TRIALS ON METHODS OF LAND CLEARING IN A TROPICAL RAIN FOREST AT I.I.T.A.

IBADAN, NIGERIA

by

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DEFINITIONS (Allan, 1973)

In relation to land clearing operations, some terms and abbreviations used in the text are defined as follows :-

(i) "Knock Down" (K.D.) a mechanical operation which comprises pushing or pulling over standing trees and in the same operation extracting the tree roots from the soil.

(ii) "Wind Rowing" (W.R.) which is the linear heaping of woody debris to facilitate its disposal by burning. (Where woody material can be disposed of as fuel, windrowing is not necessary).

(iii) "Run Time" (R.T.) which is the time taken in minutes for a tractor or tractor unit and implements to cover a particular distance or run, i.e. when travelling in one direction from the time the implement commences operation until it ceases, is lifted or commences turning.

(iv) "Minor Stop Time" (m.s.t.) in mechanical operations is the time in minutes when it is necessary to stop the tractor or power sources, but for reasons of such a minor nature that it is not necessary to stop the engine.

(v) "Major Stop Time" (M.S.T.) in a mechanical operation is the time in minutes when it is necessary to stop the tractor or power source and the reason is of such a nature that it is either necessary or desirable to stop the engine.

(vi) "Turning Time" (T.T.) in a mechanical operation is the time in minutes for a tractor unit to turn from completion of one run until the commencement of the next, e.g. from the time a cultivation implement ceases to operate on one run until it commences on the next.

(vii) "Working Time" (W.T.) in a mechanical operation is the time in minutes for a tractor or power unit and implement when the unit is actually working i.e. excludes turning and stop times. (It is often made up of the sum of a number of runs, e.g. n x R.T. = W.T.)

(viii) "Operating Time" (O.T.) for a mechanical operation is the time in minutes per specific area or unit, and is calculated by adding working, minor stop and turning times, e.g.

$$W.T. + m.s.t. + T.T. = O.T.$$

(ix) "Basal Area" (B.A.) The basal area of a tree is the area of the cross section of the stem at breast height. (b.h., or at 127.5 cms above ground level). The basal area of a crop or vegetation type is the sum of the cross sectional area of its constituent trees and is often expressed as the total basal area per unit land area. (e.g. square metres per hectare).

(x) Rate of exchange as at 1.12.74; 100 Kobo = ₦1 = US $1.64.

INTRODUCTION

Shortage of food is still one of the biggest problems of many tropical countries. Its production, however, is rising. The improvements on organization and mechanization, introduction of high-yielding varieties and multiple cropping patterns have already contributed to agricultural progress, but much is yet to be done. Farmers are putting more land under cultivation. In densely populated areas land is intensively cultivated, whereas in sparsely populated areas, shifting cultivation methods are adopted. To bring larger areas under cultivation in a short time, farmers should apply economic principles. Research on land clearing practices has hitherto been done in the savanna regions of Nigeria, where it was found that chaining is the most cost efficient method, followed by single tractor clearing. Manual stumping is costly and arduous. To compare costs and output of different land clearing trials, the basal area is a better determinant than land area. In the forest areas, south of the savanna, there are more trees per hectare, the basal areas are higher and there are shrubs on every square metre. Therefore, information about forest clearing and cultivation methods is necessary. Lalor (7) pointed out that clearing with the existing tree extractors is not recommendable. In the rain forest, many trees are either too big or too short to be gripped and many trees are obstructed by the presence of other trees within five metres.

