CHAPTER 5

Approaching "Functional" Soil Organic Matter Pools through Particle-Size Fractionation: Examples for Tropical Soils

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I. Introduction

The notion of soil organic matter (SOM) or soil organic carbon (SOC) functional pool is often quoted in literature (Tiessen et al., 1984; Duxburry et al., 1989; Theng et al., 1989; TSBF, 1989; Bonde et al., 1992; Christensen, 1992; Cambardella and Elliott, 1993, 1994; Feller, 1993; Woomer, 1993; Herrick and Wander, 1997; Monreal et al., 1997; Sternberg, 1998), but this notion is generally poorly defined, never quantified and is more generally restricted to the dynamics of SOM than applied to the different and numerous functions that SOM plays in the soils or in the soil-plant-atmosphere system. In fact, total SOM (expressed as total carbon Ct) exerts essential and different *functions* in soil:

- biological functions, such as easily mineralizable carbon or nitrogen (Cm, Nm), microbial nitrogen immobilization, enzymatic activities,
- exchange and sorption functions such as cation exchange capacity or sorption of pesticides,
- function of aggregation,
- functions of medium- to long-term storage ("sequestration") of elements and/or nutrients for plants and soil organisms, such as total organic carbon, nitrogen, phosphorus, sulfur, non-exchangeable bases associated to SOM.

It is important to identify, for a given function, which part(s) of the total SOM represent(s) the majority of the considered function. This is the notion we shall refer to when functionality of SOM pools is discussed throughout this chapter. These functions follow from *properties* of organic entities or molecules, and these properties are quantified owing to static or dynamic *descriptors* such as mineralizable carbon *Cm* or nitrogen *Nm* (expressed e.g., in g kg^{-1} C), organic CEC (in cmole(+) kg^{-1} C), sorption coefficient Koc of organic molecules M (in mg Mg^{-1} C), mean residence time (MRT) or half-life of SOC.

Total SOM is characterized by average values of such descriptors, but there exists a wide distribution of properties within different SOM pools. This distribution can be approached and simplified into sub-classes by SOM fractionation of the whole soil, without affecting the properties of the separates. Identification of functional pools through fractionation procedures would also be valuable for the modelling of soil organic matter properties and behavior (Balesdent, 1996).

The objectives of this chapter are (1) to propose a general approach for the quantification of the functionality of different soil organic fractions; (2) to propose a definition of functional SOM pools;

and (3) to illustrate the conceptual approach in the case of particle-size fractionation of SOM in relation to three different functions: short-term mineralization of carbon *(Cm),* short-term mineralization of nitrogen *(Nm),* medium- to long-term SOC sequestration.

II. Materials and Methods

A. Sites, Soils and Land Use

The results reported here were obtained from the pedological situations summarized in Table 1. With the exception of the Entisol Ps1 the clay fraction of which was rich in smectite, all the soils were low activity clay (LAC) soils with a mineralogy of the clay fraction dominated by kaolinite or halloysite associated with iron and/or aluminium oxyhydroxides. The soils belonged to the following orders of the U.S. Soil Taxonomy: Oxisol (Fr4, Fr7), Ultisol (Fr2, Fr3), Inceptisol (Fi6), Entisol (Ft1). The selected LAC soils covered a wide range of texture, from sandy (Ft1) to clayey (Fr4, Fi6, Fr7), with SOC contents ranging from 1.9 (Ft1) to 41.2 (Fr4) gC.kg^{-1} soil.

For some of these situations, comparisons were made between plots under continuous annual cropping (situations A) and plots corresponding to alternatives for soil carbon sequestration (situations B):

- situations A: groundnut (*Arachis hypogaea*)-millet (*Pennisetum typhoïdes*) rotation, food crops, corn *(Zea mays),* market gardening and sugarcane (*Saccharum* spp.);
- situations B: grass or bush fallows and artificial meadow.

Results for the sole 0 to 10 cm layers will be presented in this chapter.

Some analytical data are reported in Table 1, others are detailed in Feller (1995). All the sites chosen were apparently not eroded.

B. Soil Sampling

Each soil sample (0 to 10 cm) was constituted from 6 to 12 replicates. Each replicate was measured for total SOC content. The coefficients of variation ranged from 3 to 18% with a mean value of 11% (Feller, 1995).

