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Liberation: Acceptable production of tropical forest timber

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Abstract

Reduced impact logging in an eastern Amazonian terra firme forest left more than half of the next crop trees growing at a rate corresponding to a rotation of more than a century to attain 60-cm dbh. Two years after the logging, in 20 ha of the logged forest, tree competitors around crop trees were eliminated. Competitors were defined as trees whose crowns overtopped crop trees, those within 2 m of them, and trees as tall as or taller than the crop trees closer than indicated by a basal area of 15–25 m^2/ha, depending on their summed diameters. During the subsequent 5.7 years, increment of the liberated crop trees was 20% greater than that of comparable crop trees left in another 20 ha of the same logged forest without liberation. Had the competing trees been identified at the time of the logging the 5.8/ha that were merchantable could have increased the yield from 25 m^3/ha to as much as 43 m^3/ha. This added harvest should have more than paid the entire cost of the liberation, including the elimination of the remaining unmerchantable trees. Additionally, a prospective reduction of 25% in the wait for the next harvest, as compared with logging only, would have been created. Where the economical sustainability of tropical wood productivity and quality is a goal, the wisdom of neglect of liberation is questioned.

Keywords: Brazil; Reduced impact logging; Tree liberation; Tropical forest production; Growth

1. Introduction

Forest sustainability as a goal in much of the tropics is matched by a need to produce wood for increasing current consumption (FAO, 2003). Constrained by less land and more sharing of non-timber forest needs, compatible, concentrated, and stimulated wood productivity is urgent. Tropical forest plantations are more productive, but supply only a small fraction of foreseeable non-industrial requirements.

Attainment of a goal of wood productivity from natural forests faces a human misconception that tropical forests, once exploited, no longer are a financially profitable source of wood (Rice et al., 1997). The wisdom of investing in forests for 30 or more years with value accretion not demonstrated is questioned. But there can be no question as to an overriding social need for tropical forests and their products (Poore et al., 1989). Seen holistically, with all attendant forest benefits, select tropical woods may always be worth more than their costs.

What is termed ‘‘reduced impact logging,’’ is now touted in the tropics for leaving a standing forest. Included are adolescent trees capable of production of woods usable in foreseeable markets. Even such trees are questioned as economical sources of timber. They are commonly thought to be too few, as they may be where logging impacts have not been reduced. However, they may well be equal in number to the few trees formerly worth harvesting. Then trees rejected by loggers are commonly assumed to be defective or to require an intolerable wait. There is a pressing need to demonstrate attractive ways for stimulation of production of diverse woods of the tropics from natural forests.

2. Literature review

Forest liberation is directed toward the elimination of competitors from larger trees to favor promising immature ones (Smith, 1986). It is based on the assumption that tree growth rates are directly related to crown exposure and inversely related to crowding (Dawkins, 1955). Forest tree liberation in the tropics had its beginning in the eastern hemisphere (McGregor, 1934; Mead, 1937; Griffith, 1947; Rosario, 1955; Kadambi, 1958; Stracey, 1959; Wilkinson, 1960; Wyatt-Smith,

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Table 1
The composition of the cutover forest studied. Columns A and B show the numbers of trees >35 cm dbh in each of the two 20-ha plots. Column C includes the number of trees <35 cm dbh in a 1-ha plot in the same forest

