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DYNAMICS OF ORGANIC MATTER UNDER SAVANNA GRASS IN FRENCH GUYANA

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INTRODUCTION

The Old Coastal plain forms in French Guyana a narrow belt of about 1,500 sq. km., parallel to the coast, between swamps and mangrove on the coast in the north, and precambrian shield in the south. It is a landscape of savannas, traversed by humid forest galleries, formed on a clay fine sands deposit of old coastal shores (pleistocene).

Two kinds of soils dominate in these savannas: podzols et sols podzoliques (french classification) - spodosols (USDA) sols ferralitiques fortement désaturés lessivés hydromorphes (USDA plinthic or ochric Tropudult) (11).

The climate of the Coastal Plain presents several particular characteristics; namely the extreme variability of rainfall, the existence of an ecological dry season less than 30 mm of monthly rainfall, these characteristics producing a substancial dry season with a high hydric deficit.

The meteorological station of Sinnamary shows, following 12 years (1955 - 1966) 0 to 5 months with a monthly rainfall inferior to 30 mm, 1 to 4 months from 30 to 100 mm, and 5 to 9 months up to 100 mm. Data from Meteorological Station of Kourou (1956 - 1965 2,421 mm.) are used in this study.

From the calculation of ETP according to Penman formula, (albedo 0.25) we can define for the period 1969 - 1970, certain important climatic events: starting from the moment when the increasing rainfall equals half the ETP, (R = 0.5ETP) (6)* the humid period begins; this one goes on up to the moment when ETP becomes superior to the rainfall. Starting from this point, the post humid season is established and then the dry season. The prehumid season goes from the point when the rainfall equals 0.5 ETP, to the point when rainfall = ETP.

We can then distinguish dynamic phases:

$-B_2\ C_2$	post humid period	drying up	Rainfall	$<$ ETP
$-C_2\ A_1$	dry period	desiccation		
$-A_1\ C_1$	rainy season			
$-A_2\ B_1$	prehumid period	moistening	rainfall	$<$ ETP
$-B_1\ B_2$	humid period	saturation	rainfall	$>$ ETP

Figure 1 shows the differents periods during summer 1969, which represents the analysis of differents climatic elements during ten days period.

MATERIAL AND METHODS

The analysis concern A_1 horizon soil samples from ferrallitic soils under savannas, taken at regular periods, at the end of last decade of each month. They are distributed in differents sites (Matiti, Corossony, Bordelaise, Combi) at the rate of 3 samples for each sampling site. Soil moisture is determined at the sampling moment.

On the air dryed samples (9) we determine carbon in accordance with Walkley Black method, nitrogen by modified Kjeldahl method; humic acids are extracted by Na pyrophosphate 0.1 M, fulvic acids and humic acids are separated with sulphuric acid; dosage is done on dry matter by oxydation with potassium bichromate; separation of moving humic acids and non moving humic acids is done using electrophoresis (potential difference 7 volts/cm.)

* FRANQUIN quotes HUTCHINSON and alter: bare soil evaporation in the beginning of dry season 0.33 Eo; SLATYER (1966) during drying up season with showers = 0.30 Eo; observing that Eo is usually calculated with albedo 0.05, FRANQUIN estimates that 1/3 Eo is near 0.5 ETP calculated with albedo 0.25. TURC (1961, 1953) shows in the conditions of this field work that bare soil restores its reserves when monthly rainfall goes up to 0.5 ETP.

Structural stability is measured according to Henin (7) (determination of stable agregates, without pretreatment, with benzene and alcohol pretreatments).

The release of carbonic gas is measured by incubation (7 days 30°C) in a closed recipient, of re-humected samples (3).

Characteristics of soil samples at sampling sites (end of December 1969)
vegetation: grass savanna with schyzachirium and trachypogon

Sampling site	Soil moisture	Carbon %	Nitrogen %	C/N ratio	pH	Clay %	Silt %	Fine sand %	Coarse sand %
Bordelaise	6.6	15.2	.90	16.9	4.9	8.5	11.0	75.7	1.0
Matiti	14.3	12.1	.73	16.6	5.2	5.7	14.0	77.3	.2
Combi	5.0	14.7	.94	15.6	5.1	8.0	7.6	74.3	6.0
Corossony	8.6	11.3	.70	16.1	5.1	6.6	7.0	69.3	14.8

RESULTS*

They are represented on figures 2 and 3.

