EFFECTS OF UTILIZATION ON NUTRIENT REGIMES AND SITE PRODUCTIVITY[1]

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ABSTRACT

The nutrient removals imposed on forest sites by various degrees of utilization and the ability of soils to sustain the utilization depends principally on the degree of disruption and the promptness of recovery of the system's nutrient cycles rather than on the removal of nutrients associated with increased utilization of the phytomass. These conclusions are reached after a consideration of the accumulation and distribution of nutrients in the compartments and components of forest stands and the annual nutrient requirements to develop and sustain forest stands. Ability to sustain nutrient removal and disruption and recovery of nutrient cycles associated with increased utilization also depend on the inherent characteristics of the soils and sites.

INTRODUCTION

GENERAL CONSIDERATIONS

The basic questions at issue here are: (1) How much nutrient removal is imposed on forest sites by harvesting systems, degrees of phytomass utilization, or both? (2) What is the ability of the sites to sustain removal? These are difficult questions to answer with precision and the growing concern about these issues has been addressed by others (Boyle 1976, Boyle and Ek 1972, Kimmons 1977, Thompson et al. 1977, Weetman and Webber 1972, White 1974).

A reasonable basis for generalizing the expected effects will probably come from: (1) a more complete understanding of patterns of dry matter and nutrient accumulation and their distributions during development of forest stands; (2) consideration of the nutrient removals created by varying the degree of utilization during several stages of stand development; and (3) estimating, from the basis of soil chemistry and plant nutrition, ability of a particular locale to meet the annual nutrient requirements of forest stands and to sustain the removals. This is no small task; however, this paper is an attempt to synthesize such a picture, obscure as it may be, from the data of our several studies of the development of nutrient cycles during secondary succession (Koehler 1977, Shelton 1975, Switzer and Nelson 1972, 1973, Switzer et al. 1968).

As a background for this consideration it is important to note that forest stands or ecosystems are essentially biological units that process energy and are sustained by the quantity and availability of abiotic materials, i.e., carbon dioxide, water, and nutrients. The concept that the forest constitutes a renewable resource generally does not adequately recognize that renewability is chiefly a function of the soil or substrate's potential to sustain the living or obviously renewable portion of the system. In short, there is not adequate recognition of the adaptation of the second law of thermodynamics to the system's stock resources.

Also of importance in these general considerations is what constitutes appropriate and inappropriate technology. Many economic, sociological, and biological aspects are involved in this decision; but perhaps, at least to some, the most important is that of sustaining the long-term productivity of forest sites. Swiss and German records attest to the ability to sustain the long-term productivity of forests; however, the long-term productivity of these forests has been attained under much lower levels of utilization than those that are on the horizon or almost on the doorstep in the Southeast. Certainly the capability and suitability of technology and the inherent aspects of productivity need to be evaluated and arbitrated.

PERSPECTIVE OF AGRICULTURE

Care must be taken not to enter a cul-de-sac track with efforts to increase utilization. In this regard the historical perspective of agriculture in North America can be invoked. Along the Atlantic seaboard, European settlers found that crop production was satisfactory as long as soil organic matter was sustained; however, annual cropping quickly reduced organic

1. From: Complete tree utilization of southern Pine. C. W. McMillin, ed. Forest Products Research Society, Madison, Wisc., 1978. 484 p. (Edited to conform to style of this publication).

matter levels of the formerly forested soils. Since organic matter was the chief source of N, with this deficiency crop failures became common, and many of the settlers moved to "new ground." Eventually it was found that liming, crop rotation, and the use of legumes would restore successful crop production (Ruffin 1882). This new system in turn soon depleted the P reserves of the soil because of increased yields and the demands of the legumes.

Thus nutrient depletion in turn was remedied by use of acidulated rock phosphate or bones, i.e., those buffalo bones from the western prairies that could be diverted from shipment to Europe for similar purposes. Continued cropping under this new system also eventually depleted the K reserves of the soils, and the situation was in turn corrected by use of muriate of potash. Other examples could also be cited, e.g., the deleterious effects on forest productivity of the early European practice of removing and employing forest litter for animal bedding. Thus hindsight indicates that sustaining soil productivity under agriculture has required development of systems of nutrient subsidization or soil management. Perhaps such prospects are on the horizon of silviculture in the Southeast.

Of course all the above is tempered for forest management by the fact that annual agricultural cropping is vastly more intensive than that presently envisioned in cropping of forest soils. For example, the annual nutrient accumulation in crops such as cotton and tobacco (Barber 1977) is about the equivalent of that accumulated in the standing crop of natural stands of loblolly pine at 20 yr.

PRODUCTIVITY RELATIONS

In concluding these introductory considerations it is important to note the relation between soil properties and the productivity of southern pines. This is an area of considerable documentation starting with the early efforts of T. S. Coile in the 1930's and subsequently with his several students and others (Carmean 1975). Generally, these studies demonstrate that productivity is related to those factors that characterize the quantitative and qualitative properties of soil as a medium for root development.

Specific soil properties that are common to nearly all studies of productivity with southern pines are: (1) surface soil depth, (2) properties reflecting the moisture regime of the soil, and (3) rooting depth of the profile. Although these properties are mainly physical and obviously affect the moisture regime of the soil, they also affect the nutritional status of soil (Ralston 1964). Quite often, variables that characterize the moisture regime of soil are well correlated with the soil's nutritional status (Voight 1958).

Soil properties significant in productivity of these forest stands are found in an infinite array of combinations and loci. Regardless of combination and location, however, all can be interpreted as expressions of the ability of soil to supply the sustaining abiotic materials for the energy-processing system noted at the start of this discussion. The potential to affect these inherent properties adversely is strongly related to the degree and frequency of utilization of the phytomass. Of particular concern in this regard are influences of utilization on the soil surface and the hydrologic properties of the soil.

