ENSURING SUSTAINABLE HARVESTING OF WOOD: IMPACT OF BIOMASS HARVESTING ON THE NUTRIENT STORES OF TEAK WOODLOT STAND IN THE SUDAN SAVANNA

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ABSTRACT

The N, P, K, Ca, and Mg stores in Tectona grandis *(Teak) ecosystem were estimated. These were used to determine the impact of three harvesting methods (thinning, coppice-with-standard, and clear felling) combined with three levels of wood utilization (i.e. stemwood only, bole only, and bole together with branches) on sustained future productivity within Teak plantation stand. Clear felling, combined with any level of wood utilization, exerted the greatest impact of loss on the nutrient stores. Thus, sustainable production of Teak will be greatly impaired if such harvesting option is solely adopted. On the other hand, thinning above half of the stand density, coupled with stemwood utilization only, will increase the nutrient drain four folds, as compared to thinning below half of the stand density and combined with total shoot utilization from the reserves. Furthermore, the rates of depletion were not specific, but differed for individual nutrients. Potassium drained from the ecosystem was most rapid, followed by P, N, Mg, and Ca. Thus, K and P may severely limit the future productivity of the Teak stand if harvesting options like clear felling or coppice-with-standard were to be adopted. The combination of harvesting options and utilization to forecast the potential sustained productivity of Teak plantation stand are discussed.*

Keywords: Clear felling, Coppice-with-standard, Nutrient stores, Teak, Wood-harvesting

INTRODUCTION

Ghana might be lacking in wood supply by the turn of the present century (Iyamabo, 1990). Currently, the Sudan Savanna area is lacking in wood supply (Iyamabo, 1990) At the same time, about 32 % of the forest reserves is degraded (MLF, 1996). Figures are unavailable for areas outside the forest reserves, but it is believed that the percentage may be higher than 50 %. Again, the capacities of the existing sawmills in Ghana have been found to exceed the annual allowable cut (AAC) from the forest (Nsenkyire, 1996). Therefore, one of the recommended ways of ameliorating the expected shortfall and also rehabilitating the degraded areas is to establish and develop plantations (MLF, 1996).

As a remedial measure, many species have been put under plantations. One of the species that has dominated plantation development in Ghana and also the West African zone is *Tectona grandis* (Teak). According to Aninakwa (1996), Teak constitutes over 70 % of all plantation species in Ghana. In Nigeria, Oloye (1983) reported that Teak and *Gmelina arborea* constituted 61 % as of 1977. Teak, according to Nwoboshi (1973), was three times more expensive than most of the timber trade hardwoods like Afromosia and Sapele. Thus, Teak owes its importance and value to its desirable properties such as durability, and fine and long grains. Consequently, this species has been established to provide sustainable supply of small diameter wood lumber and poles. The proposed rotation is between 10 and 15 years, using the following harvesting methods: (i) clear felling, (ii) coppice-with-standard, and (iii) thinning and removal of as much biomass materials as possible. These proposed harvesting methods are to be combined with the following utilization methods: whole tree, bole (stemwood and stembark) only, or bole plus branches.

However, such high biomass harvesting intensities have been of concern to many researchers in recent years (Boyle, Phillips & Ek, 1973; Madgwick, Sims & Oliver, 1988; Versfeld & Donald, 1991; Stevens *et al*., 1995). This, according to them, leads to nutrient deficiencies within relatively short periods, which is particularly injurious to tree life in fragile ecosystems such as the semi-arid tropics. The impact of such harvests may vary with species and sites (Nwoboshi 1980). Besides, N, P, K, Ca and Mg nutrition of Teak has not been adequately studied in Ghana. However, Nwoboshi (1980) has shown that N, P, and K deficiencies have adverse effect on *Gmelina arborea* growth.

There is therefore the need to know the probable rates at which N, P, K, Ca, and Mg would be depleted under the various site management practices to sustain the site productivity, and thus enhance the productivity of Teak plantations.

In this study, nutrient contents within the tree parts of Teak as well as the undergrowth, soil, and litter were evaluated against the background of the species being potentially suitable for rafters, poles, and fuel wood, among others, in savanna areas; and the impact of biomass harvesting and subsequent nutrient export from site on sustained productivity. Thus, biomass harvesting, nutrient uptake and accumulation, and wood utilization were the main criteria in the assessment.

