DEFORESTATION AND SOIL PREPARATION BY BURNING

MODIFICATION OF PHYSICOCHEMICAL CHARACTERS OF THE UPPER SOIL HORIZON.

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INTRODUCTION

The density of land surface cleared by guianese farmers appears to be high if one considers the localization of agricultural lots, chiefly situated along new roads which represent an attractive means of access. Clearing is done by removing the undergrowth of the forest, cutting down the big trees, and burning : traditionally, farmers prefer a moderate fire running along the surface rather than a heavy one heating up the soil during a more or less extended spell

The moment choosen for this operation is one of the dry seasons, most often the end of the longest one (October / November). As soon as the soil has been cleared and burned, several food crops are sown or planted amidst the charred remains of the forest. The distribution of those crops conforms with the degree of hydromorphism and with the texture of the soils present on the field : one finds maize, cassava, yam on the higher parts and dasheen, plantains, bananas and vegetables on the lower ones. In a certain sense this represents an empirical practice parallelling our notions of soil chains or soil sequences.

The trends toward settling and land-ownership and the correlated wish to improve yields of land and labour led us to consider the evolution of soil fertility under traditional guianese cultivation. Though we dispose of numerous data of this kind for other regions of the world, it nevertheless seems useful to specify for French Guiana in particular, how physico-chemical characters in the superficial soil-layer are modified when passing from the natural equilibrium of forest-soils into the new one realized by traditional agricultural methods. Indeed, if one intends to have shifting cultivation supplanted by some form of permanent agriculture, methods of clearing condition future yields as well as response to chemical fertilizers and so directly affect fertility and soil conservation.

CHARACTERISTICS OF STUDIED SPECIMENS.-

Out of 34 specimens studied, 19 came from undisturbed forest soil and 15 from cleared plots, one to three months after clearing.

As it is meaningless to compare mean values from specimens collected on heterogeneous plots, particularly after burning, we especially studied significant modifications of characteristic relations between different elements conditioning soil fertility.

Climate.-

French Guiana has an equatorial rain climate with two dry seasons, a short one in March and a longer one from August to November. Yearly precipitation is of about 70 inches (2374 mm.).

Insolation is highest in September / October, when farmers clear of preference ; maximum evaporation occurs at the same time.

(1) We greatly thank our collegue Mr. OLDEMAN, botanist at the Cayenne Center, for the English translation.

The following table resumes some climatologic data from the Saint Laurent meteorological station (1956 - 1965) :

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Precipitation mm	216	184	174	218	322	327	233	164	76	79	162	219	2374
Insolation hours	156	181	196	214	168	163	226	253	253	263	223	181	2477
Evaporation Piche mm	41.1	57.8	69.6	59.8	45.9	39.7	49.5	60.9	71.9	75.	59.4	51.5	682.1

Specimens were taken from September (first clearings) to December.

It should be stressed that during this period the bared soil undergoes strong insolation and maximum evaporation.

Soil microclimate.-

LEVEQUE (1963), citing METEOROLOGIE NATIONALE, gives some fragmentary data, of which we note the maximum temperature at a de of about 3" (10 cm.) at 2.00 P.M.:

- under forest vegetation : 24°C with negligible variations ;
- under grass vegetation : 32°C with a maximum of 45°C } minima of 25° C to 26° C.
- bare soil : 35°C with a maximum of 50°C }

Measuring the increase of temperature under fire was unfeasible with the means at our disposal. NYE and GREENLAND (1960) note that 100° C at a depth of 5 cm. and 60° C at 10 cm. may be reached, but these measures are very localized.

This means that the soil is affected superficially and that the increase of temperature has a direct effect on microbial life and physicochemical soil characters.

The soils.-

The soils studied are located on hills ; they are ferralitic, scantily saturated (less than 1 meq. of exchangeable bases in the B-horizon), moderately deep and feebly leached, with a very thin layer of litter and a horizon of humic impregnation covering the upper 3 to 5 inches (10 to 15 cm.)

