BIOMASS AND NUTRIENT POOLS IN LOBLOLLY AND SHORTLEAF PINE IN SOUTHERN ILLINOIS

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Dry matter and nutrient (N, P, K, Ca, Mg) pools and fluxes in loblolly pine (*Pinus taeda* L.) and shortleaf pine (*P. echinata* Mill.) were studied in a 20-year-old plantation in southern Illinois. Samples were taken to compare pool sizes in the bole, branches and foliage components of the standing trees, and in the F and H components of the litter. Collections of needle fall were made over a one-year period to determine nutrient flux by this process, and a study was undertaken to indicate the relative importance of precipitation as a nutrient source and mode of transfer. Little difference was found between species in nutrient composition of the different pools but loblolly pine generally showed more biomass production which resulted in larger pool sizes. Needle fall was found to be important in the return of Ca and Mg to the soil in both species. The study of precipitation indicated this was a significant mode of nutrient transfer, particularly for K. Its relative importance appears to be highly dependent on species characteristics.

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INTRODUCTION

Loblolly pine (*Pinus taeda* L.) and shortleaf pine (*P. echinata* Mill.) have been widely used in reforesting abandoned agricultural land in southern Illinois even though the area is at the limit or well beyond the natural range of the two species. Shortleaf occurs naturally along the bluffs of the Mississippi River in southwestern Illinois and therefore was considered better adapted to the area and was planted much more extensively than loblolly pine. However, research has shown that on similar sites the growth and yield of loblolly is greater than that of shortleaf pine (Gilmore and Gregory 1974). Effects of these species on nutrient pools also deserves consideration. Objectives of the study were to determine (1) biomass and nutrient pool distribution, (2) nutrient return through litter fall, and (3) the importance of precipitation in the nutrient cycle for shortleaf and loblolly pine planted in southern Illinois.

The study was conducted at the Dixon Springs Agricultural Center, located in Pope County, where loblolly and shortleaf pine were planted in 1949 at square spacings of 4, 6, 8 and 10 feet to determine the effect of stand density on growth and yield (Boggess and Gilmore 1963). The

plantations were established on soils of the Grantsburg series (Ochreptic Typic Fragiudalf) which developed under upland forest cover in 102 to 203 cm of loess over sandstone residuum. These soils have a moderately well developed fragipan at about 76 cm in depth which impedes both root development and percolation of water. The climate of the area is characterized by relatively mild winters and hot summers with frequent periods of drought. The average frost-free season is about 195 days.

MATERIALS AND METHODS

The standing tree analysis was obtained by selecting nine 20-year-old trees of each species from an area of approximately 8 hectares (8 x 8 spacing) with diameters approximately the same as the tree of mean basal area. These trees were cut at the soil line and separated into the needle, branch and bole components. The average dry weight of each component was determined and samples were analyzed for nutrient content. Nutrient pool sizes were determined by multiplying the mean concentration for each nutrient by the mean dry weight for each component. Twelve $1m^2$ samples were taken of the F and H layers separately and of the total litter (F + H) under each species. To monitor needle fall, collections were made at two to four week intervals over the twentieth year from 12-$1m^2$ litter traps under each species. These and the litter samples were weighed and analyzed for nutrient content.

Data for the precipitation portion of the study were collected from two study plots in each species after each precipitation event during the twentieth year. Precipitation, stemflow and throughfall measurements and samples were taken from six standard rain gauges including two in an open area, two stemflow traps, and four litter leachate collection devices per plot. Precipitation and throughfall samples were taken from gauges which were not covered between rainfall events and thus include dustfall. A preliminary report on this study was reported by Miceli et al. 1975.

Nutrient analysis was done by atomic absorption spectrophotometry for K, Ca and Mg. P content was determined colorimetrically (Murphy and Riley 1962) and N in the biomass by the Kjeldahl method (Bremmer 1965). N in the precipitation was measured by the phenate method for ammonia and the phenoldisulfonic acid method for nitrate (American Public Health Association 1971).