Species	A	B	C
Anacardium giganteum (Hanc.) ex Engl.	1		1
Aniba canelilla(H.B.K.) Mez.		1	
Aniba parviflora Mez.			1
Apeiba macropetala Ducke	2	3	
Apuleia leiocarpa (Vog.)Macbr.		1	
Aspidosperma nitidum Benth		5	
Astronium lecointei Ducke	11	10	
Bagassa guianensis Aubl.	1	4	
Bowdichia nitida Spruce ex Benth.	8	4	
Brosimum amplicoma Ducke		4	
Brosimum parinarioides Ducke	3	2	
Brosimum sp.			3
Buchenavia capitata (Vahl.) Eichl.	8	13	
Caryocar villosum (Aubl.) Pers.	4		
Caryocar glabrum (Aubl.) Pers.	9	5	
Cecropia palmata Willd.			1
Cedrilinga catenaeformis Ducke	1	1	
Chrysophyllum oppositum Ducke			1
Chrysophyllum lucentifolium Subsp.	32	29	5
Cynometra hosimanniana Tul.			1
Clarisia racemosa Ruiz. et Pav.		3	
Copaifera duckei Dwyer	3	1	
Cordia bicolor DC.	12	10	9
Cordia gerascanthus L.	6	5	
Cordia goeldiana Huber.	5		1
Couratari guianensis Aubl.	8	6	1
Dinizia excelsa Ducke	7	1	
Diospyros praetermissa Sandwith		1	29
Diplotropis sp.		1	2
Endopleura uchi (Huber) Cuatrec.	7	1	1
Enterolobium schomburgkii Benth	3	8	
Eperua sp.			4
Eperua bijuga Marte		2	
Eriotheca globosa (Aubl.) A. Robyns	2	3	2
Eschweilera coriaceae (A. DC.) Mart. Ex Berg.	59	69	5
Eschweilera juruensis R. Knuth			20
Eschweilera obverse (O. Berg) Miers	8	7	3
Eschweilera odorata Meirs	43	20	
Eschweilera rosea Poepp.			2
Eschweilera sp.			3
Euplassa pinnata (Lam.) Johnston	1	2	
Goupia glabra Aubl.	11	3	2
Guarea sp.			9
Guatteria poeppigiana Mart.	2	5	9
Helicostylis sp.	3	2	
Holopyxidium jarana (Rub.) Ducke	10	10	2
Hymenaea courbaril L.	5	3	
Hymenaea parviflora Benth.	2	1	1
Hymenolobium nitidum Benth.			6
Hymenolobium petraeum Ducke	1	1	
Inga alba (Sw.) Willd.			4
Inga cayennensis Sagot ex Benth.			6
Inga heterophylla Willdenow	6	7	7
Inga ribiginosa (Rich.) DC.			2
Inga sp.	1	1	9
Inga sp.			1
Inga sp.			1
Jacaranda copaia (Aubl.) D. Don	4	4	
Miconia surinamensis Gleason	1	5	
Michandra elata Bth.	16	13	
Minquartia guianensis Aubl.		2	
Mouriri brevipes Benth.		1	
Not identified			22
Neea sp.	2	2	1
Newtonia suaveolens (Miq.) Brenan	17	22	5
Ocotea caudate (Nees.) Mez.	9	26	4
Ocotea fragantissima Ducke	3		
Ocotea glomerata (Nees) Benth, et Hook.	5	1	
Ocotea guianensis Aubl.			11
Ocotea sp.			1
Onychopetalum amazonicum R.E. Fr.			1
Ormosia paraensis Ducke	1	4	
Ormosia sp.			2
Parinari sp.	1		
Parkia gigantocarpa Ducke	2	4	
Parkia oppositifolia Benth	4		
Parkia paraensis Ducke	3	6	
Parkia pendula Benth		2	1
Peltogyne leicontei Ducke	4	6	
Piratinera sp.		2	
Pithecellobium pedicellare (DC.) Benth.	1		
Pithecellobium sp.			1
Platymiscium sp.		1	
Pouroma guianensis Aubl.	9	14	4
Pouteria bilocularis (H. Winkl.) Baehni.			6
Pouteria guianensis Aubl.	5	13	10
Pouteria laurifolia (Gomes) Radlk.	30	21	3
Pouteria macrocarpa (Mart.) D. Dietr.	7	6	
Pouteria macrophylla (Lam.) Eyma	9	3	5
Pouteria pomifera Eyma Baehni			13
Pouteria sagotiana (Baill.) Eymo	21	9	
Pouteria sp. 1			18
Pouteria sp. 2			2
Pouteria sp. 3	34	7	9
Protium cuneatum Swart.	1		32
Protium guacayanum Cuatrec.	45	30	
Protium peuviarum Swart	24	9	18
Pterocarpus rohri Vahl.	1		
Qualea albiflora Warm.	1	1	
Qualea paraensis Ducke		1	
Rinorea flavescent (Aubl.) Kuntze			34
Sacoglottis guianensis Benth.	20	13	4
Schefflera morototoni (Aubl.) Frodin	3	1	
Sclerolobium melinonii Harmes	12	8	3
Sclerolobium sp.	4	6	1
Simarouba amara Aubl.	4	3	
Siparuna decipiens A. D. C.		1	
Sloanea nitida G. Don.			2
Sterculia pilosa Ducke	22	16	
Sterculia sp.			4
Sterculia speciosa Schum.			6
Swartzia polyphylla DC.	2	2	
Symphonia globulifera L.	1	1	1
Syzygiopsis oppositifolia Ducke	22	6	
Tabebuia impetiginosa (Mart.) Standl.	1	1	
Tabebuia serratifolia (Vahl.) Nichols	1		

