LAND CLEARING AND DEVELOPMENT IN THE TROPICS

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Edited by
R LAL
International Institute of Tropical Agriculture, Ibadan

P A SANCHEZ
North Carolina State University, Raleigh

R W CUMMINGS, JR
USAID, Bureau for Science & Technology, Washington

Effect of land clearing on soil properties of an Ultisol and subsequent crop production in Yurimaguas, Peru*

J C ALEGRE D K CASSEL DALE BANDY & P A SANCHEZ

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1 INTRODUCTION

The choice of land clearing method to be used in clearing a particular region is an extremely important decision one which will affect both short- and long-term soil productivity In general past research has shown that clearing land in the humid tropics with the use of heavy machinery damages the soil and provides an extremely variable substrate for root growth Typically clearing with heavy machinery is fast but the machinery increases soil bulk density with concomitant reductions in macroporosity infiltration capacity available soil moisture and soil aeration (Lal and Cummings 1978 Seubert *et al* 1977 Sanchez and Salinas 1981 van der Weert and Lenselink 1972 1973) The resulting crop growth on such soils is highly variable (van der Weert and Lenselink, 1973) Attempts to modify or alleviate this compacted soil by deep plowing or subsoil dynamiting have produced conflicting results (McKibben 1971)

Slash and burn clearing on the other hand is a much slower people-oriented process and results in much less damage to the soil than mechanical clearing The influence of burning the dried vegetative matter has been shown to be beneficial (Sanchez and Salinas 1981 Nye and Greenland 1960 Brinkman and De Nascimento 1973) Burning releases plant nutrients and increases the pH of the topsoil Both effects favor improved crop growth

Land clearing research began at Yurimaguas in 1972 when the North Carolina Tropical Soils Research Program began work at this location Research emphasis is placed upon developing economically sound continuous crop production systems for acid infertile soils of the humid tropics During the past ten years three distinct phases of land clearing related research have been investigated This paper presents a brief discussion of the techniques and treatments used in the three studies along with a sampling of the soils and crop response data used to evaluate the various treatments

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2. SOILS AND CLIMATE

The three phases of the land clearing research were located on the Yurimaguas Experiment Station (5°45′ S 76°5 W 184 m above sea level) Mean annual temperature is 26°C with little monthly or daily variation Average annual rainfall is 2250 mm with a dry period in June-July-August when the average monthly precipitation is about 100 mm The three phases of the study were conducted on the Yurimaguas soil series a fine loamy siliceous isohyperthermic typic paleudult This soil occurs on level to gently sloping land

3 PHASE I

Detailed experimental procedures and results for this phase have been reported by Seubert *et al* (1977) Land clearing was performed on a 2 ha tract covered by a 17-year old secondary evergreen forest The split-split-split plot design consisted of two clearing systems (slash and burn vs mechanical) as the main plots, six cropping systems as subplots and seven fertility levels as sub-subplots Each 280 m^2 subplot was replicated four times

For the slash and burn treatment felled trees and underbrush were dried three weeks before burning The remaining tree trunks were manually removed Mechanical clearing was accomplished with a D-6C Caterpillar tractor with a conventional straight blade All vegetation including stumps were removed while attempting to minimize the removal of top soil although some top soil was removed from the plots while pushing off trees and stumps

Cumulative infiltration for a 2½ hr period for the slash and burn method was 12 times greater than the 2 cm that infiltrated the bulldozer cleared land This reduction in infiltration rate which was measured one month after clearing still remained at the end of one year Soil fertility tests revealed that the soil for the slash and burn treatment had significantly more exchangeable bases and higher organic carbon and total N contents and significantly less exchangeable acidity and percent aluminum compared with the bulldozed soil The plant nutrients in the ash were a valuable input into the cropping system

Crop yields during the two-year period following clearing are summarized in Table 1 when N P K and lime were added at rates of 50 172 and 40 kg/ha and 4 T/ha respectively Rice (*Oryza sativa*) maize (*Zea mays*) soybeans (*Glycine max*) and guinea grass (*Panicum maximum*) produced yields on the bulldozed plots which were less than or equal to 80 percent of the yields on slash and burn cleared land For unfertilized plots crop yields were reduced to about 33 percent of the yields for the slash and burn plots Based upon the limited yield responses attained when adequate fertilizer and lime were added we felt that these limited yields stemmed from poor soil physical conditions resulting from compaction After two years of continuous cropping crop yields on the bulldozed land became so poor that it was abandoned Guinea grass continued to grow on this land until 1980 when Phase II of our work began It is interesting to note that secondary forest regrowth did not occur on this compacted soil even after it had been abandoned for six years