The soil moisture of upper horizon of the soil appears as connected with difference rainfall-ETP for the dynamic phases of drying up, drying, rehumecting period, the difference being calculated with last decade data, preceeding the sampling moment. (fig. 2b, 2c.)

Months	July 1969	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. 1970	Feb.	March
Soil moisture %	16.52	8.65	3.87	3.15	11.20	8.62	17.51	21.5	21.69
ETP Penman mm.									
1st decade	40.4	45.2	45.0	53.6	47.9	37.8	27.5	38.5	28.1
2nd decade	43.6	44.5	49.6	46.1	49.1	38.7	28.1	40.6	47.1
3rd decade	47.3	52.5	49.7	54.6	38.4	60.9	43.3	25.3	31.3
Total	131.3	142.2	144.3	154.3	135.4	137.4	98.9	104.4	106.5
Rainfall mm									
1st decade	48.0	25.0	22.5	0.0	0.0	42.0	181.5	77.5	616.0
2nd decade	26.0	24.0	0.0	22.0		30.5	79.0	107.0	120.5
3rd decade	43.0	1.5	1.5	0.5	14.0	30.5	52.0	168.5	125.0
Total mm	117.0	50.8	24.0	22.5	15.5	103.0	322.5	353.0	257.5

Organic matter (fig. 3 a.) expressed in Carbon % begins by accusing a light decrease from the start of post humid period; this rate afterwards goes up for the most of the samples to reach the first maximum during the desiccation period, this maximum maintaining its value, or slightly increasing up to tha end of dry season.

* We greatly thank our collagues Mr. J. L. Thiais and G. Laplanoche, Soil Analysis Laboratory in the Cayenne ORSTOM Center for these results.

ANALYTICAL DATA

Months		July 1969	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. 1970	Feb.	March
Soil moisture %		16.52	8.65	3.87	3.15	11.20	8.62	17.51	21.58	21.6
Carbon %		10.84	9.74	12.17	12.64	13.63	13.33	11.52	12.17	12.8
Nitrogen %		.76	.67	.83	.81	.88	.81	.78	.82	.8
C/N ratio		14.2	14.5	14.7	15.6	15.5	16.5	14.8	14.8	16.0
Humic acid C %		1.92	1.85	1.85	1.62	1.67	1.79	1.78	1.65	1.5
Fulvic acid C %		2.57	1.60	1.97	1.77	1.92	1.65	1.93	1.66	1.5
Extraction rate %		41.42	35.82	31.38	26.81	26.33	25.80	22.20	27.19	24.4
Fulvic acid / Humic acid		1.38	0.86	1.08	1.08	1.11	0.92	1.11	1.02	
Mineralization of carbon										
$\frac{C\ (CO_2)}{C\ Total}$	Matiti	3.3	2.6	2.0	1.9	1.7	1.7	1.8	1.8	1.6
	Combi	3.	2.2	1.8	1.6	1.7	1.7	1.8	1.5	2.0
	Bordelaise	2.6	3.1	1.9	1.8	2.0	2.3	2.2	1.9	1.9
Non moving humic acids (% humic acid)		36.20*	48.27	52.92	47.77	47.82	50.80 *	45.92	45.64	44.1
Benzene agregates %				24.31	17.51	17.86	18.76	18.61	16.27	13.9

* significant difference between these values

During the pre-humid period, total amount of organic matter decreases from 13.4 % to 11.4 %. This last value, does not change or increases slightly later (start of humid period) it will reach a second maximum at the end of humid period.

Nitrogen (fig. 3 a): its variations follow that of total carbon, excepted in march (rehumectation, beginning of humid period) where it decreases, while carbon increases or remains constant.

Fulvic acids: are in high quantities when the post humid period starts; their minimum is connected with higher values of carbon (december) and with the beginning of leaching by rainwater at the end of post humid period.

