SESSION IV

ADVANCES IN HARDWOOD TREE IMPROVEMENT

MODERATOR: K. A. TAFT

ECONOMICS OF HARDWOOD PLANTATIONS

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ABSTRACT

The industrial demand for hardwoods is steadily increasing, and supplies of natural hardwoods have become critically short in some areas. Few commercial hardwood plantations other than cottonwood have been established due to uncertainty concerning establishment techniques, growth rates, and economical aspects. The author collected data from over 70 older hardwood plantations and constructed yield equations for sycamore, yellow-poplar, and sweetgum. The data indicate that sycamore and yellow-poplar plantations are economically feasible when stumpage prices approach $10.00 per cord. Optimum rotations are short. Minimum requirements for economically successful hardwood plantations appear to be: Proper site choice, large, healthy seedlings, adequate site preparation and competition control, and in most cases, addition of nutrients.

Keywords: Hardwood plantations, economics

INTRODUCTION

Commercial interest in hardwood plantations has increased in recent years due to localized shortages of suitable hardwood raw material. Although the total volume of natural hardwood in the South increased slightly in the past decade (Sternitzke and Christopher, 1973), many industrial consumers must now pay high stumpage prices for local hardwoods, or pay high transportation fees to import cheap stumpage.

Even companies owning reserves of natural hardwoods relatively close to the mill encounter production and supply problems. A survey initiated by the N. C. State Cooperative Hardwood Research Program in 1969 of the very best natural stands throughout the South indicated that the best forest site type was producing only 80 cubic feet per acre per year, and the average growth across all forest site types was 60 cubic feet per acre per year. Since these data came from the best stands, average annual production would be considerably lower than 60 cubic feet per acre because most stands have been high-graded and are in poor silvicultural condition. These facts suggest the following questions:

1. What growth rates can be expected of hardwood plantations?
2. How can hardwood plantations be most effectively established?
3. What raw material prices are required to make the growing of hardwoods economical?

With these questions in mind, the author attempted in 1971-72 to locate all successfully established hardwood plantations, except those of cottonwood, in the South.

GENERAL CONSIDERATIONS

While nearly every plantation surveyed occurred on a slightly differ-ent soil, the soils can be broadly grouped as follows:[1]

Group 1. Good for agriculture. Presence of well-drained, friable topsoil, having sufficient depth and moisture to support a good crop of soybeans.

Group 2. Adequate for agriculture. Compared to above, the soil is more limiting because one or more of the following conditions prevail. It is shallow, heavy-textured, sandy or gravelly, with limited nutrient and moisture-holding capacity. Some of these soils are still excellent for pine but marginal for soybeans.

Group 3. Poor for agriculture. Little topsoil, and the texture of the subsoil is tight clay or sand. These soils can support a fair crop of pines but would not economically support soy-beans.

Examination of the plantation data indicates that extreme caution must De used in making comparisons among species because of the confounding ef-fect of soils and associated factors. The principal species found growing in plantations were sycamore, sweetgum and yellow-poplar. The natural occur-rence of sycamore is along stream bottoms on fertile, well-drained alluvial soils. Sweetgum occurs naturally across a relatively wide range of sites, from the stream bottoms where its associates are sycamore and other bottom-Land species, to the drier and infertile hilltops where the oaks, hickories, and pines predominate. Yellow-poplar is usually found on relatively fertile, friable, well-drained, moist soils, but there are many exceptions.

Most sycamore plantations were found on Group 1 soils. Their absence from Group 2 and 3 soils probably indicates that they did not develop into a viable stand, even if planted there. Most yellow-poplar plantations were on Group 2 soils. This species also would not survive and grow if planted on Group 3 soils, which have serious moisture and fertility deficiencies. Nearly all sweetgum plantings were on Group 3 soils. Perhaps because sweet-gum has traditionally been scorned by most foresters, it was not generally planted on the best soils. The fact that it exists as a measurable entity

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[1]Because of the capability of good agricultural lands to grow good stands of hardwoods, site quality was judged by the capacity of the soil to pro-duce an agricultural crop. The author was able to draw on his farming experience and the extensive opportunities he has had to observe both natural and planted hardwood stands. Variables considered in assessing land quality were soil depth, texture, topography, and understory indicator plants.

on the relatively adverse sites indicates the degree of adversity under which the species will survive and grow.