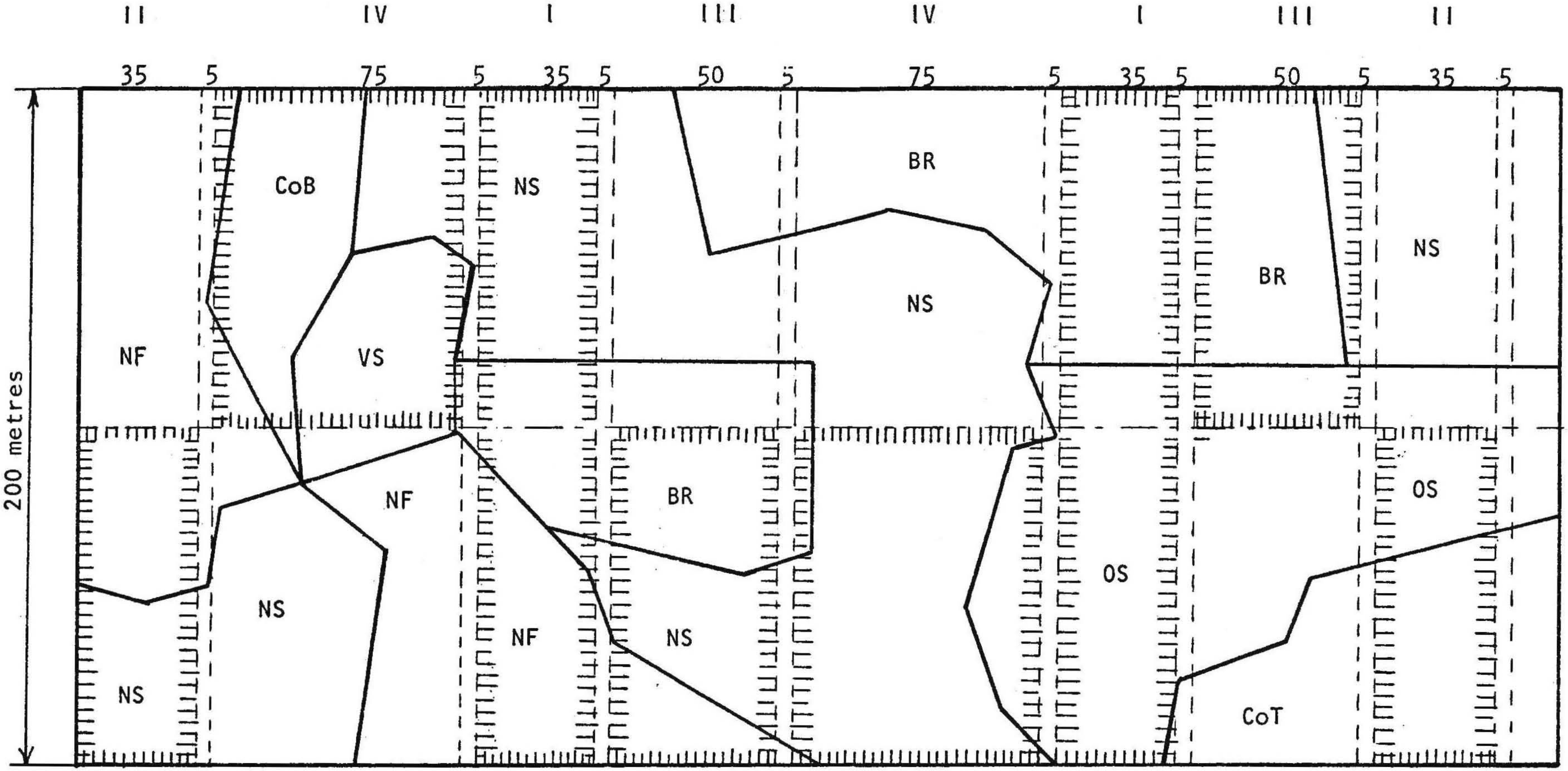
In this paper four clearing methods, followed by windrowing, are stated.

OBJECTIVES OF CLEARING TRIALS

The objective of land clearing is to prepare land for a special use such as the construction of buildings, roads and dams or bringing land under cultivation. Each use of the land will subsequently have its own restrictions according to the method of land clearing. In mechanized cultivation, land should be free of all woody vegetation such as roots and stumps. On the other side, soil disturbance must be avoided in land meant for agriculture, especially in one with a thin topsoil.

In the fdlowing trials, all land was for cultivation. The objective was to research into four different clearing methods followed by windrowing and burning (Fig.1), to determine labour input, work efficiency and other expenses. These objectives will be followed by comparing windrowing after clearing and after burning. The total result will be found later on, when bush regrowth, weeds, crop growth and yields will indicate the quality of the different land clearing trials.

These land clearing trials are the beginning and an integral part of a multi-disciplinary project.



NS = New secondary forest
NF = Natural forest
CoB = Cocoa and bushes
VS = Village site
BR = Bush regrowth
OS = Old secondary forest
CoT = Cocoa and old trees

I = Traditional clearing
II = Hand clearing
III = Single tractor clearing
IV = Chaining

Scale : 1 cm = 20 m

= burning in situ after clearing

= windrowing after clearing

Figure 1. Plan of surveyed forest area located near Ibadan Nigeria (Lalor) and the land clearing treatments.