Humic acids (fig. 3 b) non moving humic acids at electrophoresis, increase during post humid period; they decrease when desiccation goes on; a rain falling in the 3rd decade of november, which involves a change in soil moisture from 3 to 11%, seems apparently to have only a slight effect on a non-moving humic acids amount; but it is important to notice that during the following month (december) the slight drying up appearing involves an increasing of the amount of non moving humic acid.

Less than the level of soil moisture existing in the soil, it is the sense of variation of the soil moisture (rehumectation followed by drying up) which appears to act on amount of non moving humic acids. These phenomenon showing a reaction to the environment variations in remarkable.

Therefore, the amount of non moving humic acids is different, as one considers rehumectation period or drying up period, with the same value of soil moisture; during rehumectation period, there is a well marked depolymerisation, but the amount still remains high.

This phenomenon of remanence is remarkable, considering the inertia to environment variations represented by it.

When prehumid and humid periods appear, non moving humic acids decrease: phases of polymerisation or depolymerization can be distinguished, following climatic variations.

Na Pyrophosphate non extractible fraction

The composition of this fraction is complex; for the fraction non extracted by alcalin reagents, Perraud (8) finds one part of humic compound highly polymerized and strongly bound to minerals (humine surévoluée), one part coming from direct insolubilization of vegetal material, after more or less elaborated transformation, and one part of fresh organic matter remaining locked up in mineral matter (humine sequestrée). The maximum of organic matter (13.3 C % o) runs in connection with the maximum of non extracted fraction.

VARIATIONS IN COMPONENTS % OF ORGANIC MATTER WHILE SOIL MOISTURE VARIES

Months	July 1969	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. 1970	Feb.	March
Soil Moisture Variation	16.52	8.65	3.87	3.15	11.20	8.62	17.51	21.58	21.69
Non extrait	58.61 x	64.47	67.83 x	73.24	73.81	74.41 x	67.41 x	72.84	75.49
Non moving Humic Acid	6.29 x	9.19	8.11 x	6.18	5.94	6.75	7.10	6.10	5.42
Moving Humic Acid	11.14	9.92 x	7.32	6.73	6.53	6.56 x	8.41	7.38	6.91
Fulvic acid	23.95 x	16.40	16.70	13.90	13.70	12.28 x	17.07 x	13.66	12.66

x significant differense between these values

Using the elementary scheme of the division of organic matter (Fulvic acids - moving humic acids - non moving humic acids - non extractible fraction) which we are considering in this first approach, as going towards an increasing polymerization, the repartition and the variations of these fractions in % of total carbon, show dynamic phases of organic matter evolution.

The part of different fractions varies according to the season (fig. 4) and considering significant differences, we can situate two main moments in the variation of soil moisture:

In post humid periods a significant decrease of fulvic acids part, a decrease of moving acids part, and when drying up accentuates, a decrease in the non moving humic acid amount appears, then we note the significant increasine of the non extracted fraction "humin". An increase of total carbon (10.8 % to 12.6 % and 13.6 %) is connected to this variation. In prehumid period a significant decrease of Na Pyrophosphate non extracted fraction gives a significant increase of electrophoresis moving humic acids and of fulvics acids. A decrease in carbon amount (13.6 % to 11.5 %) follows this variation. We emphasize the possibility of passage during polymerization or depolymerization phases between the differents fractions forming organic matter.

Carbon mineralization coefficient (fig. 3 c) The relationship between carbon from CO_2 released in 7 days by 100 g. of rehumected soil (24%), and the total amount of carbon in the sample, shows a high coefficient value at the beginning of the post humid period: this fact can explain that in spite of polymerization phase there is a decrease of organic matter at this period.

This coefficient decreases up to the end of post humid period and the renewal of CO_2 release shows a certain delay comparison with the prehumid period.

Structural stability

If we consider agregates amount in the soil we find a maximum of this amount at the moment when the percentage of non moving humic acids is higher, and a minimum when this percentage is minimum (march). The relationship we observed by the past (10) between non moving humic acids and structural instability is here verified at the point of stable agregates after benzene pretreatment.