RESULTS AND DISCUSSIONS

Standing Tree Analysis

The relative distribution of biomass was similar for both species with about 5% in the needles; 18% in the branch component; and 77% in the boles. An important difference was found in the amount of biomass each species had accumulated (Fig 1). Loblolly pine showed significantly

($P \geq 0.05$) larger accumulations than shortleaf in the bole and branch components, and in the total standing biomass. The close link between biomass production and nutrient circulation is demonstrated in the effect this difference has on nutrient pools. Significantly larger ($P \geq 0.05$) N pools were found in all three components of the standing biomass of loblolly pine (Table 1). We also found larger ($P \geq 0.05$) pools of P and K in the boles, and P and Ca in the branches of loblolly pine. One effect of the faster growth rate of loblolly pine then appears to be the accumulation of larger pools of nutrients within the system.

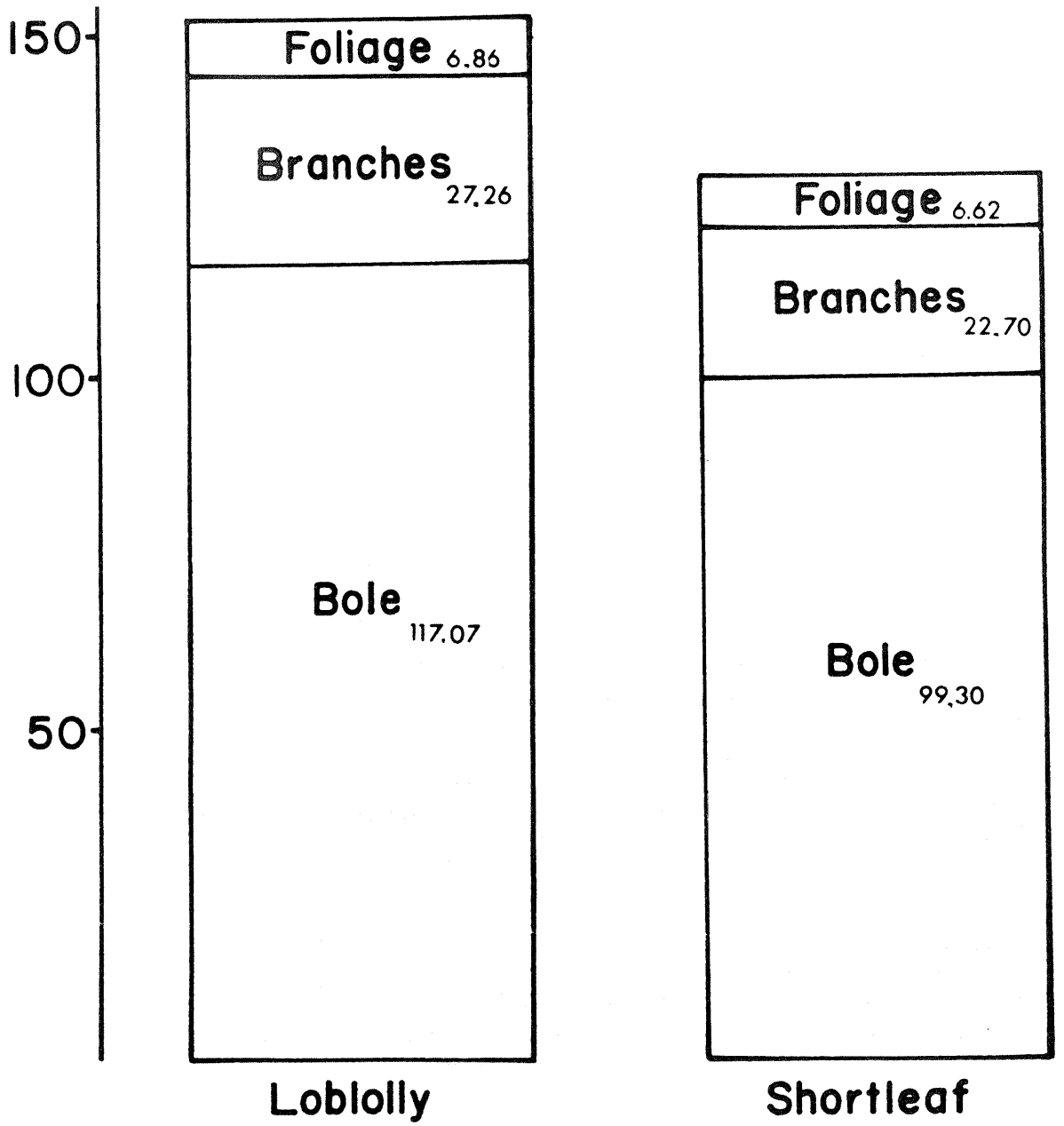

Figure 1. Above ground biomass of 20-year-old loblolly pine and shortleaf pine (metric tons/ha).

Table 1. Nutrient pools in the standing biomass of loblolly pine (L) and shortleaf pine (S).

Component		N	P	K	Ca	Mg
		kg/ha				
Bole	L	59.6*	8.2*	40.3*	39.3	9.1
	S	51.2	7.2	37.9	40.2	9.3
Branches	L	40.7*	6.8*	26.1*	24.3*	6.2
	S	34.6	6.0	24.0	18.2	5.9
Foliage	L	67.2*	6.9	27.3*	22.2	4.3
	S	61.0	6.9	31.3	20.6	4.4

* Indicates significant differences ($P \geq 0.05$).

