SOIL ORGANIC MATTER AND SOIL FERTILITY IN TROPICAL AND SUB-TROPICAL ENVIRONMENTS

J.F. TURENNE
ORSTOM, Institut Francais de Recherche Scientifique pour le Developpement en Cooperation, 213 Rue La Fayette 75010, Paris, France

Soil fertility depends on numerous factors among which organic matter plays an important role. Organic compounds have a real influence on the cation exchange capacity, on water retention or on the formation and stabilisation of the soil structure (Stevenson, 1986). The nature and configuration of these organic compounds contribute to the improvement or the degradation of the properties of the organo-mineral complex. However, the dynamics of the soil organic matter are governed by a more or less intense biodegradation affecting these different constituents.

In a tropical zone, the transformations in the soil organic pool are intense. Jenkinson and Ayanaba (1977) point out that decomposition of labelled plant material is four times faster in soils of the humid tropics (Nigeria) than in temperate soils (England). Seventy percent of the initial organic pool would disappear within two and a half months in the tropical zone, while it would take one year in the temperate zone. The general pattern of the decomposition curve of the labelled plant material is similar in both zones except for the time scale and this despite very different soil types.

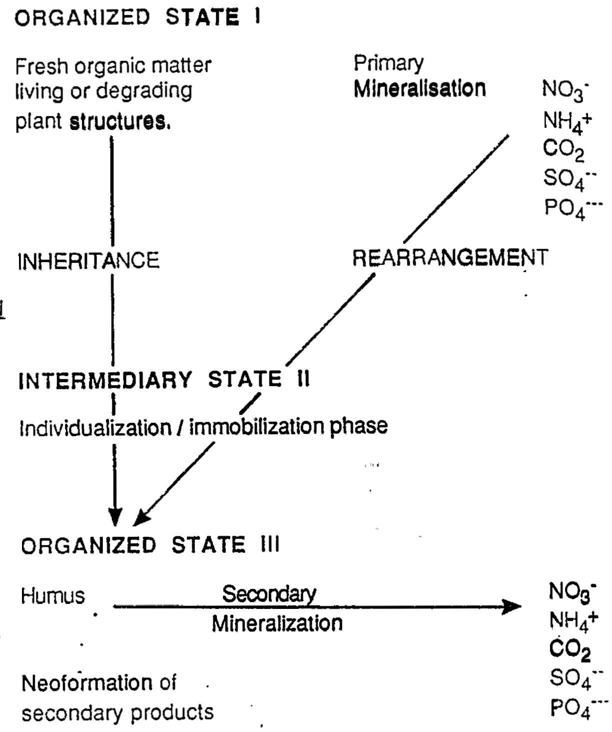
The intensity of the transformations observed particularly in the tropical zone are instrumental in determining the dynamics of fresh organic matter supplied to the soil: the nature, direction and intensity of these transformations lead to variations in the organic pool whose behaviour depend largely on the environmental conditions.

In a balanced system, these dynamics result in a turn-over rate which varies among the fractions of soil organic matter. The aim of this paper is to examine the rapid reactions of the soil organic pool in relation to environmental variations and mainly to the variations in soil humidity. The examples selected reveal the fugacity of the transformations or rearrangements of the organic pool in cultivated soils and the advantage of rational organic fertilisation and cultural practices.

Table 1 States of the soil organic matter

MORPHOLOGICAL ANALYSIS

ELEMENTARY ANALYSIS



PARTICLE SIZE FRACTIONATION

Heavy, light, coarse, fine and hydrosoluble fractions.

By density, flotation

Gel filtration
Chromatography

CHEMICAL FRACTIONATION

- acid pretreatment
- action of chelating substances and alkaline extraction:
  - fulvic acids
  - grey humic acids brown humic acids
  - non extracted or humin (carbon linked to clay, iron or inherited residual)
  - degradation: basic elements or organic polymers
  - acid hydrolysis: forms of nitrogen

Three aspects of the transformations in the organic pool will be discussed briefly in this paper: state of the soil organic pool, maintenance and reconstitution of the organic pool and seasonal variations in the cultivated soils of sub-tropical and tropical regions.

THE STATES OF THE SOIL ORGANIC POOL

Soil organic matter is a heterogeneous mixture of different phases of transformation of the plant material which vary with soil type and depth (Table 1).

An intermediate state of individualisation of the decomposition products and an organised phase of neoformation of secondary products are juxtaposed to an initial organised state (fresh organic matter, living or decaying vegetal structure). Therefore, the decomposition products of the plant material are characterised by disorganised phases and an organised phase: "phase of near chaos and a phase of pre-order or quasi-order" (Scharpenseel, 1987), namely that of humic substances with complex structures formed on the basis of elementary constituents (the "building stones") (Schnitzer, 1972; Stevenson, 1986).

