SPECIES COMPOSITION OF REGENERATION AFTER

CLEARCUTTING SOUTHERN APPALACHIAN HARDWOODS[1/]

David L. Loftis[2/]

Abstract.--Regeneration after clearcutting of Southern Appalachian hardwood stands varies substantially in species composition not only among sites of different quality and previous-stand composition, but also among sites of similar quality and similar previous-stand composition. Severe competition from less desirable species for available growing space is common in regenerated stands. The appropriate use of clearcutting, the need for quantitative models to predict species composition after harvest cutting, and the need for alternative cultural practices are discussed.

INTRODUCTION

Over the last 2 decades, clearcutting has become a widespread practice in Appalachian hardwood forests. Some land managers, including the USDA Forest Service, have adopted clearcutting as their primary harvesting practice. At least one reason for its adoption was the perception that single-tree selection was not providing satisfactory regeneration--a perception that has been proved correct by long-term research (Della-Bianca and Beck 1985). As an even-aged alternative, the practice of clearcutting appeared promising based on historical observations (Frothingham 1931) as well as current research (Merz and Boyce 1956, McGee 1975, McGee and Hooper 1970). And, of course, the short-term economics of timber harvesting--the higher volumes per acre harvested--tend to favor clearcutting.

What kinds of stands are we creating for the future? Is species composition what we hoped it would be? The data from a small but representative sample of operational clearcuts suggest that, while new stands created by clearcutting have generally been acceptable, the results have been quite variable.

1/ Paper presented at Fifth Biennial Southern Silviculture Research Conference, Memphis, TN, November 1-3, 1988.

2/ Research Forester, Southeastern Forest Experiment Station, Asheville, NC 28806.

SOURCES OF REGENERATION

Species composition of a stand created by clearcutting is a function of the sources of regeneration--advance growth and the potential for new seedling establishment--present on the site at the time of clearcutting. All hardwoods can regenerate from stump sprouts, and all hardwoods can regenerate from advance reproduction when it is present. But only yellow-poplar, birches, shortleaf pine, and, in some cases, black cherry regenerate reliably from new seedlings established after a harvest cut (table 1). All other species require advance growth--either advance reproduction or rootstocks of trees larger than 2 inches d.b.h. that produce stump sprouts or root sprouts after a harvest cut.

A distinction must be made between clearcutting as a harvesting practice (the definition used in this paper), and clearcutting as a category in classifications of regeneration methods. The Society of American Foresters equates clearcutting with clean felling, "the removal of the entire standing crop" (Society of American Foresters 1971). This usage defines clearcutting in terms of harvesting. In silviculture, clearcutting as a category in classifications of regeneration methods has a more restricted meaning. The temporal arrangement of cuttings is only one criterion used to classify a regeneration method, even in the simplest classification systems. The other criterion is the origin or source of regeneration that ultimately dominates the new stand (Smith 1962). Thus, the clearcutting method of regeneration is the removal of the entire stand in one cutting with regeneration obtained from new seedlings established after the harvest cut.

