

NUTRIENT DRAIN ASSOCIATED WITH HARDWOOD PLANTATION CULTURE

James B. Baker ^{1/}

Abstract.--Past research and a tentative evaluation indicate that nutrient drain and possible site degradation could occur in southern hardwood plantations. The extent of nutrient drain on a given site would depend on the species, length of the rotation, and harvesting system used. The evaluation for cottonwood plantations in Mississippi indicates that nutrient drain is most likely to occur when short-rotation management and whole-tree harvesting are employed. Of the systems evaluated, whole-tree utilization in a 2-year coppice operation was most demanding on soil nutrient pools and removed 3 to 7 times more nutrients from the soil each cutting cycle than were returned.

Additional keywords: Populus deltoides, Platanus occidentalis.

In the past few years, considerable but casual interest has been generated regarding nutrient drain in hardwood plantations. With the advent of whole-tree harvesting, shorter rotations, and 1- to 3-year coppice operations the casual interest is changing to concern. Intensive plantation management and new harvesting systems eventually could lead to the depletion of available nutrients from a site. At present, we do not know whether the fast-growing, nutrient-demanding southern hardwoods will deplete soil nutrients, and can only generalize and speculate based on the scant data available.

OBSERVATIONS FROM EUROPE

As early as the mid-1950's, Rennie (1955, 1957) suggested that traditional harvesting of merchantable wood removed considerable nutrients from a site. He warned that on infertile sites in Britain only a few rotations would be required to affect soil nutrient supplies and tree growth seriously. Later, Rennie (1962) concluded that the degradation of the site was caused by depletion of calcium from the subsoil and by removal of substantial amounts of the site's already limited nutrient supply.

Recently, Mälkönen (1973) compared nutrient drain from conventional (merchantable bole only) and whole-tree harvest methods in pine and spruce stands in Finland. He indicated that whole-tree harvesting would remove from 2.5 to 5 times more N and P from the site than conventional harvesting. He speculated that whole-tree harvesting of spruce stands might deplete the site to the extent that fertilization would be required.

OBSERVATIONS FROM THE U.S.

In aspen-mixed hardwood stands in Wisconsin, Boyle and his associates (Boyle and Ek 1972, Boyle 1975) evaluated the effects on soil nutrient re-

^{1/} Principal Soil Scientist at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., by the Southern Forest Experiment Station, Forest Service--USDA, in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group.

services of (1) conventional and whole-tree harvesting and (2) short-rotation and long-rotation management. Boyle and Ek (1972) concluded that on many Wisconsin hardwood sites harvesting entire aboveground woody portions of trees should not cause serious depletions of available supplies of nutrients for a minimum of two 45-year rotations. Boyle (1975) found that N, P, and K inputs into the soil should be more than adequate to supply the nutrient demands of the next forest crop on a 30-year rotation cycle. However, when he estimated the effect of harvesting three crops of aspen sprouts in 10-year rotations he found that, except for N, nutrient removals during harvesting would exceed nutrient inputs during subsequent rotations.

To date, the only report on nutrient drain in southern hardwood plantations is by White (1974). He evaluated the effect of whole-tree harvesting of cottonwood on the soil nutrient pool in southwest Alabama. His conclusions were that complete-tree utilization would possibly degrade the sites by depleting soil reserves of N, P, and K.

ESTIMATE OF NUTRIENT DRAIN IN HARDWOOD PLANTATIONS IN MISSISSIPPI

Data recently collected in studies by the U. S. Forest Service and Mississippi State University make possible a rough evaluation of nutrient drain associated with several management and harvesting systems in southern hardwood plantations. The evaluation was made using the technique and format that Boyle (1975, 1976) developed for aspen.

The object of the technique is to compare nutrient removals at harvest with nutrient gains that occur during a cutting cycle or during a rotation. An index is obtained which gives a rough but quick evaluation of potential drain on the nutrient reserves of the soil. An index value ≥ 1.0 indicates that nutrient input for a rotation equals or exceeds the loss at harvest; thus, soil reserves should not be reduced in any cutting cycle. An index value < 1.0 indicates that gains are less than losses and soil reserves will be reduced in subsequent rotations.