MATERIALS AND METHODS

The study was carried out near Bawku in the Sudan Savanna of Ghana (Latitude 11° N and Longitude 0°). The area has a single rainy season where the monthly totals increase from May until a maximum is reached in August or September. The annual rainfall averages between 850 to 1100 mm. The dry season is usually from November to May and is characterised by dry north-east trade winds with maximum daily temperatures usually of about 37 °C.

The soil is Groundwater Laterites and Groundwater Laterite-Ochrosol intergrades. These soils are equivalent to FAO/UNESCO Luvisols and Leptosol/Plunthusol intergrades. They support vegetation of savanna woodland, but in settled areas, this has been reduced to open parkland where only trees of economic value have been retained. Large plantations of Teak have been established in most parts of the Sudan Savanna since the 1960s, the spacing used mostly was 2.4 m × 1.8 m.

Sampling Procedure

Tree and Biomass Sampling

Field studies were conducted in *Tectona grandis* stand using the modified Attiwill & Ovington (1968) all tree sampling procedure. Three temporary plots were located in areas as fully stocked as possible to ensure that only sites with maximum stocking were sampled. At least between 15 and 20 m buffer strips were left around each plot to ensure that stand development was not influenced by edge effects (Tandon, Rawa & Rajinder, 1993). Diameters at breast height (DBH) for all the enclosed standing trees were measured and recorded. For better distribution of sample trees over the diameter range, the trees were grouped into four DBH classes to simulate the four strata in the natural forest and were labelled as A, B, C, and D classes. These correspond to suppressed, intermediate, co-dominant, and dominant in the natural forest, respectively. Sample trees with DBH(s) as nearest as possible to the average of each class were selected (Attiwill & Ovington, 1968). Subsequently, one tree was selected from each class, making four trees per plot and 12 trees in all the three plots. This procedure conforms to the tree summation technique of Attiwill & Ovington (1968).

One tree was felled at a time, to reduce moisture loss from the leaves as well as the branches before subsequent treatment. Total as well as merchantable heights were measured. The fresh weights of the biomass components were recorded and representative samples of known weight were collected for oven-dry weight measurement. Samples consisting of wood, bark, branches, and leaves were dried to a constant weight at 70 °C. The ratio of dry to fresh weight was used to calculate the total dry weight of each component; thus, stemwood, stem bark, branches, and leaves of the sample trees and subsequently, the stand dry biomass per hectare.

Undergrowth Sampling

The undergrowth and litter in four 1 m x 1 m quadrant within each plot were gathered and sorted into fresh undergrowth as well as litter and woody stems. These were freshly weighed in the field and subsamples were oven-dried at 70 °C for dry weight determination.

Soil Sampling

Six composite soil samples, each bulked from 10 augar points taken to the depth of 30 cm, were collected from the sampling plots (the soil zone which contained the bulk of the feeding roots) to estimate the macronutrient (N, P, K, Ca, and Mg) content. The soil samples were air-dried and sieved with a 2-mm sieving material.

Chemical Analysis

Dried subsamples of plant, soil, and litter were analyzed for the N, P, K, Ca, and Mg concentrations. The total N concentrations in plant, soil, and litter samples were determined by the semi-micro Kjeldahl method (Mackenzie & Wallace, 1954). Plant K, P, Ca, and Mg were estimated after wet digestion using a ternary acid mixture of nitric, sulphuric, and perchloric (5: 1:1) acids. Phosphorus concentration was determined by the vanadomolybdate yellow colour method of Barton (1948), and K, Ca, and Mg by atomic absorption spectrophotometry in a 1 %-lanthanum chloride solution. Available P in soil was determined using Bray P1 method (Bray & Kurtz, 1945).