Table 1.--Regeneration sources for some Southern Appalachian tree species

Species	Shade tolerance
--Regeneration from new seedlings established after cutting--	
Yellow-poplar (Liriodendron tulipifera L.)	intolerant
Sweet birch (Betula lenta L.)	intermediate
Black cherry (Prunus serotina Ehrh.)*	intolerant
Yellow pines (Pinus spp.)	intolerant
--Advance-growth-dependent species--	
Black cherry (Prunus serotina Ehrh.)*	intolerant
Black locust (Robinia pseudoacacia L)	intolerant
Red oak (Quercus rubra L.)	intermediate
White oak (Quercus alba L.)	intermediate
Chestnut oak (Quercus prinus L.)	intermediate
Black oak (Quercus velutina Lam.)	intermediate
Scarlet oak (Quercus coccinea Muenchh.)	intermediate
White ash (Fraxinus americana L.)	intermediate
Cucumbertree (Magnolia acuminata L.)	intermediate
White pine (Pinus strobus L.)	intermediate to tolerant
Hickories (Carya spp.)	intermediate to tolerant
Basswood (Tilia heterophylla Vent.)	intermediate to tolerant
Red maple (Acer rubrum L.)	intermediate to tolerant
Sugar maple (Acer saccharum Marsh.)	tolerant
Beech (Fagus grandifolia Ehrh.)	tolerant
Buckeye (Aesculus octandra Marsh.)	tolerant
Hemlock (Tsuga canadensis (L.) Carr.)	tolerant
Dogwood (Cornus florida L.)	tolerant
Silverbell (Halesia carolina L.)	tolerant
Sourwood (Oxydendrum arboreum (L.) DC)	tolerant

* Black cherry, in some cases, does regenerate from new seedlings established after harvest; but, in many cases, regeneration appears to depend on the presence of advance reproduction.

This distinction is not trivial. It might not be reasonable to expect the public to understand it, but for the silviculturist this distinction is critically important for regeneration prescription. It focuses attention on the question that must be asked: what will be the source or sources of regeneration for the next stand?

DESCRIPTION OF STUDY AREAS

Nine sites on the Pisgah Ranger District of the Pisgah National Forest near Brevard, North Carolina, were selected for sampling. All were accessible and had developed after clearcutting 9 to 11 years ago. They are representative of the clearcuts I have examined over the years. The sites range in quality from oak site index 70 to 90 feet at age 50 years (Olson 1959), and from 2500 to 4000 feet above sea level. Sites of this quality produce the bulk of the high-quality sawtimber grown in the Southern Appalachians. In each case, the mature stands occupying these sites had been harvested in the recommended manner--the merchantable stand was cut by loggers, and all residual stems taller than 4.5 feet were felled with chainsaws.

Circular 0.01-acre plots were located 200 ft. apart on transect lines also 200 ft. apart--approximately 1 plot per acre. On each plot, all stems taller than 4.5 feet were tallied by species, 1-inch d.b.h. class, and stem origin--single-stemmed or sprout clump. The five most dominant stems on each plot were noted.

RESULTS AND DISCUSSION

Composition of the stands harvested from these nine sites follows the familiar pattern of second-growth stands in the Southern Appalachians (table 2). Oaks other than northern red oak dominated the lower quality sites (oak site index=70 feet). Northern red oak and yellow-poplar became more important on higher quality sites. Red maple and hickory were present on all sites. Ash, basswood, black cherry, sweet birch, cucumbertree, and sugar maple were present on one or more of the higher quality sites. The remaining merchantable volume consisted of beech, black locust, silverbell, hemlock, white pine, shortleaf pine, and black gum.

Table 2.--Species composition of mature stands harvested by clearcutting on nine sites in the Southern Appalachians

SITE	OAK SI	Y-P	NRO	OTHER OAKS	ASH-CHERRY CUC-BASS-SM	BIR	HIC	RM
			--Percent of total volume--					
1	90	64	10	21	1	1	1	2
2	90	16	17	53	0	1	2	7
3	90	52	7	32	1	1	1	1
4	90	35	3	39	0	1	1	10
5	80	23	25	41	1	1	2	7
6	80	35	22	27	2	1	5	6
7	80	10	52	20	5	1	3	6
8	70	2	3	79	0	0	2	2
9	70	3	4	79	0	0	3	1

Species Composition

My analysis of regeneration focuses on species composition of the 5 most dominant trees per 0.01 acre plot, excluding black locust. Crown closure has occurred. The species in a dominant crown position now, excluding black locust, are long-lived and are capable of occupying the growing space on the 0.01 acre plot through all or most of the rotation.