Their texture is rather well-balanced, either of the sandy clay to clayish sand type (on granites) or of the clay to clayish sand type (on migmatites). pH is markedly acid (4,5 to 5,5).

Vegetation cover.-

The natural climax formation is the Tropical Rain Forest.

ANALYTIC DATA

Analyzed elements.-

- mechanical analysis by granulometry (Robinson pipette) ; dispersion by sodium pyrophosphate.

- organic matter : carbon by the WALKLEY-BLACK method, nitrogen by the KJELDAHL-method, humic matter extracted with sodium pyrophosphate 0,1 N. Separation of humic acids and fulvic acids by raw sulphuric acid - titration by oxidation of dry matter with potassium bichromate.

- exchangeable bases : extraction with normal and neutral ammonium acetate. Titration of different elements by photometry and colorimetry. (Mg).

- exchange capacity : modified PARKER's method ; percolation with normal and neutral ammonium acetate, washing with alcohol and exhaustion with potassium chlorate. Distillation and titration of ammonia.

- pH : with a pH-meter.

- structural instability index : method of S. HENIN - determination of the ratio of stable aggregates with and without preceding treatments with alcohol and benzene. Determination of fine elements and coarse sand in the same conditions.

Results of analyses.-

++ Organic matter.

The horizon in question does show no significant differences in organic matter contents before and after burning. There are more observations of this phenomenon : e.g. RIQUIER (ex NYE and GREENLAND, 1960), who notes - Madagascar - a marked decrease of organic matter contents in very superficial specimens only, and nothing but tiny differences at a depth of 4 inches (12 cm.)

One should not forget that all forest litter disappears by burning. This does not appear from our specimens, covering the A1-horizon only. Of course, these organic matter reserves are not available any more in soils already under cultivation.

For the whole of our specimens, the well-known and classic relation between fine elements (0 - 20 μ) and organic matter contents holds true :

§§§ organic matter C°/oo = 0.67 (0,20 μ)% + 28.76 P<0,02 §§§

Soils richer in fine elements also are richer in organic matter: burning does not change this connection.

++ Total humus (HT) - figure 2.

After clearing and burning, there is a significant increase of total humus contents : we may speak of a trend toward humification of the organic fractions. We found :

== under forest vegetation :

$$HT\ (C^{\circ}/oo) = 0.163\ MO\ (C^{\circ}/oo) + 0.26 \quad \text{mean } HT = 6.66 \quad r = 0.750$$

== after clearing and burning :

$$HT\ (C^{\circ}/oo) = 0.147\ MO\ (C^{\circ}/oo) + 2.067 \quad \text{mean } HT = 9.04 \quad r = 0.946$$

The difference between the two is significant. Besides, in the humus itself, rates of humic and fulvic acids increase in about the same proportions. It may seem that humic acids then contain a larger polymeric fraction, but we are not as yet able to prove this to be significant (figure 3).

++ Nitrogen and the C/N ratio.

Nitrogen contents in cleared soils are slightly raised. This shows in a small decline of the C / N ratio after burning : 14 9 instead of 15.3 in forest soils.

++ Absorbing complex.

The value of this complex results from numerous factors affecting the argilo-humic complex.

:: Organic matter (MO) and cation exchange capacity (C.E.C.) - figure 4.

A comparison of values shows that in forest soils :

== $CEC\ (me) = 0.241\ MO\ (C^{\circ}/oo) - 2.03 \quad r = 0.805 \quad P < 0.01$

and that after agricultural preparation :

== $CEC\ (me) = 0.068\ MO\ (C^{\circ}/oo) + 3.318 \quad r = 0.546 \quad P < 0.05$

The differences between those two values are highly significant. Cation exchange capacity increases with organic matter contents, but to a much lesser degree if we consider organic matter after clearing and burning. Its level then is lower than before these treatments.

:: Clay % and fine silt - 0 to 20 μ - (A+Lf), and cation exchange capacity (CEC) figure 5.