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Table 1 Summary of the effects of land clearing method on crop yield when Yurimaguas soil received lime and N P and K fertilizer

Crop	Number of harvests	Crop yield		
		Slash and burn	Bulldozer	Bulldozed as percentage of burned
		(T/ha)	(T/ha)	
Rice	3	2 90	2 33	80
Corn	1	3 11	2 36	76
Soybeans	2	2 65	1 80	67
Cassava	2	25 6	24 9	97
Guinea grass	6	32 2	24 2	75
Mean relative yield				78

Source After Seubert *et al* (1977)

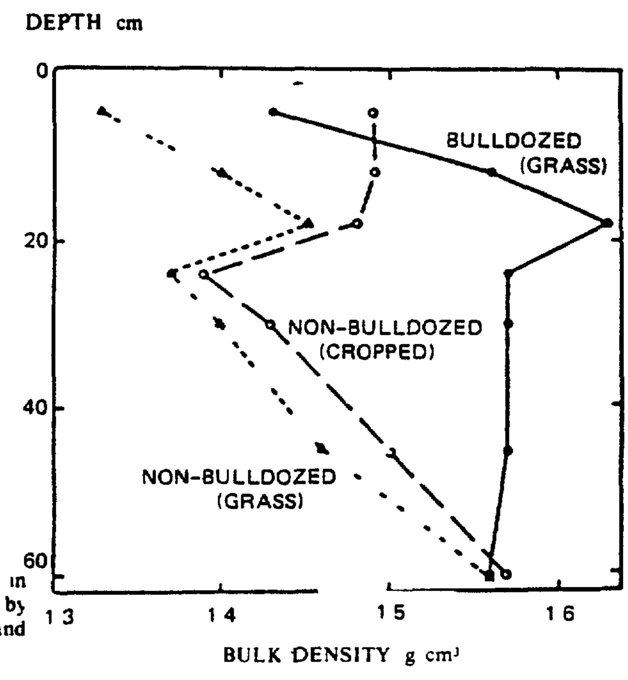

Figure 1 Soil bulk density measured in 1979 versus depth for land cleared by bulldozer and for land cleared by slash and burn in 1972

4 PHASE II

In 1980 an experiment was initiated to reclaim the land which was cleared by bulldozer in 1972 and abandoned in 1974 (Phase I) Prior to initiating this reclamation experiment an examination of selected soil physical properties in 1979 showed that compacted soil still remained in the plots cleared by bulldozer in 1972 The measured bulk density profile is shown in Figure 1 Bulk density near the soil surface (0-5 cm) exceeded 1 4 g/cm³ and reached a maximum at a depth of 18 cm Bulk density between the 20 and 60 cm depth was relatively constant being 1 57 g/cm³ Bulk density of the soil cleared by slash and burn in 1972 and which was continuously cropped to row crops during the past eight years is also shown in Figure 1 Except for the upper 10 cm of soil the bulk density of the continuously cropped, non-bulldozed soil was as much as 0 2 g/cm³ less than the bulldozed treatment. Finally, the bulk density profile for Yurimaguas soil cleared by slash and burn in 1972 and continuously cropped to guinea grass since that time was very similar to the bulk density profile of the cropped soil except in the upper 18 cm where a dense fibrous root mat existed These data confirmed the premise that the soil compaction problem created by bulldozer clearing still persisted seven years after the land was cleared The decision was made to investigate alternative soil management practices to reclaim and properly manage this land for continuous crop production