Table 1 (*Continued*)

Species	A	B	C	Species	A	B	C
Lecythis idatimon Aubl.	32	24		*Tapirira guianensis* Aubl.		1	
Lecythis paraensis Hub.	4	4	1	*Tapirira* sp.			1
Licania canescens Bonoist			32	*Trattinickia rhoifolia* Wildenow	26	23	2
Licania latifolia Benth. ex Hook			2	*Vatairea fusca* Ducke			1
Licania membranacea Sagot ex Laress			2	*Vatairea guianensis* Aubl.		1	
Licania micrantha Miquel			2	*Vatairea paraensis* Ducke	1		
Licania sp.	113	155	1	*Virola melinonii* (Benoist) A. C. Smith	9	8	1
Licaria rigida Kosterm.	7	3	5	*Vochysia inundata* Ducke	3	1	
Luehea speciosa Willd.	1			*Xylopia nitida* Dunal	1	2	1
Manilkara amazonica (Huber)A. Chev.	20	13	4	*Zanthoxylum rhoifolium* Lam.	4	1	
*Manilkara huber i*Ducke	63	58	5	*Zizyphus itacaiunensis* Froes.	1	2	
Marmaroxylon racemosum (Ducke) Killip ex Record			2	*Zoillernia paraensis* Huber	1	2	
Mezilaurus lindaiani Schwake & Mez.	2						
Total number of trees	A: 924; B: 827; C: 441						

1961; Dawkins, 1961, 1963a,b; Earl, 1968; Osafo, 1970; Hepburn, 1973; Hutchinson, 1977, 1980, 1981, and Chai, 1985). In tropical America it has been reported by Beard, 1944, Boerbohm, 1964, Neyra-Roman, 1981, Finegan, 1992, and Silva et al., 2002. Growth stimulation as a result has been reported from Puerto Rico (Wadsworth, 1953), Nigeria (Henry, 1956), Guyana (John, 1961), Sarawak (Hutchinson, 1980), and Brazil (Silva et al., 2002).

The liberation practice here tested had its origin in the Luquillo Experimental Forest of Puerto Rico. This led to practical rules applied to thousands of hectares in Sarawak (Hutchinson, 1977, 1980), and similar practices prescribed for Central America and Brazil (Hutchinson, 1993). Despite this, there still lack measurements of growth results adequate to lead to widespread application of the practice.

3. Methods and materials

An opportunity to demonstrate post-logging liberated forest increment appeared in 1996 at Fazenda Cauaxi, about 20 km southwest of Paragominas in the Brazilian State of Para. Beginning in 1995, Fundação Florestal Tropical, demonstrated reduced impact logging in several 100-ha blocks of primary, moist (220 cm/year), terra firme forest with emergent trees to 50 m. Further description of this forest is summarized in Zweede (1999), text below, and in Table 1. A leftover from logging planning was the tagging, identification, and mapping of all trees 35 cm dbh (stem diameter at 1.3 m above the ground) and over.

The timber volume removed by CIKEL Brasil Verde S.A. averaged 25.4 m^3/ha from more than 50 tree species, a result of a favorable market location. Of the 23.6 trees/ha of commercial species of good form and more that 35 cm dbh, the reduced impact logging left 16.8 (Holmes, 1999). Since the nearby forest had all already been logged as well, the contrast available for determination was increment following: (1) reduced impact