We find that in forest soils :

== $CEC\ (me) = 0.287\ (A+Lf)\ \% + 2.147 \quad r = 0.747$

and that after clearing and burning :

== $CEC\ (me) = 0.230\ (A+Lf)\ \% + 0.384 \quad r = 0.835$

This means that cation exchange capacity is systematically lower in soils after burning.

Considering cation exchange capacity as a simultaneous function of two variables we find that, in forest soils :

$$CEC\ (me) = 1.72\ MO\ (C\ \%) + 0.178\ (A + Lf)\ \% - 2.86$$

and that, after clearing and burning :

$$CEC\ (me) = 0.358\ MO\ (C\ \%) + 0.203\ (A + Lf)\ \% - 0,585.$$

The coefficients are highly significant : organic matter plays a very important part in cation exchange of forest soils, but its share is very much reduced after clearing and burning.

The evolution of relations between cation exchange capacity and the argilo-humic complex in soils under shifting cultivation is brought about by agricultural practice and climatic influences on the bared soil. These factors occasion a strong decrease of cation exchange possibilities by their influence upon organic matter.

This conclusion has been reached by many authors considering soil evolution under cultivation (e.g. BOCQUIER, 1959). However, it appears here, that under guianese conditions the phenomenon is very prompt and occurs immediately after clearing and burning.

++ Exchangeable elements (figure 6)

Heterogeneous distribution of elements in the ashes is the essential difficulty hampering exact appraisal of changes in the upper horizon after burning.

We note a comparatively important increase in Ca-, Mg-, K- and Na- content of the soil, especially accentuated for Ca and Mg. On the average, we can say that Ca, Mg and K pass from a distribution of respectively 39 %, 34 % and 27 % in forest soils to 52 %, 38 % and 10 % after clearing and burning. The Ca / Mg ratio changes from 0,4 - 3.7 in forest soils to 0.6 - 2.3 in cleared ones.

A quick comparison of the next results, for the poorer soils:

milliequivalents :	Ca	Mg	K	Na	S	CE	Saturation %
forest soils :	0.15	0.10	0.12	0.07	0.44	3.8	11.6
burned soils :	0.79	0.41	0.11	0.06	1.37	5.4	25.4

and for the richer ones :

milliequivalents :	Ca	Mg	K	Na	S	CE	Saturation %
forest soils :	0.53	0.37	0.21	0.12	1.23	12.2	10.1
burned soils :	3.90	3.02	0.38	0.18	7.48	9.80	76.3

gives the mean trends of chemical fertility under traditional guianese cultivation :

Variations	in forest soils	in burned soils	
Ca	0.11 - 0.73	0.79 - 3.90	milliequivalents
Mg	0.10 - 0.40	0.41 - 4.10	
K	0.11 - 0.21	0.11 - 0.46	
Na	0.03 - 0.20	0.05 - 0.18	

Calcium and magnesium appear to be elements which are supplied to and fixed in the soil. Potash and sodium are much less fixed and probably leached out by the first rains. pH varies from 4.1 - 5.1 in forest soils to 4.3 - 6.1 in burned ones.

++ Structural stability.

The upper horizon shows a markedly granular structure after clearing and burning. In fact, we found a distinct increase of stable aggregates after these practices :

	% aggregates(alcohol)	aggregates (benzene)	water
forest soil:	82.3	73.5	77.5
burned soil:	85.08	75.85	79.95

For aggregates without coarse sand these values are the following ones:

forest soil:	25.80	17.02	20.97
burned soil:	35.36	26.12	30.29

++ Phosphorus

We noted a slight increase of total phosphorus contents : from 0.46 o/oo to 0.59 o/oo.