The variability in species composition among stands receiving the same treatment is obvious (table 3). Sites 1, 3, and 4 are equal in quality (SI=90), and the oak components in the previous stands on these sites were all about the same. Only sites 3 and 4 have an appreciable oak component in the regenerated stands. Likewise, sites 5 and 7 are equal in quality (SI=80) and had similar oak components in the previous stands on these sites, but the oak components in the new stands are quite different on these sites.

Table 3.--Species composition of regeneration after clearcutting on nine sites in the Southern Appalachians[1/]

SITE	Y-P	NRO	OTHER OAKS	ASH-CHERRY CUC-BASS-SM	BIR	HIC	RM	DW-SW	OTHER
			--Percent of total number of stems--						
1	46	3	1	1	19	1	15	8	6
2	23	3	16	1	12	2	18	16	9
3	35	0	14	0	10	5	21	8	7
4	26	0	11	0	2	0	17	21	23[2/]
5	41	0	8	5	0	1	18	8	19[3/]
6	16	2	4	1	0	0	14	6	57[3/]
7	14	12	13	18	2	2	10	2	27[3/]
8	30	1	19	0	8	0	20	12	10
9	19	1	32	0	4	1	15	16	12

1/ Black locust excluded.
2/ Primarily pines.
3/ Primarily silverbell.

Yellow-poplar was a relatively minor component of the previous stands on sites 8 and 9, but it is a significant component of the new stands on these sites. In contrast, yellow-poplar comprised more that one-third of the volume and oaks more than one-half of the volume of the previous stand on site 6. Yellow-poplar and the oaks are greatly reduced in importance in the new stand on site 6.

Some consistent patterns are apparent when one compares the composition of the new stands with the composition of the old stands. Oaks, particularly northern red oak, are less important in the new stands than they were in the previous stands. Red maple has increased in every case. Hickory, with a couple of exceptions, was about equally represented in the new and old stands. Where silverbell was present in the old stand, it increased dramatically in the new stands.

Stocking of Desirable Species

For timber production, yellow-poplar, oaks, hickories, ash, black cherry, basswood, cucumbertree, sugar maple, birch, and pines are the most desirable species in the area. On all but one site (6), strongly competitive stems of these species outnumber those of less desirable species (table 4). However, spatial distribution (stocking) of desirable stems will be the key to the future quality and volume of these stands. On the average, more than 20 percent of the 0.01-acre plots did not have at least one desirable stem among the most dominant 5 stems per plot (table 5). Given the longevity

Table 4.--Percent of stems of desirable and less desirable timber species regenerating after clearcutting on nine sites in the Southern Appalachians

Site	Desirables	Less desirable
	--Percent of total stems--	
1	71	29
2	57	43
3	64	36
4	57	43
5	55	45
6	23	77
7	61	39
8	58	42
9	57	43

Table 5.--Percent of plots on each of nine Southern Appalachian sites stocked with at least one dominant stem of a desirable timber species after clearcutting

Site	Stocking
	--Percent--
1	71
2	84
3	78
4	80
5	78
6	47
7	85
8	74
9	83

of the less desirable species and the lack of shade tolerance of all but one of the desirable species, I would argue that 50 years from now, these 0.01-acre plots will still not be occupied by a desirable species. In other words, clearcutting with post-harvest felling of residuals has created stands less than fully stocked with desirable species, with a consequent loss of volume yield amounting to several thousands of board feet.

AN ASSESSMENT OF CLEARCUTTING

Clearcutting to regenerate Southern Appalachian hardwoods has been generally successful, particularly in comparison with the uncertain or unfavorable results obtained with the past applications of single-tree selection. Reasonably well-stocked hardwood stands have been created, and the judicious application of herbicides promises even better stocking in future harvest cuts (Loftis 1985, Zedaker 1988). However, the variability in the relative proportions of desirable species that regenerate after clearcutting must be addressed. We have reached a stage in the evolution of hardwood silviculture in which we need to ensure that our regeneration practices are meeting our regeneration goals.

