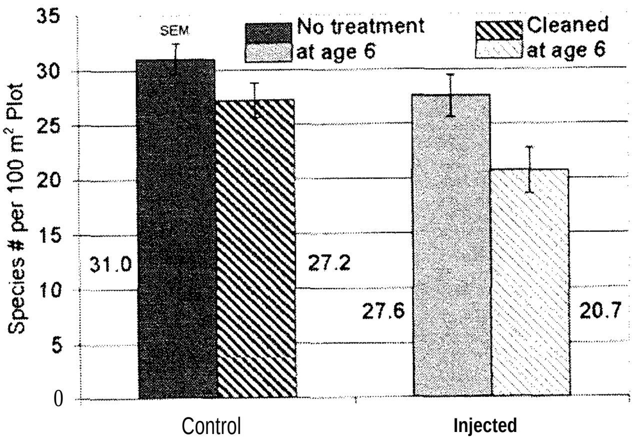

Figure 3-Effects of two successive competition treatments (immediately post harvest or at age 6) on the total plant species richness of 100 meter plots of eastern white pine (EWP).

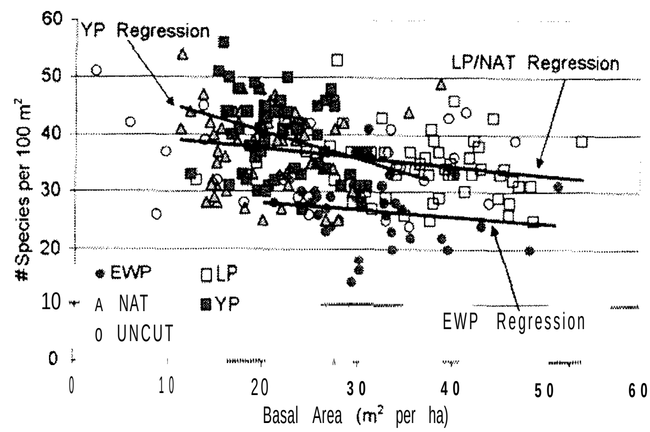

Figure 4—Relationship of plant species richness to the basal area of tall stems 1.3 meters tall within 100 square meter plots of mature mixed-oak forest (UNCUT), and 24 year-old loblolly pine (LP), eastern white pine (EWP), yellow-poplar (YP) and natural regeneration (NAT).

The effects of successive competition treatments on plant species richness in EWP were cumulative, with an average reduction of 4.5 species per treatment (figure 3). The timing of the treatment (immediately post harvest or at age 6) was not significant for the magnitude of the species change. However, the two treatments had different effects on the woody and herbaceous species. The species most impacted by the initial treatment were herbaceous (reduced by 3.8 species per 100 square meters versus 1 .l woody species). In contrast, the weeding at age 6 had little impact on the herbaceous species (0.8 species reduction), but did reduce the woody component by 3.6 species.

Current plot basal areas (all stems = 1.3 meters tall) were higher in the pine than in the hardwood plots. The NON-INJ plots averaged 30 square meters/hectare in the pines and 20 square meters/hectare in the hardwoods. INJ increased the overall basal area of the pines by 3 square meters/ hectare in EWP and 8 square meters/hectare in LP. INJ increased the average percentage of the total basal area that was pine from 58 to 69 percent in EWP and from 60 to 86 percent in LP. INJ decreased basal areas by an average of 1 square meter/hectare in both NAT and YP plots. Basal area in all of the hardwood plots was dominated by oaks (white, scarlet, and black (*Quercus velutina* Lam.)) except for some of the YP(INJ) plots which were dominated by YP.

Differences in plot BA (all stems = 1.3 meters tall) had little relationship with plant species richness in this study (figure 4). Only in YP was the slope of the regression significantly different from zero. However, there was a difference in the number of species per unit BA, as EWP stands exhibited a lower species number per given BA than all the other stand types, including LP. The relationship was similar if only pine basal area was considered in the analysis (data not shown).

DISCUSSION

Twenty-four year old clear-cut sites on the Cumberland Plateau planted to LP, YP, or allowed to regenerate naturally (NAT) to mixed hardwoods did not differ in plant species richness from the adjacent mature hardwood forests (UN-CUT). These results are not surprising to those who have planted LP on hardwood sites and had to control the hardwood and herbaceous competition that develops in the young stands. Richness has been shown to increase immediately after harvest and decline with time (Baker and Hodges 1998, Hammond and others 1998). Twenty-four years have likely been sufficient at this site to return the species numbers to the levels of the surrounding mature stand.