C. Particle-Size Fractionation Method

The particle-size fractionation method used in this study was described in Feller et al. (1991, "method R/US"). Briefly, it consists of shaking for 2 to 16 h (duration depending upon the soil texture) the 0 to 2 mm soil sample (40 g) in water (300 ml) in presence of a cationic resin (R) saturated with Na^+ to improve the soil dispersion. This was followed by wet sieving at 200 and 50 μm to separate the coarse (200 to 2000 μm) and fine (50 to 200 μm) sand fractions. An ultrasonic treatment (US) of the 0 to 50 μm suspension (100J ml^{-1}) improved the clay dispersion. The coarse silt fraction (20 to 50 μm) was obtained by sieving. The fine silt (2 to 20 μm) was separated from clay (0 to 2 μm) by repeated centrifugation.

C and N analysis were performed by dry combustion with a CHN Analyser (Carlo Erba, Mod. 1106). SOM solubilized during the fractionation procedure (less than 4% of total SOM) was not considered in this study.

The above method provided a high dispersion of the soil constituents even with no application of ultrasonic treatment to the whole 0 to 2 mm soil sample. Balesdent et al. (1991) showed that an ultra-

Table 1. Some soil, climatic, and land use characteristics of the studied sites

Location[a]	Site[a]	Climate		Soil order	Samples[a]	Vegetation of crops	Horizon 0–10 cm		
		P (mm)	T°C				Clay	Carbon	C/N
							— (g kg^{-1} soil) —		
Sites studied for C and N mineralization									
Senegal	Ft1	700	29	Entisol	Mi6	A - millet	51	1.9	10.6
Martinique	Fi6	1820	26	Inceptisol	Ca50	A - sugarcane	493	21.8	12.0
Sites studied for C sequestration									
Senegal	Ps1	700	29	Entisol	Am6	A - groundnut-millet	87	5.4	10.0
					Ja21	B - grass fallow	84	7.3	12.7
Ivory Coast	Fr2	1360	26	Ultisol	Rv10	A - rice-corn-manioc	207	9.7	13.9
					Ja12	B - bush fallow	186	15.9	17.8
Togo	Fr3	1040	27	Ultisol	Ms14	A - corn	89	5.3	13.3
					Ja6	B - bush fallow	64	12.4	12.4
Guadaloupe	Fr4	3000	25	Oxisol	Rm10	A - corn-market gardening	670	19.1	9.8
					Pr10	B - artificial meadow[b]	639	41.2	13.3
St. Lucia	Fr7	2700	25	Oxisol	Rv10	A - corn-yam-market gardening	522	18.6	12.9
					Jh10	B - grass fallow	539	29.6	14.3

[a] The symbols refer to nomenclature used by Feller (1995). For the sample symbol the number refers to the last duration (years) of the agricultural system.

[b] Planted with *Digitaria decumbens*.

(Adapted from Feller, 1995; Feller et al., 1996.)

sonic treatment of the whole soil may lead to an artificial transfer (about 50%) of OM associated with sands (plant debris) into the fine fractions (< 50 µm).

By simplification, and according to previous studies on SOM (Feller, 1995; Feller et al., 1996; Feller and Beare, 1997) and particle-size fractions (morphology, C/N, xylose/mannose ratios and dynamics), we shall only consider here the three following fractions:

- fraction 20 to 2000 µm (f20 to 2000), the "plant debris fraction": predominance of plant debris at different stages of decomposition, with carbon to nitrogen (C/N) ratios ranging between 12 to 33 (mean value 20.4);
- fraction 2 to 20 µm (f2 to 20), the "organo-silt complex": consisting of very humified plant and fungi debris associated with stable organomineral microaggregates which have not been destroyed during the fractionation. C/N ratios vary from 11 to 17 (mean value 14.5);
- fraction < 2 µm (f0 to 2), the "organo-clay fraction": with predominance of amorphous OM acting as a cement for the clay matrix. Sometimes, under forest or savanna, presence of plant cell walls occur in the coarse clay fraction but usually not in the fine clay. Very often, bacterial cells or colonies at different stages of decomposition can be observed in both fractions. C/N ratios vary from 8 to 12 (mean value 9.8).

D. Soil Carbon and Nitrogen Mineralization (Whole Soil and Particle-Size Fractions)

For the whole soil (0 to 2 mm), 25 g was moistened at 80% of its field capacity (pF 2.5) and incubated in 125-ml flasks for 28 days at 28° C. Mineral N (sum of $N\text{-}NH_4^+$, $N\text{-}NO_3^-$ and $N\text{-}NO_2^-$) was extracted at 0 and 28 days with 1*M* KCl and was determined according to Nicolardot (1988). Net mineralization in 28 days was defined as *Nm*. Evolved CO_2 was measured at 0, 2, 7, 14 and 28 days (Nicolardot, 1988) and cumulated CO_2 evolved after 28 days was defined as *Cm*. For the size fractions, the fractions larger than 20 µm were incubated alone, but each of the 2 to 20 and 0 to 2 µm fractions were mixed (1/1, w/w) with coarse commercial sand. The incubation conditions were similar to those applied to the whole soil. All determinations were conducted in triplicate.