% agregates (benzene) = 30.08 + 2,579 non moving humic acids
($n = 118$, $P < /0.01$)

DISCUSSION AND CONCLUSION

Starting from the analysis of French Guyana Coastal Plain climate it seems possible to define a certain number of dynamic phases in organic matter evolution; an analysis, of the climate following decades seems to be adequate in order to precise the minimum climatic period which can influence soil evolution in savannas.

We have only considered here the means of monthly samples, but a more detailed study should separate the sites of samplings and not to compare them one another, except considering soil moisture values equals or approximately equal defining dynamic moments; these moments do not obligatory appear at the same moment for the 4 sites. The same occurs to the organic matter level which vary according to the site.

The definition of post humid, dry, prehumid, humid period is an important factor of the knowledge of a soil and its potentialities. Going to the extreme, we could not accept in tropical conditions any data about savanna-like soil sample without soil moisture at the moment of sampling and the position of this value in connection to preceeding or following values during the period.

Although different in carbon amount, in the amplitude and in the date of variations of soil moisture, A_1 horizons studied here tend all towerds an identicel dynamics.

We show here how the organic matter react very rapidly at the variations of environment; the different factors of guyenese climate applied to homogeneous material lead to biological and physico-chemical processes which act rapidly on quantity, quality, and chemical properties of humic compounds. It even seems that besides soil moisture values vary, it is the sense of variation (increase or decrease) rather than the absolute value of the soil moisture which induces the phenomena of polymerization or depolymerization.

Fugacity of polymeric or non polymeric fractions of organic matter is characteristic of A_1 soil horizon subjected to important variation of climatic conditions.

One must consider this fugacity as soon as it is a question of reconstituating stock of organic matter or improving excessive or insufficient soil drainage.

