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Estimates of Nutrient Drain by Dormant-Season Harvests of Coppice American Sycamore

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SUMMARY

Estimates of the amount of nutrients removed by dormant-season harvests of coppice American sycamore indicated that harvesting once (at age 4) or twice (at ages 2 and 4) removed 20-145 kg/ha of N, P, K, Ca, and Mg and small quantities of Mn, Zn, Fe, and Cu. Calculations of nutrient drain indicated that for N, gains through natural processes about equal losses, but losses exceeded gains for P and K. However, on the fertile Mississippi River floodplain site used in the experiment, drain does not appear to be serious. Nutrient drain was not detectable by analysis of soil samples taken at the beginning and end of the study. On less fertile Coastal Plain soils, drain may be significant, requiring fertilization to maintain site productivity.

Additional keywords: Nutrient removal, harvesting, site productivity, nutrition, fertilization, *Platanus occidentalis.*

INTRODUCTION

Recent shortages of fossil fuels have underscored the need for wood as an alternate of supplemental source of fuel. Plantations of closely spaced American sycamore *(Platanus occidentalis* L.) grown on short rotations can possibly yield the necessary large quantities of biomass. Kormanik and others (1973) report yields of 18 metric tons/ha per year in Georgia, Wittwer and others (1978) report 13-ton yields in Kentucky, and Kennedy (1975) reports 20-ton yields in Mississippi. However, since large quantities of nutrients accumulate in tree tissues, frequent harvesting could result in a net loss of nutrients from the soil and ultimately in significant site degradation.

In this paper, I estimate the amount of nutrient removal by dormant-season harvests of coppice sycamore in the Mississippi River floodplain based on my own nutrient concentration data and the yield data of Kennedy (1975).

METHODS

Seedlings, 1-O stock of central Mississippi origin, were planted at 0.6 X 1 .O- and 1.2 X 1.0-m spacing. Soil was a Commerce silt loam, a member of the fine-silty, mixed, thermic family of Aeric Fluvaquents, and the site is very good for sycamore (Site Index = 35 m in 50 years).

For determination of nutrient concentrations, dormant-season tree samples were taken for each spacing by cutting two trees of mean height and diameter from each of two plots and separating the stems and branches. Tree tissues were combined by component, and all material was dried at 70" C and ground to pass through a 20-mesh screen. Trees were harvested annually, and samples of 1 -year-old tissue were taken in January of 1971, 1972, 1973, and 1974 for a total of four such blocks in time.

The concentration of nitrogen in tree tissue was determined by the semi-micro Kjeldahl method; P by colorimetry; and K, Ca, Mg, Mn, Fe, Zn, and Cu by atomic absorption spectrophotometry.

In a separate study, Kennedy (1975) measured the

Table 1.-*Dry matter production by cutting cycle and spacing for 4 years.*[1]

Spacing & cutting cycle	Component		
	Stem	Branches	Total
	t/ha		
0.6X1.6 meters			
1[2]	15.8	3.7	19.5
2	28.2	3.1	31.3
4	30.5	1.6	32.1
1.2X1.6 meters			
1	12.3	2.2	14.5
2	19.9	3.2	23.1
4	27.4	1.4	28.8

[1]Calculated from Kennedy (1975).
[2]Cutting cycles: 1 = 4 annual harvests, 2 = 2 biennial harvests, 4 = 1 harvest after 4 years.

dry weight of stems and branches of sycamore planted at two spacings — 0.6 X 1.5 and 1.2 X 1.5 m — and harvested after 1, 2, and 4 years (table 1). I estimated nutrients removed through harvesting over 4 years by multiplying my nutrient concentrations by Kennedy's dry weights (tables 2 and 3). This procedure seems to be justified since concentration of most nutrients was not related to spacing, the two studies were conducted on Mississippi River floodplain soils having very similar chemical and physical properties, and the studies received similar management.

Drain of N, P, and K was estimated by comparing expected nutrient gains from precipitation, mineralization, and weathering with nutrient losses through tree harvesting (Boyle 1975, 1976).

At the beginning of the study and after 6 years, soil samples were taken at depths of O-30,30-60,60-90, and 90-I 20 cm from two points on each plot. These samples were analyzed for extractable P by the Mississippi soil test method (Soil Test Work Group 1974); for exchangeable K, Ca, and Mg by atomic absorption after extraction with 1 *N* NH_4OAc; for organic matter by chromic acid oxidation; for total N by the Kjeldahl method, and reaction with the glass electrode pH meter.

Table 2.-*Average nutrient concentrations in stems and branches at two spacings.*

Spacing	Nutrient concentration								
	N	P	K	Ca	Mg	Mn	Zn	Fe	Cu
meters	percent					ppm			
					Stem				
0.6X1.0	.448	.098 *	.292	.300	.058 *	8.68	6.00	12.88	6.38
1.2X1.0	.495	.123	.310	.320	.073	11.88	7.25	15.38	7.50
					Branches				
0.6X1.0	.555	.105	.318	.573	.078	13.63	9.75 *	21.25	11.50
1.2X1.0	.573	.135	.328	.545	.100	19.38	8.25	20.13	11.50

*Indicates significant difference (.05) between spacings.

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Table 3.-Total nutrient removal (branches & stems) during a 4-year period.

Spacing & cutting cycle	N	P	K	Ca	Mg	Mn	Zn	Fe	cu
	kg/ha								
0.6X1.5 meters									
1'	91.2	19.4	57.8	68.5	12.1	.185	.130	.281	.143
2	143.8	30.9	92.4	102.6	18.8	.289	.199	,431	.216
4	146.4	31.6	94.1	100.6	18.9	.290	.198	.426	.213
1.2X1.5 meters									
1	73.4	18.0	45.4	51.2	11.1	.188	.107	.233	.116
2	117.2	28.9	72.4	81.4	17.8	.298	,171	,371	.186
4	144.0	35.6	89.7	95.5	21.5	.353	,211	.450	.223

'Cutting cycles: 1 = 4 annual harvests, 2 = 2 biennial harvests, 4 = 1 harvest after 4 years.