Plantation Systems

Potential nutrient drain was evaluated for whole-tree (aboveground portion excluding leaves) and conventional harvesting of cottonwood plantations on 4-, 12-, and 20-year rotations in Mississippi (Table 1). The analysis indicated that with a 4-year rotation and whole-tree harvesting the P and K removal at harvest would exceed gains by 250 percent during the next rotation. Under these conditions, nutrient drain and site degradation would be likely to occur at an accelerated rate. If boles only were removed, P and K losses would exceed gain by 10 to 20 percent. Soil reserves would not have to be greatly relied upon for future crops, and nutrient drain would be a long-term process.

If the rotation were 12 years and whole-tree harvesting were used, P and K losses would exceed gains by 2 lbs/a and 34 lbs/a respectively, which would drain soil reserves only slightly. Conventional harvesting at 12-year intervals would result in even smaller nutrient removals and no drain on soil reserves. If the management rotation were 20 years, nutrient gains would equal or exceed losses using either conventional or whole-tree harvests.

Table 1.--Influence of harvesting systems and rotation lengths on nutrient drain in cottonwood plantations in Mississippi.

	Nutrient		
	N	P	K
	- - - lbs/a - - -		
<u>4-YEAR COTTONWOOD ROTATION</u>			
Available soil reserves (top 12 inches) at time of harvest ¹	53	104	876
Gains expected during 4 years from precipitation, mineralization, and weathering ²	120	8	40
Losses in whole-tree harvest at age 4 ³	114	20	105
	- - - Index - - -		
Gain/loss index	1.1	0.4	0.4
	- - - lbs/a - - -		
Losses in harvest of boles only at age 4	55	9	52
	- - - Index - - -		
Gain/loss index	2.2	0.9	0.8
	- - - lbs/a - - -		
<u>12-YEAR COTTONWOOD ROTATION</u>			
Available soil reserves (top 12 inches) at time of harvest	53	104	876
Gains expected during 12 years from precipitation, mineralization, and weathering	360	24	120
Losses in whole-tree harvest at age 12	191	26	154
	- - - Index - - -		
Gain/loss index	1.9	0.9	0.8
	- - - lbs/a - - -		
Losses in harvest of boles only at age 12	130	17	108
	- - - Index - - -		
Gain/loss index	2.8	1.4	1.1

Table 1.--Influence of harvesting systems and rotation lengths on nutrient drain in cottonwood plantations in Mississippi (continued)

	Nutrient		
	N	P	K
	- - - lbs/a - - -		
<u>20-YEAR COTTONWOOD ROTATION</u>			
Available soil reserves (top 12 inches) at time of harvest	53	104	876
Gains expected during 20 years from precipitation, mineralization, and weathering	600	40	220
Losses in whole-tree harvest at age 20	228	42	227
	- - - Index - - -		
Gain/loss index	2.6	1.0	1.0
	- - - lbs/a - - -		
Losses in harvest of boles only at age 20	198	37	198
	- - - Index - - -		
Gain/loss index	3.0	1.1	1.0

¹ Soil reserve values are those reported by Broadfoot (1976) for a Commerce soil. Reserve N was estimated by converting Broadfoot's organic matter content to total N, then assuming one-percent availability.

² Values are annual gains reported by White (1974) for alluvial soils in southwestern Alabama that have been expanded for a rotation.

³ Values are those reported by Switzer, Nelson, and Baker (in press) for cottonwood plantations on Commerce soils in Mississippi.

Coppice Systems

Two-year coppicing of cottonwood and sycamore could result in significant drain on soil nutrient reserves (Table 2). With cottonwood, N, P, and K removals would exceed inputs by 159, 20, and 121 lbs/a. Each cutting cycle would remove from 3 to 7 times more nutrients from the site than would be returned. Coppicing of sycamore results in smaller nutrient removals because sycamore has lower concentrations of nutrients and produces less mass than cottonwood. However, even with sycamore, up to 4 times more nutrients are removed from the site than are returned, which could be critical over long periods.