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fig 1

PLAINE COTIERE ANCIENNE DE GUYANE FRANCAISE
EVAPOTRANSPIRATION CALCULEE PENMAN
PRECIPITATIONS. EVAPORATION PICHE

Station de Kourou

OLD COASTAL PLAIN - FRENCH GUYANA
CALCULATED PENMAN EVAPOTRANSPIRATION
RAINFALL - PICHE EVAPORATION

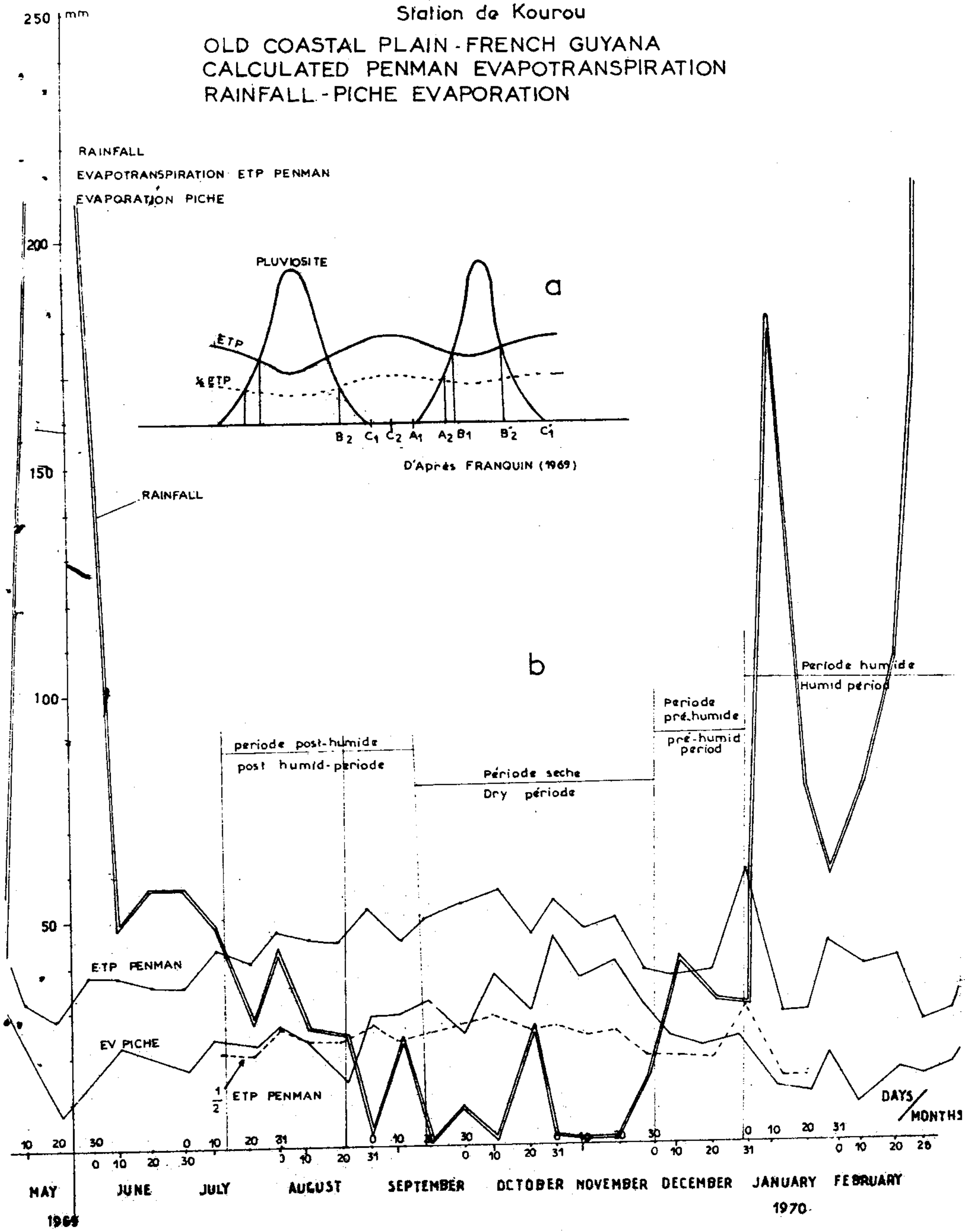


fig 2