At a given moment, the soil organic pool is therfore a heterogeneous mixture of these complex structures in variable amounts. Fresh products include lignin, cellulose, carbohydrates, proteins and other compounds in lesser amounts. These constituents disappear through biodegradation or solubilisation and they leave more or less transformed residues forming humus. The condensation and polymerisation of residual products lead to synthetic humic acids. Part of the constituents are found directly in humus and their evolution is gradual such as the case of of lignin.

Therefore, two transformation paths are identified:

- an individualisation path of soluble monomeric substances
- a gradual transformation or inherited path

Either path can be selected according to the soil mineralogy or texture. In sandy soils, the inherited path seems to prevail while, in clay soils, the individualised soluble substances are rapidly rendered insoluble. The identification and quantification of the different elements or organic compounds vary with their nature. Morphological observation and elementary analysis of the organic elements such as plant material, particle size fractionation and chemical analysis can trace the physical fragmentation of plant residues, enables analysis of the hydrosoluble fractions (chromatography, gel filtration), and arbitrary fractionation through chemical processes gives information on the groups of compounds isolated by different solubilities or resistances to acid hydrolysis.

The degradative methods give the basic elements of organic polymers whose nature varies to a small extent with environmental conditions.

Table 2 Distribution of organic fractions in a ferrisol evolution under sugar cane crop

		Fraction higher than 2 mm		Fraction ranging from 2 to 0.050		Organo mineral fraction lower than 0.050 mm		Total Soil	
	Month	C (%)	C/N	C (%)	C/N	C (%)	C/N	C (%)	C/N
Control under natural forest		1.56	16.7	1.06	14.4	33.28	9.0	35.9	9.5
Control cultivated over a long period	1	0.52	28.8	1.79	20.5	23.71	9.9	27.40	13.3
	2	1.18	21.9	2.13	15.9	21.86	10.3	26.80	11.5
	3	0.86	21.0	1.94	15.4	24.06	9.4	28.77	11.4
	4	2.45	19.9	1.29	18.8	19.48	11.3	24.97	10.6
Mineral horizon cropped again within 10 years	1	0.41	49.8	0.32	25.4	9.64	10.9	10.53	14.7
	2	0.31	38.1	0.52	24.6	9.65	9.3	10.71	11.8
	3	0.92	47.1	1.41	29.3	10.13	14.5	12.61	15.7
	4	1.20	48.0	1.28	16.7	10.17	14.4	12.86	12.9

Table 3 Distribution of carbon and nitrogen in humic compounds extractable at pH 10 in a ferrisol (Organo-mineral fraction lower than 0.050 mm) (FOM)

Ferrisol		Extracted Organic C			Extracted Organic N			C/N
		mg C/g FOM	%C FOM	FA/HA	mg N/g FOM	%N FOM	FA/HA	
Control under natural forest	Total extract	2.16	5.6		0.36	8.3		6.0
	Fulvic acids	1.94	5.0	7.8	0.33	7.6	10.8	5.9
	Humic acids	0.25	0.6		0.03	0.7		8.3
Control cultivated	Total extract	5.27	16.1		0.76	26.2		6.9
	Fulvic acids	3.86	11.8	2.8	0.48	16.5	1.7	8.0
	Humic acids	1.39	4.3		0.28	9.7		5.0
Mineral horizon cropped again within 10 years	Total extract	0.80	8.2		0.11	12.3		7.3
	Fulvic acids	0.66	6.8	4.7	0.10	11.2	10.1	6.6
	Humic acids	0.14	1.4		0.01	1.1		

RECONSTITUTION, MAINTENANCE OF THE ORGANIC POOL

Reconstitution of the Organic Pool

Land-clearing, cultivation: Following clearing, the decrease of the carbon and nitrogen contents in organic matter can amount to 20% of total carbon over a year. This loss can be considerable in the humid tropical zone ranging from 20% in the dry zone over three years to 50% in the humid forest zone over a year. These losses are very different from those observed in the temperate zone where on long duration plots the relative loss of carbon without organic manure amounts to 30% over 50 years.

The time necessary to reach equilibrium seems to be independent of the environmental conditions: it would take 80 to 100 years in order to restore an Amazonian forest organic pool damaged by burning (Turenne and Rapaire, 1979).

New cropping of deep mineral horizons - example of a ferrisol. Morphological analysis and the use of particle size fractionation (Anderson et al. 1981; Feller, 1985) give information on the influence and effectiveness of the transformation on humification agents. The carbon/nitrogen ratio decreases from the coarsest fractions (>2 mm) to the finest fractions (organo-mineral fractions lower than 0.050 mm).

When a deep mineral horizon is brought to the surface, it leads to a considerable decrease in the ferrisol organic pool. Ten years after new cropping (sugar cane, Martinique), the organic pool hardly amounts to one third of the pool under initial natural vegetation and ranges from 35 to 40% of the pool under old crops in equilibrium (Chevignard, 1984).