Nutrient accumulation within the standing biomass for both species was in the order N > K > Ca > P = Mg. This is similar to the findings of several others for young pine plantations (Switzer and Nelson 1972; Will 1968; and Ovington 1962). Switzer, Nelson and Smith (1968) noted that this order changes at about 30 years, becoming N > Ca > K > Mg > P. A large fraction of the Ca is immobilized in the boles, and as they become larger so does the Ca pool.

As expected, the highest concentration of all nutrients occurred in the needles, ranging from 0.98 percent by weight for N to 0.06 percent for Mg in loblolly pine (Table 2). Concentrations in the branches ranged from 0.15% for N to .02% for P and Mg, while those in the bole never rose above .05%. No significant differences ($P \geq 0.05$) were noted between loblolly and shortleaf pine. With the biomass distributed in an inverse sequence (bole > branches > needles), the nutrient pools were distributed more evenly through the standing trees than biomass (compare Tables 1 and 2). An overall average of about 31% of the total nutrients were found in the needle component, 28% in the branches and 42% in the bole. The implications this would have to the forest manager are discussed by Wells, Jorgensen and Burnette (1975).

Table 2. Nutrient content of the standing biomass of loblolly pine (L) and shortleaf pine (S).

Component		N	P	K	Ca	Mg
		- - - - - - percent by O.D. Wt. - - - - - -				
Needles	L	0.98	0.10	0.40	0.32	0.06
	S	0.92	0.10	0.47	0.31	0.07
Branches	L	0.15	0.02	0.10	0.09	0.02
	S	0.15	0.03	0.11	0.08	0.03
Bole	L	0.05	0.007	0.03	0.03	0.008
	S	0.05	0.007	0.04	0.04	0.009

