REGENERATION POTENTIAL OF SELECTED FORESTED STANDS ON THE CUMBERLAND PLATEAU OF NORTH ALABAMA

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Abstract—Forested areas in the Cumberland Plateau region have experienced a myriad of disturbances over the last century. As a result, hardwood forests, such as those found in north Alabama, contain a mixture of species with wide ranges of shade tolerance and growth rates. Both site characteristics and past disturbance history have contributed to stands that are considered low to medium quality. Research into the outcome of regenerating these stands is limited. In this paper, we evaluated possible regeneration outcomes in several stands using a regeneration model that ranks expected postharvest performance based on reproduction origin, size, and competitiveness.

INTRODUCTION

The history of disturbance in the lower Cumberland Plateau region is similar to other forested sites that are dominated by mixed upland hardwoods. Harvesting practices have generally tended toward high grading, leading to stands of lower quality than expected on many sites. One possible reason for the lack of management in these upland forests may be a high level of uncertainty about viable silvicultural options and their results (Dubois and others 1997). Loftis (1992) previously outlined two problems associated with regenerating these stands. First, oaks (*Quercus* spp.) demonstrate better regeneration on lower quality, xeric sites, and second, oaks are poor competitors with other species, particularly yellow-poplar (*Liriodendron tulipifera* L.) and shade-tolerant canopy species.

Most desirable species in oak-dominated forests or in forests where oaks are prominent components are intolerant of shade. Therefore, all or most of a stand must be removed in order to develop a new age class.

Natural regeneration comes from three sources: (1) stump or root sprouts, (2) advance reproduction, and (3) new seedlings established after a disturbance (Beck 1980). The oak component in a new stand comes predominantly from advance reproduction and stump sprouts (Beck 1970, Loftis 1990, McQuilken 1975, Roach and Gingrich 1968, Sander 1972, Sander and Clark 1971). That is, these pre-existing vegetative structures persist through the disturbance of a regeneration cutting. Acorns that germinate after cutting provide new seedlings, but growth of these seedlings is slow, and they rarely reach a dominant or codominant position in the new stands (Loftis 1983, Sander 1972). Yellow-poplar, a major competitor with oaks on productive sites, demonstrates a different reproductive strategy. While new yellow-poplar in a stand may also come from stump sprouts from trees removed during the harvest and advance reproduction that existed prior to cutting, it also regenerates successfully from new seedlings established after harvest (Beck 1970, Clark and Boyce 1964). Seedlings are often very numerous and on better sites can dominate the composition of the new stand (Beck and Hooper 1986, Merz and Boyce 1958, Sander and Clark 1971). In some other upland hardwood systems, desirable species such as ash (*Fraxinus* spp.) and black cherry (*Prunus serotina* Ehrh.) can also regenerate from new seedlings.

The oak strategy—pre-existing vegetative structures persisting through disturbance—is characteristic of the vast majority of upland hardwood species (Beck 1980, Johnson 1977, Loftis 1990). Prior to stand disturbance, because most species depend on advanced growth, an inventory of the number and size-class distribution of each species along with an estimate of new seedlings can predict the postharvest species composition. Researchers have developed methods for evaluating the natural regeneration potential of upland oak forests (Johnson 1977; Johnson and Sander 1988; Loftis 1988, 1990; Lowell and others 1987; Marquis and Ernst 1988; Sander and others 1976, 1984; Waldrop and others 1986). Following a model developed by Loftis (1989), this study uses size of advance growth, estimates of new seedling establishment, and competitiveness of various regeneration sources present to predict species composition after heavy regeneration cuts on two distinct land types. This paper examines model predictions of regeneration on stands located in north Alabama and compares these predictions between stands found on two distinct ecoregions.

SITES

Six upland hardwood stands located in Jackson County, AL, were surveyed in the summer of 2001. These stands can be broadly divided into two groups associated with the strongly dissected southern portion the mid-Cumberland Plateau region (Smalley 1982).

The first group of stands was located on the strongly dissected margins and sides of the plateau (the escarpment). The second group was located on the weakly dissected plateau surface (the plateau). The uniqueness of testing how stands located on these two landscape associations lies in their physiography and management potential. On

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the plateau, soils are moderately deep-to-deep, loamy, and clayey; slope does not exceed 10 percent. Soil drainage is considered well drained, and soil fertility is low. Site index is 60 (base age 50) for upland oaks and 85 (base age 50) for yellow-poplar, which typically occurs on concave surfaces on the plateau (Smalley Land type 1, broad, undulating sandstone uplands) (Smalley 1982). Oak reproduction is usually prolific on these sites, although tree size may be small. Clearcutting is commonly employed for regeneration, because competition is sparse and oak reproduction numbers are high.