CONCLUSION.-

Our results show a marked influence of methods of clearing and burning upon the cation exchange capacity of the absorbing complex. Before and after agricultural practices, no difference in organic matter contents of the upper soil layer (1/2 to 4 inches ; 1 to 12 cm.) can be observed ; yet the share of this organic matter in the absorption complex is drastically reduced. This phenomenon is well - know for soils evoluting during several subsequent years of shifting cultivation, but it should be stressed that it occurs immediately after clearing. However the reduction in cation exchange capacity should not be attributed to treatment by fire alone : we know that this treatment does not cover the soil surface entirely and we should also impute this reduction, at least partially, to strong insolation acting abruptly upon the bared soil. The effect is further stressed by the liberation of elements liable to saturate the argilo-humic complex deeper down.

Anyway, after clearing and burning one observes a more pronounced humification, an amelioration of structural stability, and an increase of nutrient content and saturation rate, though this last effect proves very irregular. In itself, the enrichment is not negligible , but it risks to upset the nutritional equilibrium by its balanced nature.

But it is obvious that these momentaneous improvements are ephemeral and limited to a short cultivation cycle (BERGER,1964) Afterwards, the soil, abandoned to climatic action, undergoes a physicochemical degradation accompanied by erosion.

If we consider substitution of some form of permanent agriculture to shifting cultivation it will be necessary to improve the soil in order to obtain an optimal physicochemical balance. During the first phase of clearing, we should steer clear of the cited evolution of organic matter and that of the absorbing complex. This can be done in different ways, e.g. by a rapid establishment of cover crops and subsequent application of manure or compost, by introduction and rotation of gramineous cover crops, the effects of which are near-equivalent to soil improvement by natural secondary vegetation, or finally by a form of exploitation combining agriculture and cattle-breeding (cf. JURION and HENRY, 1967).

Regeneration of and enrichment by organic matter do seem indispensable in order to raise the absorption level of the argillo-humic complex, thus improving the response to the application of fertilizers.