Table 2.--Influence of short-rotation coppicing on soil nutrient drain.

	Nutrient		
	N	P	K
	- - - lbs/a - - -		
Available soil reserves (top 12 inches) at time of harvest	53	104	876
Gains expected during 2 years from precipitation, mineralization, and weathering	60	4	20
Losses in whole-tree harvest at age 2			
Cottonwood ¹	219	24	141
Sycamore ²	70	15	42
	- - - Index - - -		
Gain/loss index			
Cottonwood	0.3	0.2	0.1
Sycamore	0.9	0.3	0.5

¹ Frison (1968).

² Estimated using dry weight data from Kennedy (1975) and nutrient concentration data collected from a sycamore coppice system near Stoneville, Miss. (Unpublished data on file at Southern Hardwoods Lab., Stoneville, Miss.)

CONCLUSIONS

Nutrient drain and site degradation could occur in some of the fast-growing, nutrient-demanding hardwood plantations in the South. However, the extent of nutrient drain on a given site is dependent on the species, length of rotation, and harvesting system used. Also, nutrient drain may be more critical on sites that are low in native fertility or on those that have been depleted of nutrients by agricultural crops.

It must be emphasized that because of the many assumptions that had to be made the evaluation presented here provides only a rough estimation of nutrient drain. For example, we do not know:

- (1) What the actual nutrient inputs on specific sites are and how various management and harvesting systems affect these inputs during a cutting cycle;
- (2) How rapidly a drain on available nutrient reserves will be offset by release of previously unavailable nutrients from the soil nutrient pool; and
- (3) For sites subject to flooding, how periodic deposition of nutrients accompanying flooding affects the total nutrient budget.

Additional research is needed in these areas before accurate evaluations can be made of nutrient drain associated with plantation culture of southern hardwoods.

LITERATURE CITED

- Boyle, J. R. 1975. Nutrients in relation to intensive culture of forest crops. Iowa State J. Res. 49: 297-303.
- Boyle, J. R. 1976. A system for evaluating potential impacts of whole-tree harvesting on site quality. Tappi 59(7): 79-81.
- Boyle, J. R., and Ek, A. R. 1972. An evaluation of some effects of bole and branch pulpwood harvesting on site macronutrients. Can. J. For. Res. 2: 407-412.
- Broadfoot, W. M. 1976. Hardwood suitability for and properties of important Midsouth soils. USDA For. Serv. Res. Pap. SO-127, 84 p. South. For. Exp. Stn., New Orleans, La.
- Frison, G. 1968. Production of dry matter and nutrient uptake in poplar nurseries. Proc. 13th Session Int. Poplar Comm., Item 9(A) p. 1-7.
- Kennedy, H. E., Jr. 1975. Influence of cutting cycle and spacing on coppice sycamore yield. USDA For. Serv. Res. Note SO-193, 3 p. South. For. Exp. Stn., New Orleans, La.
- Mälkönen, E. 1973. Effect of complete tree utilization on the nutrient reserves of forest soils. In IUFRO Biomass Studies, p. 379-386. Life Sci. and Agric. Exp. Stn., Univ. of Maine, Orono, Maine.
- Rennie, P. J. 1955. The uptake of nutrients by mature forest growth. Plant and Soil 7: 49-95.
- Rennie, P. J. 1957. The uptake of nutrients by timber forest and its importance to timber production in Britain. Q. J. For. 51: 101-115.
- Rennie, P. J. 1962. Some long-term effects of tree growth on soil productivity. Emp. For. Rev. 41: 209-213.
- Switzer, G. L., Nelson, L. E., and Baker, J. B. (In press.) Accumulation and distribution of dry matter and nutrients in Aigeiros poplar plantations. Proc. Cottonwood Symp., 1976.
- White, E. H. 1974. Whole-tree harvesting depletes soil nutrients. Can. J. For. Res. 4: 530-535.