III. Results and Discussion

A. Theoretical Approach and Definitions

For a given property "x" and a given fraction "i" or the total soil "t," we define:

- a "descriptor value" $DV\text{-}x_i$ or $DV\text{-}x_t$:
  $DV\text{-}x_i$ and $DV\text{-}x_t$ are expressed on the basis on the C (or N) concentration of the fraction or of the soil ($DV\text{-}x_i$ in g (or other units) $\cdot$ g^{-1} C fraction, $DV\text{-}x_t$ in g (or other units) $\cdot$ g^{-1} C soil),
- a "functionality index" $FI\text{-}x_i$ given by the formula:

$$FI\text{-}x_i = 100 \cdot (DV\text{-}x_i / DV\text{-}x_t) \cdot (C_i/C_t) \qquad (1)$$

with C_i and C_t the respective carbon amounts of the fraction and soil expressed in g C kg^{-1} soil.

$FI\text{-}x_i$ represents the participation (in % of the fraction) to the total property expressed by the whole soil.

- a "functionality index variation" $\Delta FI_{A\text{-}B}$. The objective is to quantify the participation of each fraction to the total variation observed for a given property when there is a change in the soil use or land management from a previous situation A to a new situation B.

$\Delta FI_{A\text{-}B}$ is given by the formula:

$$\Delta FI_{A\text{-}B} = 100 \cdot (C_{iA} \cdot DV_{iA} - C_{iB} \cdot DV_{iB}) / (C_{tA} \cdot DV_{tA} - C_{tB} \cdot DV_{tB}) \quad (2)$$

where :

* DV_{iA} and DV_{iB} are the descriptor values for the fractions i of the respective situations A and B,

* DV_{tA} and DV_{tB} are the descriptor values for the total soil of the respective situations A and B,

* C_{iA} and C_{iB} are the carbon amounts (g C kg^{-1} soil) for the fractions i of the respective situations A and B,

* C_{tA} and C_{tB} are the total soil carbon content (g C kg^{-1} soil) for the respective situations A and B,

$\Delta FI_{A\text{-}B}$ represents the participation in % of the fraction "i" to the total variation Δ of the property "x" expressed by the whole soil, when there is a change in soil use (or management) between a situation A and B.

Both $FI\text{-}x_i$ and $\Delta FI_{A\text{-}B}$ are expressions of the functionality of a fraction i. For a number of fraction *n* equal or higher than 2, we define the following "functionality scale":

- low functionality,when FI_{ix} or $\Delta FI_{A\text{-}B} = 75/n$ (3)
- medium functionality, when $75/n < FI_{ix}$ or $\Delta FI_{A\text{-}B} = 125/n$ (4)
- high functionality, when FI_{ix} or $\Delta FI_{A\text{-}B} > 125/n$ (5)

Although the index $\Delta FI_{A\text{-}B}$ will not be used in this chapter, this definition remains important for other potential studies.

Definition of a "functional SOM pool":

A SOM pool P_i will be considered as a "functional" pool for a given function F_x, or a given variation of that function with changes in soil use if its functionality index $FI\text{-}x_i$, or its functionality index variation $\Delta FI_{A\text{-}B}$, is "high" according to the functionality scale.

A virtual example of the "descriptor values" $DV\text{-}x_i$, and the "functionality index" $FI - x_i$ is presented in Figure 1 for a fractionation procedure involving three (n = 3) fractions f1, f2, f3. In this example, the fraction f1 can be considered as a functional pool for sample A but not for sample B. For this one, the fraction f3 is the functional pool.

B. Application to the Short-Term Mineralization of Soil C and N

The study concerns the 0 to 10 cm layer of two low activity clay (LAC) soils: the sandy soil Ft1 cultivated with millet and the clayey soil Fi6 cultivated with sugarcane.

The concentrations and the distributions in the particle size fractions are given in Table 2 for total carbon *(C)*, total nitrogen *(N)*, mineralized carbon *(Cm)* and mineralized nitrogen *(Nm)*.