The variations observed in the quality of the organic pool concern only coarse fractions: fractions >2mm are the most affected and their carbon/nitrogen ratio is twice as high as for these fractions in the rejuvenated soil. The soil which has been cultivated over a long period shows a higher biological activity which allows it to develop more rapidly (Tables 2,3).

Organo-mineral fractions are stable: this compartment (<0.050 mm) shows a humic fraction which is less humified in the rejuvenated soil. The humic compounds are half as extractable and are characterised by condensation levels which are much lower than in balanced soil (Fig. 1, example 1). Molecular weights are less than 2000 for the fulvic acids of the rejuvenated soil and they range from 4000 to 5000 for the balanced soil. Fulvic acids dominate the extractable fraction of rejuvenated soils. Carbon/nitrogen ratios are always low, and less than those of corresponding undisturbed soil. Humic acids are richer in nitrogen than corresponding fulvic acids, but the fulvic acids/humic acids ratio is twice with respect to carbon, and six times higher with respect to nitrogen of these fractions.

The fraction which is not extracted with alkaline reagents is present in reduced amounts.

The rejuvenated soil exhibits a slow humification, the heterogeniety of the organic

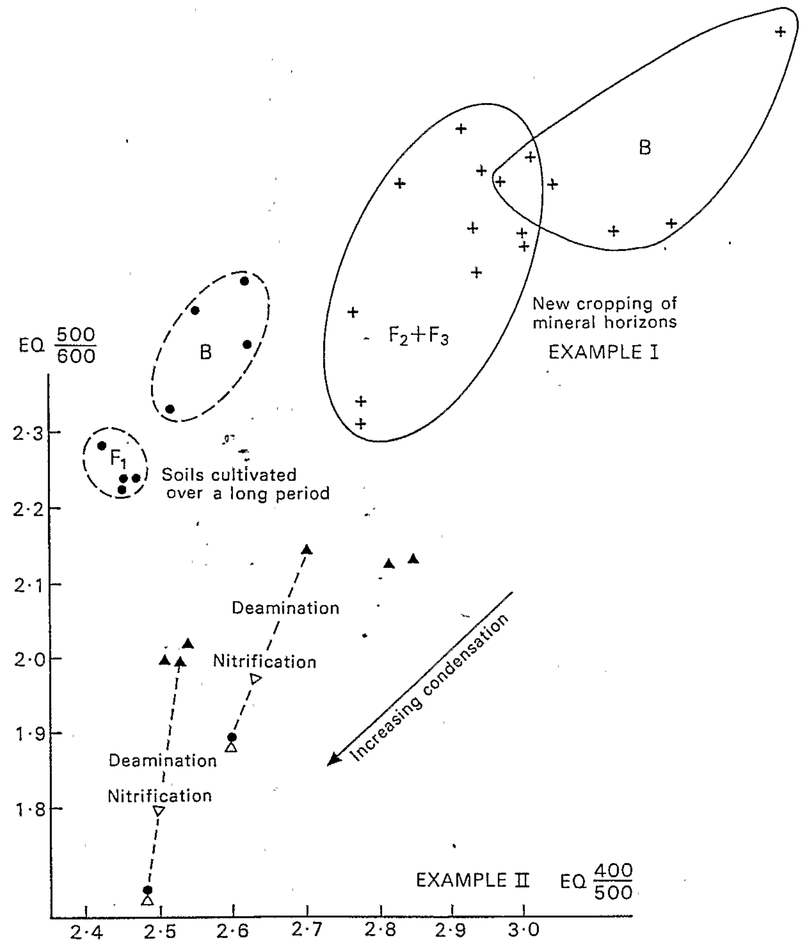


Figure 1 Optical density of humic extracts (alkaline extraction)

matter is more pronounced and the related organic compounds are of small size, thus leading to the incomplete reconstitution of the organic pool.

Under such conditions, Chevignard (1984) points out that the reconstitution of an organic pool based on a mineral horizon would take 25 years to recover 50% of the carbon organic pool. It would take 60 years for the same ratio in the nitrogen pool. The convergent evolution of the organic pool reconstitution occurred with materials which are very different from a mineralogical and physico-chemical point of view. This suggests that the reconstitution of the organic pool is more or less dependent on mineral fabric whereas biological and climatic transformations are more time-dependent.