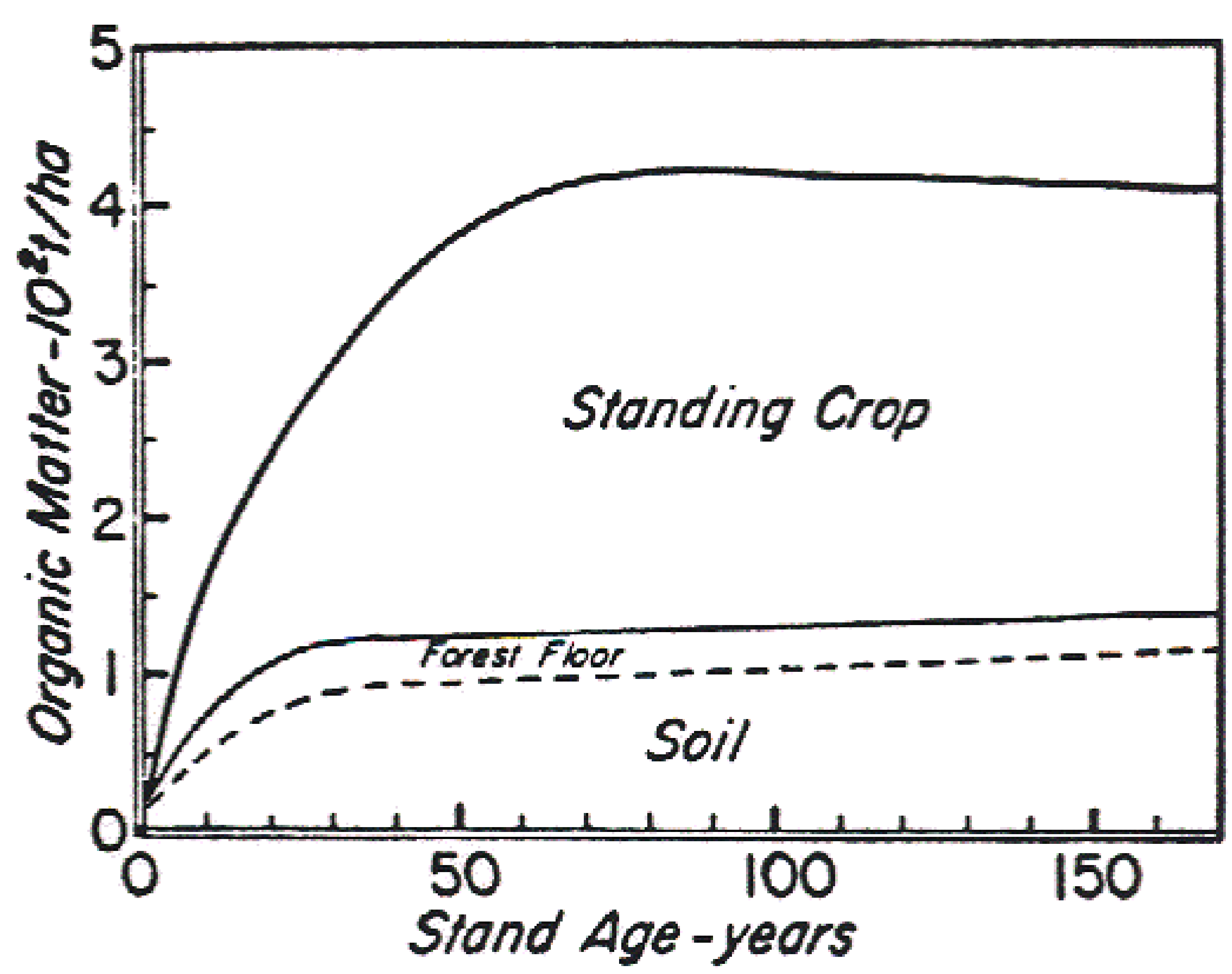
NUTRIENT RELATIONS IN PINE-DOMINATED ECOSYSTEMS

ACCUMULATION AND DISTRIBUTION OF ORGANIC MATTER

System Compartments

Accumulation of organic matter in soil, forest floor, and standing crop during secondary succession is not linearly related to time (Figure 1). Rather, it exhibits the natural tendency of ecosystems to attain maximum sustainable levels of phytomass (standing crop) as well as fairly constant levels in the forest floor and soil compartments. For the circumstances of the Gulf Coastal Plain the combined sustainable level of organic matter totals about 400 t/ha, which is attained at around 65 yr of stand age. From that time onward, about 70% of the organic matter is in the standing crop, 5% in the forest floor, and the remaining 25% is within the rooting depth of the soil (0–120 cm).

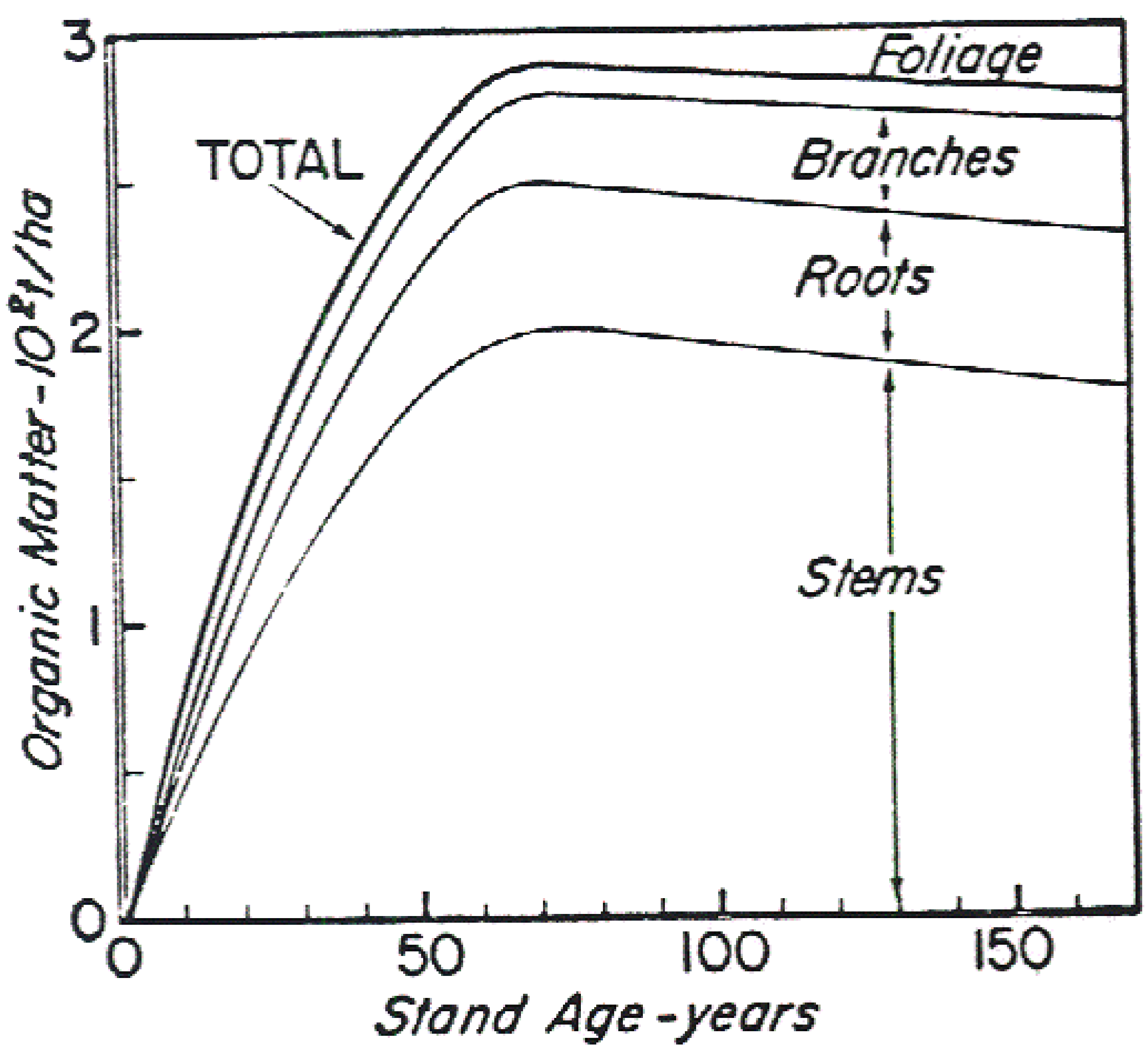
Figure 1. Content and distribution of organic matter in forest stands during secondary succession on upland old-field sites of the Gulf Coastal Plain.