Needlefall

Loblolly pine cast 49.6% by weight (based on oven-dry weights) and shortleaf pine 46.7% of their respective live needle complement over the twentieth year. This supports the statement by Switzer and Nelson (1972) that the entire needle complement, after a 50% reduction in weight due to drying, is cast over the twentieth year. There was a distinct autumnal periodicity to needlefall, 70 to 80 percent of the needles falling during the months of October and November (Fig 2). There was no significant difference between species in the amount of dry matter, N, P or Ca returned to the forest floor through annual needlefall (Table 3). However, shortleaf pine returned more K and loblolly pine more Mg by this process. This may reflect the slightly higher concentration of K found in shortleaf pine needles, but there is no immediately apparent reason for the greater movement of Mg by loblolly pine (Table 4). Concentration of nutrients in the needles change with season and age (Wells and Metz 1963), with Ca and Mg normally increasing until senescence, K and N gradually declining. After an initial period of rapid spring growth, P content remains stable until abscission (Curlin 1970). Our findings are in agreement. The order of nutrient return in needlefall for both species is Ca > N > K > Mg > P. Rodin and Basilevich (1967) and Curlin (1970) show an order of N > Ca > K > Mg = P, but Curlin notes that the needlefall of some "calciophiles" may contain more Ca than N.

The relative percent of each element that is cycled indicates the importance of cycling as a strategy to meet the stand's annual requirements for specific nutrients. Our data (Fig 3) suggest that needlefall is relatively important as a source for Ca and Mg and less important as a source for N and K, with P being intermediate.

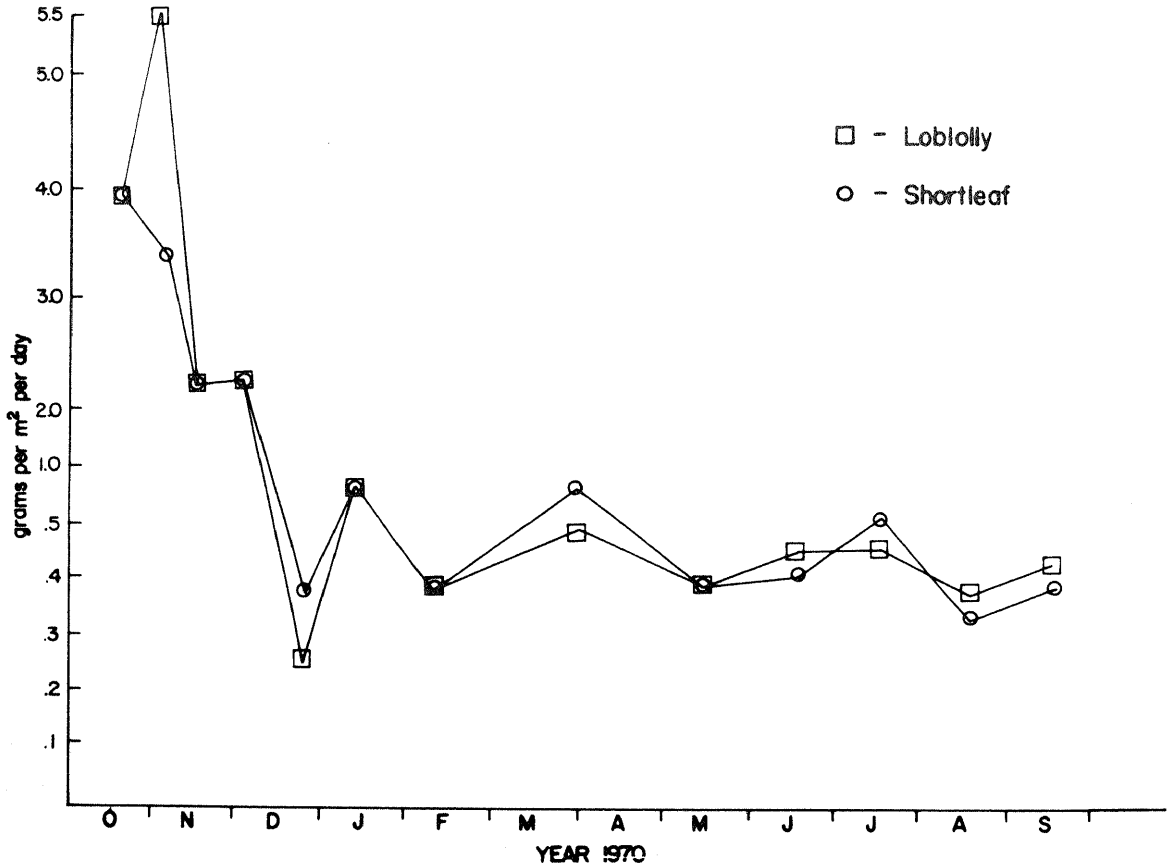

Figure 2. Average daily needle fall (g/cm^2/day) for each collection period, 1969-70.