THE TRIAL AREA

The Site: The land clearing took place at the International Institute of Tropical Agriculture (IITA), located 10 kilometres north of Ibadan at 3.54'E and 7.30'N latitude. The elevation is 330 metres.

The climate at IITA is characterised by wet and dry seasons. The wet season is from March ending till mid-October with two rainfall peaks: July and September-October. August usually is a dry period. The annual rainfall is 1250 mm. The soils at IITA are composed mostly of loamy sand to sandy loam, with a gravelly subsoil of sandy clay loam to clay texture.

The area and vegetation types are shown in Figure 1. The data about the composition of each type are stated in Tables 1, 2 and 3. The area has remained uninhabited and uncultivated for about six years.

The Trial Plots: The plots were parts of an eight-hectare area which was surveyed purposely for land clearing trials (Lalor, 7). One-fifth of each similar vegetation area was sampled by 10m x 20m randomly chosen rectangles. All trees or shrubs with roots likely to have significant effect when tilling with conventional machinery including two-wheeled tractors were counted and measured (7). The girth was measured only for trees of more than 45 cm (14.3 cm diameter). Lalor assumed the mean girth of trees less than 45 cm girth is 27 cm. He measured the tall trees at breast height and 45 cm height. The low-branched trees he measured at 45 cm height because, according to him, this "is the area of a circle within which all branches of a tree lie".

In addition, the girth at 45 cm height is the point that tree extractors must grip the trees. To compare the results with other trials, the basal area at breast height of the erect trees and the basal area at 45 cm height of the low-branching trees are added (Table 1).

Table 1: Record of tree types and basal areas for various vegetation types (Lalor, 7)

Vegetation Type	No. of Samples	Trees per ha.			Basal area (m^2/ha)		
		Total	Low branching trees[a]	Erect trees	Low branching trees	Erect trees	Total B.A. per ha[d]
New secondary forest	30	2888	288	2600	15.9[c]	25.4[b] 28.6[c]	41.3
Natural forest	10	4335	175	4160	7.8	43.6 44.8	51.4
Cocoa and bushes	3	3683	333	3350	31.4	32.0 37.1	63.4
Village site	3	5100	250	4850	13.0	36.1 39.7	49.1
Bush regrowth	17	3432	126	3306	8.8	34.6 35.2	43.4
Old secondary forest	10	3180	250	2930	8.9	25.8 27.2	34.7
Cocoa and old trees	5	3210	280	2930	13.4	34.1 39.4	47.5
Pooled	78	3365	233	3133	12.7	31.0 33.4	43.7

a Trees branching at or close to the ground level
b Based on girth at breast height
c Based on girth at 45 cm height
d With this B.A. is counted

Table 2: Number and size of erect trees per ha. found in the vegetation types[a] (Lalor, 7)

Vegetation Type	No. of Samples	Trees per ha					
		Total[b]	0-45cm Girth	45-90cm Girth	90-135cm Girth	135-180cm Girth	Over 180cm Girth
New secondary forest	30	2600	2459[c]	78	43	17	2
			2443[d]	90	33	30	3
Natural forest	10	4160	3910	175	40	20	15
			3850	225	50	10	25
Cocoa and brushes	3	3350	3183	83	67	17	0
			3133	133	50	17	17
Village site	3	4850	4633	183	17	17	0
			4550	267	17	17	0
Bush regrowth	17	3306	3215	41	21	18	12
			3209	47	12	21	18
Old secondary forest	10	2930	2800	85	30	10	5
			2780	105	15	30	0
Cocoa and old trees	5	2930	2760	70	80	10	10
			2720	100	60	40	10
Pooled	78	3133	2985	87	38	16	6
			2959	109	30	25	10

[a] Trees branching near the ground are excluded

[b] Rounding errors account for discrepancies in totals.