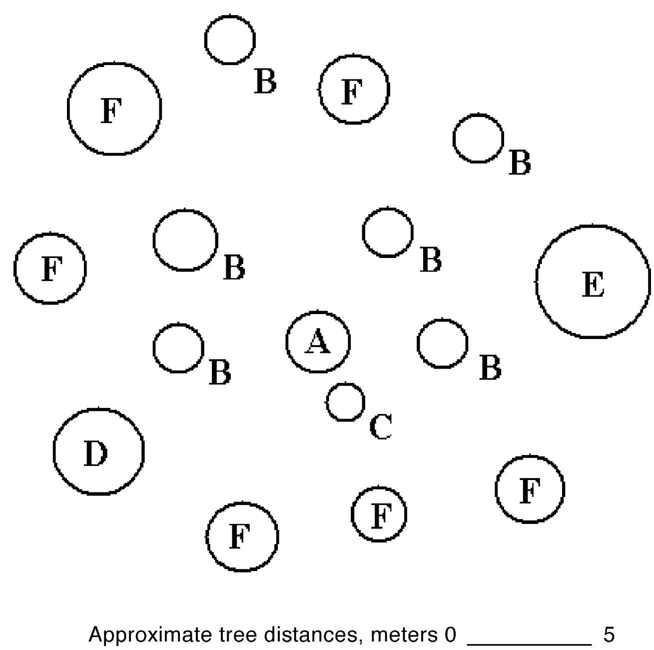

Fig. 1. The liberation of crop tree A, one of 12 crop trees/ha, averaging 30 m separation. Its competitors, other than any tree closer to it than 2 m, must all be as tall as the crop tree. These competitors are trees whose crowns overtop the crop tree or which are closer to it than the following distances, relative their summed dbh's in centimeters: 20–39 cm, 3 m; 40–59 cm, 5 m; 60–79 cm, 7 m; 80–99 cm, 8 m; 100 + cm, 9 m.

Tree	DBF (cm)	Height (m)	Distance (m)	Decision
A	30	25	0	Crop tree, leave
B		<25		Shorter, leave
C			>2	Close, remove
D	41	27	6	Close, remove
E	47	28	8	Overtops, remove
F	25–45	>25	6–9	Distant, leave

logged, versus (2) reduced impact logged and liberation. This is an acid test of the benefits of liberation, displaying only those in addition to increased increment resulting from the reduction in forest density following logging.

Two 20-ha plots (200 m × 1000 m), separated by 50 m were demarcated within one of the 100-ha cutover forests. The basal area of the forest trees >10 cm dbh in the plots averaged 36 m^2/ha (35.6 and 37.0 in the two plots). Trees of 10 cm dbh or more averaged 484/ha (482 and 487) Table 1. One plot contained 154 tree species and the other had 145, of which 91 were in both plots. In one plot 26 species and in the other 30 species were represented by only one tree.

Within each of the 20-ha study plots, future crop trees were selected of merchantable species and of good form. The average number of crop trees was 11.5/ha (12.4 and 10.9) versus only 7/ha taken in the initial logging. The mean dbh of the crop trees was 49.6 cm. They occupied 2.4 and 2.2 m^2/ha respectively in the two plots of the forest.

Defined as competitors to be removed were: (1) trees with crowns that overtop the crop trees, (2) trees of 10 cm dbh or more within 2 m of a crop tree, and (3) trees as tall as, or taller than a crop tree and closer to it than the following minimum separation (Wadsworth, 1997, 2001), based on the summed dbh's of the two trees in question: summed dbh's 20–39 cc, density maximum, 15–17 m^2 ha, and minumim separation, 3 m; 40–59 cm, 17–19 m^2 ha, and 5 m; 60–79 cm, 19–21 m^2 ha, and 7 m; 80–99 cm, 21–23 m^2 ha, and 8 m; and 100–120 cm, 23–25 m^2 ha, and 9 m.

This incompletely tested setting of minimum distances was adapted tentatively from observations in plantations where trees 10 cm dbh began to slow their growth as basal area surpassed 15 m^2/ha, and similar results with 60-cm mature trees at about 25/m^2/ha. Intermediate sized trees, reflected in the averages of neighbors, were assumed to require proportionally intermediate separation. To facilitate memorized application the classes of summed dbh's selected were large and separation values were rounded at what appeared to be acceptable precision for such a rule of thumb.

An example is seen in a 20 cm dbh crop tree with a 45 cm taller neighbor 6 m distant. The distance (6 m), with square spacing, corresponds to 278 trees/ha $(100\ \text{m}/6)^2$, which, multiplied by the mean basal areas of the two trees $((0.0314 + 0.1590)/2 = 0.0952\ \text{m}^2)$ equals 26.5 m^2/ha, beyond the 21 m^2/ha maximum density limit for trees of this average size, classifying the neighbor as a competitor and calling for its removal to liberate the crop tree. Application of the technique is illustrated in Fig. 1.

Competitor trees in one of the 20-ha plots received at a 15 cm horizontal spacing on their boles downward hacks

Table 2
The crop trees and the density of the competitors in the 20-ha control plot not treated