Table 4 Influence of compost (10 T of M.S. ha^{-1} $year^{-1}$) and nitrogen doses on the yields of Maize Cultivated in the first cycle (March and June) South Gagnoa (Ivory Coast)

Annual regular manuring
Average compost supply: 170 kg N ha^{-1} $year^{-1}$
(Chabalier, in Pichot 1983)

Treatments		Maize yields T. ha^{-1} of grain										
Nitrogen	Compost	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
N-0	Without	4.75	6.42	5.60	4.05	3.20	1.52	1.00	2.64	2.11	1.69	2.09
	With	4.96	6.30	5.70	5.41	4.04	3.20	4.20	5.59	3.43	4.71	5.28
N-40	Without	4.70	6.46	5.20	5.10	3.79	3.07	2.50	3.84	3.78	3.82	4.37
	With	5.37	7.37	6.10	5.14	4.93	4.91	5.70	5.38	4.54	6.18	6.33
N-160	Without	5.03	7.38	5.60	4.22	4.43	4.83	5.20	5.21	5.34	5.88	6.10
	With	4.17	6.92	5.70	5.99	4.77	6.17	6.30	5.46	5.71	5.90	6.69

Maintenance of the Organic Pool

Supply of compost: Table 4 gives the results obtained with a nitrogen/compost experiment which has been conducted since 1971 in the Ivory Coast (Chabalier and Pichot, 1983) as part of an intensive agricultural treatment with two cultural cycles per year and abundant manuring. The change in the maize yields indicates that:

1. The supply of compost has a small influence for the first five years; an increase in yields can be attributed to this supply only after the fifth year;
2. Nitrogenous fertiliser becomes necessary after the fifth year; the results show that a regular supply of organic matter has only a longterm effect.

The compost supply to a sandy soil in Senegal associated with a nitrogeneous fertilisation increases the soil carbon and nitrogen pools. The increase occurs mainly in the fractions ranging from 2 to 0.05 mm. The rainy season during which cropping takes place results in the disappearance of 50% of the initial carbon in the fraction >2 mm with or without compost supply, 40 days after the first rainfall. Eighty percent of the initial carbon in this fraction had disappeared by the end of the rainy season. This phenomenon is accompanied by a decrease in the C/N ratio. The residual fraction seems to be considerably enriched in lignin (Feller et al., 1981).

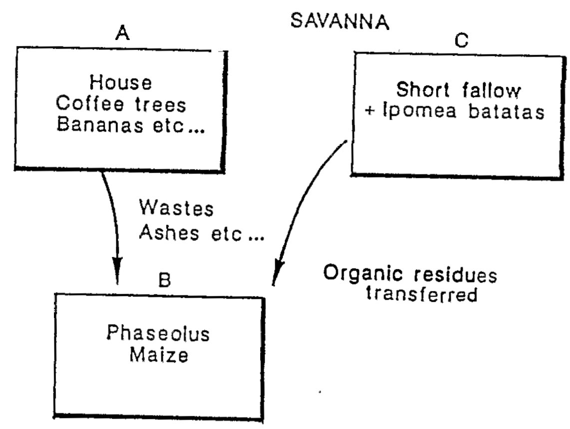
Soil moisture has a significant influence on the disappearance of the plant material fraction >2 mm through more active celluloysis and relative enrichment in nitrogen. The organo-mineral fraction shows a change in the humic compounds which leads to a decrease in the C/N ratio.

Generally, the repeated compost supplies lead to a stabilisation of nitrogen in the soil while a non-improved soil loses 25% of its nitrogen reserves within five years.

Soil fertility depends on the regularity and amount of organic matter supply. Figure 2 shows that in an intensive farming system in Haiti, based on transfer of organic residues from plots A and C to plot B, the level of nitrogen, and the yield, are dependent on the surface of the plot which provides these organic residues. In such a case, the introduction of an alternate cultivation of Desmodium in the B garden between Phaseolus and maize is proposed in order to compensate the deficit.

Cover crops. Experiments with fodder crops (Talineau, 1980) conducted on oxisols show that over five years a graminaceaous crop (*Panicum maximum*) increases the organic pool from 19 mt/ha to 26 t/ha over 0-10 cm depth; a leguminous crop (*Stylosanthes*) leads to an increase ranging from 16 t/ha to 21 t/ha. In non-cultivated plots, the amount of organic matter decreases from 18 t/ha to 13 t/ha over three years.

Brossard in Feller (1985) points out that under grassland or grazed fallows, the organic pool in vertisols ranges from 72 to 80 t of carbon per hectare. This organic pool (0 - 60



SUSTAINING ORGANIC FERTILITY

		B GARDEN		
Maize yield Q_x x ha		14,5	11,6	11,00
Nitrogen N ‰		3,79	2,81	3,03
Area (Square meters)	A	1650	1400	1050
	B	3160	3800	3650
	C	3500	2000	1000