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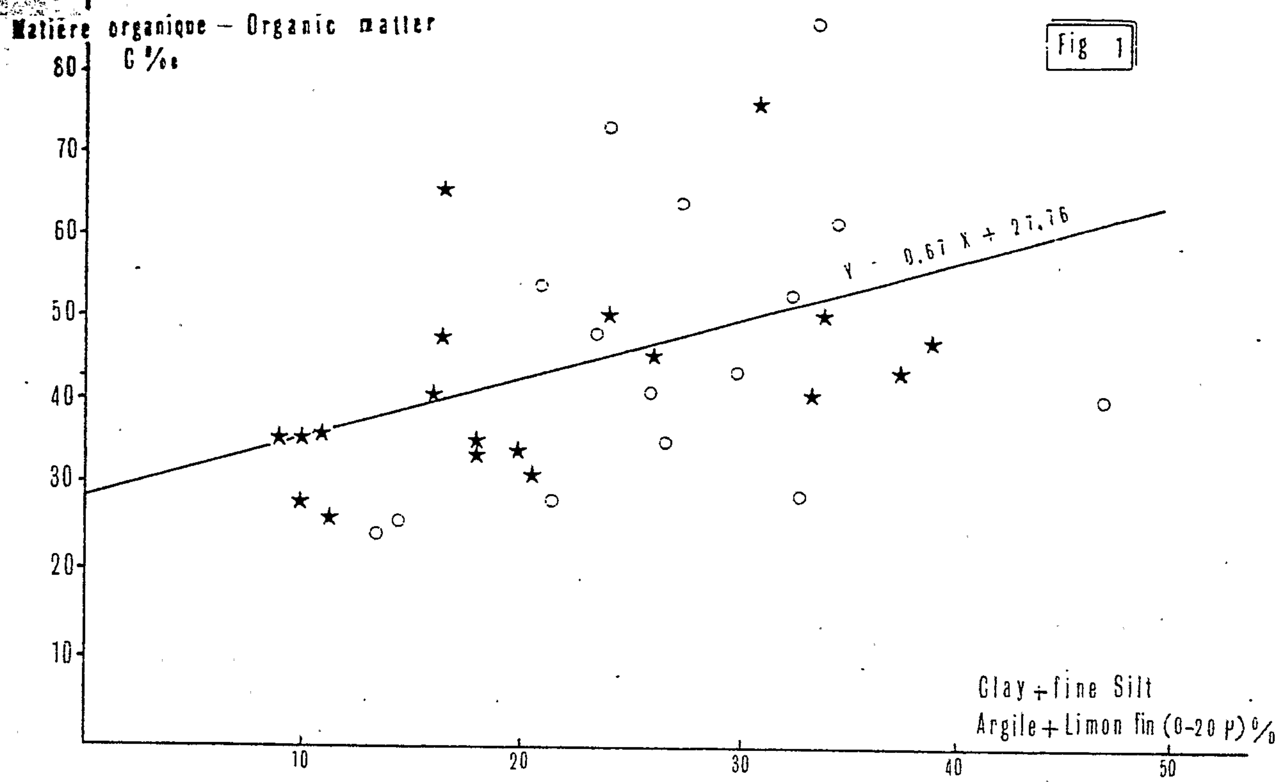
