ECONOMIC CASE FOR GENETIC MANIPULATION OF SHORT-ROTATION SYCAMORE

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Abstract.--Best estimates of costs, yields, and revenues indicate that profits from short-rotation sycamore are highest on best sites, at wide spacings, and with 4- or 5- year cutting cycles. Genetically improved stock that provides a 10 percent increase in growth would almost double net revenues. Genetic improvement that would insure adequate growth without fertilization would allow marginal sites to become profitable.

Additional keywords: Sycamore yields, costs, simulation, genetic improvement, revenues.

Short-rotation sycamore seems assured of a future. The species responds to cultural treatments, grows rapidly to meet size and quality restrictions, and can be processed into a multitude of fiber-based products. Furthermore, modest genetic gains can enhance the economic potential of short-rotation sycamore. These gains can take either of two forms: (1) superior growth where fertilizer is applied, or (2) the best growth possible without fertilization. Economic comparisons between these options and standard short-rotation sycamore yields are summarized herein.

Researchers of the Southeastern Forest Experiment Station at Athens, Georgia have grown four crops (one seedling and three coppice) and measured the yields. These data provide a basis for setting requirements for economic feasibility of short-rotation sycamore plantations and for estimating gains from specific genetic improvements in planting stock.

COSTS

Formidable outlays are required to establish short-rotation sycamore plantations. These expenditures underscore the need for rapid developments of genetically superior planting stock.

Costs are categorized as fixed, variable, or annual depending on the nature of the expenditure and when it occurs. Site preparation is one of the major fixed costs. Practitioners recommend that sites be cleared, raked, burned, and disked prior to setting out sycamore seedlings or cuttings. Where site conversion is not necessary, preparation costs were estimated at $40 per acre by commercial organizations pilot-testing the concept. Where conversion costs are necessary, they were estimated at $35 per acre. For analysis, the combined cost of $75 per acre was charged to site preparation since most tracts have required conversion.

Fixed costs were also charged for weed control, fertilization, and a miscellaneous category. Weeds can be controlled either chemically or by cultivation and, in either case, current costs are $25 per acre. Energy crises and soaring chemical costs have inflated the price of chemical weed control and fertilization. The impact on net revenues may be eased by relying on weed control by cultivation and developing genetically superior

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Table 1

Estimated costs of establishing plantations of short-rotation sycamore - per acre

Cost Description	Spacing 1'x4'	2'x4'	4'x4'	6'x4'
	---------------$ per acre-------------			
A. Fixed Costs				
Site preparation (conversion = $35; clearing, burning, raking, and disking = $40)	75	75	75	75
Weed control (by chemicals or cultivation)	25	25	25	25
Fertilization	50	50	50	50
Miscellaneous (insect or disease treatment, trucking, management costs)	5	5	5	5
Total Fixed Costs	$ 155	$ 155	$ 155	$ 155
B. Variable Costs Per Thousand Seedlings*				
Seedlings 10/M				
Planting equipment 5/M				
Supervisory labor 7.70/M				
Total Variable Costs $22.70/M	$247.20	$123.60	$ 61.79	$ 41.20
C. Total Establishment Costs (fixed and variable)				
Without land purchase (A+B)	$402.20	$278.60	$216.79	$196.20
With land purchase at $300/acre	$702.20	$578.60	$516.79	$496.20

D. Periodic Costs	Occurrence	Amount
Annual (taxes, fire protection, general management)	yearly	$ 2.00/acre
Fertilization	each harvest	$ 50.00/acre
Harvesting	each harvest	$ 0.75/ton
Hauling	each harvest	$ 1.50/ton

stock that promises adequate yields without fertilization. Miscellaneous fixed costs include general expenditures for insect control, trucking, and management efforts and are estimated at $5 per acre. Fixed costs are itemized in Table 1, with a total value of $155 per acre charged to the plantation regardless of site, spacing, or rotation length.