[c] Based on girth at breast height (127cm)

[d] Based on girth at 45 cm height

Table 3. Number and size of low-branching trees per ha in various vegetation types (Lalor, 7)

Vegetation Type	No. of Samples	Trees/ha					
		Total	0-45cm Girth	45-90cm Girth	90-135cm Girth	135-180cm Girth	Over 180cm Girth
New secondary forest	30	288	107[a]	60	62	33	27
			95[b]	137	42	5	10
Natural forest	10	175	25	40	55	45	10
			10	130	35	0	0
Cocoa and bushes	3	333	67	83	100	33	50
			50	183	83	0	17
Village site	3	250	33	100	50	50	17
			33	167	17	33	0
Bush regrowth	17	126	44	32	15	18	18
			44	50	20	3	9
Old secondary forest	10	250	85	70	60	25	10
			80	140	30	0	0
Cocoa and old trees	5	280	70	3	70	60	50
			60	170	40	10	0
Pooled	78	233	73	53	52	33	22
			65	122	35	4	6

[a] Based on girth at breast height

[b] Based on girth at 45cm height

THE CLEARING TRIALS

HAND CLEARING TRIALS

Equipment

- Matchets
- Native hoes
- Native axes
- Chainsaw

Design of Experiment: A local contractor was hired. He classified the clearing into four groups: shrubs, small trees, big trees and palm trees (Elaeis guineensis).

Other contractors working at IITA, however, had three classifications: shrubs, trees and palm trees.

Class I - The grasses and shrubs, to a diameter of about 2.5cm, were slashed down by matchets just above the ground.

Class II - Little trees to a diameter of about 8cm. They were felled using native hoes by digging the soil around the trees and cutting all the roots with native axes.

Class III - All big trees except the palm trees. The procedure is similar to Class II.

Class IV - Palm trees. They are also felled by cutting all roots but in a quite different way from Classes I and II. Palm trees have adventitious roots which sometimes require deep digging.

The contractor received ₦115 per hectare for traditional hand clearing (Classes I and II) and ₦225 for complete hand clearing (Classes I - IV)

Because many parts of the area were cultivated about six years previous, traditional hand clearing had already taken place. Many little trees that had been removed had their stumps shoot out to develop into new trees. These trees had bigger stumps than expected. The stump and not the diameter of the bole fixed the working time and the classification. The upper diameter for this class was agreed to be around 8cm.

The contractor hired a supervisor and labourers. He gave them a task work for classes I and II which contained clearing a certain amount of square metres, and for classes III and IV felling some trees. The labourers started around 8.30 a.m., finished their task and went home. Sometimes they accepted another task. They never had a break for lunch. The working rate was fairly high, especially by classes I and II as the trees protected them against sunshine. The labourers worked at an average of 4.70 hours a day during the period.

Traditional hand clearing: After finishing classes I and II, the trees left were cut off by means of a chain saw about 1 metre above the ground. The saw was used by two persons who had little experience; they alternated each other. Under temperate climatic conditions, working with a chainsaw is heavy labour (8), and recommended to be used for not more than two hours a day by an individual. The vibration and noise of a chainsaw may damage the arms and ears too. Under tropical conditions, and especially in the forest area, where after felling classes I and II, walking is difficult, certainly working should not last longer than two hours for one day. A team of three persons to relieve each other, provided with earcaps and one chainsaw, would be a better unit. The results are given in Table 4. The time for refueling the chainsaw is included in the operation time. It indicates, in comparing with Table 5, that chain saw is a good tool to clear classes III and IV more quickly. The land, however, is only suitable for traditional farming. The average time for classes I and II amounts to 244 hours per hectare, less than one third of the time for complete hand clearing. Hence, ₦115 per hectare was obviously rather high.

Complete hand clearing: The results of the complete hand clearing trials are stated in Table 5. Here, the input of about 180 man-days per hectare was very high. The amount of ₦225 per hectare is reasonable comparing the wages of the casual labourers, but will not be sufficient next time. (The wages of the labourers now rise 100 per cent, the minimum annual salary in 1975 is ₦720). Because only palm trees were felled in Class IV, the operation time could be measured; it amounted to 4.20 manhours per palm tree.

Table 4: Operation time (hours/ha) for traditional hand clearing

Class	Vegetation type				
	NS	NF	BR	OS	Pooled
I	82	53	95	81	78
II	188	108	211	158	166
Total	270	161	306	239	244
III & IV[a]	22	27	14	26	22

[a] Operation time (hours/ha) for felling by chainsaw and two operators.