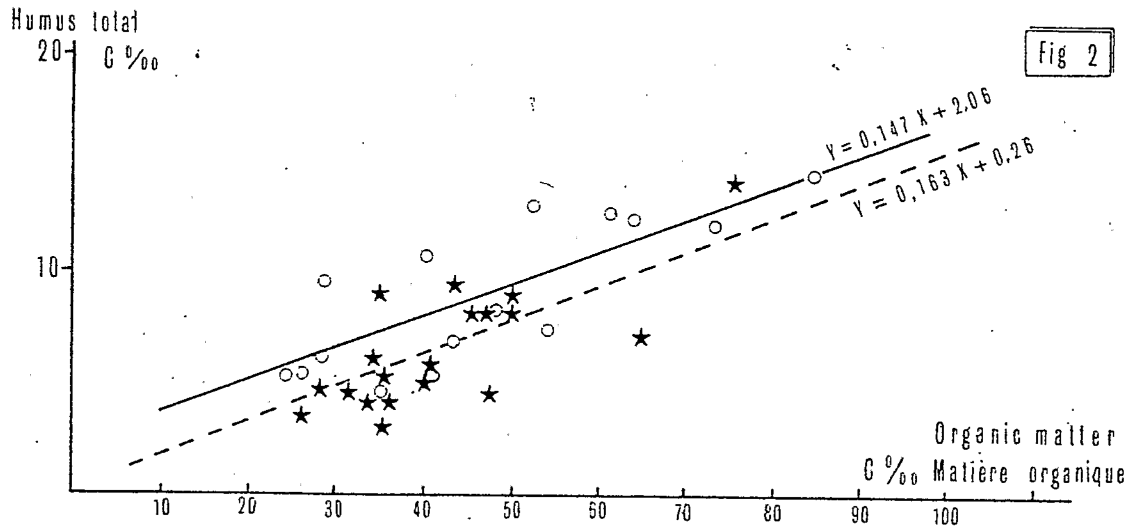
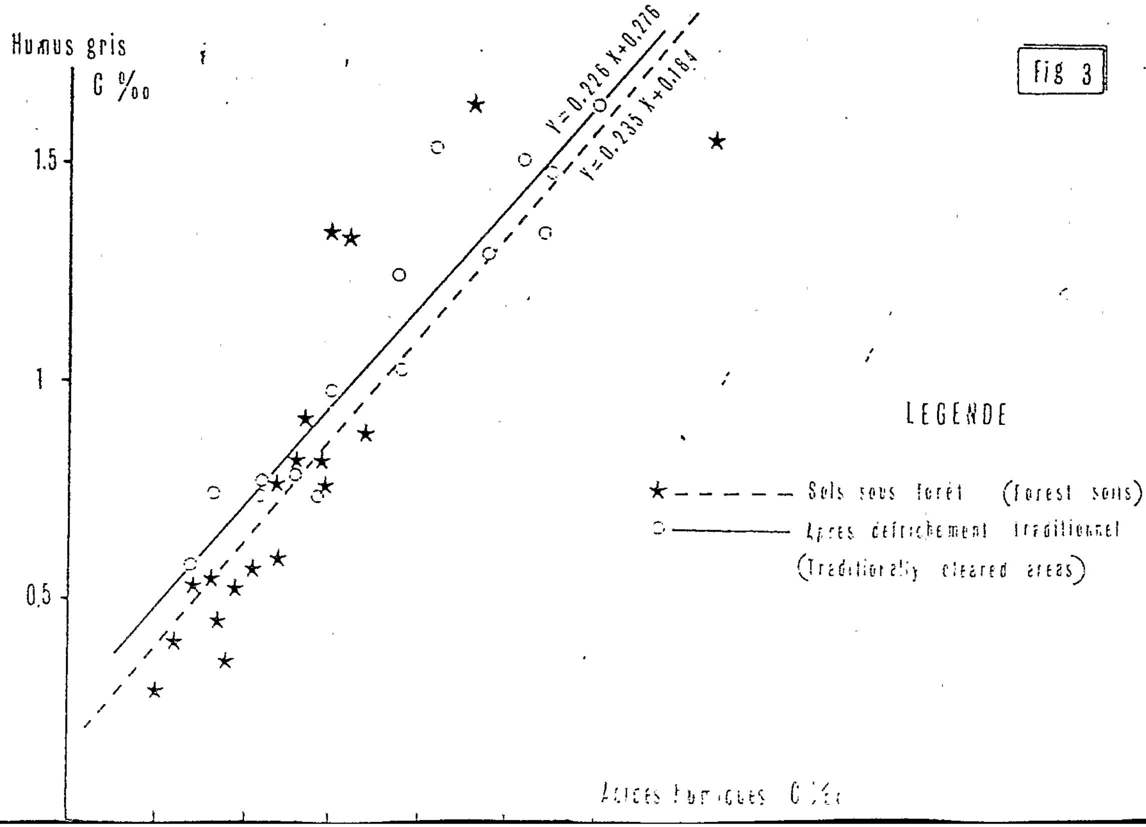