This reclamation study was designed to reclaim the compacted land and included the eight treatments listed in Table 2 At the beginning of the study guinea grass which was growing on all plots was cut, dried in place and burned, thus allowing all eight treatments to benefit from the nurtients added by the ash Treatment 1 received no tillage and was planted with a planting stick whereas treatment 2 was tilled with a 14 hp rototiller and planted with a Planet Jr A large 65 hp tractor was used to rototill the soil for treatment 3 and to chiselplow and rototill for treatment 4 The chisel plow shanks spaced at 30 cm intervals, extended 35 cm below the soil surface and physically disrupted the compacted soil to this depth The intent with treatment 5 was to minimize surfaee soil compaction induced by the workers during hand weeding This treatment although good in concept, is not feasible unless the workers are under constant supervision It is awkward for the workers to weed between rows while squatting between adjacent rows Treatment 7 was a simulated subsoiling operation because a subsoiler for the 65 hp tractor was not yet available at the time the study began Subsoiling was simulated prior to planting by loosening the soil to the 35 cm depth at the field positions where the rows would be planted later Dry plant material at the approximate rate of 2 T/ha was brought in from outside the plot boundaries to serve as mulch for treatment 8

Table 2 Treatments imposed in the 1980 land reclamation study

1	Control no till cut grass and burn plant with stick
2	Control till cut and burn rototill (14 hp) and plant with stick
3	Rototill cut and burn rototill (14 hp) and plant with Planet Jr
4	Chisel plow cut and burn chisel plow (35 cm) rototill (65 hp tractor) plant with Planet Jr
5	Controlled traffic cut and burn rototill (14 hp) and plant with Planet Jr Assignment of pathways for foot traffic inside the plot
6	Bedding cut and burn rototill (14 hp) and plant with stick
7	Simulated subsoiling cut and burn rototill (14 hp) and plant with Planet Jr
8	Mulching cut and burn rototill (14 hp) and plant with Planet Jr Mulch was applied when seedlings were 10-25 cm high

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Table 3 Grain yield for the first three crops in the reclamation study expressed as a percent of the highest treatment yield

Treatment	Rice	Soybeans	Corn
Control no till	93	22	33
Control till	100	82	84
Tilled	96	77	70
Chisel plow	89	99	100
Controlled traffic	98	66	56
Bedding	70	36	72
Simulated subsoiling	96	100	91
Mulch	73	96	83

A completely randomized block design with four replications was used The cropping sequence was rice-soybeans-corn-soybeans-corn-rice The first planting of rice (cv IR 4-2) was February 2 1980 Prior to planting all plots received lime at the rate of 1 T/ha and were fertilized at rates of 80 44, 66, and 12 kg/ha for N, P, K and Mg respectively Plant spacing for rice was 20 cm × 20 cm when planted with the planting stick for treatments 2 to 8 rice was planted with a Planet Jr in a continuous row with rows being 20 cm apart The rice crop was hand weeded twice The second crop soybeans (cv Jupiter) was planted on June 30 and harvested on October 15, 1980 Nitrogen P, K and Mg were applied at rates of 20, 44 66 and 24 kg/ha prior to planting, and the seed was inoculated with Rhizobium (Nitragin) Soybean seed spacing was 40 cm × 5 cm when stick planted, for treatments 2 to 8, soybeans were planted with a Planet Jr in a continuous row with 40 cm between rows The soybean crop was hand weeded once The first corn (cv Amarillo Planta Baja) crop was seeded on November 7 1980 and harvested on February 16, 1981 Nitrogen P K Mg and S fertilizer rates were 100 44 66 12 and 20 kg/ha liming rate was 0 5 T/ha Seed spacing for all plots was 80 cm × 20 cm The final rice crop was planted November 26, 1981, and harvested March 31, 1982

Table 3 shows relative grain yield for the first rice soybean and corn crops Yields are expressed as a percent of the maximum treatment yield Yields of rice grain for the bedding and mulch treatments were appreciably lower than yields for the remaining 6 treatments The density of corn plants in the bedding treatment was lower than the other treatments because the rows on the beds were spaced a little further apart thus allowing only 5 rows compared to 6 rows per plot for the other treatments The mulch treatment had competition resulting from grass that germinated from some grass seed which was introduced during the mulching process

Bulk density within the 0 to 15 cm depth initially and prior to rice harvest and mechanical impedance prior to rice harvest are shown in Table 4 Bulk density values for all treatments were lower before rice harvest than values measured before the study began All tillage treatments reduced mechanical impedance compared to treatment 1 the no-till control

Conclusions derived from the Phase II study for which only a limited amount of data have been presented are that all seven tillage treatments improved the soil physical conditions of the initially compacted soil i e mechanical impedance and