PLANTATION ESTABLISHMENT

The successful plantations sampled in the current survey were growing either on old fields or they had been cultivated to assure establishment. Plantations on old fields do not have the sprout competition that occurs on most cleared forest sites but, even so, the growth of planted trees on some old fields is poor, although survival is generally good. The poor growth is suspected of being attributable to hardpans, or plowpans, which often form in tilled soils and to deficient nutrient levels.

On any site where vines such as honeysuckle, morning glory, smilax, rattan, kudzu, or others exist, competition control is absolutely necessary. Plantings that survived well initially have been observed after several years with nearly every stem tightly wrapped and many badly damaged or killed by girdling or by the weight of the vines. The few trees that out-grow the vines are not likely to compensate for the majority that are deformed or lost.

The many herbicides tested for control of competition in hardwood stands have given inconsistent results to date. The difficulty of predicting the future vegetation on a forest site makes the successful use of preemergence chemicals difficult, and postemergence chemicals generally damage or kill the broad-leafed hardwoods if the application is sufficient to control the competition.

Only partial control of competition in hardwood plantings has been advocated in some cases. One method of attaining this is to plant the seedlings on beds or ridges to provide a temporary cultivation effect and to temporarily control competing vegetation. On some sites this procedure has been initially successful in obtaining adequate survival and growth. On other sites, competition from grasses and weeds has doomed the plantation to failure.

Except on sites where flooding or other factors hinder competing vegetation, cultivation for hardwood establishment appears essential. There is evidence that fertilization in the absence of cultivation may be detrimental due to the stimulation of grasses and weeds. When competition is controlled, fertilization, except on Group 1 soils, appears beneficial although profitability remains a question.

Basic to the successful planting of any species is the need to have a viable seedling. Pine seedlings are produced in nurseries by the millions with such routine success that many nurserymen have assumed that hardwoods can be produced with identical techniques. However, there are many basic differences between the two species complexes. Many weeds and grasses that grow in pine nursery beds can be controlled with mineral spirits with no harm to pine seedlings. Although the same material is relatively harmless to sweetgum, hardwood seedlings in general are sensitive to herbicides. Therefore, the irksome and expensive task of weeding must be done by hand. To reduce the necessity for weeding, some nurserymen grow hardwood seedlings at a dense spacing resulting in small, spindly plants. mere is now universal agreement among hardwood managers that no hardwood seedling should be planted that measures less than 3/8 inch at the root collar; and the larger the diameter, the better will be the survival and growth. To achieve these sizes, it is necessary to use seed-bed densities of only six to ten per square foot. This means thinning and hand weeding for most species, with much higher seedling production costs than for pine.

Some nurserymen believe that row planting of hardwood seeds, as opposed to bed planting, will allow thinning and weeding to be mechanized and the cost lowered. In any event, it seems reasonable that greater specialization in hardwood seedling production will reduce costs below the current level.

The best estimates available as to the total cost of establishing hardwoods range from $75/acre to $125/acre, and these estimates agree with costs reported by Dutrow (1970) for cottonwood establishment. Minimum hardwood cultural requirements are very expensive compared with pine, yet good growth can insure an acceptable rate of return if harvest prices are sufficiently high. Cost per acre will be minimized when large acreages are planted, and when improved techniques are devised for the production of quality hardwood seedlings.

DETERMINATION OF VOLUME

Total volume (TV) was calculated for each species by the equation $TV = .00204(DBH)^2(HT) - .6477$ found in the U.S. Forest Service Research Note SO-113. Although this equation was developed for cottonwood, stem analysis of plantation grown trees of sycamore, sweetgum, and yellow poplar indicate that their volume is predicted with suitable accuracy. This can be explained by the similarity of form of most trees grown in plantations where age and spacing are constant. Sufficient samples were obtained to allow the calculation of yield equations for the above three species.

ECONOMIC ANALYSIS

Each species was evaluated according to the following financial criteria over a range of establishment costs, harvest values, and interest rates:

1. The optimum rotation length (financial maturity) of a plantation, in years, based upon a volume production function over time and a particular set of costs, returns, and interest rate assumptions. Optimum rotation is the age which maximizes the net present value of a series of plantations through time, and is the Faustmann criterion of maximizing soil rent or land expectation value (Riley, 1956).

2. The maximum present value (soil rent or soil expectation value) of all future rotations, which will occur when each plantation is harvested at the optimum age.

3. The present value of one rotation, rather than of all future rotations, when harvested at the optimum rotation length.

All calculations assume that the combined cost for taxes and administration is $1 per acre per year, and that all costs and revenues have been taken into account. Many companies earn revenues in addition to wood values from hunting leases and other alternatives, but these have been ignored in the present calculations. As long as hunting leases are on an acreage basis and are not variable by plantation age, there is no effect on optimum rotation length even though the bare land value is increased.

