Tree Species Response to Clear-cutting a Southern Appalachian Watershed[1]

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ABSTRACT: A 16.1-ha watershed was experimentally clear-cut in 1939 and again in 1962. All material over 1 cm in diam was cut and left in place, thereby minimizing soil disturbance. Density data collected on permanent quadrats before cutting, 13 years after the first cut and 15 years following the second cut, indicate vegetation response varies by species and physiographic position. There was also a difference in response between the two clear-cuts. There was little change in number of tree species found per unit area following the two clear-cuts. However, certain species such as *Liriodendron tulipifera* became much more abundant while others decreased in abundance especially on lower slope to cove and mid to upper N and E physiographic positions following the second cut.

INTRODUCTION

Disturbances, such as clear-cut harvesting, in the eastern deciduous fore ecosystem change the relative composition of tree species (Oliver, 1980). For exampl *Liriodendron tulipifera* has been shown to increase in density relative to other speci following clear-cutting throughout most of the eastern United States (Swank an Helvey, 1970; Kovner, 1957; Merz and Boyce, 1958; Potzger and Friesner, 1934).

Seed source, vegetative and advanced reproduction, site characteristics and time year are important factors determining compositional changes of forest stands follov ing disturbance. Many tree species regenerate by stump or root sprouts or from seec lings already on the ground while others originate from stored seed pools (McGee an Hooper, 1970; Roach, 1962; Marks, 1974). Autumn and winter clear-cut harvestin has been shown to increase establishment of *Liriodendron tulipifera* seedlings (Trimb and Tryon, 1969).

The degree of disturbance appears to be more important in influencing speci change than either topography or aspect for much of the eastern United States (Me and Boyce, 1958; Roach, 1962). *Liriodendron tulipifera* has been observed to sprea across the moisture gradient from stream valleys to dry ridges in southern Indian following clear-cut harvests on the Hoosier National Forest. This apparently is not tru for central and northern hardwood forests of the Appalachian Mountains (Trimble an Hart, 1961). The length of time these composition changes remain for various pos tions along the moisture gradient has not been fully studied (Collins, 1962; Cristofoli and Cristofolini, 1967; Levering, 1968).

One of the first experimental clear-cuts in the eastern deciduous forest occurred a Coweeta Hydrologic Laboratory in the southern Appalachians. A 16.1-ha watershe (WS-13) was clear-cut in 1939 and again in 1962. These cuts are different from a com mercial clear-cut because no material was removed from the site, thereby eliminatin skid trails and logging roads.

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We report here the change in density and spatial pattern of tree species on th watershed following each clear-cut in relation to the original forest. Changes in specie composition, density and diversity are discussed in relation to physiography.

METHODS

The Coweeta basin was acquired by the U.S. Forest Service in 1924. Prior to tha time, the basin had a history of burning, grazing and selective logging (Johnson an Swank, 1973). Watershed 13, one of the experimental units in the basin, has a north eastern aspect, a mean land slope of 49%, and mean annual precipitation is ca. 182 mm.

The second-growth stand with scattered overmature trees (this watershed was selec tively logged on a 15-inch diam limit from 1918 to 1924) on WS-13 was first clear-cu between September 1939 and January 1940. Twenty-two years later the even-age coppice forest was recut in November and December 1962. All woody vegetation wa cut and left in place during both treatments to minimize soil disturbance.

Vegetation of the watershed has been sampled five times since the original inven tory of 1934. This paper discusses data from inventories of 1934, 1952 and 1977. Thes inventories occurred prior to and 13 and 15 years after the clear-cuts of 1939 and 1962 respectively. All three inventories included three transects totaling 20 evenly space plots extending from ridge to ridge on the watershed (Fig. 1). Rectangular plots of .0 ha were used in 1934 and 1952 and circular plots of .05 ha were measured in 1977 Stems of all tree species with diameters greater than 1 cm at 1.37 m aboveground wer tallied on each plot. More detailed discussion of the history and methods of WS-13 i given in Swank and Helvey (1970).

Plot elevation on the watershed ranges from 724 m on the lower transect (T-1) t 853 m on the upper transect (T-3). This elevation range is not expected to result in an major changes in vegetation due to orographic effects on climate (Shanks, 1954; Whit taker, 1956). Therefore, plots on all transects have been combined based upon thei physiographic position for discussion in this paper (Table 1). Physiographic position were determined using a map of the watershed with a 10-ft contour interval.