RESULTS AND DISCUSSION

Biomass Distribution

Table 1 shows the stand biomass accumulation per hectare of *Tectona grandis* at 10 years and the distribution according to tree size classes and components. The stemwood constituted the dominant component in A, B, and C size classes while branches were dominant in size class D. The foliar parts formed the smallest component. On the other hand, for total biomass per stand, the order was size class C > size class B > size class D > size class A. The size classes B and C produced about 75 % of the above

,TABLE 1

Biomass accumulation and distribution among DBH classes in a Teak plantation (kg/ha)

Part component	*DBH size classes (cm)*				*Total*
	A (6.7 - 9.6)	*B (9.7 –12.6)*	*C (12.7-15.6)*	*D (15.7-18.6)*	
Trees (no./ha)	475	600	475	75	1,625
Leaves	33.3^{a}(0.07)	72.0^{ac}(0.12)	123.5^{ac}(0.26)	84.8^{a}(1.13)	313.6^{ac}(1.58)
Branches	256.5^{ac}(0.54)	996.0^{ac}(1.66)	1,543.8^{bc}(3.5)	648.0^{a}(8.64)	3,444.3^{de}(14.1)
Stembark	223.3^{ac}(0.47)	324.0^{ac}(0.54)	323.0^{ac}(0.68)	121.5^{a}(1.62)	991.8^{ac}(3.3)
Stemwood	451.3^{ac}(0.95)	1,260.0^{ab}(2.10)	2,517.5^{b} (5.3)	548.3^{a}(7.31)	4,777.1^{d}(15.7)
Total	964.4^{a} (2.03)	2,652.0 ^{b}(4.42)	4,507.8^{a} (9.48)	1,402.6^{a} (18.7)	9,526.8^{f}(34.63)

LSD (0.05) = 1471.98

Values in parentheses are weights of the sampled trees (kg/tree).

Values with same letter, as superscripts were not significantly different (P>0.05).

ground stand biomass. The suppressed and dominant size members made up the remaining 25 % of the biomass. Thus, the total dry matter produced by each of classes A, B, C, and D were 964.40, 2652.0, 4507.80, and 1402.60 kg/ha, respectively. The dry matter produced by the single trees in each of the classes followed a similar trend.

Nutrient (N, P, K, Ca, and Mg) Uptake and Distribution

Table 2 shows the contents of N, P, K, Ca, and Mg [calculated as the product of the nutrient concentrations (%) and the component biomass] in Teak component parts in the four tree size classes. The nutrient contents (in all component parts) varied with the component part and did not follow any consistent pattern in all the size classes. The stemwood contained the highest quantity of nutrients with the leaves having the lowest in all the size classes. For component concentration, Ca was the highest in the branches and stembark. Nitrogen also constituted the highest proportion in stemwood. The B and C size classes, which had the bulk of the biomass, also held the bulk of the nutrients. The stand at 10 years accumulated a total of 70.71kg Ca, 31.52 kg N, 27.4 kg K, 24.02 kg Mg, and 3.54 kg P. Between 47 and 50 % of K, Ca and Mg nutrients were held in the branches (Table 2). Forty-six and 47 % of N and P, respectively, were held in the stemwood.

The Nutrient Stores in the Stand

Table 3 shows the amount of total N, available P as well as exchangeable K, Ca and Mg in the soil to 30 cm depth and quantities of these elements in the above-ground biomass,

TABLE 2

Nutrient (N, P, K, Ca and Mg) content and distribution among DBH classes in a 10-year-old Teak plantation (kg/ha)

Nutrient elements	*Tree components*	*DBH classes (cm)*				*Total*
		A (6.7 – 9.6)	*B (9.7 – 12.6)*	*C (12.6 – 15.6)*	*D (15.6 – 18.6)*	
N	Leaves	0.26	0.45	1.04	0.65	2.4
	Branches	0.90	2.1	6.5	1.8	11.3
	Stembark	0.78	0.9	1.13	0.3	3.11
	Stemwood	1.26	3.5	8.8	1.15	14.71
	Total	3.2[a]	6.95[b]	17.47[c]	3.9[d]	31.52[e]
P	Leaves	0.02	0.04	0.09	0.06	0.21
	Branches	0.10	0.40	0.62	0.19	1.31
	Stembark	0.09	0.13	0.13	0.04	0.39
	Stemwood	0.27	0.38	0.76	0.22	1.63
	Total	0.48[f]	0.95[f]	1.6[g]	0.51[f]	3.54[ad]
K	Leaves	0.23	0.49	0.84	0.58	2.14
	Branches	0.82	1.79	8.34	2.98	13.93
	Stembark	0.58	0.23	0.58	0.29	1.77
	Stemwood	0.90	2.52	5.04	1.10	9.56
	Total	2.53[h]	5.12[lp]	14.8[j]	4.95[ir]	27.4[v]
Ca	Leaves	0.83	1.95	3.1	2.5	8.38
	Branches	2.05	8.76	14.8	7.78	33.39
	Stembark	3.0	7.13	8.09	2.8	20.93
	Stemwood	1.08	2.02	4.03	0.88	8.01
	Total	6.96[b]	19.86[l]	29.93[m]	13.96[n]	70.71[o]
Mg	Leaves	0.11	0.31	0.3	0.30	0.92
	Branches	0.74	2.90	5.9	1.90	11.44
	Stembark	1.18	0.78	1.55	0.70	4.21
	Stemwood	0.58	1.76	3.52	1.59	7.42
	Total	2.61[h]	5.75[p]	11.27[q]	4.39[r]	24.02[s]