1. Mass, Carbon and Nitrogen Balances of the Fractionation Procedure

The mass balance of the fractionation procedure (Sum of fractions / non-fractionated soil) was 99.9 and 100.4% for samples Ft1 and Fi6, respectively. The corresponding balances for the total carbon (C) were 88.2 and 108.9% and those for mineralized carbon (Cm) were 78.3 and 78.4%. The N and Nm balances for sample Fi6 were 105.5 and 84.2%, respectively.

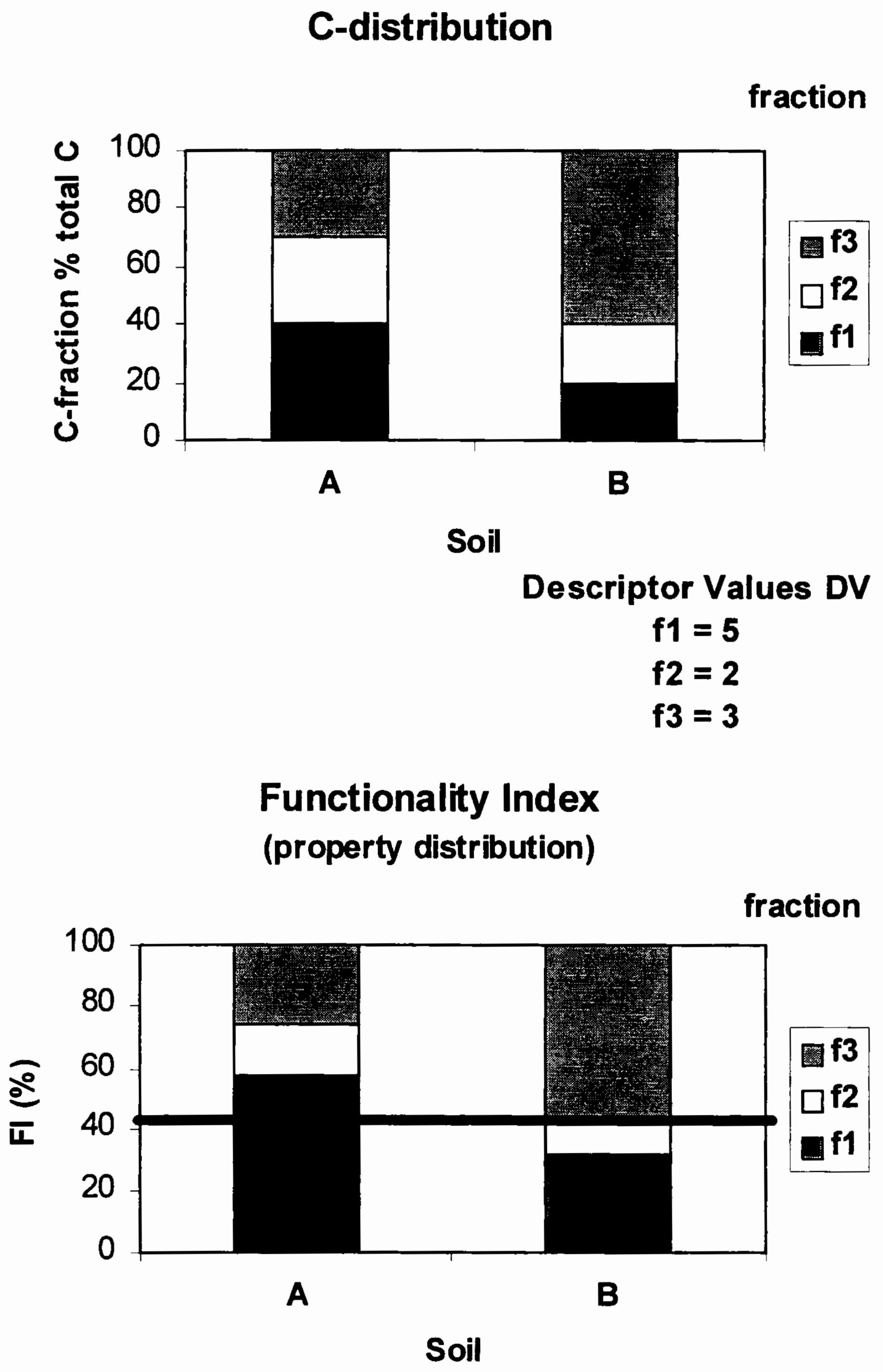

Figure 1. A virtual example of the calculation and expression of the functionality index (F1) from C-distribution and descriptor values data.