VOLUME PRODUCTION AND FINANCIAL EVALUATION BY SPECIES

A primary goal of this study was to determine yield equations (production functions) to relate volume growth to age. Plots have been grouped for calculation purposes by species, soil type, and establishment procedures. The groupings are shown below:

Species	Number of Plantations Used in Calculations	Soil Group	Age Range	Establishment Procedures
Sycamore	14	1	3-27	Cultivated[a]
Yellow-Poplar	11	2	7-33	Old field, no cultivation
Sweetgum	14	3	4-33	Old field, no cultivation[b]

[a] One 27-year-old plot was on an old field and the plantation had not been cultivated. It was included to extend the range of the data.

[b] One plot on Group 1 soil was cultivated; another plot on Group 2 soil was not cultivated.

SYCAMORE

The data obtained for sycamore are from stands grown on good sites and with cultivation. Most stands were established at 8' x 8' or 10' x 10' spacing, and most were not thinned. The resulting yield equation is:

$$V = \text{total volume per acre (cuoft.)}$$
$$V = \underset{(71.88)}{321.7}\,(\text{age}) - \underset{(2.43)}{3.1}\,(\text{age})^2 - 980.6$$

The R^2 for the regression is 0.92, and the standard error is 483.4 cubic feet.

The cubic foot volume predicted by the sycamore yield equation was evaluated financially at prices ranging from $0.06/cubic foot to $0.20/cubic foot, at establishment costs of $75 and $100 per acre and at 6, 8, and 10 percent interest rates (Tables 1 & 2).

For example, when establishment costs are $100 per acre, taxes and administration are $1 per acre per year, net stumpage value is $0.12/cubic foot, the interest rate is 6 percent, the optimum rotation length is 15 years, the maximum soil rent is $82, and present value for one rotation is $47. An alter-

SYCAMORE

Table 1. Optimum rotation length, maximum soil expectation value, and single rotation present value (establishment costs $75/acre, tax and administration $1/acre/year)a

$/Cu.Ft.	Optimum Rotation (Years)			Maximum Soil Rent ($)			Single Rotation Present Value($)		
	6%	8%	10%	6%	8%	10%	6%	8%	10%
.06	17	16	15	(9)	(35)	(49)	(6)	(25)	(32)
.08	15	14	13	34	(6)	(28)	20	(4)	(20)
.10	14	13	12	80	24	(7)	44	15	(4)
.12	14	13	12	126	55	16	70	35	11
.14	13	12	11	172	87	39	91	52	25
.16	13	12	11	219	119	63	116	72	41
.18	13	12	11	267	151	86	142	91	56
.20	12	11	11	314	183	110	158	105	71

[a] Parentheses indicate negative values.

SYCAMORE

Table 2. Optimum rotation length, maximum soil expectation value, and single rotation present value (establishment costs $100/acre, tax and administration $1/acre/year)a

$/Cu.Ft.	Optimum Rotation (Years)			Maximum Soil Rent ($)			Single Rotation Present Value(S)		
	6%	8%	10%	6%	8%	10%	6%	8%	10%
.06	19	18	17	(48)	(70)	(82)	(32)	(52)	(65)
.08	17	16	15	(6)	(43)	(62)	(4)	(30)	(47)
.10	16	14	14	37	(14)	(42)	22	(9)	(31)
.12	15	14	13	82	16	(20)	47	11	(14)
.14	14	13	12	127	46	2	71	30	2
.16	14	13	12	173	78	25	97	49	17
.18	13	12	11	220	109	48	117	66	31
.20	13	12	11	267	141	71	142	85	46

[a] Parentheses indicate negative values.

native way of looking at the values in Table 2 is that if the land investment is $82 per acre, and establishment costs are $100 per acre, sycamore wood must be valued at $.12 per cubic foot if the total investment is to earn 6 percent.

A company that is not selling stumpage on the open market could determine the net stumpage value per cubic foot from a given tract as a shadow price:

$$\$/\text{cubic foot} = D-H-T$$

Where:

D = Delivered mill price per cubic foot of externally obtained wood,
H = Cost per cubic foot for harvest of plantation wood,
T = Cost per cubic foot for transportation from plantation to the mill.