On the escarpment, soils are deep to very deep and loamy. Soil drainage is considered well drained, soil fertility is moderate to moderately low, while slopes range from 5 to 70 percent. Stands on the escarpment surveyed for this study have slopes from 15 to 30 percent. Upland oak site index is 75 to 80, and yellow-poplar site index is 100 (Smalley Land type 16, plateau escarpment and upper sandstone slopes and benches, north aspect) (Smalley 1982). These stands are mixed mesophytic types; beneath mature stands oak reproduction numbers are low, the size is typically small, and competition, particularly by yellow-poplar, is great.

PROCEDURES

Researchers have studied species composition of regeneration and its predicted response following disturbance in the Southern Appalachian forest and in other predominantly deciduous forest regions. Prediction of oak response has led to the development of a regeneration model (Loftis 1989). Composition of a new stand following a regeneration cut is a function of the species composition and size structure of the advance reproduction and overstory of the existing stand; as well, new seedlings become established shortly after harvest. In particular, the model uses height as a basis for ranking expected postharvest performance of advance reproduction. Stump sprouts of the various species (from stems > 1.5 inches in diameter at breast height (d.b.h.) are assigned a rank for expected postharvest performance and a probability of sprouting. If data are available, a provision is also made for estimating probability of sprouting as a function of stem d.b.h. For the few species able to regenerate from new seedlings established after disturbance, a ranking of expected postharvest performance is assigned to new seedlings, and a probability of new seedling establishment is estimated.

The regeneration model accompanies an inventory of the existing stand that uses small (0.01 acre) regeneration plots to enumerate all existing regeneration sources. In particular, the model uses advance reproduction by height class and overstory trees (stems > 1.5 inches d.b.h.) that can potentially produce stump sprouts. The best performing regeneration sources present on each plot are chosen as "winners" based on their competitive rankings (table 1). Rules in the model chose fewer winners when space-consuming stump sprouts occur, and algorithms deal with ties if numerous individuals have the same rank.

Choosing winners on each plot in this fashion treats competition explicitly; i.e., the best competitors on these small plots are the winners. The use of small regeneration plots provides a representation of the variation in competitive situations in the stand. Combined data from the individual plots provide a summary of stand-level results. Overall, the results provide a projection of likely species composition of dominant and codominant stems at the time of crown closure. Since there are stochastic elements in the model, multiple simulations provide not only a mean regeneration outcome, but also a range of regeneration outcomes.

Six stands were inventoried in the summer of 2001. Twenty-one regeneration plots were randomly located within each stand. All trees on a 0.01-acre plot were tallied by species and 1-foot height classes following the categories 0 to 0.9 feet, 1.0 to 1.9 feet, 2.0 to 2.9 feet, 3.0 to 3.9 feet, > 4.0 feet but < 1.4 inches d.b.h., and > 1.5 inches d.b.h. Sixty-three 0.01-acre plots were inventoried on forested tracts on the escarpment (3 stands with 21 inventory plots each), and 63 were inventoried on the plateau. Overstory tree data (species, height, and d.b.h.) were obtained on 0.025-acre plots corresponding to the regeneration plots. Each stand was run through the regeneration model 20 times, and model output for the stand summary was assessed. The site index used for the plots on the plateau was < 75; site index for stands on the escarpment was set at > 75.

Table 1—Ranking of expected postharvest performance

Ranking	Expected postharvest performance
1	Yellow-poplar-SP, black cherry-SP, black locust-SP, basswood-SP
2	Red maple-SP, sugar maple-SP, silverbell-SP, Fraser magnolia-SP, cucumber-SP, ash-SP, birch-SP, white pine-L, yellow-poplar-L, black cherry-L, birch-L
3	Basswood-L, yellow-poplar-M, black cherry-M, birch-M, silverbell-L, Fraser magnolia-L
4	Oak-SP, oak-L, ash-L, red maple-L, cucumber-L, hickory-SP, dogwood-SP, sourwood-SP, blackgum-SP, beech-SP, buckeye-SP, yellow-poplar-S, birch-S, black cherry-S, sugar maple-L, hemlock-L, white pine-M
5	Yellow-poplar-SE, black cherry-SE, birch-SE, oak-M, basswood-M, ash-M, red maple-M, silverbell-M, Fraser magnolia-M, cucumber-M, white oak-SP, hickory-L, dogwood-L, sourwood-L, blackgum-L, beech-L, buckeye-L, fire cherry-SE, sugar maple-M
6	Hickory-M, white oak-M, sourwood-M, blackgum-M, beech-M, buckeye-M, hemlock-M, white pine-S
7	Oak-S, ash-S, basswood-S, silverbell-S, Fraser magnolia-S, red maple-S, dogwood-M
8	White oak-S, hickory-S, dogwood-S, sourwood-S, blackgum-S, beech-S, buckeye-S

SP = stump sprout; L = large advance reproduction (> 4 feet; > 3 feet for yellow-poplar); M = medium advance reproduction (> 2 feet; ≥ 1 feet < 3 ft for yellow-poplar); S = small advance reproduction (< 2 feet; < 1 ft for yellow-poplar); SE = new seedlings established after harvest.