THE NEED FOR REGENERATION MODELS

If one has a goal of creating a new stand with a particular mix of desirable species, the need for predictive regeneration models that can be applied prior to implementing regeneration practices becomes obvious. If such a model predicts that the regeneration goal cannot be met by clearcutting, then some alternative regeneration method must be applied, or the goal must be changed.

Some regeneration models have already been developed. For example, I have developed a model that predicts, prior to harvest, the number of dominant and codominant northern red oak stems to be expected in the next stand from on an existing population of advance red oak reproduction (Loftis 1988). This model is based on the relationship between the probability of a red oak stem becoming dominant after harvest and its preharvest basal diameter and the quality of the site on which it is growing. Competition is considered implicitly as a function of site quality. That is, for a given size of advance red oak stem, the dominance probability decreases with increasing site quality (and competition). The model requires as input an estimate of site quality and an estimate of the size distribution of advance red oak reproduction. These estimates must be obtained from sampling in the stand prior to a regeneration cut.

I believe a model for predicting species composition, as opposed to the amount of a single species, must explicitly account for interspecific competition (or other interference mechanisms). For example, consider my subjective ranking of relative post-harvest performance of different sources of regeneration--stump sprouts (SP), large (L), medium (M) and small (S) advance reproduction, and new seedlings (SE) established after harvest:

1. yellow-poplar SP; black cherry SP
2. red maple SP; silverbell SP; cucumber SP; ash SP; basswood SP; yellow-poplar L; black cherry L; birch L
3. basswood L; yellow-poplar M; black cherry M; birch M; silverbell L
4. oak[3] SP; oak L; ash L; red maple L; cucumber L; hickory SP; dogwood SP; sourwood SP; yellow-poplar S; birch S; black cherry S
5. yellow-poplar SE; black cherry SE; birch SE; oak M; basswood M; ash M; red maple M; silverbell M; cucumber M; white oak L; hickory L; dogwood L; sourwood M
6. hickory M; white oak M; sourwood M
7. oak S; ash S; basswood S; silverbell S; red maple S; dogwood M
8. white oak S; hickory S; dogwood S; sourwood S.

Sources on the same numbered line are approximately equal in post-harvest performance. Application of this ranking to a sample from the stand being considered for regeneration using, say, 0.01-acre plots on which all sources of regeneration are enumerated would allow prediction of species composition on each 0.01-acre plot. Combining the results from all plots would yield a prediction of stand composition. Note also that the effects on species composition of using herbicides to eliminate sprout competition of less desirable species can be compared with the species composition to be expected using post-harvest felling.

This conceptually simple approach to regeneration modeling may be less than satisfying to more sophisticated modelers. I would defend this approach with some observations about regeneration modeling as an important special case of succession modeling. In silviculture, the type and timing of major disturbances are controlled. Many of the uncertainties associated with disturbance regime in more general succession models need not be part of a silvicultural regeneration model. The silviculturist must prescribe for regeneration in specific stands, rather than in oak stands or cove hardwood stands in general. Given the importance of advance growth and the observed relationship between size of advance growth and post-harvest performance, the best estimate of the population of advance growth and its size distribution is provided by measurement (sampling) rather than by a stochastically determined set of values.

---

[3] Oaks other than white oak--red, black, scarlet, and chestnut oaks.

Although this modeling framework may appear to be highly deterministic, stochastic elements can be and should be introduced where appropriate. For example, for species like yellow-poplar, which can regenerate from new seedlings established after a harvest cut, the probability that a plot will be stocked with new seedlings must be estimated. Furthermore, although I have provided a subjective ranking of post-harvest performance, the ranking should be based on quantitative relationships established from field data. For example, for advance-growth-dependent species, regression models of post-harvest growth as a function of preharvest attributes can be developed. For advance growth sampled on a 0.01-acre plot, the expected values from the regression models can be used to predict a unique output for species composition, or the variance associated with expected values from the regression models can be used to provide a range of possible outputs.