Table 3. Fresh needle fall (oven dry weight) in loblolly pine and shortleaf pine plantations.

Species	Biomass	N	P	K	Ca	Mg
		kg/ha/yr				
Loblolly	3400	9.2	3.7	6.6	18.3	4.8*
Shortleaf	3090	9.8	2.3	8.3*	20.4	4.1

* Significantly different at P $\geq$ 0.05.

Table 4. Nutrient concentrations of live needles and annual needle fall in loblolly pine and shortleaf pine plantations.

	Species	Biomass (kg/ha)	N	P	K	Ca	Mg
			- - - - - % oven dry weight - - - - -				
Live Needle	Loblolly	6860	0.98	0.10	0.40	0.32	0.06
Complement	Shortleaf	6620	0.92	0.10	0.47	0.31	0.07
Needle Fall	Loblolly	3400	0.27	0.11	0.19	0.54	0.14
	Shortleaf	3090	0.32	0.11	0.27	0.66	0.13

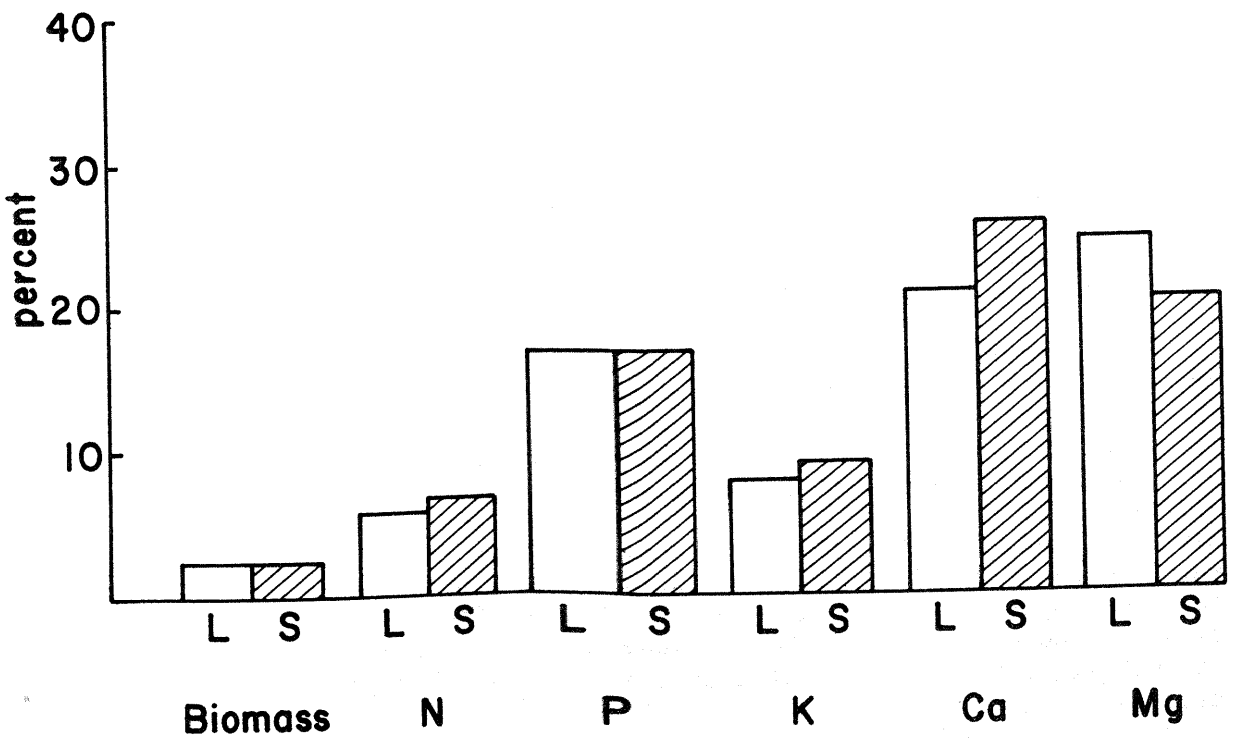

Figure 3. Percent of standing pool of biomass and nutrients returned in needle fall during the twentieth year in loblolly pine (L) and shortleaf pine (S) plantations.

Precipitation

Our study of precipitation as a vehicle for nutrient movement indicates that this is a significant mode of input to and transfer within these plantation ecosystems. The annual addition in precipitation (including dustfall) and transfer by foliar leaching to the forest floor was similar to the contribution of needlefall for Ca, Mg, P and N, but higher than needlefall for K. This is probably in part due to the relative ease of leaching for K.

The volume of water and nutrients in stemflow was small relative to the whole ecosystem budget, but its localized distribution and high nutrient content may serve to increase its relative importance.