Table 4 Bulk density in the 0 to 15 cm depth initially and prior to rice harvest and mechanical impedance prior to rice harvest expressed as percent of the maximum Yurimaguas Peru 1980

Treatment	Bulk density		Mechanical impedance before rice harvest
	Initial g/cm³	Before harvest g/cm³	%
Control no till	1 55	1 42	100
Control, till	1 55	1 33	79
Tilled	1 55	1 37	72
Chisel plow	1 55	1 35	32
Controlled traffic	1 55	1 33	51
Bedding	1 55	1 23	31
Simulated subsoiling	1 55	1 34	45
Mulch	1 55	1 30	47

bulk density were reduced in the upper 15 cm of soil Except for the first rice crop, the chiselplowed and simulated subsoiled treatments, i e those treatments which disturbed the soil deeper had the highest yields The Phase II study can be summarized by noting that for this severely compacted Yurimaguas soil, some tillage is good, and deeper tillage is even better It is emphasized that the deep tillage procedures used in this experiment merely broke up the compacted soil but did not invert or mix soil from below the 25 cm depth with the surface soil

5 PHASE III

In 1980 shortly after plans for the land reclamation study described in Phase II were formulated, it became obvious that a second land clearing study at the Yurimaguas site was needed The Phase I study had provided useful information about the effects of bulldozer clearing on crop performance, but, except for several measurements of infiltration rate and bulk density, little effort had been made to quantitatively assess the changes in soil physical properties as a function of time By mid-1980 early results from the Phase II land reclamation study indicated that the poor physical properties resulting from bulldozer clearing could be overcome at least partially, by using appropriate tillage practices, especially deep tillage Moreover we felt that the soil and crop management practices, especially tillage or the lack of tillage practices, following clearing might be just as important or possibly even more important then the actual land clearing method itself The decision was made to investigate several systems—each system would involve a combination of a specific land clearing method and a specific soil tillage (or management) method following clearing The remainder of this paper discusses the methodology of the Phase III study The specific objectives of the study were (1) to determine the rates of change of selected soil physical properties resulting from several land clearing-continuous cultivation management systems and (2) to determine crop performance for the various systems Few results will be presented as the research is still in progress and results have not been appropriately summarized

Table 5 Selected soil chemical properties on August 22 1980 prior to land clearing Yurimaguas

Depth	pH	Acidity	Ca^{++} plus Mg^{++}	Avail P	Al saturation
cm		me/100 cm^3	me/100 cm^3	PPM	%
0-15	4 29	3 76	0 57	5 9	85
15-30	4 24	4 52	0 91	3 6	82
30-45	4 30	4 41	0 88	2 2	83

A 2 5 ha site was selected for the study The land which was covered with twenty-year old secondary evergreen forest was less than 200 m away from the location of the Phase I study A forest mensuration survey indicated 232 m^3 wood per ha for trees with diameters $\geqslant$ 3 2 cm The soil was the same except that a small portion of the land in the present study had a 4 percent slope Table 5 shows selected chemical properties of the soil prior to clearing In addition selected soil physical and chemical properties (discussed later) were quantified prior to clearing

The experimental design was a split plot replicated three times The intent to replicate treatments four times was negated by limited availability of contiguous land having the same age of secondary forest The six main plot treatments were land clearing-soil tillage combinations and are defined in Table 6 The slash and burn treatment was located near the center of a block in order to prevent soil compaction during the process of mechanically clearing the other five treatments The field diagram for Block I is shown in Figure 2 The two plots cleared by 'bulldozer with straight blade' were located side by side, as were the three plots cleared by 'bulldozer with shear blade The main treatments minimized the use of large tractors for land preparation following clearing because no large tractors are available in the area One treatment that we wanted to impose was that of chaining, i e , the pulling down of trees by a chain dragged through the forest by two bulldozers Unfortunately we were

Table 6 Land clearing - soil tillage treatments used in the Phase III study Yurimaguas Peru

Treatment no	Description
1	Slash and burn with tree trunk removal by hand plant with stick
2	D-6 bulldozer with straight blade trees immediately windrowed plant with Planet Jr
3	D-6 bulldozer with straight blade trees immediately windrowed land chisel plowed rotovated with 65 hp tractor plant with Planet Jr
4	D-6 bulldozer with shear blade vegetation dried on land burned then logs removed by bulldozer disk with bulldozer plant with Planet Jr
5	D-6 bulldozer clearing with shear blade rotovate land with 65 hp tractor plant with Planet Jr
6	D-6 bulldozer with shear blade disk with bulldozer 14 hp rotovator plant with Planet Jr