RESULTS

Table 1 summarizes the density of stems greater than 10 cm dbh for major specie by physiographic position before and after the two clear-cuts. *Acer rubrum, Liriodendro tulipifera* and *Quercus prinus* have increased. The greatest change in *Acer rubrum* occurre following the first clear-cut on mid to upper slope positions. In contrast, *Liriodendro tulipifera* increased on all physiographic positions with additional increases occurrin following each clear-cut. Relative density of *Quercus prinus* increased on all but the lowe slope and cove physiographic positions with most of the increase occurring followin the first clear-cut. Density of this species increased following the first cut on al physiographic positions and decreased to near precut levels following the second cut o all but upper S slope with small stream and lower slope to cove positions.

Quercus alba, Q. coccinea, Q. velutina and *Robinia pseudoacacia* changed very little i relative density following each clear-cut. *Quercus alba* remained a minor component o the community following both cuts. The largest increase in *Quercus coccinea* occurred o upper S slopes with small stream channels and ridge positions following the first clear cut. Density of this species decreased relative to precut density on all but the ridge posi tion following the second clear-cut.

All other species decreased in relative density following clear-cutting. Most decreas ing species were still present on the plots but in size classes less than 10 cm dbh as in dicated by P in Table 1. *Pinus rigida* was not sampled on any plots following the seconc clear-cut but is still present in the watershed. *Castanea dentata* declined primarily due tc chestnut blight rather than clear-cutting (McCormick and Platt, 1980). Other mino species (other species in Table 1) declined on ridge and mid to upper S and W

TABLE 1.—Density and relative density of stems (≥ 10 cm dbh) for tree species by physiographic position on Watershed 13 at Coweeta Hydrologic Laboratory before (1934) and 13 (1952) and 15 (1977) years following clear-cutting

		Physiographic Position[2]											
		R		MU-SW		U-S Stream		L-Cove		MU-NE		Weighted average all sites	
		#/ha	Rel %	#/ha	Rel %	#/ha	Rel %	#/ha	Rel %	#/ha	Rel %	#/ha	Rel %
Acer rubrum	1934	17	2.4	17	4.4	-	-	36	6.8	27	6.1	25	4.9
	1952	17	2.6	71	15.4	12	2.6	25	7.4	53	14.1	35	8.1
	1977	20	5.4	47	17.2	30	11.1	37	9.4	20	15.0	32	10.6
Carya spp.	1934	13	1.8	17	4.4	6	1.4	45	8.4	35	7.9	30	5.9
	1952	4	0.6	21	4.6	19	4.0	29	8.5	3	0.8	18	4.2
	1977	20	5.4	P[1]	-	P	-	P	-	P	-	3	0.9
Castanea dentata	1934	238	34.7	55	14.1	56	12.5	104	19.5	147	33.2	121	23.8
	1952	P	-	5	1.1	32	6.7	P	-	2	0.5	4	0.9
	1977	-	-	P	-	P	-	P	-	P	-	-	-
Cornus florida	1934	17	2.4	8	2.1	-	-	11	2.0	29	6.5	14	2.8
	1952	4	0.6	8	1.7	12	2.6	2	0.5	P	-	4	0.9
	1977	P	-	P	-	P	-	P	-	P	-	-	-
Liriodendron tulipifera	1934	8	1.2	-	-	-	-	27	5.0	P	-	12	2.4
	1952	13	1.9	-	-	-	-	80	23.7	40	10.6	42	9.8
	1977	67	17.9	27	9.9	120	44.4	194	48.9	38	28.6	111	36.6
Pinus rigida	1934	42	6.1	8	2.1	126	27.7	73	13.8	27	6.1	55	10.8
	1952	196	29.6	46	10.0	62	13.2	4	1.0	8	2.1	46	10.7
	1977	-	-	-	-	-	-	-	-	-	-	-	-
Quercus alba	1934	-	-	4	1.0	-	-	7	1.3	9	2.0	5	1.0
	1952	-	-	4	0.9	12	2.6	7	2.1	8	2.1	6	1.4
	1977	P[1]	-	P	-	-	-	11	2.9	P	-	4	1.3
Q. coccinea	1934	21	3.1	50	12.8	94	20.8	64	12.1	28	6.3	51	10.0
	1952	92	13.9	33	7.2	132	27.9	22	6.4	35	9.3	48	11.2
	1977	27	7.1	13	4.8	50	18.5	26	6.4	11	8.3	24	7.9
Q. prinus	1934	154	22.5	100	25.6	26	5.6	56	10.5	41	9.3	71	14.0
	1952	214	32.3	171	37.1	82	17.3	100	29.6	108	28.6	128	29.8
	1977	193	51.8	91	33.3	60	22.2	6	1.4	30	22.6	57	18.8