Table 2—Preharvest stand composition for escarpment and plateau stands in north Alabama

	Escarpment				Plateau			
Species	BA/A	Total	SPA	Total	BA/A	Total	SPA	Total
		%		%		%		%
Red oaks	11.5	11	6	5	56.6	44	44	8
White oaks	27.9	26	19	15	45.9	35	208	38
Ash2.3	2	3	2	0	0	0	0	
Black cherry	1	1	1	1	0	0	0	0
Black locust	1.5	1	3	2	0	0	0	0
Blackgum	6.6	6	8	6	1.7	1	52	9
Basswood	0.9	1	2	2	0	0	0	0
Beech	2.6	2	4	3	0	0	0	0
Dogwood	0.4	0	1	1	0.1	0	4	1
Hickories	18.2	17	22	18	5	4	22	4
Red maple	4.4	4	11	9	7.6	6	82	15
Sassafras	0.8	0.5	2	2	1.3	1	18	3
Sourwood	1.7	2	4	3	9.5	7	114	21
Yellow-poplar	14	13	13	10	2.6	2	8	1
Sugar maple	14.1	13	23	19	0	0	0	0
All others	0.7	0.5	2	2	0.04	0	2	0
Total	108.6	100	124	100	130.3	100	554	100

BA/A = basal area per acre in square feet; SPA = number of stems per acre.

RESULTS

Tree stand composition differed at each site. Stands located on the plateau averaged 130.3 square feet of basal area per acre (BA/A) and had 554 stems per acre (SPA) (table 2). In these stands the dominant species were oaks (*Q. alba* L., *Q. prinus* L., *Q. velutina* Lamarck, *Q. coccinea* Muenchh.), representing 79 percent of the total BA/A. Other common mid- and overstory species on the plateau included sourwood (*Oxydendrum arboreum* DC.), red maple (*Acer rubrum* L.), and hickory [*Carya glabra* Sweet, *C. ovata* K., *C. glabra* var. *odorata* (Marsh.) Little,*C. ovalis* (Wangenh.) Sarg.], representing 7, 6, and 4 percent of the total BA/A. On the escarpment, basal area averaged 108.6 square feet per acre, with 124 SPA. Oaks (*Q. alba*, *Q. prinus*, *Q. velutina*, *Q. rubra* L.) accounted for 37 percent of the total BA/A of stands on the escarpment, followed by hickories (17 percent), sugar maple (*A. saccharum* Marsh.)(13 percent), and yellow-poplar (13 percent). Species richness was higher on the escarpment compared with the plateau.

There were more mid- and overstory canopy (canopy) SPA on the escarpment compared with the plateau. Escarpment trees had a quadratic mean diameter (q.m.d.) of 11.4 inches, with a range from 1.6 to 35.8 inches d.b.h. Quadratic mean diameter of plateau trees was 5.4 inches (1.6 to 24.0 inches d.b.h. range). Red oaks on the escarpment averaged 6 SPA, were 11 percent of the total BA/A, and had a q.m.d. of 18.7 inches. White oaks, at 19 SPA and 26 percent of the total BA/A, averaged 16.4 inches q.m.d. The q.m.d. for escarpment sourwood, red maple, black locust (*Robinia pseudoacacia* L.), sassafras [*Sassafras albidum* (Nutt) Nees], sugar maple, and yellow-poplar was 10.1 inches. White oaks on the plateau were 35 percent of the total BA/A, averaging 208 SPA, 6.3 inches q.m.d., with a range of 1.9 to 16.0 inches d.b.h. Plateau red oaks had 44 percent of the total BA/A and 44 SPA, averaging 15.4 inches q.m.d. (range 1.6 to 27.4 inches d.b.h.). The q.m.d. of plateau blackgum (*Nyssa sylvatica* Marsh.), sourwood, red maple, and sassafras was 3.5 inches.