While there was not a significant difference in the woody plant richness of the non-EWP plots, there was likely a change in the relative abundance of different species, a pattern found after harvest in Southern Appalachian forests (Oliver 1980, Parker and Swank 1982). Numbers of unique species (those found only in one plot type) were actually higher in the planted sites and lowest in the uncut forest and naturally regenerated plots.

Areas planted to EWP did exhibit reduced plant richness. One possible explanation for the difference in EWP is the high leaf area it supports and the reduced light levels at the forest floor. However, even EWP plots with reduced basal area (pine or hardwood) and presumably more open canopies exhibited fewer species than LP, YP, or UNCUT plots with similar basal areas (figure 4). Because other coniferous species such as Eastern hemlock (*Tsuga canadensis* (L.) Carr.) have been shown to influence species distributions through effects on soil properties (Beatty 1984), one future area of investigation will be potential differences in soil properties beneath the EWP relative to the other plots.

Studies have shown variable effects of competition control on species richness in pine plantations. While woody competition control had no effect on understory species richness in 12-14 year old LP plantations in the Virginia Piedmont, canopy woody plant richness was reduced by either woody plant or herbaceous control (Shabenberger and Zedaker 1999). While there was no effect of broadcast herbicide treatments on the overstory or understory plant richness in planted LP on the Georgia Piedmont after seven years (Boyd and others 1995), non-pine woody competition control increased forb and grass cover in 8 to 11 year-old longleaf pine (*Pinus palustris* Mill.) plantations (Harrington and Edwards 1999).

The injection of residual stems at harvest had a negative impact on species richness in the planted pine sites in this study, but resulted in an increase in richness in the hardwood sites. While the only difference that was statistically significant (a = 0.05) was the increase with INJ in the YP plots, the downward trend within the pines was very consistent, and with a larger number of samples would likely have shown statistically significant differences as well.

The difference in the response of richness in the pine and deciduous hardwood plots is possibly due to differences in the rate of full site occupancy in the INJ pines and hardwoods. Injection in the pines likely allowed the fast growing pines to fully occupy the sites and prevented the successful establishment of other species. The overall slower growth of hardwoods, and the removal of some of the hardwood basal area through injection in the INJ hardwood plots would have provided additional resources (light, moisture, etc.) for other species to become established.

The increased richness in the injected hardwood sites was due to herbaceous, not woody, species. Woody plants declined slightly in INJ plots of all species (figure 2). While changes in woody plant species were generally small (losses of 1 to 4 per 100 square meters), changes in herbaceous species ranged from -8 in pines to +18 in YP. Hammond and others (1998) also found that changes in woody plant diversity were generally less than those of herbaceous species after harvest of southern Appalachian mixed oak sites.

The plots with the highest species richness and the greatest increase in richness with injection were the YP(INJ) plots. This is possibly due to the increased light that passes through YP crowns relative to oaks. While YP actually dominated some of the YP(INJ) plots, oaks (white, scarlet, and black) dominated all of the YP(NON-INJ) plots as well as all of the NAT plots.

While one possible explanation for differences in species richness beneath the pines could be the effects of high pine basal area, the explanation does not appear to apply to the results of this study. There was no apparent relationship between species richness and either total or pine basal area at either the 900 square meter or 100 square meter plot size except a slight decline in YP (figure 4).

CONCLUSIONS

The effect of planting pine on plant species richness will depend upon the species of pine planted. Species numbers in 24-year-old LP on the Cumberland Plateau were not significantly different from planted YP, NAT, or the surrounding older hardwood forest. Planting EWP, however, did reduce plant diversity, and competition control increased the overall effect.

The study area did not receive any intermediate stand treatments other than the release of EWP at age 6. Since injection of competing stems at harvest caused slight reductions in species richness, it is possible that more intensive management would have a greater impact on plant richness. It is interesting to note, however, that injection of residuals at harvest actually appeared to increase richness in the hardwood stands. Thus silvicultural harvest of mixed-oak stands may tend to foster greater plant richness than harvests which leave more residual stems on the site.

ACKNOWLEDGMENTS

This study was made possible through a grant from the USDA Forest Service Southern Research Station. Many thanks to Charles E. McGee and the scientists at the USDA Forest Service Sewanee Silviculture Lab for their forethought and careful work in the design and implementation of the original study. Special thanks to Charles F. Grimes, Forest Service Technician, for his many hours of assistance in the collection and entry of data.