LSD (0.05) = 0.57

Values with the same letters as superscript were not significantly different ($P>0.05$).

undergrowth, and litter on the forest ground floor, among others. Also included in these nutrient stores are nutrient additions and losses from other sources. The overall ecosystem nutrient content for the various elements were Ca (321.5 kg/ha), N (106.6 kg/ha), Mg (94.6 kg/ha), K (41.9 kg/ha), and P (6.3 kg/ha).

The distribution of these nutrients among the various ecosystem components also varied. For Ca, about 74 % was held in the soil while 36 % was obtained from other sources including the standing crop (Table 3). Available P was 28 % in the soil, 56 % in the tree biomass, and the remaining 16 % in the litter, undergrowth, and rainfall. Sixty-one percent of total nitrogen was in the soil, 30 % in tree biomass, and 9 % in the other components. Twenty-eight and 69 % of K and Mg, respectively, were held in the soil, 65 and 25 % in the tree biomass, and the remaining 7 and 6 %, respectively, were held in the litter, undergrowth, and rainfall (Table 3).

For all the nutrients, the standing crop and the soil constituted the major nutrient pools or sources. The other nutrient sources from the undergrowth and forest floor litter were, however, a small fraction of the total nutrient stock of these nutrient elements.

Effect of Harvesting Practices and Biomass Removal on the Nutrient Budget

Soils differ widely in their ability to supply the nutrients necessary to sustain forest productivity (Cole, 1995). Thus, long-term forest ecosystem productivity is sustained largely by efficient circulation of mineral nutrient elements. Jorgensen, Wells & Metz (1975) reported that the key to an adequate supply of nutrient elements to the forest ecosystem is the nutrient cycle. Thus, processes supplying nutrients to the pool should be efficient and also exceed those enhancing nutrient losses from the pool. Therefore, any alteration of the ecosystem that directly or otherwise, leads to substantial loss of nutrients in the nutrient cycling process will lead to loss of productivity on sites where such nutrients are in limited supply.

The approaches used by Jorgensen *et al.*

TABLE 3

Nutrient (N, P, K, Ca and Mg) stores in Teak plantation in the Sudan Savanna of Ghana

Ecosystem component	*Biomass (kg/ha)*	*Nutrient (kg/ha)*				
		N	*P*	*K*	*Ca*	*Mg*
Trees						
Leaves	313.6	2.4	0.21	2.14	8.38	0.92
Branches	3,444.3	11.3	1.31	13.93	33.39	11.44
Stembark	991.8	3.11	0.39	1.77	20.93	4.21
Stemwood	4,777.1	14.71	1.63	9.56	8.01	7.42
Sub-total	9,526.8	31.52	3.54	27.4	70.71	24.02
Undergrowth						
Leaves and branches	375.0	4.5	0.469	2.00	6.4	3.6
Woody stem	30.0	0.48	0.05	0.01	0.57	0.21
Sub-total	405	4.98	0.519	2.01	6.97	3.81
Sub-total litter	264.0	4.47	0.44	0.57	6.34	1.21
Rainfall		0.75	0.03	0.17	0.51	0.11
Soil reserve**		64.7	1.74*	11.74*	237.0	56.4
Total ecosystem		106.4	6.3	41.9	321.5	94.6
Losses						
Erosion/Run-off		0.12	0.4	1.7	12.7	0.7

*Available P and K in the soil.
**Sampled up to 30 m depth.

(1975), Kimmins (1977), Kinbin (1995), and Miller (1995) were adopted in this study to assess the effects of intensive forest management practices on site productivity. Thus, losses of N, P, K, Ca, and Mg through thinning, coppice-with-standard, or clear felling combined with either the removal of stemwood only, bole, or bole and branches were determined.