Species	1, Number	2, Mean	3, Maximum	Species	1, Number	2, Mean	3, Maximum
Anacardium giganteum	1	46	46	*Manilkara huberi*	17	162	748
Astronium lecointei	3	85	239	*Mezilaurus lindaviani*	1	1128	1128
Bagassa guianensis	1	7	7	N. I.	3	123	368
Bowdichia nitida	2	142	260	*Newtonia suaveolens*	3	173	449
Brosimum parinarioides	2	0	0	*Ocotea caudate*	3	21	56
Buchenavia capitata	1	1073	1073	*Ocotea fragantissima*	1	516	516
Caryocar glabrum	2	176	205	*Ocotea glomerata*	1	99	99
Caryocar villosum	1	323	323	*Parkia oppositifolia*	4	2	6
Cedrilinga caeteniformis	1	0	0	*Parkia paraensis*	1	12	12
Cordia bicolor	4	348	773	*Peltogne leocontei*	1	56	56
Cordia goeldiana	1	37	37	*Pithecelobium* sp.	6	8	33
Dinizia excelsa	2	6	12	*Chrysophyllum lucentifolium*	23	209	542
Endopleura uchi	6	143	259	*Pouroma guianensis*	5	83	294
Enterolobium schomburgkii	2	86	172	*Protium guayacanum*	9	231	1420
Eriotheca globosa	1	522	522	*Protium pernevatum*	1	0	0
Eschweilera odorata	24	363	1158	*Sacoglottia guianensis*	10	533	938
Goupia glabra	2	92	125	*Schefflera morototoni*	1	0	0
Guatteria poeppigiana	1	216	216	*Sclerolobium* sp.	5	33	127
Heliocostylis sp.	2	53	72	*Simarouba amara*	2	38	71
Holopyxidium jarana	5	361	1289	*Sterculia pilosa*	13	106	398
Hymenaea courbaril	1	11	11	*Symphonia globulifera*	1	0	0
Hymenaea parviflora	1	29	29	*Trattinickia rhiofolia*	9	121	438
Lecythis idatimon	21	333	1134	*Vatairea guianensis*	1	476	476
Lecythis paraensis	3	295	383	*Virola melinoni*	5	84	255
Leunania spruceana	2	10	19	*Zanthoxylum rhoifolia*	2	99	166
Licaria rigida	2	154	233	*Zollernia paraensis*	1	102	102
Manilkara amazonica	8	329	1168				

Total number of competitor trees	231
Mean percent basal area in competitor species	82
Mean of the percent basal area of the maximum competitors in relation to crop tree	348

Column 1 lists the number of crop trees by species. Column 2 presents the mean basal area of the competing trees expressed as a percent of the basal area of the corresponding crop trees. Column 3 presents the same information for the maximum basal area of competitors relative to that of the corresponding crop trees.

Table 3
Extreme maximum 6-year basal area increment rates of individual trees in the untreated forest plot, illustrating a potential

Species	Years
Sclerolobium sp.	9
Enterolobium schomburgki	12
Cedrilinga catenaeformis	14
Pithecolobium sp.	16
Dinizia excelsa	17
Protium pernevatum	19
Newtonia suaveolens	24
Parkia oppositifolia	25
Trattinickia rhoifolia	27
Parkia paraensis	27
Schefflera morototo	27
Bagassa guianensis	28
Ocotea glomerata	28
Chrysophyllum lucentifolium	30
Sterculia pilosa	31
Manilkara huberi	32
Symphonia globulifera	34
Protium guayacanum	34
Heliocostylis sp.	35
Lecythis paraensis	36
Brosimum parinariodes	36
Ocotea caudata	38

The figures of years are for the time required to grow from seedling to 60 cm dbh at the 6-year basal area increment rate recorded.

saturated with 33% glysophate. Of the 527 competing trees treated 74% were dead or dying after 6 months. Competition offered by the dying competitors during the growth period was considered insignificant.

4. Results

Reduced impact logging at Fazenda Cauaxi required mapping routes to each harvested tree to minimize skidding distances, the use of equipment that did not expose the soil, and practices such as directional felling. Its objective was to retain as much of the former forest condition as possible, as if to facilitate forest restoration.

Reduced impact logging in the two plots left around the crop trees an average of 24.2 competing trees/ha (22.1 and 26.4, respectively). In the plot to be liberated only 1.9 of the 10.9 crop trees/ha (17%) were free of competitors. The other 83% of the crop trees had an average of 2.9 competitors each, either overtopping or too close. Table 2 shows that the competing trees averaged 82% of the basal area of the crop trees.

Basal area increment of the crop trees in both plots was followed from June 1998 to February 2004. Of the crop trees left by the logging without liberation 52% had been growing at rates requiring more than a century for a rotation to 60 cm dbh. That the cause is competition among trees is seen in the contrasting growth maximums of 40 years or less to the basal area equivalent of 60 cm dbh of 22 of the crop tree species in the same unliberated forest (Table 3).