Table 5: Operation time (hours/ha) for complete hand clearing

Class	Vegetation type				
	NS	NF	OS	CoT	Pooled
I	82	53	81	44	65
II	188	108	158	198	163
III	293	524	434	392	411
IV	269	98	241	293	225
Total	832	783	914	927	864

KNOCK-DOWN TRIALS

KNOCK-DOWN USING THE SINGLE TRACTOR TECHNIQUE

Equipment

- 1 Caterpillar D5 tractor
- 1 Cab Guard for D5 tractor
- 1 Radiator Grill for D5 tractor
- 1 Dozer Blade for D5 tractor

Design of Experiment: The knock-down trials were held at the end of November and in the beginning of December. The tractor started at one side of the plot and cleared about 5 metres at the outside applying the blade just above the surface. It pushed the wood forward till a lot of wood gathered in front of the blade and then turned to the cleared open side. The tractor then reversed and advanced to pick up the fallen and bent trees by adjusting the blade to about two centimeters beneath the surface, and turning them again to the cleared area. Whenever the tractor met a big tree, it lifted up the blade and pushed the tree over. The tractor then reversed and advanced to the fallen tree. It put the blade under the root stump and pushed the tree with all the roots and attached soil to the cleared area. All trees which could not directly be pushed over were measured and the extra time before they were pushed over was recorded (Table 6). Most of them were palm trees. They were dug out by the blade and pushed over later. Other trees like Cola acuminata were pushed over after cutting the lateral roots by the rear mounted rippers or dug out by the blade. In this case the soil disturbance was high.

It was still decided to fell these big trees to compare this method with Class IV of hand clearing. The best solution should have been to apply a tree pusher which could be mounted on the bulldozer blade, but it arrived late.

It has been applied in another forest at IITA and worked well. All palm trees and other trees, except the low-branching trees, could easily be pushed over. Only some very big trees, like mahogany species, had to be felled by hand.

Table 6 : The time measurements of the K.D. trials using the single tractor technique

PLOTS	Area (hectare)	W.T. (mins)	m.s.t. (mins)	O.T. per hectare (mins)	B.A. per hectare (sq. metre)	Time per sq. metre of B.A. (mins)	Remarks
1.	1.0	613.27	21.69	634.96	43.18	14.70	All trees are included
	1.0	415.95	21.69	437.64	36.50	11.99	Trees which fall in one push.
				197.32	6.68	29.54	Trees which require more efforts. (44 palm trees, 5 kola trees and 1 mahogany tree)
2.	1.0	525.10	26.09	551.19	40.6	13.58	All trees are included
	1.0	369.53	26.09	395.62	37.4	10.58	Trees which fall in one push
				155.57	3.2	48.62	Trees which require more efforts (30 palm trees)

CHAINING

KNOCK-DOWN USING TWO TRACTORS DRAGGING AN ANCHOR CHAIN

Equipment

- 1 Caterpillar Power Shift D7 series F tractor (CAT D7F)
- 1 Caterpillar Direct Drive D8 series H tractor (CAT D8H)
- 1 Caterpillar D5 tractor
- 3 Cab Guards for D5, D7 and D8 tractors
- 3 Radiator Grills for D5, D7 and D8 tractors
- 3 Dozer Blades for D5, D7 and D8 tractors
- 1 Screen for D7 tractor
- One 91.4 metre long anchor chain with links each 5.0cm in diameter, weighing 5100 kilograms. The chain had four swivels to prevent twisting, one at each end and two equally spaced in the chain.

Design of Experiment: The chaining trial took place on 29 November 1974, about one month after the end of the rainy season. The soil moisture content on weight base was 5.3 per cent in the layer from 0-15 cm and 6.2 per cent in the layer 15-30 cm. Two plots of 1.5 hectare (200 x 75m) were available, and trails had been made by matchets to give the tractor driver the possibility to see the right way inside the forest. These trails were about 11, 16 and 20 metres apart. The CAT D7, which drove inside the forest, had an angled dozer. The CAT D8 drove outside the forest. The tractors had no insect screen and the operators were not provided with bee protective clothes.

To commence the operation, the tractors (D7 and D8) advanced into the plot, 11, 16 or 20 metres apart, with the chain being pulled in an arc behind. The inside tractor led and drove four metres in front of the outside tractor.

The speed was limited by the inside tractor because of the thickness of the forest. Sometimes the inside tractor had to stop, reverse and continue. If there was a stop when the chain struck a big tree, it was more difficult to pull down the tree.