Other things being equal, plantations close to the mill have the highest net value, the shortest optimum rotation length, and the highest present value. Therefore, land is more valuable near the mill. As interest rates increase, optimum rotation length decreases. Conversely, as establishment, harvest, or transportation costs go up, optimum rotation age goes up and present values go down. Higher constant annual costs do not affect optimum rotation length, but they do lower present values.

The appropriate set of values within these ranges can be chosen best by the individual who is contemplating growing sycamore. It is unlikely anyone can establish and cultivate a plantation for one year on former forest land for $75 per acre; a more reasonable estimate of the investment through the first growing season is $90 to $120 per acre. There is the possibility with hardwood species, sycamore included, of growing additional coppice (sprout) crops from the original rootstocks. If the same yield equation holds for coppice rotations, at least for a couple of additional rotations, the attractiveness of the investment increases. For example, assuming an initial establishment cost of $100 and subsequent coppice rotation costs of $75 at the beginning of each new rotation, the appropriate rotation length is obtained from the $75/acre table and soil rent (land value) in that table should be reduced by $25/acre ($100 - $75 = $25). Specifically, if a sycamore plantation is established for $100 per acre, and is subsequently regenerated for $75 per acre at an interest rate of 8 percent and a residual stumpage value of $0.16/cubic foot, the optimum rotation length is 12 years, the present value of all future rotations (maximum soil expectation value) is $119 - $25 = $94, the present value per acre of the first rotation is $72 - $25 = $47, and each subsequent plantation has a discounted value of $72 at the beginning of the rotation (Table 1).

While it is unreasonable to expect the yield equation to hold over many coppice rotations, allowing it to hold for two rotations subsequent to initial establishment results in the value for maximum bare land value for the three rotations being similar to that for an infinite series. Even if coppice regeneration is not used, reestablishment of second or third plantations is certain to be less costly than for the first plantation due to the relative absence of unmerchantable debris.

YELLOW-POPLAR

Yellow-poplar is not a generally preferred species for pulping but its value for lumber has generated some interest in plantation establishment. Most of the plantations located were in the North Carolina mountains, all were on old fields, and none had been cultivated or fertilized. The yield equation is:

$$V = \text{Total volume/acre (cu.ft.)}$$

$$V = \underset{(133.67)}{285.55\,(\text{age})} - \underset{(3.29)}{4.06\,(\text{age})^2} - 1073.65$$

(R^2 = .71; standard error = 775 cubic feet)

Because the data were obtained only from plots of Group 2 soils, care must be exercised in extrapolating to plantations on other soil groups. The values in tables 3 & 4 were calculated on the basis of the yellow-poplar yield equation in a parallel fashion to those calculated for sycamore.

There is the temptation to compare the present values of yellow-poplar and sycamore. However, this is not a valid comparison because the yellow-poplar yield equation is based on less productive soils. Attempts were made, to no avail, to locate plantations of both species on soils of the same group. Until this is done, valid species comparisons cannot be made.

Since most yellow-poplar plantations were located in one area (western North Carolina) there is some risk when extrapolating growth rates to other areas. For example, on loess soils and with cultivation, yellow-poplar plantings have grown to an average total height of 11 feet with 95 percent survival after two growing seasons. [2] If these growth rates are maintained at a moderately decreasing rate, the per acre yields suggested are somewhat greater than the above yield equation predicts, however risky such speculation may be. If yellow-poplar plantations are grown for both pulp and lumber production, rotation lengths would be lengthened by the effect of sawtimber values at older ages and by the intermediate harvest value of pulp thinnings.

SWEETGUM

There is no native hardwood that occupies a wider range of sites, but for various reasons the species has generally been scorned. Of the plantations located, most were grown on Group 3 soils, and of these none were cultivated. Some were on old fields, others were on cleared forest land. There was considerable variability in performance among plantations. After testing several models, the following simple linear one was found to fit the data best:

[2] Personal communication with Mr. W. L. Bond, Grief Bros., Vicksburg, Miss.

YELLOW-POPLAR

Table 3. Optimum rotation length, maximum soil expectation value, and single rotation present value (establishment costs $75/acre, tax and administration $1/acre/year)[a]

$/Cu. Ft.	Optimum Rotation (Years)			Maximum Soil Rent ($)			Single Rotation Present Value($)		
	6%	8%	10%	6%	8%	10%	6%	8%	10%
.06	18	17	16	(43)	(57)	(65)	(28)	(42)	(51)
.08	17	16	15	(13)	(37)	(51)	(8)	(26)	(39)
.10	16	15	14	19	(16)	(36)	12	(11)	(26)
.12	15	14	13	52	6	(20)	30	4	(14)
.14	14	13	13	85	28	(4)	48	18	(3)
.16	14	13	12	119	51	12	66	32	8
.18	14	13	12	153	73	29	85	46	20
.20	13	12	12	187	96	45	99	58	31

[a]Parentheses indicate negative values.