THE NEED FOR ALTERNATIVE REGENERATION METHODS

When regeneration models are developed, the silviculturist will be able to compare predicted species composition with regeneration goals. If predicted results do not meet regeneration goals, alternative regeneration methods must be considered. The ranking of post-harvest performance above provides a useful way to examine the effect on species composition of alternative regeneration methods. For example, I recently devised a shelterwood method that ensures maintenance of a red oak component in regenerated stands (Loftis 1988). The method involves a basal·area reduction from below using herbicides, leaving the main canopy largely intact, with no large canopy gaps. The overwood is removed about 10 years after this initial treatment. The effect of this treatment is to eliminate the sprouting potential of tolerant subcanopy and lower canopy species (e.g., dogwood, red maple, silverbell), while increasing the size of red oak advance reproduction. The responses of other advance-growth-dependent species to this kind of regeneration treatment must be studied.

CONCLUSIONS

In general, clearcutting, with chainsaw felling of residual trees, has created new stands reasonably well-stocked with desirable species. However, sprouts from less desirable species frequently occupy considerable growing space, reducing stocking of desirable species. As a result, yield at rotation will be well below that potentially attainable. This problem can be overcome by using herbicides prior to, at the time of, or soon after harvest.

Even among sites of similar quality and mature-stand composition, the relative proportions of desirable species in regeneration after clearcutting can be extremely variable. This variability results from the variability in the sources of regeneration present at the time of harvest. Models are needed that can predict species composition of stands to be regenerated. Further, alternative regeneration methods are needed that can be used when the predicted results of clearcutting do not meet regeneration goals.

LITERATURE CITED

Della-Bianca Lino; Beck, Donald E. 1985. Selection management in Southern Appalachian hardwoods. Southern Journal of Applied Forestry. 9(3): 191-196.

Frothingham, E.H. 1931. Timber growing and logging practice in the Southern Appalachian region. Tech. Bull. 250. Washington, D.C.: U.S. Department of Agriculture, Forest Service. 93 pp.

Loftis, David L. 1985. Preharvest herbicide treatment improves regeneration in Southern Appalachian hardwoods. Southern Journal of Applied Forestry. 9(3): 177-180.

Loftis, David L. 1988. Regenerating red oak in the Southern Appalachians: predictive models and practical application. Raleigh, NC: North Carolina State University. 62 pp. Dissertation.

McGee, Charles E. 1975. Regeneration alternatives in mixed oak stands. Res. Pap. SE-125. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 8 pp.

McGee, Charles E.; Hooper, Ralph M. 1970. Regeneration after clearcutting in the Southern Appalachians. Res. Pap. SE-70. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 12 pp.

Merz, Robert W.; Boyce, Stephen G. 1958. Reproduction of upland hardwoods in southeastern Ohio. Tech. Pap. 155. Columbus, OH: U.S. Department of Agriculture, Forest Service, Central States Forest Experiment Station. 24 pp.

Olson, David J., Jr. 1959. Site index curves for upland oak in the Southeast. Res. Notes 125. Asheville, N.C.: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 2 pp.

Society of American Foresters. 1971. Terminology of forest science, technology practice and products. Ford-Robertson, F.C., ed. Washington, D.C.: Society of American Foresters. 349 pp.

Smith, David M. 1962. The practice of silviculture. 7th ed. New York: John Wiley & Sons, Inc. 578 pp.

Zedaker, Shepard M. 1988. Herbicide and nonchemical vegetation control during hardwood regeneration. pp. 112-123. In: H. Clay Smith, Arlyn W. Perkey, William E. Kidd, Jr., eds. Guidelines for regenerating Appalachian hardwood stands; 1988 May 24-26; Morgantown, WV. SAF Publ.88-03. Morgantown, WV: West Virginia University Books, Office of Publications.