DYNAMICS OF THE SUGAR MAPLE COMPONENT OF A WHITE OAK - YELLOW-POPLAR COMMUNITY[1]

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Abstract.--The sugar maple (Acer saccharum Marsh) component in a southern Illinois forest increased over a 48-year period. By 1983 sugar maple was three times greater in importance than any other species in the stand. If the observed rate of increase were to continue, sugar maple would exclude all other species within another 50 to 60 years.

INTRODUCTION

A notable phenomenon in many central hardwood forests is an increase in the importance of sugar maple (Acer saccharum Marsh.) during the last half century. This increase has been documented by a number of researchers (Anderson and Adams 1978; Boggess and Bailey 1964; McGee 1986; Newman and Ebinger 1985; Nigh et. al. 1985a and 1985b; Parker et. al. 1985; Schlesinger 1976) and has been ascribed variously to more mesic climatic conditions, exclusion of fire from the forests, and progression of the forests toward their "natural" climax.

In central hardwood forests with predominantly oak overstories, sugar maple is not generally believed to be the primary climax component. Thus, the question arises whether observed increases in the importance of sugar maple will continue. The purpose of this paper is to present and discuss the information from one stand especially as it relates to the perpetuation of the maple "wave" in the future.

BACKGROUND

The stand we studied is located in the unglaciated hill country (Shawnee Hills Division) of southeastern Illinois (latitude 37.5 degrees N, longitude 88.3 degrees W). This stand was classified by Braun (1950 p. 137) as a typical example of the white oak (Quercus alba L.) - yellow-poplar (Liriodendron tulipifera L.) community. The development of the stand from 1935 to 1973 was reported previously (Schlesinger 1976). This paper presents the results after an additional 10 years of growth and development.

The soils are a mixture of weathered bedrock (limestones and sandstones) and loess. The primary series are Alford (fine-silty, mixed, mesic Typic Hapludalf) and Baxter (clayey, mixed, mesic Typic Paleudult). The climate is continental, with hot summers and cool winters. The annual precipitation averages 112 cm with about 60 percent occurring during the growing season from April through September. Although the precipitation is generally well distributed throughout the year, a 2- to 3-week dry period during the growing season is common.

The study area has been protected from grazing and fire since it was acquired by the USDA Forest Service in 1933. Also, no timber harvesting or silvicultural work has been done in the area. Increment core data show an abrupt increase in diameter growth rates starting in 1880 and again in 1910. Because that period coincides with the rapid expansion of the Nation's railroads and because many of the oldest trees are yellow-poplar or hickory, it is possible that a selective harvest of oaks, which were favored for railroad ties, may have been made during that time.

METHODS

Eight permanent plots were established in 1935 near the center of the 7.4 ha stand. Within each 0.101-ha plot, each tree 4 cm dbh (diameter breast height) and larger was measured and permanently tagged. Stems less than 4 cm dbh were identified, mapped, and their heights recorded on four 4 sq m (1 milacre) subplots located in the corners of the main plots. The plots were remeasured in 1940, 1958, 1965, 1973, 1978, and 1983, at which times trees growing into the 4-cm diameter class were measured and tagged. Tree heights were measured in 1935, 1958, and 1978. Map coordinates were

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determined for the individual trees following the 1973 inventory and for ingrowth trees at the 1978 and 1983 remeasurements.

The changes in the stand during the 48-year period were examined using the traditional measures of density and basal area plus stocking percent, a measure of relative density or crowding that combines tree numbers and sizes. The tree area ratio concept (Chisman and Schumacher 1940), minimum tree area equations (Gingrich 1967), and average maximum competition levels (Ernst and Knapp 1985), collectively are used to define 100 percent stocking. The minimum tree area equation for oaks and hickories is from Gingrich (1967); equations for other species are from Stout and Nyland (1986).