It especially depended on the height of the chain at the moment of hitting the trees. In this forest, the chain was often lifted by rolling over the felled vegetation. This made it easier to pull down the big trees, but caused the

shrubs and little trees to bend over without extracting the root system. The D5 tractor followed the chain at the left or right back side where it was easier to drive because of the windrowing effect of the chain and as soon as the chain stopped moving, it drove to the obstructing tree and applied its blade. With the pull of the two foward tractors and the push of the following one, such trees were eventually knocked down, except one Blighia sapida (Table 7, plot 2, run 5) which lasted 19 minutes to fell.
As for the thick forest, it was difficult for the driver of the D5 to move quickly near the obstructing trees.
All the drivers, except one, had some experience in the savanna near Bacita.
The waiting time for the two tractors in front of the D5, is stated in Table 7.
Each run started when the inside tractor entered the forest (because at that moment, its blade knocked down the trees) and ended when the chain was completely out of the forest. Then both tractors turned in a large circle to the next swath. The end time of the run was at the same time the starting time of the turn. The turn time ended when the inside tractor entered the forest again.
As there was only one tractor with a screen, the tractors drove to the right, to the swath on the other side of the plot, and so the inside tractor remained inside. Usually, the tractors turn together to the swath that borders up the first, and they reverse positions. The area for turning in this way must be at least 80 metres broad beyond the forest. The results are stated in Tables 7 & 8.

In conclusion, the mean cutting time per square metre of basal area is 30 per cent higher than what Allan found in the savanna vegetation near Kaduna, Nigeria (2). But it indicates also that a swath of 16 or 20 metres is more efficient. The swath cannot be more than 16-20 metres because of poor coordination between the tractor operators, due to the thick forest. In this thick forest, a wider swath restricts the mobility of the third tractor which sometimes has to cross the swath to assist the two tractors in front.

For large scale operations, it is therefore recommended that two tractors follow each on one side of the swath. A swath of 16 or 20 metres gives also the possibility to chain in opposite directions with the tractors 32 or 40 metres apart and windrowing can be done more efficiently with the same distance of 32 or 40 metres between the linear heaps.

Such as already set out by hand clearing (class II), there were many small trees with big stumps. They were bent over by the chain. Hence, the standard of knocking down was moderate for little trees and shrubs. Special trees with tap roots, like Albizia zygia, Antiaris africana and Newbouldia leawis were difficult to knock down. Often they bent over or broke off just above the ground. But big trees, like kola and mahogany trees, were mostly half extracted, but could have been easily removed by windrowing. Palm trees, however, were always fully extracted.

Chaining in the opposite direction caused a higher total operation time per square metre (B.A.), but improved the result. Trees were pushed over to the opposite side and all the lateral roots were extracted. Still some shrubs and small trees bent over. A chain with 6.5cm diameter links might have improved the overall quality of the clearing. The best result was obtained when a big tree stayed in front of the chain. Then any woody debris was pushed forward and many standing trees knocked down.

Table 7: Operating times for the chain knock-down trials.

PLOTS	Run	R.T. (mins)	m.s.t. (mins)	Waiting* time (mins)	T.T. (mins)	O.T. (mins)	O.T. per hectare (mins)	O.T. per sq.metre B.A. (mins)	Width of the swath (m)	Remarks
1.	1	12.30		2.50	2.00	14.30	65.00	1.57	11	B.A. 41.3m^2 per ha
	2	13.30		1.55	3.20	16.50	51.56	1.25	16	
	3	9.90		1.30	2.25	12.15	37.97	0.92	16	
	4	5.80	4.60		1.45	11.85	53.86	1.30	11	m.s.t. between run 4 and 5 to clear the CAT D7
	5	9.45		1.05	1.90	11.35	28.38	0.69	20	
		50.75	4.60	6.40	10.80	66.15				
2.	1	6.90			2.00	8.90	27.81	0.56	16	B.A. 49.6 m^2 per ha.
	2	10.70			1.90	12.00	30.00	0.60	20	
	3	9.00		0.60	1.80	10.80	49.10	0.99	11	
	4	8.75			1.80	10.55	32.97	0.66	16	Run 5: 1 Blighia sapida with a girth of 213 cm lasted 19 mins. before being pushed over.
	5	27.50		0.20	2.70	30.20	137.41	2.77	11	
		62.85		0.80	10.20	73.05				

* Waiting time of the two tractors in front before the D5 assists by pushing over obstructing trees.

Table 8: Mean operation times per unit area and per basal area for chain knock down.