Tables 4 and 5 show the quantities of biomass and also the N, P, K, Ca, and Mg nutrients removed by the harvesting and utilization options, respectively. Thinning at 25 % and removing bole together with branches exerted less impact on the nutrient stores than clear felling combined with bole together with branches, about 11 times more severe (Table 4). Likewise, the drain of all nutrients for the harvesting options were 25 % thinning <50 % thinning <coppice-with-standard <clear felling. The utilization options for nutrient drain were in the order total shoot > bole plus branches >bole only >stemwood only for all the nutrient elements (Table 5). These nutrients would become limiting at the earliest possible time if clear felling is combined with removal of total shoot from site. Consequently, productivity will be impaired especially for subsequent rotations (Nwoboshi, 1980; Cole, 1995; Miller, 1995) if such harvesting and utilization options were to be adopted.

The quantities of these nutrient elements eventually removed from circulation in the ecosystem correspond to the amount of the biomass carried away from the site. Therefore, if similar quantities of each element are assumed in each tree component at the end of each subsequent 10-year rotation, the stand capability to sustain future productivity under the above harvesting and utilization options can be estimated with number of potential rotations. Such estimations (Table 5) indicate that the higher the harvesting intensity and the utilization levels, the greater the impact or lower the number of potential rotations of sustained productivity.

The impact on all the nutrient elements will be most severe under clear felling harvesting option. Clear felling is also known to induce other forms of nutrient losses. Besides, clear felling accelerates processes like leaching of soluble salts, and enhances nutrient losses

TABLE 4

Potential biomass removal under the various harvesting options

Utilization levels	*Harvesting options*			
	Thinning		*Intensive harvesting*	
	25 % (A class)	*50 % (A + B classes)*	*Coppice-with-standard (A+B+C classes)*	*Clear felling (A+B+C+D classes)*
	Stand (kg/tree)			
Stemwood only	0.95^{a}	3.05^{b}	8.35^{c}	15.66^{d}
*Bole only	1.42^{ah}	4.06^{e}	10.04^{f}	18.97^{g}
Bole and branches	1.96^{h}	6.26^{i}	15.49^{j}	33.06^{k}
Total shoot	2.03^{h}	6.45^{i}	15.94^{j}	34.64^{l}
LSD (0.05) = 0.73				
	Stand (kg/ha)			
Stemwood only	451.3^{a}	$1,711.3^{b}$	$4,228.8^{c}$	$4,777.1^{d}$
*Bole only	674.6^{e}	$2,258.6^{f}$	$5,099.1^{g}$	$5,768.9^{h}$
Bole and branches	931.1^{i}	$3,511.1^{j}$	$7,895.4^{k}$	9213.2^{l}
Total shoot	964.4^{m}	$3,616.4^{n}$	$8,124.2^{o}$	$9,526.8^{p}$
LSD (0.05) = 1.60				

*Bole is stemwood plus stembark.
Values with the same letters as superscript were not significantly different (P>0.05).
NB: The values in this table were estimated using the component values from Table 1.

TABLE 5

Potential N, P, K, Ca and Mg removals under various harvesting options and their impact on sustained site productivity