The major difference found between species was in their foliar interception capacity. Loblolly pine foliage intercepted about twice as much water as shortleaf pine, about 30% of the incoming rainfall compared to 15%. This resulted in about twice as much stemflow in loblolly pine; differences shown in figure 4 are significant ($P \geq 0.05$). These figures are very close to those found by Boggess (1956) in young shortleaf pine and Hoover (1953) for young loblolly pine. The litter under loblolly pine was also about twice as thick as that of shortleaf--about 10cm compared with 5cm, apparently due mainly to differences in compaction. This resulted in less water flow and nutrient leaching through the litter under loblolly pine.

Litter Analysis

The only component of recognizable litter analyzed was needle fall; data collected on non-leaf litter was insufficient for analysis. On the average, non-leaf litter, including fruit, branches, bark and other components, makes up about 27 to 31% of the total, with a wide range of variation (Bray and Gorham 1964).

The biomass of the litter under loblolly pine was significantly greater ($P \geq 0.05$) than that under shortleaf (36,775 kg/ha and 33,590 kg/ha, respectively). This could be the result of two factors or a combination of them. The difference could be due to a slight but real difference in needle production and fall, possibly in previous years; or a difference in the relative rate of decomposition, due to species characteristics such as C/N ratios, anatomical differences, etc., or a different decomposer population. In a laboratory experiment, Kowal (1969) found decomposition half-times of shortleaf pine needles to be about 252 days. Based on data from Thomas, Auerbach and Olson (1967), he calculated the half-time for loblolly pine needles to be 418 days under natural conditions.