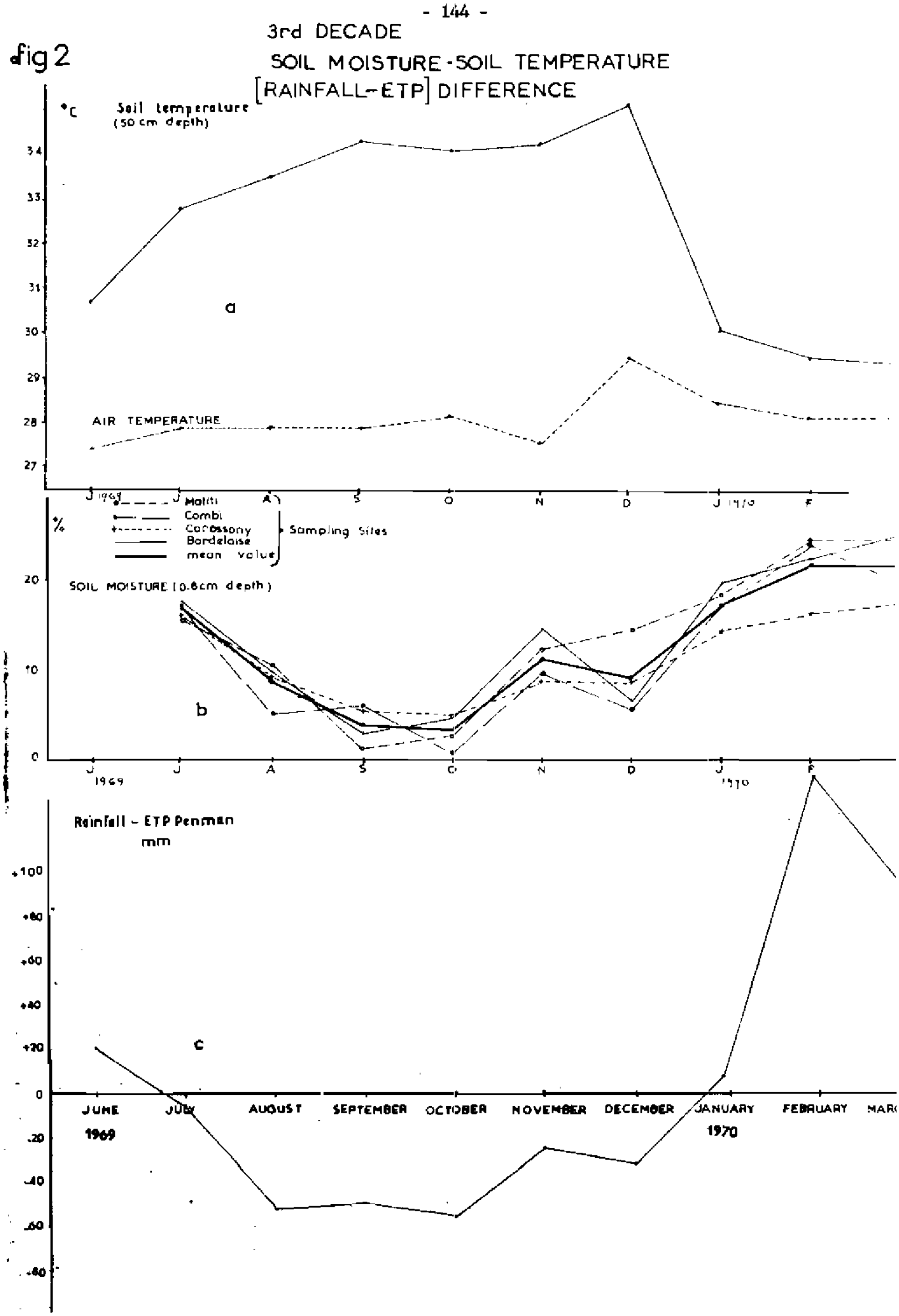

3rd DECADE
SOIL MOISTURE-SOIL TEMPERATURE
[RAINFALL-ETP] DIFFERENCE
°C
Soil temperature
(50 cm depth)
a
AIR TEMPERATURE
J 1969
J
A
S
O
N
D
J 1970
F
%
Matiti
Combi
Carossony
Bordelaise
mean value
Sampling sites
SOIL MOISTURE (0.8cm depth)
b
Rainfall - ETP Penman
mm
c
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
1969
1970