PLOT	O.T.	Area (hectares)	B.A. (sq. metres)	O.T. per hectare (mins)	O.T. per sq. metre B.A. (mins)
1.	66.15	1.50	62.1	44.10	1.07
2.	73.05	1.50	74.4	48.70	1.00

Table 9: Operation times for chaining in the opposite direction.

PLOT	Run	R.T. (mins)	Waiting* time (mins)	T.T. (mins)	O.T. (mins)	O.T. per hectare (mins)	O.T. per sq. metre B.A. (mins)	Width of the Swath (m)
1.	1	4.70		2.00	6.70	30.45	0.74	11
	2	6.80		3.60	10.40	19.26	0.47	27
	3	7.40			7.40+	10.28+	0.25+	36
		18.90		5.60	24.50			
2.	1	8.65	0.50	4.30	12.95	40.47	0.82	16
	2	7.10		2.60	9.70	30.31	0.61	16
	3	9.00	1.30	2.00	11.00	27.50	0.55	20
	4	5.40			5.40+	12:27+	0.25+	22
		30.15	1.80	8.90	39.05			

* See Table 7

\+ These times are not comparable with the others as there is no turning time.

Table 10: Mean operation time per unit area and per unit basal area for chaining in the opposite direction.

PLOT	O.T. (mins)	Area (hectares)	B.A. (sq.metres)	O.T. per hectare (mins)	O.T. per sq.metre B.A. (mins)
1.	24.50	1.50	62.1	16.33	0.39
2.	39.05	1.50	74.4	26.03	0.52

WINDROWING

Equipment - The D5 tractor (see single tractor K.D.) with root rake.

Design of Experiment: Following the hand clearing and knock down trials 50 per cent of the area was windrowed. The windrows were planned on 5-metre-wide strips between the different plots. For this operation, the root rake was lowered to ground level and all the pulled vegetation pushed to the windrow. The tractor then reversed to the middle of the two windrows and made a further pass parallel to the others and perpendicular to the windrow. Two factors which influenced the result were the clearing method and the distance between the windrows.

Complete hand clearing: As the distance between the linear heaps amounted to 35 metres, the passes of the tractor were an average distance of 17.5 metres. They could have been longer as the trees had the roots cut and there was no big strain on the tractor. The operation was accomplished to a very good standard without soil disturbance.

Single tractor knock down: By this clearing method, the wood was always pushed to the open side in front of the forest, that is to both sides of the plots. So there was already a windrowing effect and in the middle between the planned rows (50 metres apart) there were few trees. The passes of 25 metres did not cause a big strain on the tractor. The operation was to a good standard with little soil disturbance. A few shrubs and very small trees were still standing in the plots. They were not knocked down and could not easily be removed by windrowing.

CHAINING

The windrowing effect with chaining had no advantage on the windrow operation. The parallel linear heaps were planned at other places; 75 metres apart (Fig.1) Chaining made the windrow operation even more difficult. The trees were intertwined by the chain, it required more time to push the wood together onto a heap. Besides, too much wood collected in front of the rake and the D5 tractor was not able to do passes of an average of 37.5 metres. It made first passes of about 25 metres, which caused a big strain on the tractor, and pushed the other wood later on to the heap. Many stumps of trees which had been broken just above the ground could easily be removed by applying the root rake just into the soil. The standard of operation was good, although more shrubs and small trees were still standing than by windrowing after the single tractor K.D. but this was due to chaining. There was only little soil disturbance.

Table 11: Operating time per unit area and per unit basal area for mechanized windrowing.

W.R. after	O.T. (mins)	Area (hectares)	B.A. (sq.metres)	O.T. per hectare (mins)	O.T.per sq.metre of B.A. (mins)
Hand clearing	46.60	0.35	18.0	133.14	2.59
Hand clearing	44.80	0.35	14.5	128.00	3.09
Single tractor K.D.	59.95	0.50	20.9	119.90	2.87
Single tractor K.D.	53.38	0.50	19.9	106.76	2.68
Chaining	157.84	0.75	31.6	107.12	4.99
Chaining	144.20	0.75	34.5	192.27	4.18

Table 11 shows that the operating times per square metre of B.A. for these trials are less than in the savanna, where eleven minutes per square metre of B.A. were measured (1, 3). Comparing the operating times per hectare (except W.R. after chaining, where the distance between the linear heaps was too large) windrowing in the savanna area is only 30 per cent faster than in this forest area.