Planting stock or seedlings comprise a major proportion of variable costs which vary with spacing. Options simulated include 1X4, 2X4, 4X4, and 6X4, with seedling requirements ranging from 11,000 per acre for 1- by 4-foot spacing to 2,000 seedlings per acre for 4- by 6-foot spacing. Seedling costs were set at $10 per thousand. Planting-equipment costs of $5 per M seedlings and supervisory and labor costs of $7.70 per M also add to the variable costs. When the variable costs are summed to $22.70 per M seedlings, the importance of spacing as a factor in the financial outcome is obvious. Variable costs in the densest plantations amount to almost $250 (Table 1), well over half the establishment costs.

Combined harvesting and hauling costs are set at $2.25 per ton, Table 1, based on estimates provided by commercial experimenters and equipment manufacturers. With a conversion figure of 3 tons of whole-tree chips per cord, sycamore chips can be harvested and delivered to an industrial receiving point for $6.75 per cord, which compares favorably with costs of $15 per cord for bolts (Bellamy, 1974; Myers, 1973). Short-rotation sycamore stems can be clearcut by a machine comparable to a silage chopper. Harvesting, chipping, and blowing the chips into a tractor-drawn wagon or truck would be a single operation. The required technology and even prototype equipment exist.

A final cost entering the calculations was for reestablishment of rootstock to support new series of coppice crops. This item was assumed to equal the initial establishment costs minus conversion costs of $35 per acre.

PHYSICAL YIELDS

Yields from seedlings and three coppice crops have been established. Table 2 presents yields for short-rotation sycamore options that appear economic. Other cutting cycles (1 and 2 years) and closer spacings 1X4 and 2X4) were analyzed, but proved uneconomic for the yields, prices, and costs assumed.

Silvicultural precautions are prerequisite to achieving the listed yields. Foremost amongst critical factors is the selection of a site. Sycamore appears to grow best on well aerated, fertile, mildly acid to mildly alkaline soils with sufficient drainage but with some ground water in the root zone. Poorly drained coastal plain sites were found to severely inhibit growth, whereas similar, but well drained sites supported vigorous growth (Steinbeck, McAlpine, and May, 1972). Table 2 also stresses the critical effect of site on yields. Regardless of spacing and rotation length, yields, and resultant profitability varied substantially between "favorable" and "medium" sites. The key index was the proportions of sand, clay, and silt in the soil. Favorable sites had approximately 40 percent sand and were classified as sandy clay loam. Medium sites were about 25 percent sand and classified as silty clay.

Table 2

Physical yields of short-rotation sycamore - green weight

Plantation Management Options	Favorable Site	Medium Site
Case 1. Spacing: 4'x4'; Cutting cycle - 3 years		
Seedling yield at age 3	15.7 tons/acre	12.0 tons/a
Coppice yields each 3 years	25.5 tons/acre	15.0 tons/a
Total decline in productivity of stand by age 24 (7 coppice crops)	8 percent	8 percent
Case 2. Spacing: 4'x4'; Cutting cycle - 4 years		
Seedling yield at age 4	26.0 tons/acre	20.0 tons/ac
Coppice yields each 4 years	38.0 tons/acre	23.0 tons/ac
Total decline in productivity of stand by age 32 (7 coppice crops)	10 percent	10 percent
Case 3. Spacing: 4'x4'; Cutting cycle - 5 years		
Seedling yield at age 5	35.0 tons/acre	27.5 tons/acre
Coppice yields each 5 years	51.2 tons/acre	35.0 tons/acre
Total decline in productivity of stand by age 40 (7 coppice crops)	12 percent	12 percent
Case 4. Spacing: 6'x4'; Cutting cycle - 3 years		
Seedling yield at age 3	15.0 tons/acre	10.5 tons/acre
Coppice yields each 3 years	24.0 tons/acre	12.0 tons/acre
Total decline in productivity of stand by age 24 (7 coppice crops)	8 percent	8 percent
Case 5. Spacing: 6'x4'; Cutting cycle - 4 years		
Seedling yield at age 4	22.0 tons/acre	15.0 tons/acre
Coppice yields each 4 years	36.0 tons/acre	21.0 tons/acre
Total decline in productivity of stand by age 32 (7 coppice crops)	10 percent	10 percent
Case 6. Spacing: 6'x4'; Cutting cycle - 5 years		
Seedling yield at age 5	30.0 tons/acre	20.0 tons/acre
Coppice yields each 5 years	50.0 tons/acre	35.0 tons/acre
Total decline in productivity of stand by age 40 (7 coppice crops)	12 percent	12 percent

Achieving high plantation survival is difficult with many hardwoods, but this has not been the case with short-rotation rates near 90 percent (Steinbeck, et.al., 1972; Kennedy, 1974; Kormanik, et.al., 1973).