RESULTS AND DISCUSSION

Nutrient accumulation and removal through harvesting

For all elements studied, concentrations in branches exceeded those in stems (table 2). With the exception of P and Mg in stems and Zn in branches, nutrient concentrations were not related to spacing.

I measured nutrient concentrations only for tissue harvested on an annual cutting cycle. Since nutrient concentration tends to be lower in older tissue (Steinbeck and others 1974), the contents I calculated for Kennedy's cycles of 2 and 4 years are perhaps slightly elevated.

During the 4 years, annual dormant-season harvests of trees grown at 0.6 X 1.5-m spacing removed 91 kg/ha of N, 19 of P, 58 of K, 68 of Ca, and 12 of Mg (table 3). Trees at the wider spacing removed 73 kg/ha of N, 18 of P, 45 of K, 51 of Ca, and 11 of Mg. Extending the cutting cycle from 1 year to 2 and 4 years increased nutrient removal by 50-60 percent at the closer spacing and 70-90% at the wider spacing (table 3). As Kennedy (1975) found with yield, there appears to be no difference in nutrient removal between the 2- and 4-year cutting cycles. Very small quantities of Mn, Zn, Fe, and Cu were removed, regardless of spacing or cutting cycle (table 3). Removal ranged from 0.11 kg/ha for Zn when trees were harvested annually for 4 years and spaced at 1.2 X 1.5 m to 0.45 kg/ha for Fe when trees were grown at the same spacing and harvested one time, at age 4.

Nutrient drain

Sycamores obviously remove nutrients from the soil, but the real question is whether or not this removal represents a net loss of nutrients from the site. To answer this question, I compared the losses of N, P, and K from harvesting with the gains that could be expected over the 4 years from weathering, mineralization, precipitation, and other sources (table 4).

Gains in soil N sometimes exceeded losses; the greatest net gain occurred when trees were harvested annually (table 4). Increasing the cutting cycle to 2 and 4 years yielded an index of 0.9 at the closer spacing, indicating a slight drain of N during the 4 years. At the wider spacing, the gain/loss index fell below 1 .O only with the 4-year cycle.

Losses of P exceeded gains by 9 to 27 kg/ha, depending on the cutting cycle and spacing. Gain/loss indices ranged from 0.3 to 0.5, with a tendency toward greater drain with longer cutting cycles. Of the three nutrients studied, P losses were greatest. These results are similar to those of Wood and others (1977), who found N removal to about equal gains and P removal to exceed gain. Potassium drain was intermediate between N and P. Gain/loss indices ranged from 0.5 to 1.0.

Besides gain/loss indices, nutrient reserves of a site must be considered. Although gain/loss indices indicate a drain of P and K, the study site has a reserve of 464 kg of P/ha and 1 ,148 kg of K. Assuming a maximum drain of 27 kg/ha of P over a 4-year rotation, about 17 rotations of 4 years each would be required to deplete the site of available P. Since the maximum drain of K is 49 kg and the soil has a reserve of 1,148 kg, it would take 23 rotations of 4 years each to deplete the available K. Yet, drain probably should not be considered in terms of time required to exhaust nutrient supplies. The soil would not supply adequate nutrition for tree growth long before total depletion. Also, if harvests were conducted during the growing season, removing foliage

Table 4.—*Soil nutrient reserves, expected gains, losses, and gain/loss indices for coppice sycamore* harvested *over* a *4-year* period.

	Nutrient		
	N	P	K
0.6X1.5-m spacing		kg/ha	
Available soil reserve (O-30 cm)[1]	63	464	1146
Gains expected in 4 years[2]	134	9	45
Loss in harvest (by cutting cycle):			
1[3]	91	19	58
2	144	31	92
4	146	32	94
		Index	
Gain/loss index (by cutting cycle):			
1	1.47	.47	.78
2	.93	.29	.49
4	.92	.29	.48
1.2X1.5-m spacing		kg/ha	
Available soil reserve (O-30 cm)	63	464	1148
Gains expected in 4 years	134	9	45
Loss in harvest (by cutting cycle):			
1	73	18	45
2	117	29	72
4	144	36	90
		Index	
Gain/loss index (by cutting cycle):			
1	1.84	.50	1.0
2	1.14	.31	.62
4	.93	.25	.50

[1] Nutrient reserves were determined by analysis of soil from the study site. Available N was estimated from total N, assuming 2% availability.

*Expected gains are those estimated by White (1974) for soils in south Alabama. Gains include inputs from mineralization, weathering, and precipitation.

[3]Cutting cycles: 1 = 4 annual harvests, 2 = 2 biennial harvests, 4 = 1 harvest after 4 years.

from the site, nutrient drain would occur at a more rapid rate.

Soil analyses did not reveal significant losses in nutrients, perhaps because of the inability to measure small changes in available forms of nutrients.

This study was conducted on a highly fertile soil. If the reserve of soil P were only 40 to 50 kg/ha, as in many soils of the southern Coastal Plain, two rotations could deplete the extractable P, assuming biomass production comparable to that observed in this study. Since the rate of biomass production and nutrient accumulation is usually lower on Coastal Plain soils, three or four rotations, or 12 to 16 years, might be required to deplete soil P. But sub-optimum nutrition would occur in a much shorter period. On such sites, fertilization would probably be necessary.

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