Figure 2 Haitian farming system

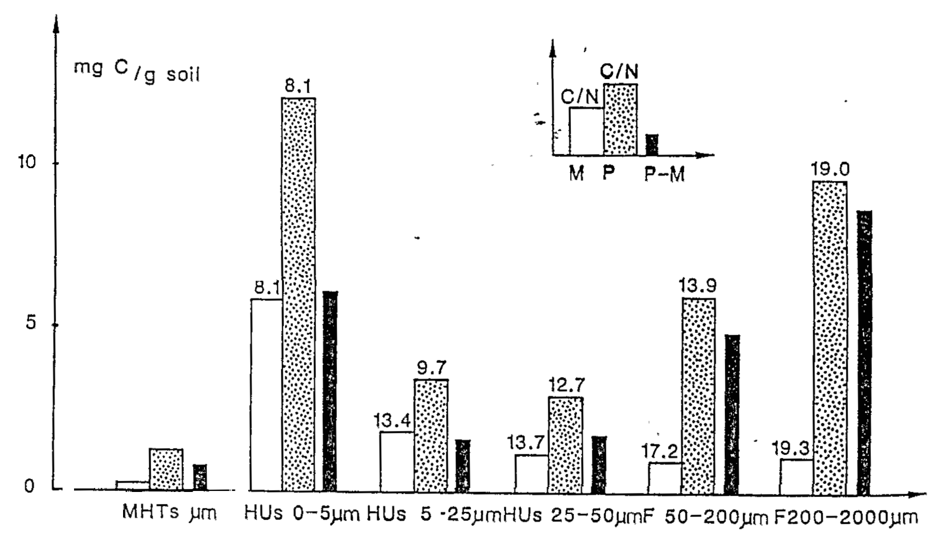


Figure 3 Organic matter particle size fractionation in a vertisol (Martinique)
M = vegetable cultivation P = grassland

cm depth) amounts to 75 t/ha under vegetable crops with rotational grazed fallows but is only 39 t/ha under intensive rotational vegetable crops. Similar variations are observed in an oxisol, the organic pool ranging from 95 to 104 t/ha under fallows and from 75 to 89 t in the case of short duration crops/fallows. Finally, he points out that the installation of grassland doubles the initial organic pool, the fractions concerned being the plant residues >0.025 mm and the colloidal organic compartment linked to the clay fraction <0.005 mm (Fig. 3). The humic fraction extracted by sodium hydroxide is the least affected by increases. Thus the fractions concerned are those which are directly inherited and transferred in the humin forms.

The exchange capacity varies with organic matter level; intensive crop rotations without fallows and not highly fertilised lead to a decrease in the exchange capacity of exchangeable calcium and increases in H^+ and Al^{3+}, thus resulting in a decrease in pH (Table 5).

Tiessen et al (1983), who make use of the abundance of natural 15N as an indicator of organic matter transformation, divide the soil into different particle size fractions: 2-0.050 mm, 0.050-0.005 mm, 0.005-0.002mm, <0.002 mm. They show for cultivated soils and soils under natural meadow in the United States:

- the significance of the compartment ranging from 2 - 0.050 mm as an input compartment;
- the role of the compartment ranging from 0.050 to 0.002 mm as the centre of the organic transformations in the early forming stages of the organo-mineral complex;
- the role of the compartment <0.002 mm in combination with the microbial biomass and young microbial products.

In the case of the ferrisol (Table 6) the use of labelled nitrogen (Urea), shows that 15N is found in the fraction >200 µm and in the organo-mineral fraction <2 µm. The decay of labelled nitrogen plant root residues shows a direct transfer to the 0-0.2 mm fraction (Francois, in Feller, 1985).

Cerri et al (1985) who made use of natural C3 and C4 plant labelling could measure directly and in situ the kinetics of decomposition of an initial organic pool under forest, as well as derived from sugar cane. They show that the 2-0.02 mm fractions derived from the forest pool disappear completely after 50 years. The 2-0.02 mm fraction derived from sugar cane reaches equilibrium in less than 12 years, thus showing a very rapid renewal of this fraction. The increase in pools ranging from 0.2 to 0.050 mm and <0.050 mm shows that renewal takes about 40 years.

Table 5 Ferrisol, levels of organic matter according to different crop rotations (Brossard, 1985)

	C (%)	N (%)	C/N	pH		Cation	Total	Al^{+++}	H^{+}
					KCl	milli equivalents			
Long grazed fallow	2.76	0.22	12.8	5.9	5.7	14.0	6.1	0.1	0.1
Short grazed fallow	2.37	0.21	11.4	6.1	5.8	12.2	6.3	0.1	0.1
Short fallow	2.56	0.21	12.1	6.0	5.3	13.2	7.5	0.1	0.1
Crop rotation with grazed fallow	2.22	0.20	11.2			12.7	6.8	0.1	0.1
Crop rotation	1.98	0.18	11.1	5.3	4.7	12.7	5.8	0.6	0.4