Comparative basal area increment rates for 24 species of crop trees represented at least twice in both plots appear in Table 4. Mean annual increment of the crop trees alone after reduced impact logging but without liberation, was 2.16 m^2/ha/year of stem basal area and 0.56 m^3/ha/year (Baima et al., 2001), compared to 2.89 m^2/ha/year and 0.67 m^3/ha/year for the logged and liberated crop trees.

Table 4
Comparative annual basal area increment of trees unliberated (control) and liberated. Species included are those with at least 2 trees in both plots

Species	Control cm^2/year increment			Liberated cm^2/year increment		
	Number of trees	Mean	Max	Number of trees	Mean	Max
Astronium lecointei	3	24.1	27	5	50.3	96.6
Brosimum parinarioides	2	67.2	75	2	56.9	68.5
Caryocar glabrum	2	18.2	28.9	4	52.2	140.7
Cordia bicolor	4	14.9	30.1	6	17.2	40.5
Eschweilera odorata	24	20	50.1	15	21.1	41.4
Goepia glabra	2	31.1	47.7	2	104.3	158.7
Holopyxidium jarana	5	14.8	24.1	8	25.5	38.4
Lecythis idatimon	21	11	41.3	19	16.1	41.7
Licaria rigida	2	54.1	65.7	2	61.6	94.4
Manilkara amazonica	8	28.1	66.6	7	57	171.1
Manilkara huberi	17	41.1	72.4	10	45.8	86.1
Newtonia suaveolens	3	82.2	129.3	8	139.2	587.1
Ocotea caudate	3	35	60	9	73.6	149.7
Pithecelobium sp.	6	82.4	181.4	12	59.2	232.6
Chrysophyllum lucentifolium	23	16.8	62.8	17	20	40.8
Pourouma guianensis	5	68	93.5	6	70.4	87.1
Protium guayacanum	9	35.3	68.6	6	56.4	75.4
Protium pernevatum	18	39.6	151.3	8	51.8	100.7
Sacoglottis guianensis	10	36.8	59.1	7	39.3	63.7
Sclerobium melinonii	5	247.6	336.3	5	235.1	409
Simarouba amara	2	55.2	68.2	3	45.9	92.6
Sterculia pilosa	12	63.4	104.4	11	70.4	168.7
Trattinickia rhoifolia	9	54.6	140	5	82.8	104
Virola melinonii	5	25.2	42.2	7	48.9	111.2

5. Conclusions

Reduced impact logging, as occurred in the area studied, is an improvement over past practices, in that damage is reduced and more trees survive, but it may stifle growth of the better trees by leaving competitors. Logging directed solely at low impact is not focused on high productivity. It is not the abundance of residual trees saved but rather the freedom of the best to grow that dictates future productivity.

Pre-logging planning and inventory are growing business requirements, if not also legal ones, so identification of the trees for the next crop and the competitors that constrain their growth before logging, using easily memorized rules, need not be an onerous task. Then, liberation, if integrated with reduced impact logging, should prove cost effective.

At Cauaxi, the crop trees and their competitors to be eliminated were identifiable before logging. Those merchantable, listed in Table 4, could have been selected first for the harvest. These merchantable trees alone made up 18 m^3/ha, three quarters of the volume harvested. They could have been added to the harvest of 25.4 m^3/ha (to 43 m^3/ha) or be substituted for otherwise harvestable trees that were not competitors a so their removal was less urgent. The elimination of all of these competitors appears desirable as a stimulus if future productivity is a goal of management of the forest. After removal the residual basal area would still average about 32 m^2/ha. The added yield apparently would have paid the costs of the identification and removal of any competitors that are not merchantable.

The harvest before the study removed only 7 trees/ha and left from 10 to 12 crop trees of more than 35 cm dbh, enough to yield a second 25 m^3/ha within 5 years, with or without liberation. Such an immediate harvest would be of trees averaging only 50 cm dbh, not the 61 cm of the first harvest. To attain a mean dbh of 61 cm at the current growing rates of the crop trees, 0.56 m^3/ha/year for the logged but unliberated forest and 0.67 m^3/ha for that liberated, would, for the solely logged forest require 34 years, whereas for the liberated forest it would be possible in 26 years, a time gain of 25% over that from logging. With time and increasing competition this difference can be expected to increase, even without further judicious liberation. Moreover, indications in Costa Rica suggest that increment of nearby trees not liberated may also increase as a result of the treatment (Hutchinson and Wadsworth, 2006; Table 5).