In the analysis, a gradual decline in productivity of rootstock was simulated. Decline rates were set at 8, 10, or 12 percent of yields for cutting cycles of 3, 4, or 5 years for a full production schedule of one seedling and seven coppice crops. For example, a full rotation of seedling and coppice crops on a 5-year cutting cycle would take 40 years. The final yield would be 12 percent less than the first to reflect declining capability of roots to support regrowth.

Established yields are subject to improvement by genetic manipulation of growing stock. Short rotations permit both rapid evaluation of genetically altered stock and adoption of improved planting material. For economic analysis, genetic improvement was assumed to have one of two possible effects: (1) a 10-percent increase in yields where fertilizer is applied, or (2) 80 percent of normal yields in the absence of fertilizer.

STUMPAGE AND DELIVERED PRICES

From the market value for chips, harvesting and hauling costs were deducted to derive stumpage prices as residuals. In 1973, bark free, green hardwood chips delivered to the mill were worth $10 per ton (Bellamy, 1974). It is unlikely that chips containing bark and possibly leaves would bring more than $7 or $8 per ton. Deducting harvest and hauling costs lowers stumpage to about $5 per ton, which was used as the base figure for most of the economic calculations and comparisons.

An imputed delivered price of $10 per ton was used for firms that might manage, harvest, and process sycamore chips from their own plantations. It was assumed that industry would consider short-rotation sycamore as an alternative to buying on the open market and as a means of minimizing unfavorable price fluctuations. If so, an internal price of $10 per ton would serve as an imputed opportunity cost for comparing forest management options. Industry would choose short-rotation sycamore if resultant present net worth or internal rates of return exceeded those derived from other means of supplying the mill with wood fiber.

As noted earlier, substantial costs are involved with establishing and managing short-rotation sycamore plantations. Offsetting these costs, however, are tangible advantages in harvesting and hauling. Labor requirements would be minimal for harvesting large volumes of sycamore on small areas by mechanical means. Further savings would accrue through the higher operating efficiency of harvesting equipment when large volumes of wood fiber would be gathered from compact cutting units. Harvesting and hauling sycamore chips appears to be less than half as costly as conventional pulpwood operations. For a conversion of 3 tons of chips per cord of wood, sycamore chips can be delivered for less than $7 per cord. Conventional harvest-and-haul costs currently range upward from $15.

PROCESSING AND UTILIZATION OF JUVENILE SYCAMORE

Recent technological innovations favor expanded markets for particle-based and reconstituted wood products. Tests have found sycamore chips suitable for production of linerboard, quality bond paper, newsprint, particleboard and hardboard, (Ga. Forest Research Council, 1973). Pulp produced from young sycamore trees had shorter cooking cycles and equal or superior strength characteristics. Quality improved with age of trees but even 2-year old sycamore produced material comparable to general mill results.

Processing advantages associated with sycamore include utilization of the entire tree-stems and branches including bark, but preferably not leaves. Furthermore, lower cooking pressures and temperatures suffice, and digester times are shorter than for conventional hardwoods. With closer utilization of wood fiber from every acre and research to expand production potentials, it is likely that uses for short-rotation sycamore and other juvenile woods will multiply.

Attention should be drawn, however, to processing shortcomings. With lower specific gravity, pulp yields per unit of wood fiber will be less so that given levels of production require greater procurement, transportation, and storage costs. Interestingly however, juvenile sycamore unlike many other species, for relatively high specific gravity and long fibers--approximately 80 to 90 percent of mature wood values (McGovern 1973; Saucier and Ike 1969).