(Table 1 continued)

		R		MU-SW		U-S Stream		L-Cove		MU-NE		Weighted average all sites	
		#/ha	Rel %	#/ha	Rel %	#/ha	Rel %	#/ha	Rel %	#/ha	Rel %	#/ha	Rel %
Q. velutina	1934	17	2.4	29	7.4	P	-	16	3.0	24	5.4	18	3.5
	1952	38	5.7	9	2.0	26	5.4	11	3.2	59	15.6	26	6.0
	1977	33	8.9	20	7.3	P	-	29	7.2	4	3.0	20	6.6
Robinia pseudoacacia	1934	9	1.3	59	15.1	13	2.9	38	7.1	21	4.7	31	6.1
	1952	4	0.6	46	10.0	32	6.9	36	10.6	40	10.6	33	7.7
	1977	7	1.8	40	14.7	-	-	49	12.2	11	8.3	29	9.6
Other species[3]	1934	150	21.9	42	10.8	132	29.1	56	10.5	54	12.2	75	14.8
	1952	80	12.0	46	10.0	50	10.6	23	6.9	35	9.3	40	9.3
	1977	7	1.8	P	-	10	3.7	46	11.5	19	14.3	23	7.6
Total	1934	685		390		452		532		443		508	
	1952	662		460		471		339		391		430	
	1977	373		273		200		397		133		303	
# Samples (N)		3		3		2		8		4		20	

[1]P = species present on plot with all stems < 10 cm dbh

[2]R = ridge; MU-SW = mid to upper S and W slopes; U-S stream = upper S slope with small stream; L-Cove = lower slope to cove; MU-NE = mid to upper N and E slopes

[3]Includes *Acer pensylvanicum, A. saccharum, A. spicatum, Alnus spicatum, Amelanchier arborea, Betula lenta, Calycanthus fertilis, Castanea pumila, Diospyros virginiana, Fagus grandifolia, Fraxinus americana, Hamamelis virginiana, Kalmia latifolia, Magnolia acuminata, M. fraseri, Nyssa sylvatica, Ostrga virginiana, Oxydendrum arboreum, Prunus serotina, Pyrularia pubera, Quercus marilandica, Q. stellata, Rhododendron calendulaceum, R. maximum, Salix* spp., *Sassafras albidum, Tilia* spp., *Tsuga canadensis*

physiographic positions but remained constant on lower slope to cove and mid to uppe N and E physiographic positions. Most of the decrease in relative density occurre following the second clear-cut.

Total density (all species with stems > 10 cm dbh) remained about the same following the first clear-cut as precut density on all physiographic positions except the lowe slope and cove positions, which decreased. Total density decreased following the second clear-cut on all physiographic positions except the lower slope to cove, which wa slightly larger than density following the first clear-cut.

Weighted (number of plots) average density of stems greater than 10 cm dbh for a species was much reduced following the second clear-cut compared to the densit following the first clear-cut, although 2 additional years were available for growth. Thi reduction is believed due to the much greater sprouting and subsequent slowe diameter growth which occurred following the second cut. Swank and Helvey (197C report total density of stems (> 1 cm dbh) was 2000 per ha greater in 1969, 7 year after the second cut, than in 1948, 8 years after the first cut.

Data from this study indicate very little change in number of species present pe unit area following both clear-cuts (Table 2). The distribution of individuals (> 10 cr dbh) among species has shifted to a greater dominance among fewer species, howeve This shift was largest on lower slope to cove and mid to upper NE slope physiographi positions, increasing following each cutting (Table 1). For example, the four most com mon species on the lower slope to cove position included 56% of the relative density i 1934. This increased to 72% in 1952 and 78% in 1977.