fig 3

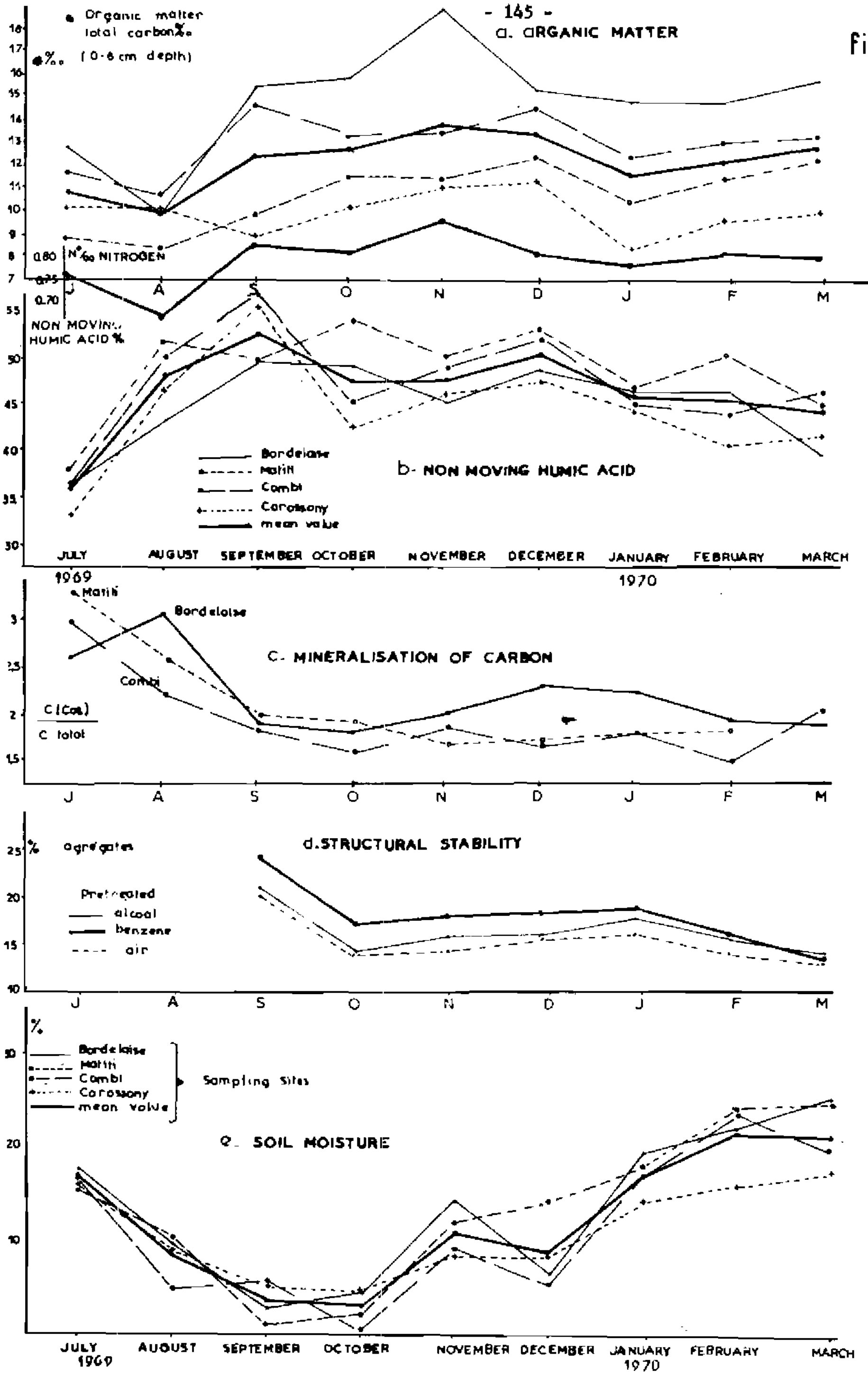
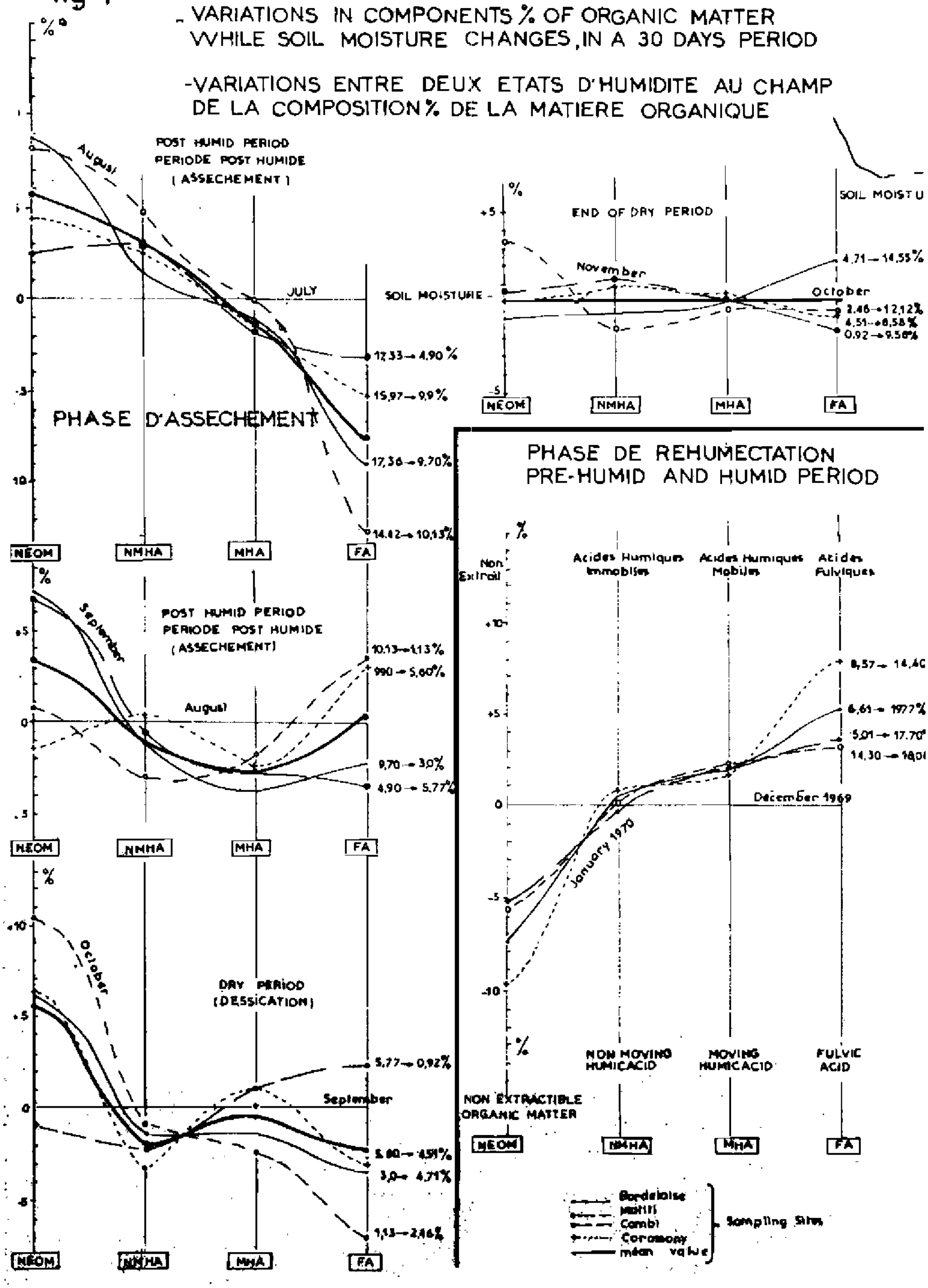