Standing Crop

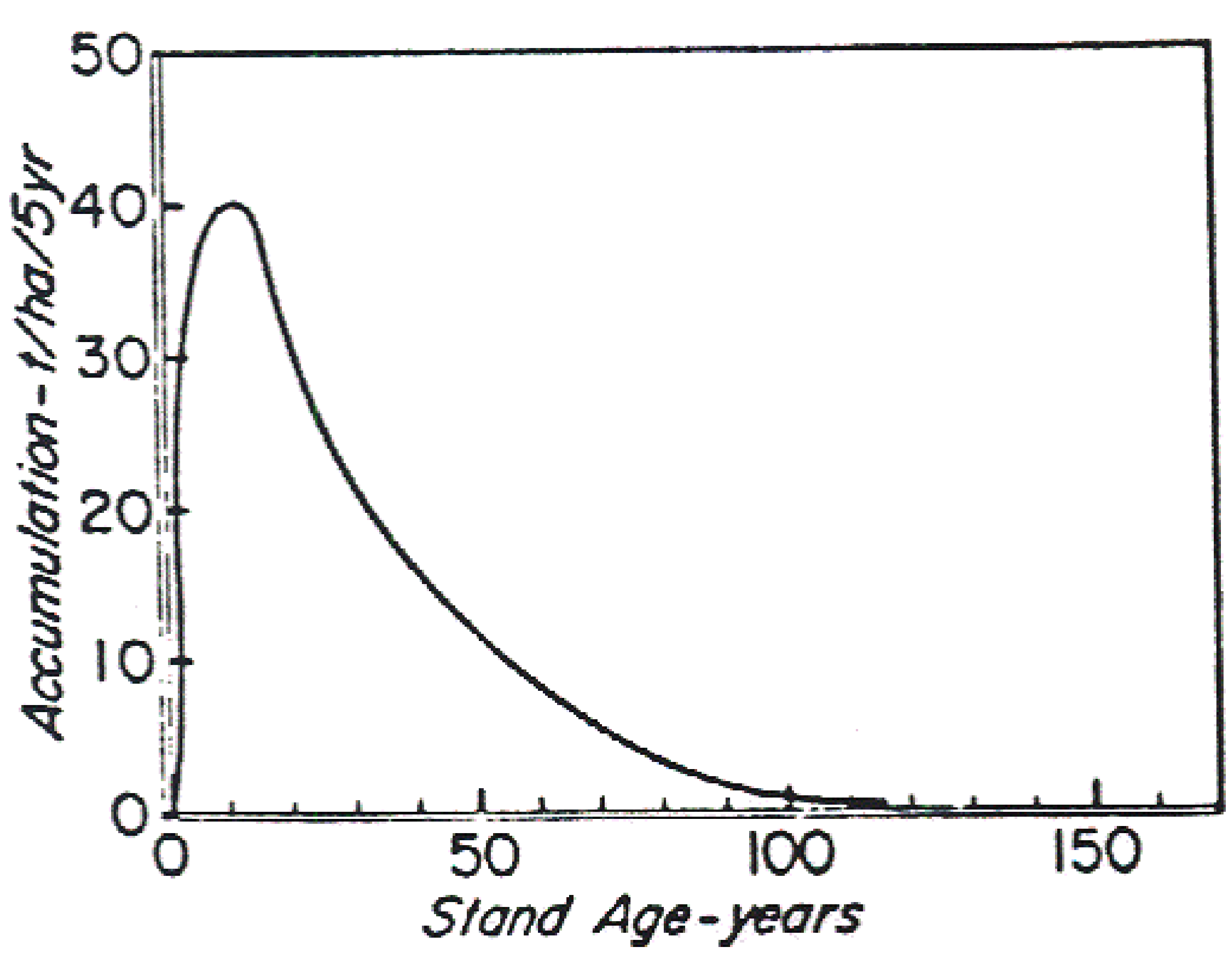
Distribution of the accumulated mass among the components of standing crop is rather constant in the early periods of stand development (Figure 2). Average distribution among the components during this period is about 66% in stems, 10% in branches, 8% in roots, and the remainder in foliage. This distribution changes with time, and after 60–70 yr a larger portion of the standing crop is found in branches and roots, while that in stems and foliage is reduced. This change principally reflects an increase in the hardwood component as stands develop toward their climax composition.

Figure 2. Content and distribution of organic matter among components of standing crop during secondary succession.