Utilisation options	*25 % thinning (A class)*		*50 % thinning (A+B classes)*		*Coppice-with-standard (A+B+C classes)*	
	Qty per rotation (kg)	*No. of 10-year rotations*	*Qty per rotation (kg)*	*No. of 10-year rotations*	*Qty per rotation (kg)*	*No of 10-year rotations*
			Nitrogen			
Stemwood only	1.26	84.4^{a}	4.76	22.3^{e}	13.56	7.8^{i}
Bole only	2.04	52.1^{b}	6.44	16.5^{f}	16.37	6.5^{j}
Bole and branches	2.94	36.2^{c}	9.44	11.3^{b}	25.57	4.1^{k}
Total shoot	3.2	33.2^{d}	10.15	10.5^{h}	27.62	3.8^{k}
LSD (0.05) = 0.60						
			Phosphorus			
Stemwood only	0.27	12.7^{c}	0.65	9.0^{d}	1.41	4.2^{f}
Bole only	0.36	16.3^{b}	0.87	6.7^{c}	1.76	3.3^{fj}
Bole and branches	0.46	12.7	1.37	4.3^{f}	2.88	2.0^{gi}
Total shoot	0.48	12.2^{c}	1.43	4.1^{f}	3.03	1.9^{g}
LSD (0.05) = 1.07						
			Potassium			
Stemwood only	0.90	44.6^{a}	3.42	11.8^{c}	8.46	4.8^{gh}
Bole only	1.48	27.2^{b}	4.32	9.3^{f}	9.94	4.0^{hi}
Bole and branches	2.30	17.5^{c}	6.93	5.8^{g}	20.89	1.9^{i}
Total shoot	2.53	15.9^{d}	7.65	5.3^{g}	22.45	1.8^{i}
LSD (0.05) = 1.23						
			Calcium			
Stemwood only	1.08	286.0^{a}	3.1	99.6^{c}	7.13	43.3^{d}
Bole only	4.08	75.6^{b}	13.23	23.3^{f}	25.26	12.2^{g}
Bole and branches	6.13	50.4^{c}	24.04	12.8^{g}	50.87	6.1^{f}
Total shoot	6.96	44.4^{d}	26.82	11.5^{h}	56.75	5.4^{ij}
LSD (0.05) = 1.22						
			Magnesium			
Stemwood only	0.58	163.0^{a}	2.34	40.4^{c}	5.86	16.1^{h}
Bole only	1.76	53.7^{b}	4.30	22.0^{f}	9.37	10.0^{i}
Bole and branches	2.50	37.81^{c}	7.94	$11.9g^{k}$	18.91	5.0^{j}
Total shoot	2.61	36.20^{d}	8.36	11.3^{g}	19.63	4.8^{j}
LSD (0.05) = 1.36						

Values with the same letters as superscripts were not significantly different ($P>0.05$).

through erosion and run-off in the ecosystem (Lal, 1978; McCall & Grigal, 1979; Kinbin, 1995).

However, the rate of nutrient drain from the Teak stand varied with the nutrient elements. Under clear felling and at total shoot and bole plus branches utilization levels, potassium loss was most rapid. This is apparently due to its lower content in the ecosystem and to the accumulation of about 65 % of K in the tree crop. Thus, harvesting and removing trees from site mean exporting nutrients rapidly from site. Thus, in this study, the order in which nutrients will become limiting, is K > P > N > Mg > Ca.

Therefore if the clear felling system is adopted as harvesting option and combined with total shoot utilization in an area with K, P, N, Mg, or Ca quantities such as this study site, and all other things being equal, K and P fertilisers will have to be applied during the second rotation. This would be followed by the application of N and Mg in the fourth rotation, and lastly Ca fertilization during the fifth rotation (Table 5). Furthermore, if coppice-with-standard is adopted, P and K will be a limiting factor during the second rotation, followed by N in the fourth, Mg in the fifth, and lastly Ca in the sixth rotations. On the other hand, thinning at 25 and 50 % combined with total shoot utilization will be less severe on the future site productivity.

CONCLUSION

The following were observed from the study: (i) adapting a clear felling harvesting option means exporting biomass and nutrient from site; (ii) potassium was the most limiting nutrient in the study site; (iii) for all elements except P and K, the largest proportion of each nutrient was in the soil reserve; and (iv) the greater the biomass harvested, the faster the nutrients are exported from site.

For these forecasts to become valid, the soil extraction procedures should measure the amount of soil nutrient that becomes available to the plants over the forecasted or predicted rotations. The rooting system should also be restricted to the surface 0-30 cm of the soil. Very little is known about the N_2-fixation and chemical weathering rates in these soils and in practice, some roots do penetrate beyond 30 cm depth. This indicates that mineral weathering, biological N_2-fixation, and deeper rooting could prolong the period of sustained productivity without fertilization. It is therefore clear that adoption of either clear felling or coppice-with-standard will enhance the rate of P and K depletion, and more slowly N, Mg and Ca status in the ecosystem. The removal of additional biomass to the conventional bole will further accelerate the rate of nutrient depletion.

In the absence of physical damage to the soil, nutrient drain can be replaced by fertilization. The choice of more intensive harvesting or utilization levels rests on whether or not the value of the additional biomass will compensate for the additional cost of fertilization. Therefore in the tropics where forest fertilization is not a routine silvicultural tool or practice, the study advocates the adoption of heavy thinning and utilization levels that leave tree components with high content as slash on the forest floor, and also methods like peeling of bark on site.

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