Organic matter
total carbon ‰
%‰ (0-6 cm depth)
a. ORGANIC MATTER
N ‰ NITROGEN
NON MOVING HUMIC ACID %
b- NON MOVING HUMIC ACID
Bordelaise
Matiti
Combi
Carossony
mean value
JULY 1969
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1970
FEBRUARY
MARCH
C- MINERALISATION OF CARBON
C (CO2) / C total
d. STRUCTURAL STABILITY
% agrégates
Pretreated
alcool
benzene
air
Sampling Sites
e. SOIL MOISTURE

fig 4


- VARIATIONS IN COMPONENTS % OF ORGANIC MATTER WHILE SOIL MOISTURE CHANGES, IN A 30 DAYS PERIOD
-VARIATIONS ENTRE DEUX ETATS D'HUMIDITE AU CHAMP DE LA COMPOSITION % DE LA MATIERE ORGANIQUE
POST HUMID PERIOD
PERIODE POST HUMIDE
(ASSECHEMENT)
August
JULY
17,33 → 4,90 %
15,97 → 9,9 %
17,36 → 9,70 %
14,42 → 10,13 %
PHASE D'ASSECHEMENT
NEOM
NMHA
MHA
FA
END OF DRY PERIOD
November
October
SOIL MOISTURE
4,71 → 14,55 %
2,46 → 12,12 %
4,51 → 6,58 %
0,92 → 9,56 %
PHASE DE REHUMECTATION
PRE-HUMID AND HUMID PERIOD
POST HUMID PERIOD
PERIODE POST HUMIDE
(ASSECHEMENT)
September
August
10,13 → 1,13 %
9,90 → 5,60 %
9,70 → 3,0 %
4,90 → 5,77 %
Non Extrait
Acides Humiques Immobiles
Acides Humiques Mobiles
Acides Fulviques
8,57 → 14,40
6,61 → 19,77 %
5,01 → 17,70
14,30 → 18,01
December 1969
January 1970
October
DRY PERIOD
(DESSICATION)
September
5,77 → 0,92 %
5,60 → 4,51 %
3,0 → 4,71 %
1,13 → 2,46 %
NON MOVING HUMIC ACID
MOVING HUMIC ACID
FULVIC ACID
NON EXTRACTIBLE ORGANIC MATTER
Bordelaise
Mohifi
Combi
Coromony
mean value
Sampling Sites