Matière organique – Organic matter
C ‰
Fig 1
Y = 0,67 X + 27,76
Clay + fine Silt
Argile + Limon fin (0-20 μ) %


Humus total
C ‰
Fig 2
Y = 0,147 X + 2,06
Y = 0,163 X + 0,26
Organic matter
C ‰ Matière organique


Humus gris
C ‰
Fig 3
Y=0,226 X+0,276
Y=0,235 X+0,184
LEGENDE
Sols sous forêt (Forest soils)
Après défrichement traditionnel
(Traditionally cleared areas)

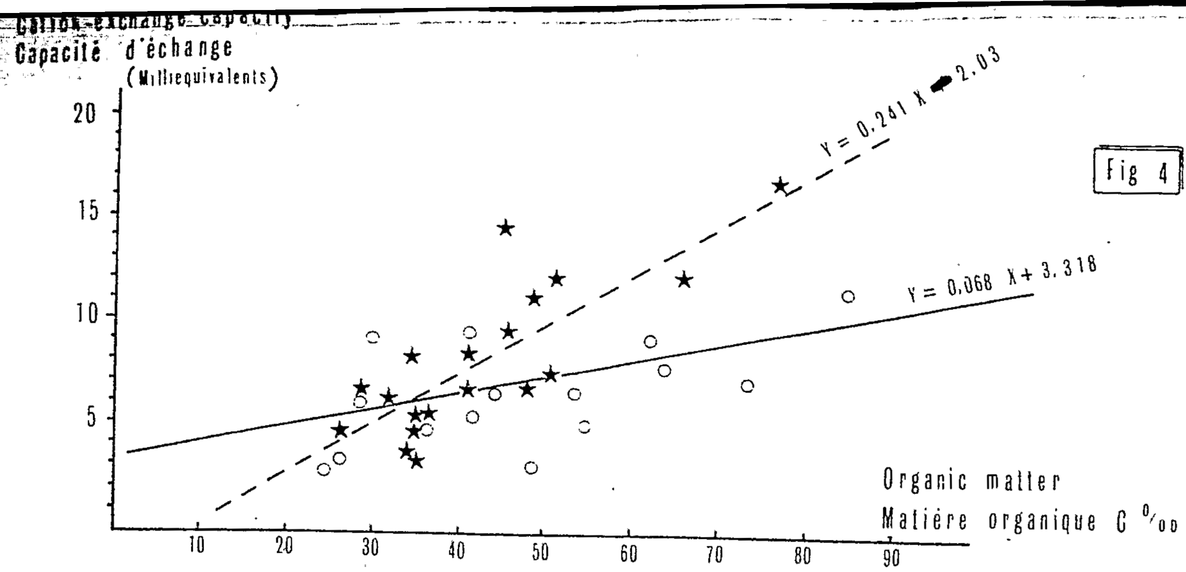


Fig 4

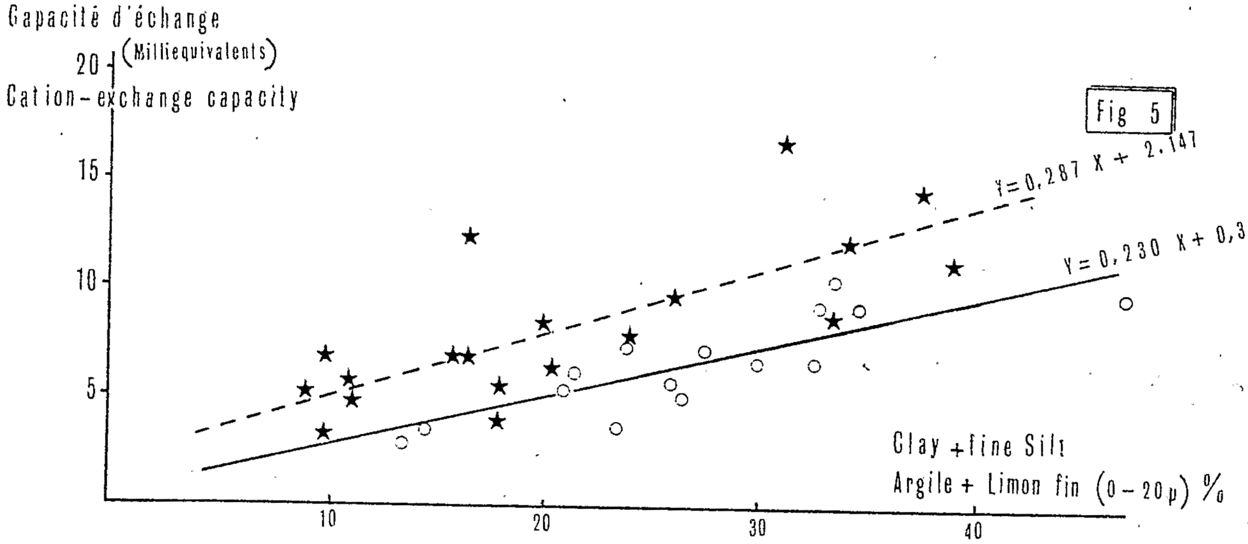
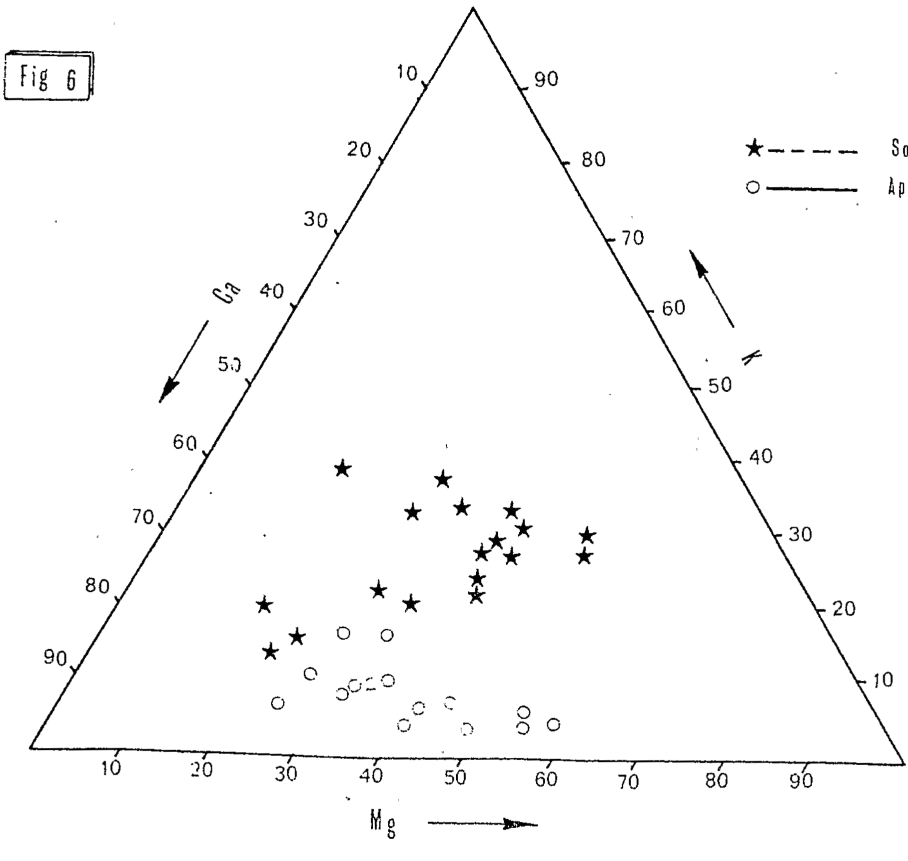