The sugar maple[1] component was segregated into nine groups, based on three dbh size classes in 1935 (4 to 9.9 cm, 10 to 19.9 cm, and 20 to 29.9 cm) plus the six ingrowth groups (all less than 9.9 cm at the time first measured) from the remeasurements. Each group was evaluated for mortality, net growth, and surviver growth for each period between remeasurements. The sugar maple component was further examined in relation to the changes in the community during the 48-year period of observation.

To examine the potential for maples to occupy canopy gaps that occur when overstory trees die, the maps for each plot giving the tree locations were divided into 35 areas of equal size. Each of these subareas was 28.9 sq m, approximating the minimum tree area of a 30-cm-dbh sugar maple. The presence of overstory trees alive in 1983, overstory trees that died between 1978 and 1983, and all sugar maples were determined for each area.

RESULTS AND DISCUSSION

The overall changes in stand structure during the study period indicate that the stand was recovering from past disturbance (fig. 1). The total number of trees declined between 1935 and 1940, increased gradually until 1965, and again declined through the last measurement. Stand basal area increased from 22.7 sq m per ha in 1935 to a high of 32.8 in 1978, declining slightly to 31.3 by 1983. The stocking rose from 76.2 percent in 1935 to 100.8 percent in 1978, and then dropped to 94.6 percent by 1983.

The changes for the various species during the 48-year period followed five different patterns. Sugar maple, white ash (Fraxinus americana L.), ironwood (Ostrya virginiana (Mill.) K. Koch) and beech (Fagus grandifolia Ehrh.) all increased in numbers, basal area, and stocking (table 1). By 1983, 51.6 percent of the trees were sugar maples, accounting for 15.4 percent of the total basal

[1]The "sugar maple" group included some Florida maple (Acer barbatum Michx.) and black maple (A. nigrum Michx.) as well as putative double and triple hybrids between the three maple species.

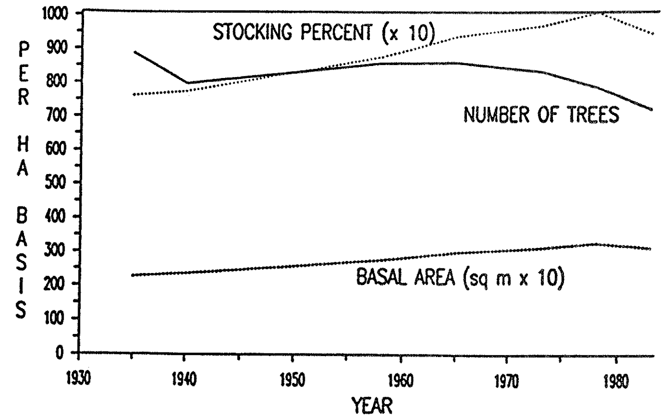

Figure 1.--Stand changes in the total (per ha) number of trees, basal area, and stocking percent from 1935 to 1983.

area, and 21.6 percent of the stocking. Together, the four species composed 71.3 percent of the trees, 18.4 percent of the basal area, and 26.0 percent of the stocking.

The two "characteristic" species, yellow-poplar and white oak, plus black oak (Q. velutina Lam.) and northern red oak (Q. rubra L.) all decreased in numbers, comprising only 12.3 percent of the total number in 1983. Collectively, their basal area increased to 57.5 percent of the stand, and their stocking percent to 44.7 percent.

Scarlet oak (Q. coccinea Muench.) and shagbark hickory (Carya ovata (Mill.) K. Koch) decreased in both numbers and stocking percent, but gained slightly in basal area; while slippery elm (Ulmus rubra Muhl.) increased in numbers, but decreased in both basal area and stocking percent. These species made up 3.5 percent of the trees, 11.2 percent of the basal area, and 11.2 percent of the stocking.

The remaining species all decreased in numbers, basal area, and stocking, and composed 13.0 percent, 12.9 percent, and 12.7 percent of the trees, basal area, and stocking, respectively, in 1983. This group included several overstory species, black gum (Nyssa sylvatica Marsh.), black walnut (Juglans nigra L.), red maple (A. rubrum L.), mockernut hickory (C. tomentosa (Poir.) Nutt.), and pignut hickory (C. glabra (Mill.) Sweet), plus flowering dogwood (Cornus florida L.), sassafras (Sassafras albidum (Nutt.) Ness), and the group of miscellaneous minor species.