In summary, liberation, integrated with a harvest contributes to two harvests. In identifying merchantable competitors, it provides more options for immediate yield, in pre-selecting crop trees it assures improved quality, and in stimulating future growth it brings significantly closer a next harvest of equal or better volume and value, contributing to productive sustainability. Under conditions of the study can we afford to wait without it?

Table 5
Merchantable trees competing with crop trees left by the logging in the 20-ha treated plot

Species	No.	Vol
Buchenavia capitata	2	13.34
Caryocar glabrum	4	16.37
Couratari guianensis	6	13.05
Dinizia excelsa	3	16.77
Eriotheca globosa	3	0.93
Eschweilera coriacea	15	27.58
Eschweilera odorata	15	34.75
Holopyxidium jarana	1	7.47
Lecythis idatimon	5	7.66
Manilkara amazonica	1	4.95
Manilkara huberi	16	84.12
Newtonia suaveolens	5	23.88
Ocotea caudate	4	17.2
Ocotea fragantissima	1	1.21
Ocotea glomerata	1	3.49
Ormosia paraensis	1	1.36
Parkia paraensis	1	1.80
Pithecelobium sp.	1	3.95
Chrysophyllum lucentifolium	1	3.95
Pouteria guianensis	1	1.63
Pouteria sagotiana	7	20.27
Pouteria sp.	1	5.22
Protium guayacanum	3	1.64
Protium pernevatum	4	0.60
Sacoglottis guianensis	6	19.1
Sclerobium sp.	4	15.92
Sloanea nitida	1	1.16
Trattinickia rhoifolia	1	3.27
Vochysia inundata	1	3.72
Zollernia paraensis	2	4.56
Total		360.92
Per hectare		18.04

Since they were merchantable they might have been harvested at a profit as well as to benefit the next crop. The first column presents numbers of trees by species and the second column sums their wood volume in cubic meters.

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References

Beard, J.S., 1944. A silvicultural technique in Trinidad for the rehabilitation of degraded forest. Caribbean Forester 6 (1), 1–18.