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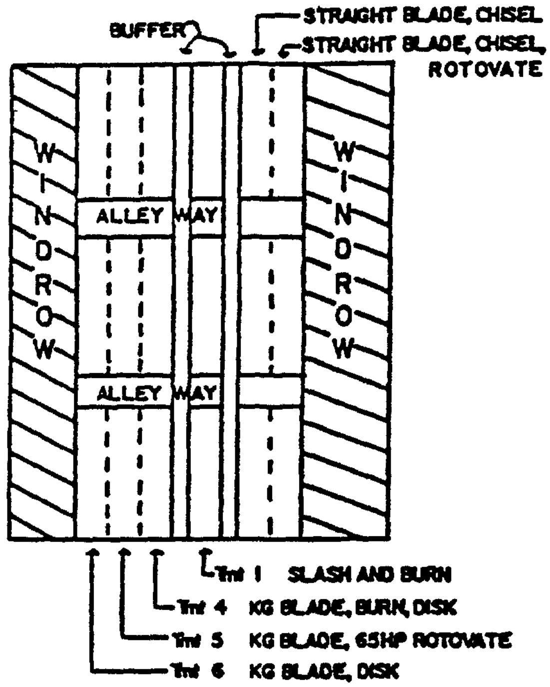

Figure 2 Schematic of block 3 in the land clearing study

unable to locate a chain in sufficient time to transport it to the experimental site The disking operation imposed in treatments 4 and 6 was performed by the same bulldozer that was used for clearing The disking operation cut up the larger tree roots that remained in the soil and incorporated trash left on the soil surface One potential disadvantage of disking is soil compaction Moreover disking too deeply mixes finer textured, B horizon material with the surface soil which may lead to soil crusting problems

Subplot treatments were various combinations of fertility and soil management practices The three subtreatments were (1) flat planted, no fertilizer or lime added (2) flat planted fertilizer and lime added based on soil test data, and (3) soil bedded or ridged at 1 1 m spacing, fertilizer and lime applied at the same rate as in subtreatment (2) Subplot size was 26 m × 6 5 m The cropping sequence was rice-soybeans-corn-rice-corn The first rice crop was planted on November 28 1980

Table 7 shows the soil physical and chemical properties that are being intensively monitored at various times throughout the study Detailed procedures for measurement of these soil properties are not presented here

Changes in two of the soil physical properties listed above as influenced by clearing method are shown in Table 8 Land clearing resulted in an increase in bulk density in the 0 to 15 cm depth for all treatments including slash and burn Increases in Db induced by clearing method were greatest in the following order straight blade > shear blade > slash and burn Bulk density increased by only 0 1 g/cm^3 in the 15 to 25 cm depth for both types of mechanical clearing The before-clearing infiltration rate of 64

Table 7 Soil physical and chemical properties monitored during the land clearing study Yurimaguas Peru

	Before clearing	Immediately after clearing	Later
Physical			
Bulk density	×	×	×
Particle size analysis	×	×	×
In situ field capacity	×	×	×
Soil water characteristic	×	×	×
Pore size distribution	×	×	×
Mechanical impedance	×	×	×
Infiltration rate	×	×	×
Aggregate stability	×	×	×
1500-KPa percentage	×	×	×
Chemical			
Organic matter content	×		×
Effective CEC	×		×
Exchangeable cations	×	×	×
pH	×	×	×
Available P	×	×	×
Inorganic N	×	×	×

cm/ hr was reduced to values 8 and 14 percent of this initial rate for the straight blade and shear blade respectively The soil cleared by slash and burn maintained a high infiltration rate of 51 cm/ hr

Grain yields for rice the first crop planted on the cleared land are given in Table 9 As expected rice yields for the non-fertilized plots were greater for treatments 1 and 4 because these treatments benefited from nutrients released by burning the vegetation No ash was present on the other four treatments because the vegetation was physically removed from the plot area during the clearing operations Fertilizer and lime applied to both the flat planted and bedded subplots increased grain yield for all treatments Without the addition decreased rice yields compared with the slash and burn treatment These results for the first rice crop are similar to those for Phase I study and to previous results of other investigators