ECONOMIC IMPLICATIONS

Costs, yields, and prices were combined in several options to calculate present net worth, internal rate of return, benefit-cost ratio, and equivalent annual income for sycamore investments. Results of analyses of standard yields are shown in Tables 3 and 4. Benefits from genetic gains are given in the text. Answers were sought to the following questions:

> How do different sites and cutting cycles affect profitability of short-rotation investments?
>
> Do different spacings significantly alter costs and revenues?

The full range of calculations, evaluations, and comparisons was made possible by the investment program MULTIPLOY developed by (Row, 1974).

Investment possibilities are presented in Table 3. Measurements common to each of the alternatives include stumpage prices of $5 per ton, one seedling and seven coppice crops with gradual decline in productivity, and a discount rate of 8 percent. Economic criteria tabulated include present net worth, equivalent annual income, benefit-cost ratios, and internal rates of returns. Each of these measures has advantages and drawbacks as a ranking device and each has its advocates and critics. All are included here to serve the needs of a wide audience. Yields depicted in Table 2 are combined with costs presented in Table 1 with revenues set at $5 per ton to measure investment potential of different management options.

Table 3

Economic implications - stumpage sales

Plantation management and investment opportunities	PNW [a] ($/acre)	EAI [b] ($/acre)	B/C [c] ($/$)	IROR [d] (%)
1. Favorable site; 4'x4' spacing; stumpage price: $5/ton				
3 year cutting cycle with 8 harvests	- 48.47	- 4.60	0.88	6
4 year cutting cycle with 8 harvests	45.45	3.97	1.12	10
5 year cutting cycle with 8 harvests	96.89	8.13	1.28	11
2. Medium site; 4'x4' spacing; stumpage price: $5/ton				
3 year cutting cycle with 8 harvests	-186.66	-17.73	0.54	00*
4 year cutting cycle with 8 harvests	-104.79	- 9.16	0.72	2
5 year cutting cycle with 8 harvests	- 31.68	- 2.66	0.91	7
3. Favorable site; 6'x4' spacing; stumpage price - $5/ton				
3 year cutting cycle with 8 harvests	- 48.46	- 4.60	0.88	5
4 year cutting cycle with 8 harvests	34.40	3.01	1.10	9
5 year cutting cycle with 8 harvests	92.79	7.78	1.28	11
4. Medium site; 6'x4' spacing; stumpage price = $5/ton				
3 year cutting cycle with 8 harvests	-207.24	-19.68	0.47	00*
4 year cutting cycle with 8 harvests	-119.46	-10.45	0.66	00*
5 year cutting cycle with 8 harvests	- 36.19	- 3.03	0.89	7

a. PNW = present net worth
b. EAI = equivalent annual income
c. B/C = benefit/cost
d. IROR - internal rate of return

* Negative rates of return; i.e., the discounted costs exceed benefits at all rates of return

Table 4

Economic implications - sale at delivery point

Plantation management and investment opportunities	PNW[a] ($/acre)	EAI[b] ($/acre)	B/C[c] ($/$)	IROR[d] (%)
1. Favorable site; 4'x4' spacing; delivered price = $10/ton *				
3 year cutting cycle with 8 harvests	144.58	13.73	1.25	14
4 year cutting cycle with 8 harvests	268.10	23.45	1.47	16
5 year cutting cycle with 8 harvests	330.85	27.75	1.59	17
2. Medium site; 4'x4' spacing; delivered price = $10/ton				
3 year cutting cycle with 8 harvests	- 67.24	- 6.39	0.87	4
4 year cutting cycle with 8 harvests	38.38	3.36	1.08	10
5 year cutting cycle with 8 harvests	134.63	11.29	1.27	12
3. Favorable site; 6'x4' spacing; delivered price = $10/ton				
3 year cutting cycle with 8 harvests	133.61	12.69	1.24	14
4 year cutting cycle with 8 harvests	240.15	21.00	1.45	16
5 year cutting cycle with 8 harvests	313.51	26.29	1.60	17
4. Medium site; 6'x4' spacing; delivered price = $10/ton				
3 year cutting cycle with 8 harvests	-109.77	-10.43	0.77	00**
4 year cutting cycle with 8 harvests	4.83	0.42	1.01	8
5 year cutting cycle with 8 harvests	116.50	9.77	1.25	12

a. PNW = present net worth
b. EAI = equivalent annual income
c. B/C = benefit/cost ratio
d. IROR = internal rate of return

* Sale at delivery point of $10/ton includes an additional cost of $2.25/ton for harvesting and hauling operations.