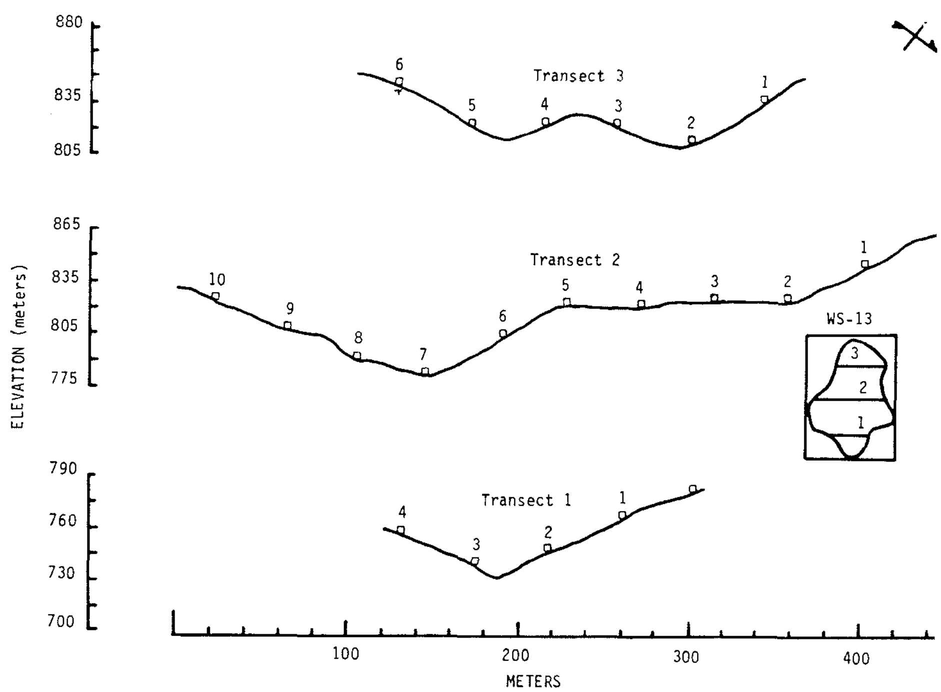

Fig. 1.—Cross-sectional diagram of Watershed 13 showing location of transects and quadra

DISCUSSION

Two clear-cuts, 22 years apart, resulted in shifts in relative density compared to tl stand which existed in 1934 and in the distribution pattern of tree species in relation physiography on a southern Appalachian watershed. Changes in relative density we: greatest following the second cut, probably because the stand cut at that time was much younger, second-growth forest which resulted from the first cut and consequent more sprouting occurred. Changes in relative density also differed by physiograph position. Some species, *Liriodendron tulipifera* in particular, increased their spatial ar(following each cut. This species was one of the dominants on all physiographic pos tions following the second cut. These results are consistent with Oliver's (1980) analys of forest development in North America in which frequent disturbances could be e: pected to shift the predominant type to earlier successional stages. Other commerci clear-cutting experiments at Coweeta have also shown a shift toward early succession species following disturbance (Douglass and Swank, 1976). Day and Monk (197 found *L. tulipifera* was negatively correlated with distance from the stream chann while *Quercus prinus* and *Q. coccinea* were positively correlated with distance on an ol(growth watershed at Coweeta. If and when the vegetation in this clear-cut watershe returns to a precut pattern are not known. Although these data span 43 years, fore development after disturbance represents only the early physiognomic stages of star development (Oliver, 1980).

One can only speculate as to the mechanisms controlling structural changes follov ing a perturbation such as clear-cutting. Hydrologic data from clear-cut watersheds i dicate a large increase in streamflow following the cut and a gradual return to prec flow with regrowth of the forest. Precut streamflows are reestablished approximate 25 years after cutting in the southern Appalachians (Swank and Helvey, 1970). I creased streamflow indicates there is higher soil moisture content throughout tl watershed which would allow establishment of mesic species on dryer physiograph positions. Rogerson (1976) found soil water deficits were greatly reduced following cu ting of forests in northern Arkansas. Whether the gradual reestablishment of the sc moisture gradient as regrowth occurs is sufficient to return the vegetation to prec spatial patterns is not known. It may be that periods of extreme drought coupled wi the moisture gradient are necessary to reestablish predisturbance spatial patterns.

TABLE 2.—Mean number of tree species[1] found per quadrat by physiographic position (Watershed 13 at Coweeta Hydrologic Laboratory before (1934) and 13 (1952) and 15 (197 years following clear-cutting

	Physiographic position[2]					
Date	R	MU-SW	U-S Stream	L-Cove	MU-NE	Average #/Quadra
1934	14	13	12	14	14	14
1952	14	16	16	17	17	16
1977	13	15	12	14	13	14
# Samples (N)	3	3	2	8	4	

[1]Includes species with stems ≥ 1.0 cm dbh

[2]R = ridge top; MU-SW = mid to upper S and W slopes; U-S stream = upper S slope wi small stream; L-Cove = lower slope to cove; MU-NE = mid to upper N and E slopes

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