When considering the accumulation of organic matter by forest stands it is important to resolve the overall pattern of development into periodic rates. For development of the standing crop illustrated in Figure 1, maximum rates of periodic accumulation are attained during the first 20 yr (Figure 3). During this interval they reach rates of 40 t/ha in 5 yr or about 8t/ha/yr. These rates are not sustained for long, and fall to rather low levels beyond 50 yr, when stand productivity is devoted largely to maintenance of the accumulated mass.

Figure 3. Five-year periodic accumulation of organic matter in standing crop during secondary succession.



Thus, in terms of mass, forest stands have a developmental period when rates of accumulation are high, followed by a period of maturity when accumulation is low and productivity is devoted to maintenance of the accumulated mass. The relative lengths of these two periods differ markedly, with the developmental period considerably shorter than that of maturity. The importance of this difference will be considered later.

QUANTITY AND DISTRIBUTION OF NUTRIENTS

System Compartments

The quantity and distribution of nutrients in compartments of oldfield loblolly pine stands that have attained their sustainable or equilibrium levels of phytomass are given in Table 1. Distribution among the system compartments varies by nutrient; however the ordering for compartmental content of all nutrients is soil >> vegetation > forest floor. Generally about 91% of a system's nutrient content is found in soil, 7% in vegetation, and 2% in the forest floor.

This comparison obscures distribution of nutrients in the various horizons of the soil profile; e.g., if the A horizon is

Table 1. Average nutrient content (in kilograms per hectare) by compartment in 60-yr-old natural stands dominated by loblolly pine on uplands of the Gulf Coastal Plain.

	Stand compartment			
Nutrient	Forest floor	Standing crop	Soil[a]	Total
	Soil to 120 cm depth			
N	250	470	6700	7420
P	15	57	1400	1472
K	23	330	2500	2853
Ca	180	650	5000	5830
Mg	24	114	6100	6238
	Soil to 20 cm depth (A horizon)			
N	250	470	1820	2540
P	15	57	230	305
K	23	330	190	543
Ca	180	650	700	1530
Mg	24	114	155	293

[a]Soil values are total N, moderately available P, and exchangeable K, Ca, and Mg.

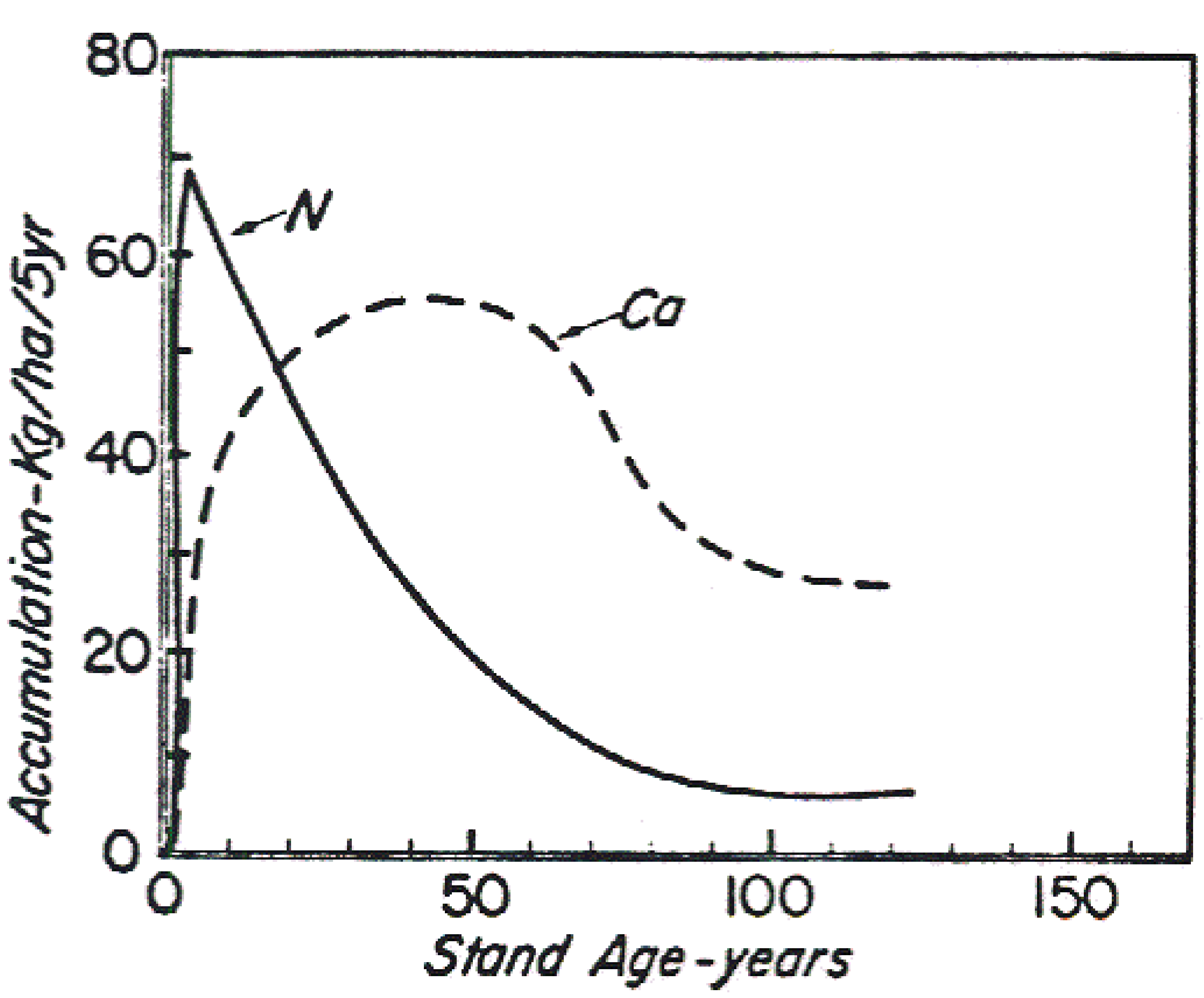
used as a basis for comparison, the combined nutrient content of vegetation and forest floor increases to 40% and the soil's content is reduced to 60% (Table 1). Moreover, two other things become apparent: (1) about 70% of the system's N and P are found in the A horizon, while (2) only 15%–50% of the K, Ca, and Mg are found in this fraction of the soil compartment. Thus the A horizon constitutes a principal reserve for the system's N and P, while the lower soil horizons contain the reserve for K, Ca, and Mg.