Table 6 Soil organic matter particle size fractionation and nitrogen distribution in a ferrisol
(After 3 months of sugar cane cultivation)
(From Feller and Francois, 1986)

	15N from Urea				15N from labelled roots
	Ferrisol control		Mineral horizon		ferrisol
	C/N	% 15N	C/N	% 15N	% 15N
Roots	95.8	12.89	123	9.21	
Fractions (µm)					
> 2000					47.7
200 - 2000					13.6
> 200	30.6	5.16	48	3.28	
50 - 200	15.1	3.85	18.2	2.96	0.8
25 - 50	12.7	2.13	14.8	1.89	1.2
0 - 25	10.1	13.65	9.5	21.84	1.1
5 - 25	12		14.1		
0 - 5	9.6	11.83	8.8	19.88	
2 - 5					2.3
0.2 - 2					6.2
0 - 0.2					7.9
Plant					12.4
Total		24.79		30	

SEASONAL VARIATIONS IN CULTIVATED SOILS

Nitrification and Variations in the Organic Pool

Nitrification is sensitive to climatic variations: the effect of drying on the increase in soil nitric nitrogen has often been pointed out (Cornforth, 1974) as well as the major influence of soil moisture (Pichot, 1975) especially in tropical countries. This phenomenon concerns directly the different compartments of organic matter and particularly the humic compartments (fulvic and humic acids).

Therefore, a sudden increase in the soil nitric nitrogen can correspond to a rather dry period. Table 7 shows:

- a decrease in the amino-nitrogen fraction, mainly in the soil humic extract;
- an increase in the carbon/nitrogen ratio of humic acids during nitrification;

Table 7 Field moisture, evolution of NO_3-Nunder cultivated soil (Banana plantation) (Annual rainfall 2,000mm; Halloysite brown soil)

	Days					
	0	49	71	85	112	152
Moisture (%)	24.8	24.2	22.06	17.73	27.6	31.02
NO_3-N (mg/100g soil)	3.17	6.67	21.62	22.82	13.3	5.17
C/N Humic acids	8.06	8.69	10.68	10.96	9.37	
Amino acid linked to humic acids (μmol)	14	19.6	13.2	13.8	15.19	

- a decrease in the percentage of amino acids linked to the carbon of humic acids;
- a condensation of humic forms (Figure 1, example II).

These variations are observed over a 20 day period. They reveal that the phenomenon is rapid and that the levels of rearrangement can affect the soil organic pool. In this case, nitrification directly influences the humified compartments, but the other compartments also can be affected. The comparison of seasonal changes in aminated nitrogen content in two types of soil - a vertisol and brown halloysitic soil - according to soil moisture changes confirms well known variations. An increase of α-aminated nitrogen corresponds to re-wetting or the end of the dry season (Fig. 4).

When deamination is observed, corresponding to the rainy season, this phenomenon occurs at the same time for the two types of soils. But only the amplitude of variation differs for the two mineralogical soil types. This is important in order to characterise nitrogen levels in soil. Less than the level itself, the amplitude of seasonal changes in nitrogen level of different organic fractions is also characteristic.

The analysis of mineral nitrogen and of organic nitrogen, related to meteorological changes, account for:

- the reversible processes of organisation and mineralisation of soil nitrogen;
- the differences in amplitude according to the mineralogical soil type or hydric regime.

Structural Stability and Crop Rotations

The polycondensation phenomena of humic compounds are also involved in the development of soil structure. This is due to the abundance of functional groups (hydroxyl, carboxyl, amine), (Harris et al. 1966 in Allison, 1973) or to molecular weight changes (Dell'Agnola and Ferrari, 1971). The bonding between organic polymers and montmorillonite is well demonstrated in the laboratory.