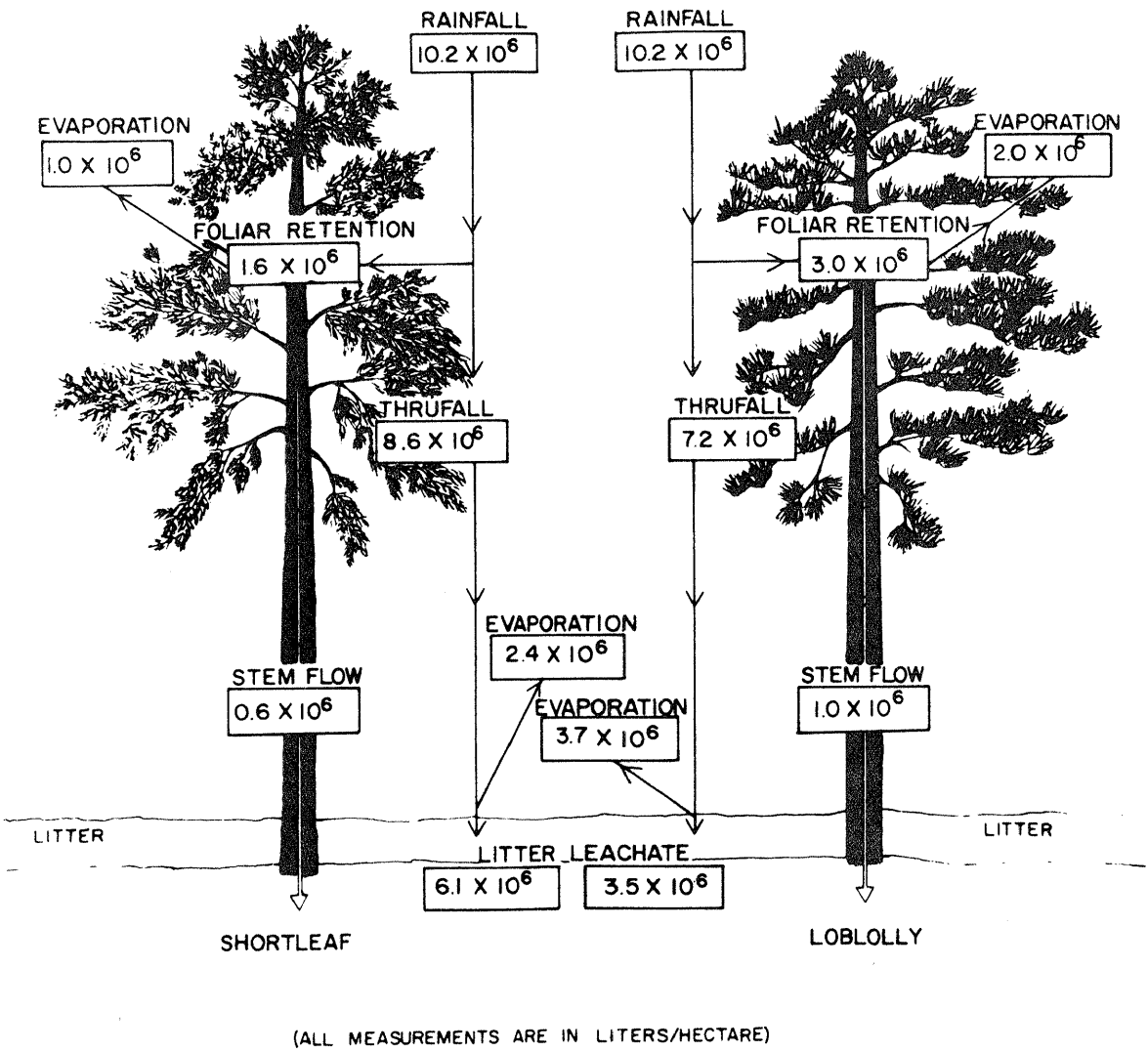

Figure 4. Distribution of precipitation during the twentieth year in loblolly pine and shortleaf pine plantations.

The litter was divided into two parts for nutrient analysis, the top needles, roughly corresponding to the $A_{oo}F$ layers described by Millar (1974), and the humus, corresponding to his A_oH layer. Changes were evident in the nutrient makeup of the needles as they underwent transition from relatively undecomposed top needles to humus. Concentrations of N, P, K and Ca increased in the humus. Mg was the only element that showed

a notable difference between species, remaining stable through decomposition in shortleaf pine, but decreasing in concentration with decomposition in loblolly pine (Fig 5).

The biomass of the litter on the forest floor was about 10 times the biomass of annual needlefall for both species. Most of the dry weight was in the humus. About 20% of the above ground biomass in the system for both species was contributed by the litter.