YELLOW-POPLAR

Table 4. Optimum rotation length, maximum soil expectation value, and single rotation present value (establishment costs $100/acre, tax and administration $1/acre/year)[a]

$/Cu.Ft.	Optimum Rotation (Years)			Maximum Soil Rent ($)			Single Rotation Present Value($)		
	6%	8%	10%	6%	8%	10%	6%	8%	10%
.06	21	20	19	(80)	(90)	(96)	(56)	(71)	(80)
.08	18	17	16	(52)	(72)	(83)	(34)	(53)	(65)
.10	17	16	15	(22)	(52)	(69)	(14)	(37)	(53)
.12	16	15	14	10	(32)	(54)	6	(22)	(40)
.14	15	14	14	42	(10)	(39)	24	(7)	(29)
.16	15	14	13	75	12	(23)	44	8	(17)
.18	14	13	13	108	34	(7)	60	21	(5)
.20	14	13	12	142	56	9	79	36	6

[a]Parentheses indicate negative values.

$$V = \text{Total volume/acre (cubic feet)}$$

$$V = \underset{(21.21)}{104.69}(\text{age}) - 556.85$$

R^2 = .69, standard error = 648 cubic feet)

It is certain that sweetgum will perform better on soils superior to those on which the present plantations are found. One plantation found on Group 1 soil produced 749 cubic feet at age 7 (vs. 176 cubic feet from the equation), and another on Group 2 soil produced 1976 cubic feet at age 13 (vs. 804 feet from the equation). With such limited data from the better sites, the calculated production function only estimates sweetgum performance on marginal hardwood sites where the species was established with pine planting techniques and probably with inferior seedlings. Any direct comparison between sycamore, established on the best sites and receiving cultivation, and sweetgum established by pine planting techniques on the poorer soils, will be misleading.

Tables of calculations for sweetgum are not presented since present values are all negative at establishment costs of $75 and $100 per acre. The establishment cost of most of the plantations measured was probably under $50 per acre, since all but one were established using pine techniques. However, these costs are misleading because a majority of the plantations failed completely, resulting in a very high cost per acre of live plantation. The conclusion is that sweetgum plantations on marginal sites are poor investments. The use of more intensive management techniques on better soils will certainly result in a higher growth rate and perhaps yield a higher net return, but data are not yet available to confirm this speculation.

DISCUSSION

The available data indicate that the management of hardwoods in plantations may be economically feasible. Companies who need the product qualities added by hardwoods can economically justify hardwood plantations only on the better sites and at certain price levels. If the average land investment is taken to be $80 per acre, then at a 6% interest rate, and $100 establishment costs, sycamore plantations on the best soils become profitable at about $.12/cubic foot, and yellow poplar on average soils becomes profitable at about $16/cubic foot.

Matching the species to the soil is the most restrictive limitation to hardwood plantation management. It should be reiterated that hardwood prices must soar to extremely high levels to make production on marginal sites feasible. Increasing world prices for soybeans and feed grains will make the opportunity cost of growing trees on the best soils increasingly more expensive, but there are many bottomland sites with excellent soil that are too wet for agriculture but which can produce excellent tree crops. It is generally possible to operate equipment on these areas during the dry seasons to establish a plantation. Where such lands are available they will likely be the most economical choice for hardwood production.

The failure rate of past hardwood plantings should not be considered as evidence that hardwoods cannot be successfully grown. With the use of proper techniques, the uncertainty regarding survival and growth rates can be reduced to a level that will justify hardwood plantations at some current stumpage prices.

In summary, many questions remain concerning the financial returns from various degrees of site preparation and cultivation for different hardwood species. But we now know this much--consistently good survival and growth require the following:

1. Plantations on Group 1 and 2 soils
2. Large, healthy seedlings
3. Intensive site preparation, including subsoiling and cultivation in most circumstances, or bedding on sites that are frequently flooded
4. Fertilization, except on Group 1 soils, if plantations are to be cultivated
5. Proper seed source

When prices, either current or anticipated, rise to a level that stimulates serious interest in producing hardwoods in plantations, it appears that expensive establishment costs can be financially justified; in fact, the evidence indicates that efforts to establish hardwood plantations with inferior seedlings, poor competition control, or on marginal sites, cannot be justified at any price.

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