Table 8 Bulk density and infiltration rate before and immediately after land clearing

	Clearing method	Bulk density 0-15 cm g/cm³	Bulk density 15-25 cm g/cm³	Infiltration rate cm/hr
Before clearing		1 16	1 39	64
After clearing	Straight blade	1 42	1 49	5 1
	Shear blade	1 31	1 50	10
	Slash and burn	1 27	1 37	51

Table 9 Rice grain yields as affected by land clearing-soil tillage method

Treatment	No fertilizer	With fertilizer	Bedded with fertilizer	X
1	3 10	3 56	3 98	3 55
2	0 91	2 75	3 38	2 35
3	1 14	2 84	2 85	2 28
4	2 39	3 06	3 68	3 04
5	1 27	3 02	3 20	2 49
6	0 91	2 58	2 74	2 07
X	1 62	2 98	3 30	

LSD = 0 43 Treatment
0 26 Subplots
0 65 Treatment × subplots

6 CONCLUSIONS

As noted earlier the data for the Phase III study have been only partially analyzed Hence, conclusions resulting from this land clearing study cannot be made at this time Additional data for evaluating the changes in soil properties are still being collected It appears at this time however that the shear blade has an advantage over the straight blade from the standpoint of inflicting less compaction damage to the soil and thus resulting in higher yields

Some general observations that can be made at this time are

1 Detrimental effects of land clearing with a bulldozer with straight blade last at least six years
2 All land clearing methods alter soil physical properties
3 Reclamation of bulldozed cleared Yurimaguas soil was successful through the use of subsoiling and chisel plowing
4 Traditional slash and burn clearing causes the least damage to soil physical properties and improves soil chemical properties by providing ash

SUMMARY

Land clearing research and related studies have been conducted for a period spanning ten years in the low jungle of the Amazon at Yurimaguas Peru Three distinct research phases have been conducted at this site Phase I began in 1972 ended in 1974 and was designed to compare the effects of mechanical bulldozer clearing and slash and burn clearing on soil properties and crop production Phase II began in early 1980 when a study was initiated to reclaim land that was severely compacted by bulldozer clearing in 1972 Phase III began late in 1980 with the design and initiation of a second more comprehensive land clearing experiment

Results of Phase I indicated that land clearing using a D-6C bulldozer with a straight blade compacted the soil and drastically reduced the infiltration rate Crop yields were reduced significantly The soil that was compacted in Phase I was successfully reclaimed in the Phase II study in 1980-1981 The use of any tillage practice which

loosened the upper 15 cm of soil increased crop yield, however the two deep tillage treatments - subsoiling and chiselplowing - produced the greatest corn and soybean yields

Results of the Phase III study have not been completely analyzed Both methods of bulldozer clearing i e clearing with a 'straight blade' and with a 'shear blade resulted in some soil compaction A cursory examination of the results suggests that shear blade bulldozer clearing is preferred over that of the straight blade

REFERENCES

Brinkman W L F and J C DeNascimento (1973) The effect of slash and burn agriculture on plant nutrients in the tertiary region of Central Amazonia *Turrialba* 23 284-290

Lal R and D J Cummings (1979) Clearing a tropical forest I Effects on soil and micro-climate *Field Crops Research* 2 91-107

McKibben E G (1971) Introduction *Compaction of Agricultural Soils* ASAE Monograph pp 3-6

Nye P H and P J Greenland (1960) The soil under shifting cultivation *Commonw Bur Soils Tech Commun* 51 155 pp

Sanchez P A and J G Salinas (1981) Low-input technology for managing Oxisols and Ultisols in Tropical America *Advances in Agronomy* 34 279-406

Seubert C E P A Sanchez and C Valverde (1977) Effects of land clearing methods on soil properties of an Ultisol and crop performance in the Amazon jungle of Peru *Trop Agric* (Trinidad) 54 307-321

van der Weert R and K J Lenselink (1972) The influence of mechanical clearing of forest on some physical and chemical soil properties *Surin Landb* 20 2-14

van der Weert R and K J Lenselink (1973) The influence of mechanical clearing of forest on plant growth *Surin Landb* 21(3) 100-111

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