Baima, A.M.B., da Silva, S.M., Silva, J.N.M., 2001. Ecuações de volume para floresta tropical de terra firme em Moju, Pa. In: Silva, J.N.M.J.O., de Carvalho, P., Yared, J.A.G. (Eds.), A Silvicultura na Amazônia Oriental: Contribuções do Projeto EMBRAPA/DFID, Belem. Embrapa Amazônia Oriental: DFID, pp. 367–392.
Chai, E.O.K., 1985. Liberation thinning in hill mixed dipterocarp forest of Sarawak: methods and progress. Kuching Sarawak Forest Department 25 pp.
Boerbohm, J.H.A., 1964. The Natural Regeneration of the Mesophytic Forest (tropical rain forest) after Exploitation. Wageningen, The Netherlands, 56 pp.
Dawkins, H.C., 1955. The refining of mixed forest, a new objective for tropical silviculture. Empire Forestry Review 34 (2), 188–191.
Dawkins, H.C., 1961. New methods of improving stand composition in tropical forests. In: Proceedings Fifth World Forestry Congress, Seattle, Washington, pp. 441–446.
Dawkins, H.C., 1963a. New methods of improving stand composition in tropical forests. The Caribbean Forester 22 (1/2), 12–20.
Dawkins, H.C., 1963b. Uganda Silvicultural Research Plan. 1959–1963. Entebbe, Uganda.
Earl, D.E., 1968. Latest techniques in the treatment of natural high forest in South Mengo District. In: Papers 9th British Commonwealth Forestry Conference. January 3–27, New Delhi, India. Entebbe Uganda Ministry of Agriculture, Forest Department, 26 pp.
FAO, 2003. State of the world's forests. Food and Agriculture Organization of the United Nations, Rome, Italy, 151 pp.
Finegan, B.E., 1992. El potencial de manejo de los bosques húmedos secundarios subtropicales en las tierras bajas. CATIE Manual Técnico No. 188. Turrialba, Costa Rica, 28 pp.
Griffith, A.L., 1947. India's tropical wet evergreen forests. In: Papers Eighth British Empire Forestry Conference, June 16–July 19, London, UK.
Henry, P.W.T., 1956. Development of the regeneration obtained by the tropical shelterwood system when applied as a pre-exploitment treatment only. Information Bulletin, vol. 40. Forest Department, Lagos, Nigeria, 3 pp.
Hepburn, A.J. 1973. Silviculture and management of the productive forest estate in Sabah with reference to the new manual of silviculture, Laporan 1971 Penyelidek Hutan. Negeri Sabah 1971 Annual Report. Forest Department Sabah. Malaysia, pp. 89–104.
Holmes, T.P. and others 1999. Financial costs and benefits of reduced impact logging relative to convential logging in the eastern Amazon. Phase 1, Final Report, U. S. Forest Service, Southern Research Station, New Orleans, Louisiana, 48 pp.
Hutchinson, I.D., 1977. Study to establish interim guidelines for silviculture and forest management in the mixed dipterocarp forest in Sarawak. In: UNDP/FAO/MAL/75/013, Sarawak Forest Department, Kuching, 245 pp. (in edit.).
Hutchinson, I.D., 1980. Sarawak liberation thinning, a practical guide and an initial analysis of performance. In: UNDP/FAO/MAL/76/008, Sarawak Forest Department, Kuching, 245 pp. (in edit.).
Hutchinson, I.D., 1981. Sarawak liberation thinning: background and initial analysis of performance. In: UNDP/FAO, Kuching, Sarawak, 121 pp.
Hutchinson, I.D., 1993. Puntos de partida y muestreo diagnostico para la silvicultura de bosques naturales del tropico humedo. Coleccion Silvicultura de Bosques Naturales 7. Turrialba, Costa Rica. CATIE, 32 pp.
Hutchinson, I.D., Wadsworth, F.H., 2006. Efectos de la liberación en un bosque secundario de Costa Rica. Recursos Naturales y Ambiente 46, 155–160.
John, C.A., 1961. The Rate of Growth of Virola surinamensis Warb. University of Oxford, Department of Forestry, Commonwealth Forestry Institute, Oxford, UK, 75 pp.
Kadambi, K., 1958. Methods of increasing growth and obtaining regeneration of tropical forest. In: Proceedings Fourth World Forestry Congress, vol. 3, Dehra Dun, India, pp. 173–184.
McGregor, W.D., 1934. Silviculture in the mixed deciduous forests of Nigeria with special reference to the southwestern provinces. Oxford Forestry Memoirs No. 18. Commonwealth Forestry Institute, Oxford, UK, 108 pp.
Mead, J.F., 1937. The silvicultural treatment of young meranti stands. Malayan Forester 6 (1), 53–56.
Neyra-Roman M. G., 1981. Investigaciones y desarrollo industrial forestal. CO/FAO/COL/74/005 Documento de Trabajo No. 32, 220 pp.
Osafo, E. D. 1970. The development of silvicultural; techniques applied to natural forests of Ghana. Technical Note No. 13. Forest Products Research Institute, Accra, Ghana, 18 pp.
Poore, D., et al., 1989. No Timber Without Trees. Earthscan Publications, London, UK, 252 pp.
Rice, R.E., et al., April, 1997. Can sustainable management save tropical forests? Scientific American 44–49.
de Rosario, R.A., 1955. The silviculture and management of tropical rain forest with special reference to Ceylon. Ceylon Forester 2 (1), 5–25.
Silva, J.N.M., et al., 2002. Growth, mortality, and recruitment in terra firme forests of the eastern Amazon: observations in Tapajós and Jarí. In: Ismael, S. bin M., et al. (Eds.), Proceedings of the Malaysia-ITTO International Workshop on Growth and Yield of Managed Tropical Forests, Kuala Lumpur, 25–29 June, pp. 205–218.
Smith, D.M., 1986. The Practice of Silviculture, eighth ed. John Wiley, New York, 527 pp.
Stracey, R.D., 1959. The silviculture and management of tropical rain forest in India. Indian Forester 85 (7), 345–407.
Wilkinson, T.L., 1960. The management of indigenous woodlands. Rhodesia Agricult. J. 41 (4), 200–207.
Wyatt-Smith, J., 1961. A review of Malayan silviculture. Malayan Forester 24, 5–18.
Wadsworth, F.H., 1953. New observations on tree growth in tabonuco forest. The Caribbean Forester 14, 106–111.
Wadsworth, F.H., 1997. Forest production for Tropical America. Agricultural Handbook, vol. 710. Department of Agriculture, Forest Service, Washington, DC, United States, 603 pp.
Wadsworth, F.H., 2001. Not just reduced but productive logging impacts. Int. Forest. Rev. 3 (1), 51–53.
Zweede, J.C. (Coord.), 1999. Relatorio de conducção e avaliação de tratamento silvicultural: Desbaste de liberação de copa a corte de cipós. Fundação Floresta Tropical, Belém, Para, Brazil, 20 pp. and apendices.