Comparative Costings of Clearing Operations

The mechanization costs as stated in Table 12 include interest, depreciation, repairs, fuel, lubricants, and operators' wages, but exclude the costs of transport to the site and management overheads. The basis of the costings is given in detail in references 1, 2 and 3. Table 12 shows that chaining is the most efficient method, followed by the single tractor technique and contract hand labour.

Comparing the costs per square metre basal area with those in the savanna regions, there is little difference (based on 1974 costings). The costs per square metre basal area for contract hand labour are obviously cheaper.

The windrowing costs per square metre basal area, however, are very low, about 25 per cent of the costs found by Allan in the savanna regions.

Table 12: Estimated (1974) land clearing costs in the tropical rain forest (with reference to the executed trials)

Method and equipment	Replication	Cost/hour (₦)	Operating time/ha (mins)	Cost/ha (₦)	O.T. m² B.A. (mins)	Cost/m² B.A. (₦)
Contract hand labour						
1. Traditional hand clearing plus chain saw				155.00		3.55
2. Complete hand clearing				255.00		5.15
Knock-down						
3. Single tractor clearing; Caterpillar D5 tractor	1	10	634.96	105.83	14.70	2.45
	2	10	551.19	91.87	13.58	2.26
4. Chaining; Caterpillar D8, D7, D5 tractors and chain	1	52	44.10	38.22	1.07	0.93
	2	52	48.70	42.21	1.00	0.87
5. Chaining plus chaining in the opposite direction; Same equipment as 4.	1	52	60.43	52.37	1.46	1.27
	2	52	74.73	64.77	1.52	1.32
Windrowing						
2. Caterpillar D5 Tractor	1	10	133.14	22.19	2.59	0.43
	2	10	128.00	21.33	3.09	0.52
3. Caterpillar D5 Tractor	1	10	119.90	19.98	2.87	0.48
	2	10	106.76	17.79	2.68	0.45
5. Caterpillar D5 Tractor	1	10	197.12	32.85	4.99	0.83
	2	10	192.27	32.05	4.18	0.70
Total costs						
2. Complete hand clearing plus windrowing	1			247.19		5.58
	2			246.33		5.67
3. Single tractor clearing plus windrowing	1			125.81		2.93
	2			109.66		2.71
5. Chaining plus chaining in the opposite direction plus windrowing	1			85.22		2.10
	2			96.82		2.02

SUMMARY

During November and December 1974, four different land clearing trials were carried out in a tropical rainforest at the International Institute of Tropical Agriculture at Ibadan. The trials included : traditional hand clearing, complete hand clearing, single tractor clearing and chaining. These clearing methods were followed by windrowing. Prior to knocking down the forest, an area of 8 hectares was surveyed and sampled to determine the vegetation types and basal area of the wood population (Lal, 7). Observations and time studies of the different methods were evaluated and the costs were calculated.

It is concluded that the mechanized methods are more cost efficient, and particular chaining plus chaining in the opposite direction is even more efficient than the single tractor clearing. Comparing the costs per hectare with those in the savanna regions in Nigeria, cost of rain forest clearing was higher for all methods. As for the costs per square metre basal area, cost of rain forest clearing was lower for contract hand labour and was about the same for single tractor clearing and chaining. The windrowing costs per square metre basal area are only 25 per cent of the costs in the savanna regions.

CONCLUSIONS

The trials started late after the rainy season; this was responsible for the little soil moisture during the trials. One can, however, conclude that:

- in the rain forest, the Caterpillar D5 with blade is not able to knock down many palm trees and big trees directly, it has to fell them by digging them out with blade or cutting the roots with the rippers. This is, however, cheaper than hand stumping but causes too much soil disturbance. Most of these trees can easily be knocked down by the D5 provided with blade and tree pusher.
- Chaining is applicable in the rain forest and is the most cost efficient land clearing method just like in the Guinean Zone. It needs a good preparation and organization.
- Chaining plus chaining in the opposite direction is more cost efficient than the single tractor technique and causes less soil disturbance.
- Windrowing after chaining is more difficult than after complete hand clearing and the single tractor technique; the distance between the linear heaps has to be 40 metres or less.
- In the rainforest, the cost per square metre basal area for single tractor clearing and chaining are about the same as those in the savanna regions. The costs for windrowing are much cheaper.
- In future wages will rise and in comparing with hand stumping, mechanized stumping will become even more cost efficient.

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