The regeneration tally appears in table 3. There were 9,713 SPA tallied for plateau stands and 9,527 SPA for escarpment stands. Of these totals, 67 percent of plateau reproduction and 66 percent of escarpment reproduction were < 1 foot in height. The majority of these small size-class stems was in the "other" species category (*Diospyros virginiana* L., *Magnolia acuminata* L., *Ulmus* spp., *Cercis canadensis* L., *Ostrya* spp., *Ilex* spp., *Vaccinium* spp., and others). Small stems of oak were 28 percent of the total on the plateau and 13 percent on the escarpment. On the plateau, 468 SPA were > 1.5 inches d.b.h., or 5 percent of the reproduction total. Species distribution in this size class was 31 percent white oaks, 21 percent sourwood, 14 percent blackgum, and 13 percent red maple. On the escarpment, 229 SPA were 1.5 inches d.b.h. or larger (4 percent of the total number of stems) and were distributed as 32 percent sugar maple, 15 percent others, 11 percent hickory, and 9 percent blackgum.

The model predictions of SPA at crown closure appear in table 4. The model predicted an average of 462 SPA for stands on the escarpment, consisting of 27 percent black cherry, 21 percent black locust, 15 percent sugar maple, and 12 percent yellow-poplar. For plateau stands, the model

Table 3—Preharvest regeneration average stems per acre and percent of totals by size classes for escarpment and plateau stands in north Alabama

Species	< 1 foot				> 1 foot – < 1.5 feet d.b.h.				> 1.5 feet d.b.h.				All classes			
	Escarpment		Plateau		Escarpment		Plateau		Escarpment		Plateau		Escarpment		Plateau	
	ASPA	Total	ASPA	Total	ASPA	Total	ASPA	Total	ASPA	Total	ASPA	Total	ASPA	Total	ASPA	Total
	no.	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*	*no.*	*%*
Red oaks	186	3	1,014	16	16	1	162	6	3	1	38	8	205	2	1,214	13
White oaks	649	10	790	12	29	1	168	6	14	6	143	31	692	7	1,102	11
Ash	281	4	14	0	141	5	3	0	13	6	0	0	435	5	17	0
Black cherry	235	4	79	1	65	2	40	1	0	0	0	0	300	3	119	1
Black locust	5	0	5	0	14	0	17	1	2	1	2	0	21	0	24	0
Blackgum	171	3	90	1	89	3	113	4	21	9	65	14	281	3	268	3
Basswood	2	0	0	0	11	0	0	0	0	0	0	0	13	0	0	0
Beech	27	0	2	0	113	4	5	0	13	6	0	0	152	2	6	0
Dogwood	3	0	0	0	17	1	0	0	2	1	0	0	22	0	0	0
Hickories	332	5	225	3	48	2	57	2	25	11	40	8	405	4	322	3
Red maple	562	9	571	9	67	2	179	6	11	5	60	13	640	7	810	8
Sassafras	275	4	1,090	17	130	4	279	10	3	1	13	3	408	4	1,383	14
Sourwood	11	0	2	0	11	0	75	3	8	3	97	21	30	0	173	2
Yellow-poplar	29	0	0	0	13	0	2	0	6	3	3	1	48	0	5	0
Sugar maple	1,211	19	0	0	360	12	0	0	73	32	0	0	1,644	17	0	0
All others	2,287	37	2,595	40	1,910	63	1,667	60	35	15	8	2	4,232	44	4,270	44
Totals	6,265		6,478		3,033		2,767		229		468		9,527		9,713	

ASPA = average stems per acre; d.b.h. = diameter at breast height.

Table 4—Average stems per acre of predicted stand-level winners and post-harvest proportion in stand by species for escarpment and plateau stands in North Alabama[a]

Species	Escarpment			Plateau		
	Predicted		Preharvest regeneration	Predicted		Preharvest regeneration
	SPA	Total	total	SPA	Total	total
		- - - - *percent* - - - -			- - - - - *percent* - - - - -	
Red oaks	3	1	2	16	5	13
White oaks	5	1	7	61	18	11
Ash	23	5	5	0	0	0
Black cherry	124	27	3	28	8	1
Black locust	97	21	0	15	4	0
Blackgum	12	3	3	44	13	3
Basswood	4	1	0	0	0	0
Beech	6	1	2	0	0	0
Dogwood	2	0.5	0	0	0	0
Hickories	10	2	4	20	6	3
Red maple	23	5	7	69	20	8
Sassafras	5	0.5	4	32	9	14
Sourwood	2	1	0	47	14	2
Yellow-poplar	56	12	0	2	1	0
Sugar maple	71	15	17	0	0	0
All others	19	4	44	7	2	44
Totals	462			341		

SPA = stems per acre.