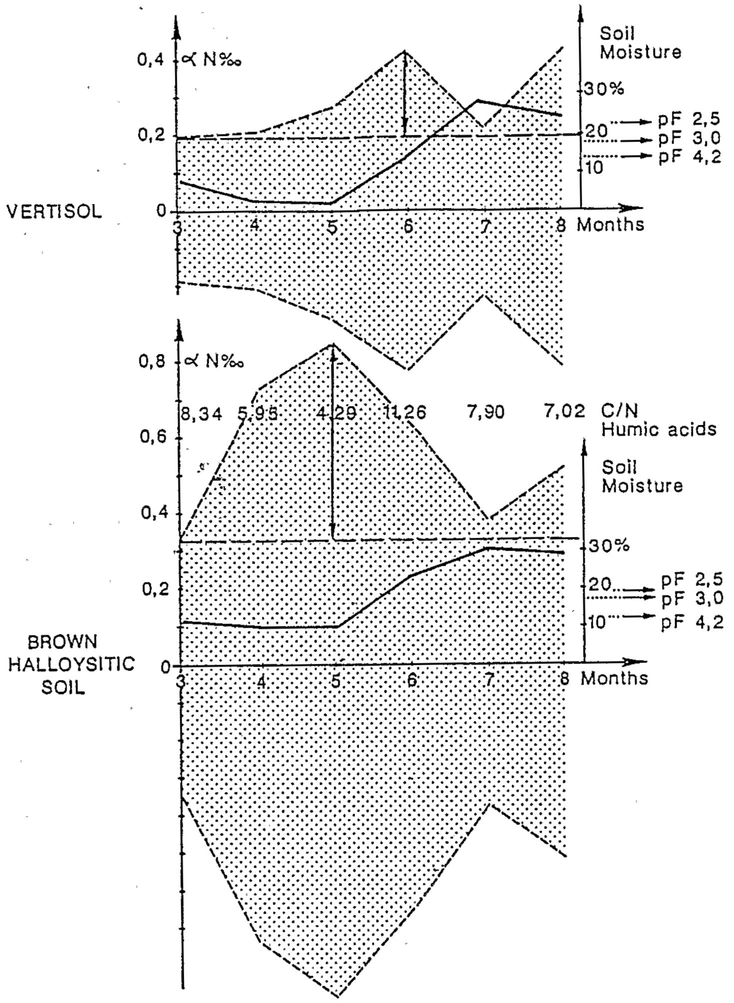


Figure 4 Seasonal changes α - aminated nitrogen in humus fraction

The observations of the evolution of the different humic fractions of an organic pool under vegetable crops intercalated with a sorghum crop on vertisols with 900 mm annual rainfall show from Turenne (1982):

- a relation between the percentage of amino nitrogen extracted from the humic fraction and the percentage of stable aggregates (Fig. 5);
- the increase in the percentage of grey humic acids in the sorghum crop which is accompanied by a decrease in the exchange capacity (Table 8);
- a variability in the stablisation of the structure obtained after the sorghum crop: the irrigation of this crop leads to a more rapid and higher increase in the stability of the

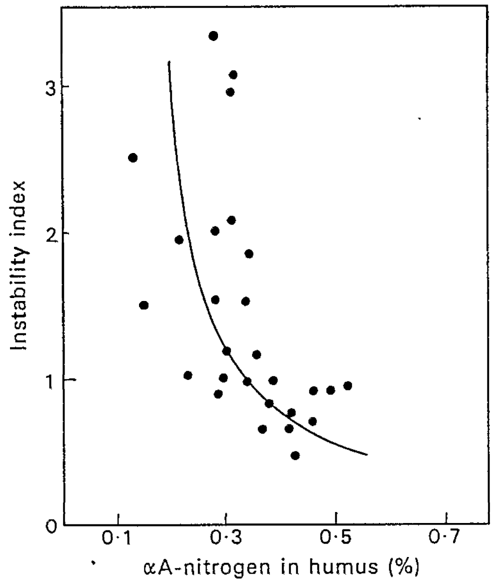


Figure 5 Relationship between instability index (Is) and α – amino humus fraction