The tolerance and persistence of sugar maple could lead to its dominance by allowing it to become established and grow in the understory so that it can take advantage of canopy openings created by the death of overstory trees. There is evidence for these characteristics from the plot records.

Table 1.--Present stand and changes since 1935.

	Numbers		Basal area		Stocking		Importance	
	1983	Change	1983	Change	1983	Change	1935	1983
	--(per ha)--		--(sq m)--		--(percent)--		--(IV-200)-	
Sugar maple	373.1	218.7	4.81	3.80	21.59	16.80	21.9	67.0
Black gum	39.5	-18.5	1.67	-.37	4.50	-1.24	15.6	10.8
Yellow-poplar	19.8	-3.7	6.45	2.81	7.60	2.68	18.7	23.3
White ash	71.7	59.3	.42	.34	1.96	1.63	1.7	11.2
Black walnut	0.0	-6.2	0.0	-.13	0.0	-.44	1.3	0.0
White oak	39.5	-71.7	5.54	2.12	17.94	5.03	27.6	23.2
Scarlet oak	12.4	-27.2	2.87	.27	9.01	-.41	15.9	10.9
Black oak	23.5	-29.7	5.04	2.16	15.98	5.30	18.7	19.3
Red oak	6.2	-11.1	.98	.33	3.18	.60	4.8	4.0
Red maple	0.0	-21.0	0.0	-.28	0.0	-1.04	3.6	0.0
Shagbark hic.	6.2	-23.5	.59	.07	1.99	-.14	5.6	2.7
Mockernut hic.	9.9	-21.0	.89	-.46	3.13	-1.80	9.5	4.2
Pignut hic.	13.6	-42.0	1.30	0.0	4.27	-.71	12.0	6.0
Slippery elm	6.2	2.5	.03	-.03	.16	-.04	0.7	1.0
Ironwood	58.1	44.5	.23	.14	1.19	.77	1.9	8.8
Dogwood	27.2	-148.3	.16	-1.33	.78	-5.54	26.3	4.3
Sassafras	0.0	-71.7	0.0	-.96	0.0	-3.77	12.3	0.0
Beech	12.4	7.4	.30	.20	1.29	.85	1.0	2.7
Other[1]	3.7	-2.5	.01	-.03	.06	-.11	0.9	0.6

[1]Includes the following species: redbud (Cercis canadensis L.), service berry (Amerlanchier arborea Michx.f.), persimmon (Diospyros virginiana L.), juniper (Juniperus communis L.), and eastern red cedar (J. virginiana L.).

In 1935, the sugar maple component ranked third in importance (IV-200, based on relative number of trees and relative basal area) behind white oak and dogwood (table 1). Its importance value of 21.9 was less than half the combined importance of white oak and yellow-poplar (46.3). The importance of sugar maple increased steadily throughout the 48-year period, ranking first by 1958. In 1983, its importance value of 67.0 was more than 40 percent larger than the combined importance of white oak and yellow-poplar (46.5).

Even when the number of sugar maple trees was no longer increasing, ingrowth continued over the study period (table 2). There were about 20 new stems per ha in 1978 and 24 in 1983, almost as

Table 2.--Sugar maple groups[1] - number of trees per hectare.