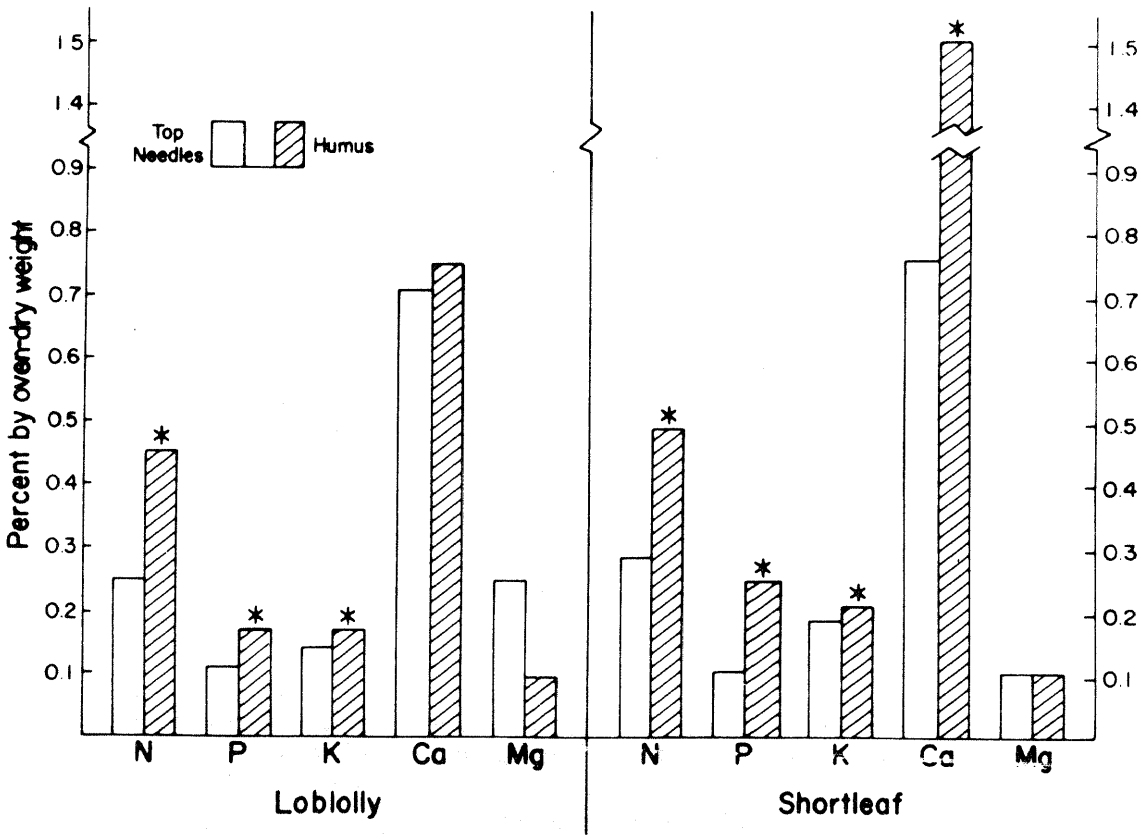

Figure 5. Nutrient content in two components of the litter in loblolly pine and shortleaf pine plantations.

CONCLUSIONS

Since loblolly pine accumulated significantly more biomass in the bole and branch components than shortleaf pine, it would likely be the species of choice in a management program concerned primarily with pulp production. There was certainly more usable wood fiber produced by loblolly pine. These larger biomass accumulations resulted in larger pools of nutrients accumulating in loblolly pine and a greater circulation of nutrients in the soil-plant system. In terms of site amelioration, loblolly pine would be desirable.

This study, and similar ones, make one point very clear. The decreasing order of nutrient concentration from foliage to branches to bole lead to a more even distribution of nutrients than biomass. Thus, the method of harvest may have a definite impact on future site quality. However this is also dependent upon the rate of nutrient release through continued weathering of the solum. Harvest of the boles alone would result in a removal of about 77% of the biomass and only 42% of the nutrients contained in the standing trees. Removal of the boles and branches would result in 95% of the biomass and 69% of the nutrients being removed. Harvest of the whole trees would result in nutrient removal at unprecedented rates for forestry (Wells, Jorgensen and Burnett 1975). With current emphasis on maximum wood production over shorter and shorter rotation times, total tree harvest may result in significant nutrient deficiencies on these southern Illinois sites.

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