Stand Components

Accumulation of nutrients in standing crop of forest stands roughly parallels that of organic matter. Since nutrient concentrations vary among components of the standing crop, however, there is also some variation in patterns of nutrient accumulation. For a resolution of these differences each nutrient should be considered separately. When that is done, two differing patterns of nutrient accumulation appear: one in which nutrient accumulation parallels that of the mass of the entire stand (viz., N and P), and one in which nutrient accumulation more nearly reflects the accumulation of only the permanent tissues of the stand (viz., Ca). Accumulations of N and Ca are discussed here.

Patterns of periodic accumulation of N and Ca are different (Figure 4). Nitrogen accumulation is greatest during the early decades of stand development when canopy and actively absorbing root masses are developing. During the subsequent period N accumulation declines to considerably lower levels. This sharp decline in periodic accumulation of N probably reflects the development of cycling, since canopy and root systems contain considerable amounts of ephemeral tissues which reach rather stable quantities early in stand development and also have fixed rates of replacement. In contrast, the less mobile Ca has a broad period of peak demand (from 25 to 65 yr), which strongly corresponds to the period of peak increment of the relatively permanent stem tissues. Rates of Ca accumulation beyond 65 yr are considerably higher than those of N, and reflect the compositional change to hardwoods with their larger branch mass as well as increased concentration levels.

Figure 4. Five-year periodic accumulation of N and Ca in standing crop during old-field succession.



POTENTIAL REMOVALS OF NUTRIENTS IN PHYTOMASS

General

The pattern of phytomass accumulation shown in Figure 3 has some pertinent implications in the objective management and use of this resource. The various pressures to maximize yield of mass, without regard to other considerations, result from realities of the yield-time relationship shown in Table 2.

Table 2. Yield-time relation.

Rotation length (yr)	Stem yield (t/ha)
20	108
60	196

The data show that in a tripling of rotation length yield is roughly doubled (increased by 82%). Obviously, employing three 20-yr rotations rather than a single 60-yr rotation can increase yields by two-thirds, i.e. 324 versus 196 t/ha. The temptation to move toward shorter rotations is great, but what are the realities in terms of imposed nutrient removal? The following discussion of nutrient removals is made against this yield-time relation, with additional consideration of various degrees of utilization of the phytomass.

Utilization and Nutrient Removals

The nutrient contents of the utilized portion of the standing crop under 20- and 60-yr rotations are given in Tables 3 and 4. Although there is a variation in effects for each nutrient, these data indicate that the various combinations that utilize woody tissues (stems, branches, and roots) increase yields from about 25% to 30%. These yield increases are of similar magnitude regardless of rotation length. Gains in yield accomplished by such utilization are accompanied by increases in nutrient removals of 30%–70%. Thus, as an approximateion, yield increases effected by more complete utilization of these woody tissues are accompanied by a doubling in percentage increases

Table 3. Dry-matter yield and nutrient content of utilized portion of standing crop at 20 yr.[a]

Utilized portion	Yield (t/ha)	Nutrient content (kg/ha) N	P	K	Ca	Mg	Total
Stems	108	92	8	68	103	26	297
Stems and branches	127	147	14	105	167	37	465
Stems and roots	123	104	9	77	168	30	388
Stems, branches and roots	142	154	15	114	232	41	556
Aboveground	136	238	22	141	183	46	630
Entire	151	250	24	150	199	50	673

[a]All values are for standing crop of natural stands that have received no prior removals. Root values are for only the primary or taproot portion of the root mass.

Table 4. Dry matter yield and nutrient content of utilized portion of standing crop at 60 yr.[a]

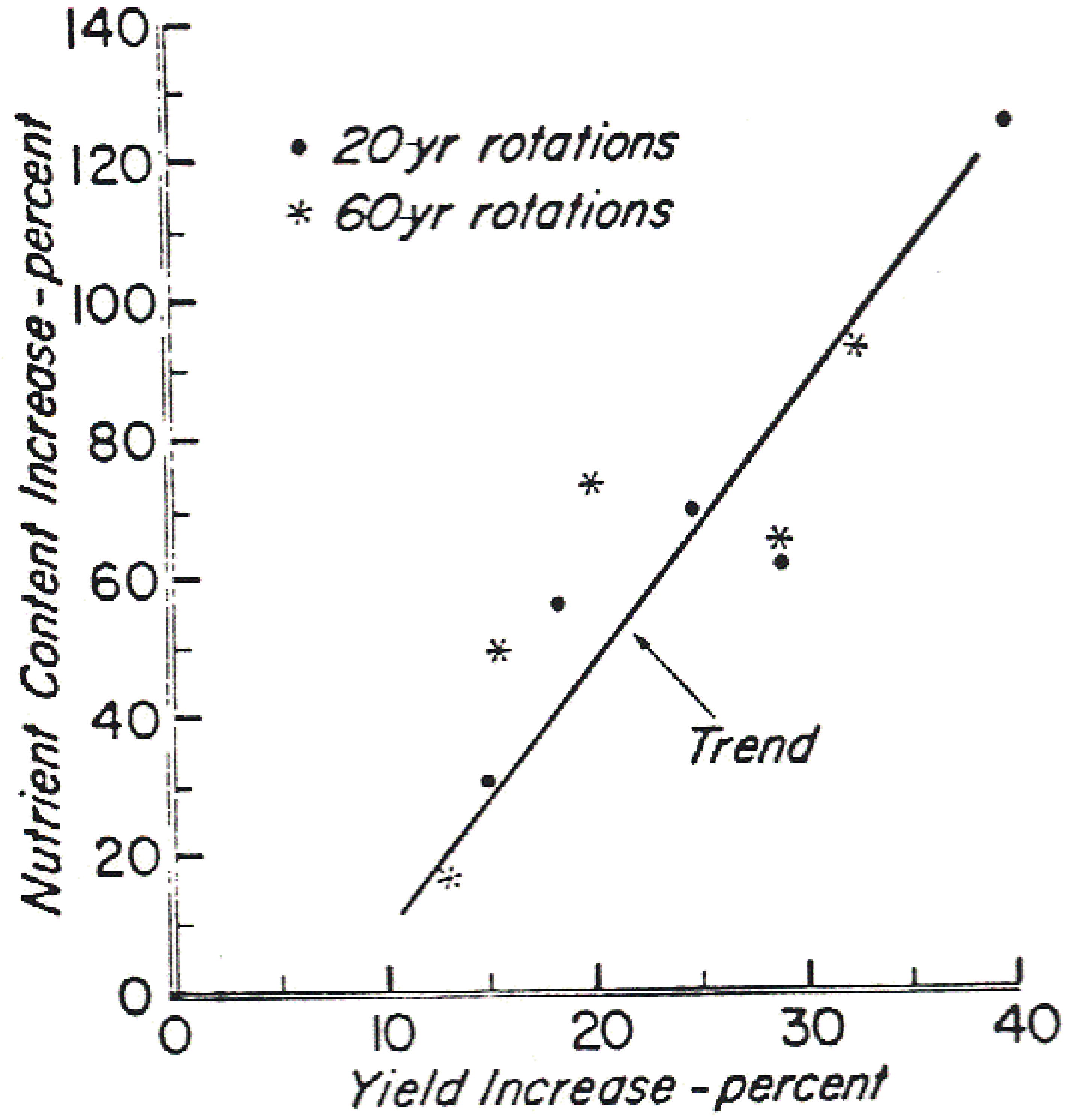
Utilized portion	Yield (t/ha)	Nutrient content (kg/ha) N	P	K	Ca	Mg	Total
Stems	196	174	13	135	310	49	681
Stems and branches	226	256	23	194	477	69	1019
Stems and roots	222	200	15	156	363	58	792
Stems, branches, and roots	252	282	25	215	530	78	1130
Aboveground	234	344	31	231	513	80	1199
Entire	260	370	33	255	566	89	1313