Year	Status	L-35	M-35	S-35	S-40	S-58	S-65	S-73	S-78	S-83	All
1935	alive	8.6	17.3	128.5							154.4
1940	alive	8.6	17.3	126.0	27.2						179.1
	dead			2.5							2.5
1958	alive	8.6	17.3	113.7	27.2	169.3					336.1
	dead			12.4							12.4
1965	alive	8.6	17.3	105.0	25.9	160.6	29.7				347.2
	dead			8.6	1.2	8.6					18.5
1973	alive	8.6	17.3	97.6	24.7	149.5	27.2	45.7			370.7
	dead			7.4	1.2	11.1	2.5				22.2
1978	alive	8.6	17.3	91.4	23.5	143.3	27.2	45.7	19.8		376.8
	dead			6.2	1.2	6.2					13.6
1983	alive	8.6	16.1	85.2	17.3	131.0	27.2	44.5	19.8	23.5	373.1
	dead		1.2	6.2	6.2	12.4		1.2			27.2
Total	alive	8.6	16.1	85.2	17.3	131.0	27.2	44.5	19.8	23.5	373.1
	dead		1.2	43.2	9.9	38.3	2.5	1.2			96.4
	% surv.	100.0	92.9	66.3	63.6	77.4	91.7	97.3	100.0		79.5

[1]S-35 refers to the small maples (<10 cm) present in 1935, M-35 refers to those 10 to 19.9 cm in 1935, L-35 refers to those 20 to 29.9 cm in 1935, and S-40 to S-83 refer to the ingrowth at the various inventories.

many new stems in each of those 5-year periods as in the first 5-year period from 1935 and 1940.

During the last 10 years, sugar maple mortality and ingrowth appeared to be in balance. Ingrowth in 1978 and 1983 totaled 43.3 trees, while mortality was 40.8 trees (table 2). The maple mortality appeared to be related to both size and duration of minimal growth. Of the trees dying, 95 percent were smaller than 10 cm when they died. Within the S-35 cohort (trees 4 to 10 cm in dbh in 1935), mortality was 33.7 percent over a 48-year period; while within the S-58 cohort (ingrowth into the 4- to 10-cm dbh class in 1958), mortality was 22.6 percent over a 25-year period.

Total stocking was highest during the last 25 years, increasing from 87.7 percent to 94.6 percent between 1958 and 1983; stocking increased from 76.2 percent to 87.7 percent between 1935 and 1958. Yet the growth of the S-58 cohort in the last 25-year period was similar to that of the S-35 cohort during the first 23-year period (table 3). The tolerance of the maple is likewise indicated by the survival of the portion of the S-35 cohort that remained within the 4- to 10-cm size class, which averaged only 0.079 cm in diameter growth per year (table 3), 0.83 sq cm in basal area growth, and 0.085 m in height growth over the 48-year period.

Table 3.--Dbh growth of maple by groups based on size in 1983.

Size class	L-35	M-35	S-35	S-58	L-35	M-35	S-35	S-58
	--------(cm)--------				------(cm)-------			
		DBH 1935			Growth/yr '35 - '83			
4-10			4.8				.079	
10-20		11.4	6.2			.082	.191	
20-30	25.4	13.8	7.3		.095	.253	.320	
30-40	22.7	18.7			.278	.281		
40-50	27.2	19.6			.376	.466		
		Dbh 1958			Growth/yr '35 - '58			
4-10			7.0	5.0			.098	
10-20		13.0	10.6	6.2		.068	.191	
20-30	26.9	19.6	14.5		.066	.251	.311	
30-40	30.1	25.9			.321	.312		
40-50	35.3	29.2			.353	.420		
		Dbh 1983			Growth/yr '58 - '83			
4-10			8.6	7.5			.061	.099
10-20		15.4	15.4	12.2		.095	.192	.240
20-30	30.0	25.9	22.7		.122	.256	.328	
30-40	36.0	32.2			.238	.253		
40-50	45.2	41.9			.396	.508		

Maple basal area has increased at an average annual rate of 3.05 percent over the entire 48-year period. This rate, which is analogous to an internal rate of return (IRR) on an investment, has ranged from a maximum of 4.08 from 1940 to 1958 to a low of 1.97 from 1958 to 1965 (table 4). It reflects the combined effects of mortality, ingrowth, and survivor growth between each measurement period.

Table 4.--Components of the maple basal area dynamics.