** Negative rates of return; i.e., discounted costs exceed benefits at all rates of return.

It is immediately obvious that the difference in yields between favorable and medium sites is critical when expressed in dollar terms. A landowner with medium sites anticipating a stumpage price of $5 per ton would use that land for some purpose other than short-rotation sycamore. Regardless of spacing or cutting cycle, medium sites don't pay. The bleak prospects pertain only to the landowner who hopes to grow sycamore on medium sites and profit from stumpage sales at $5 per ton. Industrial managers could conclude otherwise from different criteria of economic worth.

Favorable sites provide different prospects. Present net worths of nearly $100 per acre are likely for 5-year cutting cycles with 4X4 or 4X6 spacing. That is, an additional $96 or $92 per acre could be invested in short-rotation sycamore and the investment would still pay at an 8 percent discount rate. Or, as shown in the right-hand column, internal rates of return of 11 percent are anticipated; this value indicates the interest rate that equates all costs and revenues. For those who prefer other measures, 5-year cycles on favorable sites promise benefit cost ratios of almost 1.3 and equivalent annual incomes around $8 per acre.

Two other items important to investment analysis are shown in Table 3 rand occur throughout the full range of options. First, returns increase with cutting cycle length. But, the gain from 4 to 5 years is less than from 3 to 4 years, which indicates that revenues are rising at a decreasing rate and that even longer cutting cycles are not necessarily recommended. This is especially true for 8 harvests with a 6-year cutting cycle which would be almost 50 years long with a high probability of declining rootstock and productivity. The other item shown in Table 3 is that returns, regardless of the criteria chosen, are greater with 4X4 spacing than 4X6 spacing. Thus, close spacing takes greater advantage of site potential than wide spacing.

Opportunities for industrial landowners, growing short-rotation sycamore to process in company facilities are outlined in Table 4. Significant changes in these data are a $10 per ton delivered price and an internal charge of $2.25 per ton for harvesting and hauling. The $10 price an opportunity cost for industry. The presumption is that industry can purchase chips as needed on the open market at $10 per ton. If the wood fiber can be grown on company lands, harvested, and hauled to delivery point for less than $10 per ton, it would be advisable to do so.

All economic criteria reflect a positive surge in Table 4. In fact, the present net worth of the investment on favorable sites with 5-year cutting cycles exceeds $300 per acre. In these cases, the company could buy land at $300 per acre to establish sycamore plantations. Where a choice exists, financial considerations dictate planting favorable sites to a 5-year cutting cycle. Even with the $10 price, 3-year cutting cycles promise financial loss on medium sites. Because of the substantial costs, which remain relatively constant regardless of cutting cycle, the higher yields and closer utilization of site potential of the longer cycles are required for economic optimization. Three-year cutting cycles were relatively unprofitable throughout the analyses, and the results of this option were deleted from most of the tables.

The economics of planting genetically improved planting stock that permits yields 10 percent above those listed as standard in Table 2 were assessed. With stumpage sales, medium sites remained marginal but present net worths improved substantially even though they remained negative. On good sites, the net worth for the 4-year cycle doubled and those for the 5-year cycle increased by 50 percent. For 80 percent of standard yields without fertilization, net worths on medium sites became positive for the 5-year cycle. Good-site yields were improved for both 4- and 5-year cycles. It would pay a company to invest its research and development dollars to develop planting stock that did not require fertilization.

CONCLUSIONS

Short-rotation sycamore promises industrial owners a profitable means of supplying a processing facility with wood fiber. Favorable sites and longer cutting cycles appear most advantageous, regardless of price, spacing, or number of crops obtained. Genetics research to increase yields would help speed adoption of short-rotation sycamore. Of especial importance is a genetically improved stock that would not require fertilization because it would greatly expand the supply of suitable acreage.

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