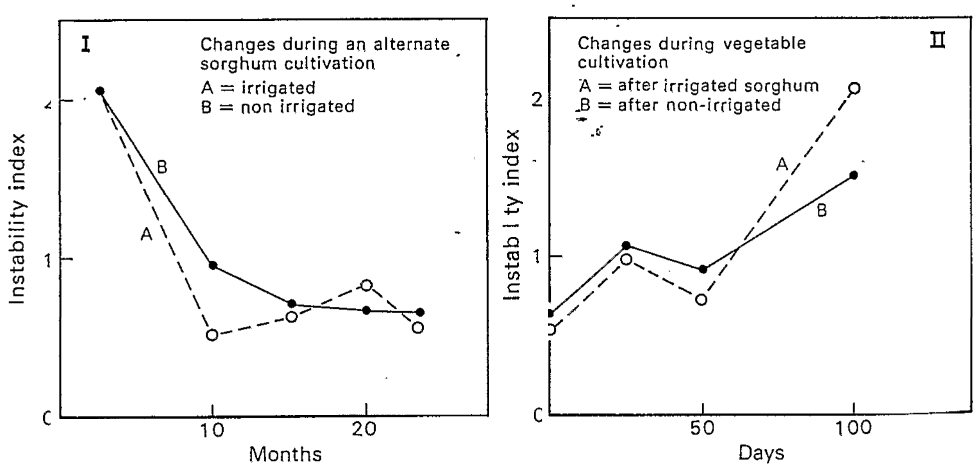


Figure 6 Changes of Instability index (Is) during cultivation

Table 8 Vertisols: Effect of a rotational sorghum crop on the organic pool

	Duration in Months				
	2	10	15	20	24
Irrigated:					
Carbon (%)	1.68	1.57	1.46	1.57	1.68
Nitrogen (%)	.13	.13	.13	.14	.18
Carbon/Nitrogen	12	12.5	11	11.5	9.6
Grey humic acids (%)	19.3	25.8	27.7	23.6	31.6
Humic acids/ total C	9.4	33	22	29	33
Exchange capacity	40	37	33	32	34
N and total amino acids	0.462	0.574	0.618	0.518	0.714
Non Irrigated:					
Carbon (%)	1.68	1.46	1.64	1.45	1.60
Nitrogen (%)	.13	.14	.13	.13	.13
Carbon/Nitrogen	12	10.4	12.3	12.2	12.4
Grey humic acids (%)	19.3	20.7	29.2	28.0	35.0
Humic acids/ total C	9.4	7.8	26	30	26
Exchange capacity	40	42	38	33	34
N and total amino acids	0.460	0.672	0.630	0.580	0.546

structure, which seems to be less resistant to degradation (Fig. 6). The sorghum crop without irrigation leads on the contrary to a better aggregation: the alternation between dry and wet periods to which the soil is subjected during this non-irrigated cropping leads to a structure more resistant to degradation. The type of water regime prevailing when sorghum is cultivated influences the type and duration of the resulting improvement.

The variations in the structural stability or the amounts of humic fractions are associated with a roughly constant percentage of total carbon. Thus, the variations observed within the organic matter fractions are more significant than the variations in the level of total organic carbon which remains largely constant.

CONCLUSION

The examples given in this paper have been deliberately centred on results obtained in the field. They show that the maintenance of organic fertility depends on an intensification of cultural practices.

The supplies of organic matter and more generally the management of cultural practices must make the transformation products of plant residues the most effective through a homogeneous distribution of these products in the soil, through an interaction between the different phases of the organic pool and through their maintenance at the highest level. Several observations can be made from the examples used:

- the effect of an organic supply in the form of compost is a long-term effect and the supply must be maintained over several years; the ploughing in of crop residues is equally important for the maintenance of the organic pool;
- the reconstitution of an organic pool involves labile organic fractions which are unevenly distributed in the mineral complex. The condensation degree of humic substances is low and the heterogeneity of organic matter is more pronounced;
- the water regime is important in many respects: a rainy season accelerates the disappearance of carbon supplied in the form of plant residues. The alternation between dry and wet periods leads to a condensation of organic fractions, the dry periods lead to structures with high molecular weights (30,000), while the wet periods are accompanied by decondensation;
- the presence of amino compounds and their combination with humic chains and to a larger extent the interaction between carbon and nitrogen is an element of fertility, both in the case of the constitution of a nitrogen pool as well as the stabilisation of the structure especially in tropical black soils;
- the transient reactions concerning the rearrangements of organic compounds must be emphasised; in order to characterise the organic matter of cultivated soils, it is necessary not only to evaluate the carbon and nitrogen levels of the different compartments, but also to determine the intensity of the internal transformations likely to occur in the organic pool;
- the effect of cover crops (grasslands, alternate crops) or of a fallow is observed on the whole fertility elements: carbon, nitrogen constants, aluminic acidity, exchange capacity, structural stability;
- the interaction between mineral fertilisation and organic fertilisation must be considered as an effective method for maintaining fertility.

The methods of study vary considerably with the fields concerned and the study of the soil organic matter is made with various objectives, but it is to analyse a heterogeneous mixture whether in the case of the dynamics of ecosystems, of pedogenic processes or of agricultural potentialities. There is a striking similarity with the methodologies which led to improved understanding of the weathering complex. In order to understand the genesis and dynamics of a type of humus (Toutain, 1985), it is necessary to know:

- the morphological and chemical characteristics of the initial plant material;
- the specific action of organisms which are involved in the transformations of this plant material (microbial biomass);
- the chemical and biochemical characteristics of the neoformation or inherited products;

- the interaction between these different phases.

Two great types of organic matter are involved - a young organic matter which is subject to an intense rearrangement and plays an important role as source of mineral elements and a more stable organic matter which is less affected by this transformation. Therefore, the nature of the mixture and the relations between the different phases must be identified.

The physical or chemical fractionation methods combined with the most natural or artificial plant labelling are undoubtedly the most complete types of study of the organic fractions. There are few examples where all these techniques have been used simultaneously.

The study of the living microbial biomass and of the physico-chemical structures of plant or animal debris as well as the biochemical analysis of humic compounds must enable identification of a number of compartments, the relationships between them, and use of models which refer to these exchanges between compartments.

These methods applied to dynamic situations which allow identification of the factors of transformation of the organic pool (nature of the clay minerals, water regime, cultural methods, nature of plant residue) must characterise the soil organic pool through three parameters: nature and abundance of organic compounds or structures, interaction between the different compounds, and amplitude of the interaction phenomena on which the dynamics of the organic or nutrient pool depend.

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