Year	Live trees	Dead trees	New trees	Survivor Growth Amount	Survivor Growth %/yr	IRR
	----square decimeters-----				--percent--	
1935	101.71					
1940	123.61	.35	3.93	18.32	3.61	3.98
1958	254.06	2.78	38.00	95.23	4.38	4.08
1965	291.20	5.35	5.29	37.20	2.14	1.97
1973	376.26	6.24	8.06	83.24	3.65	3.25
1978	419.10	3.73	3.67	42.90	2.30	2.18
1983	481.39	24.36	3.97	82.68	4.19	2.81

The growth of surviving trees was the primary contributor to the basal area increases during all measurement periods (table 4), ranging from 71 percent for the period ending in 1958 to 95 percent for the final period. The annual rate of increase of this component ranged from 2.14 percent to 4.38 percent and was 4.19 percent during the most recent growth period.

Initially, the contribution of ingrowth to the basal area increase was much greater then mortality (table 4). From 1965 to 1978, mortality and ingrowth were essentially in balance. During the final measurement period, the loss in basal area from mortality substantially exceeded ingrowth. However, the growth of the surviving trees was sufficient to maintain a net increase of 2.81 percent in basal area.

Sugar maple most recently composed 7.3 percent of the overstory, which consists of trees 24 to 36 m in height and larger than 35 cm dbh (table 5). The four oak species, which made up 57.3 percent of the overstory, accounted for 83.3 percent of the overstory mortality during the study period.

Table 5.--Species composition of the present overstory and mortality of overstory trees during the study period.

Species	Number of trees: Present 1983	Number of trees: Mortality
	-----(per hectare)-----	
Sugar maple	7.4	0.0
Black gum	7.4	1.2
Yellow-poplar	16.1	0.0
White oak	19.8	2.5
Scarlet oak	11.1	12.4
Black oak	22.2	6.2
Red oak	4.9	3.7
Shagbark hickory	2.5	0.0
Mockernut hickory	4.9	2.5
Pignut hickory	3.7	1.2
Beech	1.2	0.0
Total	101.2	29.7

The present distribution of sugar maple within the stand appears to provide it the opportunity to occupy canopy gaps created by the death of overstory trees. At present, oak, hickory, or yellow-poplar overstory trees are found in 30 percent of the 280 28.9-sq m subareas (i.e. the eight main plots divided into 35 equal-sized areas). An additional 4 percent of the subareas are occupied by sugar maple overstory trees. Overstory mortality occurred in 4 percent of the subareas between the 1978 and 1983 inventories. The 1983 inventory showed understory sugar maples in 69 percent of the subareas. Thus, sugar maple is sufficiently well distributed throughout the stand to quickly capture most growing space made available by overstory mortality.

CONCLUSIONS

The sugar maple component of this white oak - yellow-poplar community has increased dramatically during the 48 years of record. Before 1973, the stand was apparently still recovering from past disturbance, but since then has been at or near its average maximum (100 percent) stocking level. The sugar maple component has continued to increase, but to what extent this increase will continue is not certain.

At the past and current rate of increase (3.05 percent and 2.81 percent respectively), sugar maple basal area would equal the total stand basal area of 31.3 sq m per ha between the years 2038 and 2051. This increase in sugar maple would necessarily be accompanied by the elimination of essentially all other species, an unlikely event at best.

Braun (1938) argued that the mixed mesophytic forest is a climax association of the deciduous forest, with much variation in species mixtures from stand to stand. Raup (1956) and others (see White 1979) have discussed the role of natural disturbance factors in old-growth forests. Horn (1976) and others (see Pickett, et. al. 1987) have noted that succession is an idealize representation of what actually occurs in nature. Thus, one could conclude that the mixed mesophytic climax forest varies not only in space but in time as well.

If so, there may be an ebb and flow of individual species over time. The observed sugar maple wave that has been building over the past 48 years may continue unchecked or it may break upon the shores of some natural disturbance.

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