[a]All values are for standing crop of natural stands that have received no prior removals. Root values are for only the primary or taproot portion of the root mass.

in nutrient removal. Inclusion of foliage in utilization achieves only slight increases (about 10%) over yields obtained by increased utilization of woody tissues. Since foliage is the tissue with the highest nutrient concentration, however, particularly for N, P, and K, utilization of foliage can increase total nutrient removals by 100% over stem-only utilization. Such increases are greater when 20-yr rotations are employed since foliage is a larger portion of the phytomass in stands of that age.

The overall pattern of the relation between yield and nutrient removal increases envisioned for these stands is illustrated in Figure 5. Using stem-only utilization as the basis for comparison, the general trend indicates that each percentage increase in yield is accompanied by about a 3% increase in nutrient removal. Of course, as noted, the effect of yield increase on

Figure 5. General relation between increased utilization of phytomass of forest stands and increased nutrient content of utilized tissues.



nutrient removal is specific for a particular nutrient and for those tissues that constitute the basis of yield increases.

Another aspect influencing nutrient removal is the temptation also to increase yields by shortening the rotation. Details of such possible effects in the southern pine forest have been treated elsewhere (Switzer and Nelson 1973). General effects for the case at hand are summarized in Table 5. Clearly, yield and nutrient removals are increased by shortening rotation regardless of the utilization employed, and increased yield is accompanied by an accelerated increase in nutrient removal. Consider what happens during a 60-yr period by reducing the rotation length to 20 yr and employing stem and root utilization. These changes effect a yield that is two-thirds greater

Table 5. Increase in yield and nutrient removal (in percent) effected by three 20-yr rotation vs. one 60-yr rotation under various degrees of utilization.

Utilization	Increase in Yield	Nutrient removal
Stems	65	31
Stems and roots	66	46
Entire	74	54

than that of a 60-yr rotation. The rate at which the site's nutrients are being exploited, however, has been increased by nearly one-half. Generally, if nutrient drain is a paramount consideration and if rotations are shortened to increase yields, conservative levels of utilization should be employed.

Other Potential Removals

The potential for nutrient losses from forest sites includes factors beyond the degree of phytomass utilization, length of rotation, and interaction of utilization and rotation length. Chief among the additional considerations are losses of nutrients through accelerated erosion and leaching due to exposure of the forest floor and disturbance of the soil surface. These conditions are strongly dependent upon harvesting techniques and promptness and completeness of the establishment of succeeding vegetation.

The forest floor mass ranges from 25 to 35 t/ha during stand development and represents from 6% to 10% of the system's organic matter (Figure 1). Maximum forest floor mass is attained at around 60–70 yr. At that time the forest floor contains 2% of the system's nutrients if the basis for the soil compartment is 120 cm, and 9% if the soil depth is 20 cm. This quantitative evaluation can lead to some misunderstanding about the nutritional role of the forest floor. Organic matter in this compartment and in the soil surface represents former living tissues that are in the process of decomposition. These decompositional processes result in the mineralization of the organic matter's nutrient store. Thus nutrients found in the forest floor at any instant represent those in transit. Such nutrients are primarily those associated with ephemeral foliar and nutrient-absorbing root tissues.

Compared with the nutrient removals imposed by increased utilization, those associated with loss of the forest floor can also be significant. Using a 20-yr rotation with full-tree utilization as reference, loss of forest floor nutrients via erosion or leaching may increase total system nutrient losses by 50% (Table 6). Losses of N increase by as much as 80%. Thus any scheme of increased utilization must also recognize potential nutrient losses that may result from removal of the forest floor.

Table 6. Nutrient content of utilizable phytomass and forest floor in 20-yr-old loblolly pine stands.

Stand compartment	Nutrient content (kg/ha)					
	N	P	K	Ca	Mg	Total
Entire utilizable mass	250	24	150	199	50	673
Forest floor	207	13	17	79	21	337

ABILITY TO SUSTAIN INCREASED UTILIZATION

General

Permanence of forest vegetation, relative to that of annual crops, does not obviate the necessity of understanding annual nutrient requirements. Annual nutrient requirements of forest stands vary by stages of stand development and are derived from a variety of nutrient sources. The ability to satisfy the annual nutrient requirements of the various stages of development of these systems is not accomplished by a sustained depletion of nutrient sources. Rather, it is chiefly accomplished by a continued reuse or cycling of nutrients from the available reserves of the system and by incorporation of small quantities in the permanent tissues. It has been reported that the annual N requirements of a 20-yr-old loblolly pine stand are on the order of nine times greater than the quantity accumulated during that year in the aboveground mass of the stand (Switzer et al. 1968).