Fig 5

Ca. Mg. K – % De Ca+Mg+K meq

Fig 6



LEGENDE

★ – – – – Sols sous forêt (Forest soils)

○ ——— Après defrichement traditionnel (Traditionally cleaed areas)

Sommaire

DEFORESTATION ET PREPARATION DU SOL PAR BRULIS
MODIFICATIONS DES CARACTERES PHYSICO-CHIMIQUES DE
L'HORIZON SUPERIEUR DU SOL

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Dans le système traditionnel de culture itinérante en Guyane Française, le sol défriché par nettoyage de la forêt et brûlis subit dès cette opération d'importants changements. A côté d'une amélioration de la stabilité structurale, d'une humification plus élevée, et d'un apport hétérogène d'éléments minéraux après le défrichement, il faut noter la modification radicale de la capacité d'échange du complexe argilo-humique, avec une très forte baisse des possibilités d'échange de la matière organique. Les éléments échangeables apportés subsistent avec dominance de Ca et Mg.

Si l'on envisage de passer à une forme de culture permanente, le mode de défrichement traditionnel sur lequel on doit s'appuyer conditionne le devenir de la plantation et la réponse aux fertilisants qui pourront être apportés. Dans ce cas la régénération et l'apport de matière organique semblent impérativement nécessaires.

Summary

CLEARING and BURNING as SOIL PREPARATION,
MODIFICATIONS OF PHYSIC AND CHEMIC CHARACTERS OF THE UPPER SOIL
HORIZONS.

Traditional shifting cultivation systems of French Guiana prepare the soil by clearing and burning the forest, subjecting it to important changes subsequent to this operation.

Besides an increase of structural stability and humification as well as a heterogenous addition of nutrients, one notices the drastic change in exchange capacity of the organic clay complex. This change is partially due to an important decrease of organic exchange capacity. Added nutrients remain in the soil, but Ca and Mg are the most persistent ones.

The traditional forms of agriculture are fundamental to any transition to permanent agriculture, and condition the future of plantations and their response to fertilizers. In such cases, soil regeneration and enrichment by addition of organic matter seem to be absolutely necessary.