[a] Regeneration percentages for all size classes for preharvest stand data are also listed.

predicted 341 SPA, with 23 percent of this total oak, 20 percent red maple, 14 percent sourwood, and 13 percent blackgum. For those species categorized in "all others," note that these species are not necessarily eliminated from the new stand, but their dominance is altered in the predicted output.

The total predicted SPA of all oak species was greater on the plateau (77 SPA) compared with the escarpment (8 SPA). This difference is a reflection of the advanced growth-dependent reproductive strategy of oak and of stand composition prior to disturbance. On the plateau, 79 percent of the BA/A, and 46 percent of canopy SPA were oak. Oaks were also well represented in the reproduction tallies, averaging 24 percent of the total SPA, with 22 percent of the total oaks tallied > 1 foot tall. Large advance reproduction appeared as highly ranked winners in the model output (ranked fourth as stump sprouts). Oaks' competition were red maple stump sprouts (ranked second), sourwood stump sprouts and large seedlings (ranked fourth and second, respectively), and blackgum stump sprouts (ranked fourth). On the escarpment, oaks were 37 percent of the total stand BA/A, and 20 percent of the total canopy SPA. Only 9 percent of the advance reproduction total was oak, and only 7 percent of all oak advance reproduction was > 1 foot tall.

The four primary species competing with oak on the escarpment were black cherry, black locust, yellow-poplar, and sugar maple. Sugar maple was well represented on the escarpment (13 percent of the BA/A, and 23 percent of the canopy SPA). Reproduction of sugar maple averaged 1,644 SPA, with 74 percent of these stems < 1 foot tall. The shade tolerance of sugar maple and its ability to reproduce under an overstory of sugar maple and other less tolerant species, as well as the escarpment's higher site quality compared to the plateau, supports these predictions. The presence of yellow-poplar in the overstory should have increased the likelihood of new yellow-poplar seedlings postdisturbance, but did not (12 percent predicted postdisturbance compared with 13 percent of total SPA canopy predisturbance). Black cherry and black locust were predicted as higher proportions of the new escarpment stands than was yellow-poplar. Both yellow-poplar and sugar maple were minor components of plateau stands and retained this status in the new stands.

The proportion of the stands occupied by black cherry and black locust was predicted to increase substantially following overstory removal. On the escarpment, black cherry stems increased from 1 canopy SPA to 124. The presence of black cherry in the overstory (3 percent of the BA/A) and the presence of medium-sized reproduction (22 percent of the total reproduction, 65 of 300 black cherry SPA) contributed to its response, ranked first as stump sprouts and third as medium-sized reproduction. Although black cherry was not present in the overstory on the plateau, 17 SPA were tallied as advanced reproduction, and 43 percent of the total was medium-sized. The model predicted 28 SPA of black cherry, or 8 percent of the total stand composition. The lack of other high-ranking competition allowed for black cherry to assume this proportion in the new stand.

On the escarpment, black locust was predicted to have 97 SPA, or 21 percent of the total number of stems. Prior to disturbance, black locust had three SPA canopy and 1 percent of the BA/A. The number of black locust stems tallied was 21 SPA, with 67 percent of these stems in the medium-sized reproduction class. These black locust were winners (ranked first) postdisturbance, primarily as sprouts. Although black locust was not present in the overstory on the plateau, 71 percent of the 24 SPA tallied in the plateau reproduction were medium sized. Postdisturbance, these contributed to 15 SPA of black locust, or 4 percent of the total SPA.

CONCLUSIONS

Topographic position often dictates management in the Cumberland Plateau region. In general, clearcutting regenerates stands on the plateau, as lower site quality, less competition from other species, and relatively high numbers of advance reproduction of oaks contribute to a desirable species composition in the next stand. After disturbance, 23 percent of the new stand was predicted to be oak, followed by red maple and sourwood.

If the preservation of the oak component for escarpment stands is desired, management techniques can encourage more and larger advanced oak reproduction and can reduce competition. Following Loftis (1983), altering the light level by reducing overstory or midstory basal area is being tested on escarpment stands to examine the impact on oak regeneration. The large increase in black cherry and black locust and the relatively unchanged proportion of yellow-poplar that the model predicted were surprising. Black cherry is a small component of escarpment stands and most likely will not be competitive after crown closure. The rapid growth, shade intolerance, and short-lived nature of black locust negates its importance as a long-term competitor (McGee and Hooper 1975). However, yellow-poplar may play a more dominant role than predicted by the model, as documented by others on similar sites (Beck 1970, Kuers and Kuthe 1998, Loftis 1988, McGee 1967). Results from these predictions will be compared with measured response in the field, and the model will be adjusted accordingly.

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