Cycling of nutrients within forest stands has three pathways: (1) the geochemical, which involves inputs and losses to the system through the hydrologic cycle; (2) the biogeochemical, which involves the incorporation of soil nutrients into biologic materials and their return to the soil via the litter chain; and (3) the biochemical, which involves the translocation of nutrients within the living portions of the system to tissues as they are formed, while they are functioning, and from them before they are discarded. The ability to sustain nutrient removals imposed by increased utilization ultimately depends on how such practices affect the cycles. The principal nutritional influence of increased utilization will probably be expressed in the biogeochemical cycle, since the availability of nutrients for this cycle is strongly influenced by changes in the physical environment. Possible effects on the geochemical cycle, expressed in erosion and leaching losses, may also be profound.

Requirements versus Accumulation

As just noted, the quantity of nutrients accumulated during a year does not dictate the quantity required by a stand for development of tissues produced during that year. Nutrient requirements for production of the aboveground portion of loblolly pine stands at 5, 25, and 65 yr of age are estimated in Table 7. Five yr of age is just prior to canopy closure, 25 yr represents the period of maximum requirements, and 65 yr represents the period when the phytomass of the stand has attained its maximum and sustainable level. The data of Table 7 indicate that the greatest portion of annual requirements is utilized in foliage, regardless of age or period of stand development. Also, requirements for bark and wood show marked declines as the stand ages, and reach their lowest levels when equilibrium mass is attained. A final significant fact is that the requirements summarized in Table 7 approach those of many agricultural crops (Barber 1977).

Table 7. Annual nutrient requirements (kg/ha) for arboreal portion of aboveground phytomass of loblolly pine stands at 5, 25, and 65 yr of age on well-drained upland sites.

Nutrient	Component	Age (yr) 5[a]	25[b]	65[c]
N	Foliage	47	95	94
	Bark & wood	25	6	3
	Total	72	101	97
P	Foliage	5.8	8.5	7.4
	Bark & wood	3.6	0.5	0.2
	Total	9.4	9.0	7.6
K	Foliage	22	37	37
	Bark & wood	12	5	2
	Total	34	42	39
Ca	Foliage	16	16	32
	Bark & wood	16	8	8
	Total	32	24	40
Mg	Foliage	4.4	8.3	10.3
	Bark & wood	4.3	1.6	0.8
	Total	8.7	9.9	11.1

[a]Nelson et al. (1970). [b]Includes invading hardwood species.

Sources of Nutrients

In this discussion, P will be used as an example because it is present in least amounts in the system (Table 1). Also, it seems to be the nutrient most often limiting in the soils of the Southeast (Pritchett and Smith 1972), and the supply in the soils is the only source other than fertilizers. It is additionally assumed that harvesting practices have not had an adverse effect on physical properties.

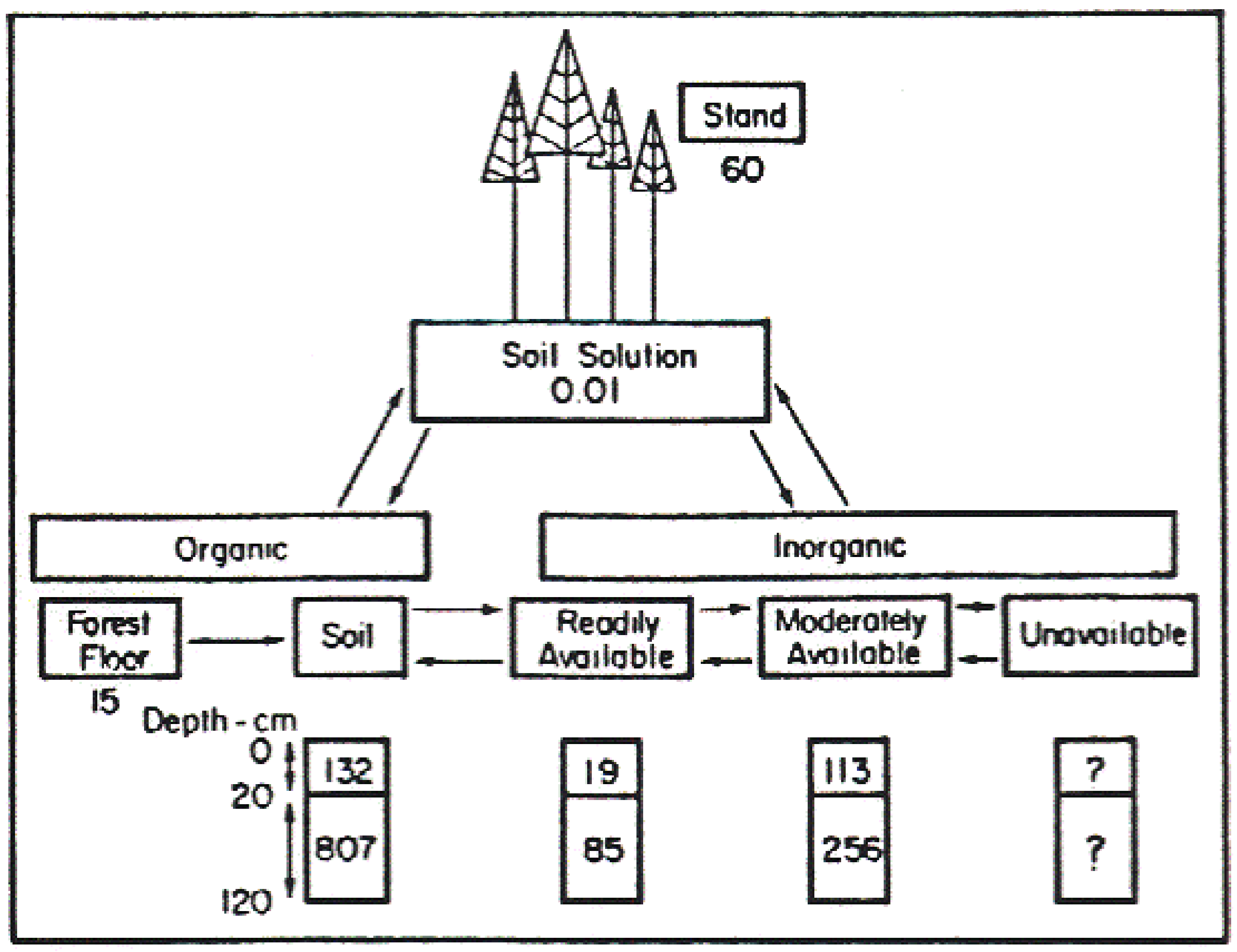
According to the "bank account theory" (Hopkins 190), the P supply appears to be adequate for a long time. For example, maximum removal predicted for a 20-yr rotation is 24 kg/ha, and the soil contains 1400 kg/ha to a depth of 120 cm (Tables 1 and 3). This suggests that the P supply should be sufficient for 58 rotations or 1160 yr. Such an analysis is simplistic and misleading, as illustrated by the status of available P in forest ecosystems (Figure 6).