REFERENCES

Baker, J.C.; Hodges, J.D. 1998. Changes in woody stem species diversity over time following clearcutting in the Mississippi river floodplain. in: Waldrop, T.A. (ed.) Proceedings of the Ninth Biennial Southern Silvicultural Research Conference. February 25-27, 1997, Clemson, SC. Gen. Tech. Rep. SRS-20. Asheville, NC: U.S.Department of Agriculture, Forest Service, Southern Research Station. 468-472.

Beatty, S.W. 1984. Influence of microtopography and canopy species on spatial patterns of forest understory plants. Ecology. 65(5): 1406-1419.

Boyd, R.S.; Freeman, J.D.; Miller, J.H.; Edwards M.B. 1995. Forest herbicide influences on floristic diversity seven years after broadcast pine release in central Georgia, USA. New Forests 10(1): 17-34.

Czekanowski, J. 1913. Zarys Metod Statystycznyck. Warsaw.

Dethero, J.B. Jr. 1992. Stand development of white pine and competing vegetation on the Cumberland Plateau, TN. School of Forestry and Environmental Studies, Duke University. Masters thesis.

Hammond, D.N.; Smith, D.W.; Zedaker, S.M.; Wright, D.K.; Thompson, J.W. 1998. Floral diversity following harvest on southern Appalachian mixed oak sites. In: Waldrop, T.A. (ed.) Proceedings of the Ninth Biennial Southern Silvicultural Research Conference. February 25-27, 1997, Clemson, SC. Gen. Tech. Rep. SRS-20. Ashville, NC: U.S. Department of Agriculture, Forest Service. Southern Research Station: 461-465.

Harrington, T.B.; Edwards, M.B. 1999. Understory vegetation, resource availability, and litterfall responses to pine thinning and woody vegetation control in longleaf pine plantations. Canadian Journal of Forest Research. 29(7): 1055-1064.

Hepp, Todd E. 1989. Pine and Hardwood regeneration options on a Cumberland Plateau Site: An economic perspective. In: Waldrop, Thomas A. (ed.) Proceedings of Pine Hardwood Mixtures: A Symposium on Management and Ecology of the Type. 1989 April 18-19, Atlanta, GA, Gen. Tech. Rep. SE-58. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 223-229.

Krochmal, A.; Kologiski, R. 1974. Understory plants in a mature loblolly pine plantation in North Carolina. Research Note SE-208 USDA Forest Service Southeastern Forest Experiment Station, Asheville, NC. 8 p.

McGee, Charles E. 1980. Expanding options for reforestation of the Cumbedand Plateau. Southern Journal of Applied Forestry. 4(4):158-162.

McGee, Charles E. 1982. Low quality hardwood stands. Opportunities for management in the interior uplands. Gen. Tech. Rep. SO-40. U.S.Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, LA. 22 p.

McGee, Charles E. 1986. Regeneration after shear felling and chipping of upland hardwoods. Research Paper. SO-224. U.S.Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, LA. 22 p.

McMinn, J.W. 1998. Influence of harvest variables on woody plant diversity in upper coastal plain mixed types. In: Waldrop, T.A. (ed.) Proceedings of the Ninth Biennial Southern Silvicultural Research Conference. February 25-27, 1997, Clemson, SC. Gen. Tech. Rep. SRS-20. Asheville, NC: U.S.Department of Agriculture Forest Service, Southern Research Station: 466-467.

Oliver, C.D. 1980. Forest development in North America following major disturbances. Forest Ecology Management. 3: 153-l 68.

Parker, G.R., and Swank, W.T. 1982. Tree species response to clear-cutting a southern Appalachian watershed. American Midland Nationalist. 108(2): 304-310.

Peet, R.K., Wentworth, T.R., and White, P.S. 1998. A **flexible,** multipurpose method for recording vegetation composition and structure. Castanea 63(3): 262-274.

Shabenberger, L.E., and Zedaker, S.M. 1999. Relationships between loblolly pine yield and woody plant diversity in Virginia Piedmont plantations. Canadian Journal of Forest Research. 29(7): 1065-1072.

Smalley, G.W. 1982. Classification and evaluation of forest sites on the mid-Cumberland Plateau. Gen. Tech. Rep. SO-38. U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, LA. 58 p.

Wender, B.W., Hood, S.M., Smith, D.W., Zedaker, S.M., and Loftis, D.L. 1999. Response of vascular plant communities to harvest in southern Appalachain mixed-oak forests: Two year results. In: Haywood, J.D. (ed.) Proceedings of the Tenth Biennial Southern Silvicultural Research Conference, February 16-18, 1999, Shreveport, LA. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 34-38.