Phosphorus is present in the soil-plant system in organic and inorganic forms. Organic P is present in the forest floor and soil organic matter. The remainder of the P is inorganic and, since the forested soils of the Gulf Coastal Plain are typically acid, inorganic P is relatively unavailable (Black 1968). Plants utilize orthophosphate ion only from the soil solution, where it is present in extremely small quantities (0.033 μg/ml). Therefore, as it is utilized it must be replaced by solution of inorganic sources or by mineralization of organic P. Thus all forms are in equilibrium, and replenishment of P in the soil solution depends on the rate of mineralization of organic P and solubility of inorganic P sources.

How does utilization affect this system? Obviously, the site contains less P after harvesting by an amount determined by the degree of utilization. Subsequent productiviy depends on renewal of P in the soil solution as it is removed by the developing stand. The P in organic matter originally came from the inorganic P that was removed by plants and returned in organic form as residues. These residues became part of the forest floor, which in turn became part of the soil organic matter.

Once a stand is harvested, there is an increase in decomposition of organic matter and consequently mineralization of organic P. That provides available inorganic P that may be taken up from the soil solution by plants or may revert back to less available inorganic forms. Once the forest floor has redeveloped and reached an equilibrium level, the contribution of P from organic matter is dictated by the quantity returned in litter, since addition of P in organic matter is balanced by losses due to decomposition and mineralization.

Figure 6. Status of P in the soil-plant system of a 25-yr-old loblolly pine stand on welldrained upland soils of the Gulf Coastal Plain. Values are in kilograms per hectare.



On well-drained upland sites litter returns 4.2 kg/ha during the 25th yr. If a like amount is mineralized to the readily available form, the additional 4.8 kg/ha required to supply the total requirement of 9 kg/ha must come from inorganic forms or biochemical cycling (Table 7). The supply appears to be ample; however, with each succeeding harvest the readily available source will decrease and the P reserve will consist of increasingly less available forms.

The nature of the soil affects the amount of P that can be taken up. For example, Pritchett and Smith (1972) examined 84 soils of the Lower Coastal Plain of the Southeast and found that total P in the 0- to 15-cm horizon averaged 230 kg/ha with only 2.2 kg/ha in the readily available form. Responses to fertilizer P have been obtained consistently on soils having poor drainage (CRIFF 1977). Obviously, most P under these conditions is present in such insoluble forms that replenishment of the soil solution is too slow to meet the needs of the stand. Some success has been achieved in predicting P response using extraction of soil P with ammonium acetate, pH 4.8, or with double acid (Pritchett and Gooding 1975).

Rooting depth may also affect P supply (Figure 6). There are greater reserves of P in the 20- to 120-cm layer than in the 0- to 20-cm layer. Thus the quantity of P that can be exploited depends on rooting depth; however, knowledge of the availability of these reserves or the rates at which they become available is limited. Some 70% of reserves in the 20- to 120-cm layer are in organic form, and it is not known at what rate they are mineralized and made available. Rooting depth also may be involved in responses observed on the Lower Coastal Plain by Pritchett and Smith (1972), since poor drainage may limit the volume of soil that can be exploited.

CONCLUSIONS

Pertinent to any conclusion about the ability of a region's forest sites to sustain nutrient removals is an evaluation of the productivity of present forests found on the old fields of the area, i.e., those areas that formerly have been employed in more intensive agricultural cropping. Such a perspective indicates that if previous agricultural practices led to loss of surface soil, productivity has been diminished and the potential for pathological problems has been increased. Such areas are particularly common on the Piedmont Plateau. Where surface soil has not been abused severely by agriculture, however, productivity of the old fields has been satisfactory, and related pathological problems are not as apparent. Although no basis of comparison with former levels of productivity on such sites exists, certainly no one can deny that the widespread occurrence of old-field stands, particularly in the range of loblolly pine, constitutes an important and productive resource for the region.

Thus, how far are we from an exploited or depleted soil resource and how will increased utilization affect depletion? Appraisal of the examples considered here indicates that the potential for nutrient depletion through increased utilization probably can be sustained for a considerable number of croppings. This is particularly so if such increases are attained by harvesting only the woody tissues of the phytomass, which have lower nutrient concentrations.

Exceptions to this should be noted. There are soils in the Southeast on which responses to fertilization have been obtained. These responses may be the result of an inherently infertile soil, such as some of the deep sands, or of a physical property that limits root growth and affects rooting volume, as may be the case for poorly drained soils. Thus, for these and other reasons, the nature of the soil and its location must be an important consideration in evaluating a site's capacity for maintaining productivity.

Sustaining increased utilization will probably hinge to a great degree on the effect utilization has on the physical properties of the system. Of particular concern are those physical properties intimately associated with meeting annual nutrient requirements of forest stands, i.e., those associated with decomposition and mineralization of organic matter, retention of nutrients from leaching, maintenance of proper soil aeration and drainage, and so on. Physical effects of increased utilization appear to have more potential for reducing productivity that the relatively small increases in removal of nutrients accumulated in the harvested mass.

We think we are a "safe distance" from exploiting the nutrient store of forest sites by increased utilization if: (1) reasonable rotation lengths are employed, (2) the inherent limitations of the soils sites are recognized, and (3) judicious attitudes and responsible actions are employed to preserve those physical properties that assure minimal disruption of the nutrient cycles that play such a large role in satisfying the nutritional requirements of productive forest stands.

Certainly, practices that are conservative in terms of the soil's desirable physical properties, particularly of the soil surface, are in turn going to be conservative of the system nutrients. Finally, these cannot be considered as definite conclusions, since the experience of the agriculturist, horticulturist, and the like indicates that there is much to be learned about the capacities of soils to supply nutrients in the available forms.

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