Table 2. Characteristics of the total (C,N) and mineralized (Cm, Nm) carbon and nitrogen if the particle-size fractions and their descriptor value (DV) and functionality index (FI) NF soil = not fractionated soil

		Fraction (µm)					
Site	Characteristics	20–2000	2–20	0–2	H_2O^a	Sum	NF soil
Ftl	mass (g 100g^{-1} soil)	954.9	11.1	27.5	5.0	998.5	1000.0
	C (g kg^{-1} fraction)	0.9	27.2	28.5	nd		
	C (g kg^{-1} soil)	0.9	0.3	0.8	nd	1.9	2.2
	Cm (mg kg^{-1} fraction)	85.8	281.8	392.4	nd		
	Cm (mg kg^{-1} soil)	81.9	3.1	10.8	nd	95.8	122.5
	DV-Cm	95.3	10.4	13.8	nd	49.3	55.7
	FI-Cm (%)	85.5	3.3	11.3		100.0	
	C/N	12.3	12.1	8.9	nd		12.7
Fi6	mass (g 100g^{-1} soil)	200.3	164.5	601.9	37.0	1003.7	1000.0
	C (g kg^{-1} fraction)	21.4	24.0	21.1	nd		
	C (g kg^{-1} soil)	4.3	3.9	12.7	nd	20.9	19.2
	Cm (mg kg^{-1} fraction)	540.0	202.0	330.2	nd		
	Cm (mg kg^{-1} soil)	108.2	33.2	198.7	nd	340.1	434.0
	DV-Cm	25.2	8.4	15.6	nd	16.2	22.6
	FI-Cm (%)	31.8	9.8	58.4	nd	100.0	
	N (g kg^{-1} fraction)	0.9	1.5	2.2	nd		
	N (g kg^{-1} soil)	0.2	0.2	1.3	nd	1.7	1.6
	Nm (mg kg^{-1} fraction)	9.4	42.1	86.8	nd		
	Nm (mg kg^{-1} soil)	1.9	6.9	52.3	nd	61.1	72.5
	DV-Nm	11.0	28.3	39.8	nd	35.3	44.2
	FI-Nm (%)	3.1	11.3	85.6		100.0	
	C/N	25.2	16.1	9.7			11.7

[a]Water content (105 °C) of the air-dried sample.

The Cm and Nm balances were systematically lower than C and N, with values varying from 78 to 84%. This can be due to the loss of water soluble C and N (but these were not taken into account in this work), and to environmental differences in the incubation of bulk versus fractionated samples, including interaction between fractions within the bulk sample. Therefore, we shall now only consider the three particle-size fractions and their sums in the study on functionality.

2. Functional Pools for Short-Term Carbon Mineralization

The descriptor value (DV) symbolized by DV-Cm ($DV-Cm = Cm_i / C_i$) was expressed in g Cm kg^{-1} C fraction. The DV-Cm value of the whole soil was higher for the sandy sample Ftl than for the clayey one, Fi6, but both samples varied in the order : f20 to 2000 > f0 to 2 > f2 to 20. The two soils differed more in the value of the f20 to 2000 fraction (higher for Ftl) than in that of the f0 to 2 and f2 to 20 fractions. This trend toward higher DV-Cm values (or an equivalent index) for the "sand-

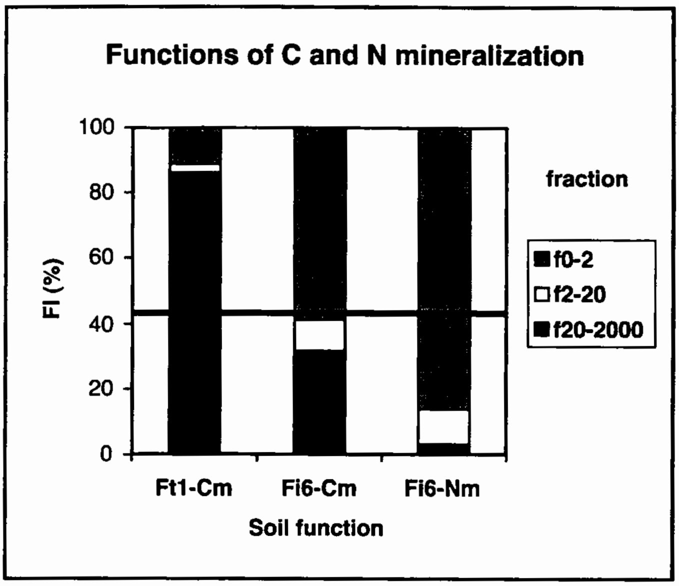

Figure 2. Functionality Index (FI) for the C and N mineralization function.

size fractions" with regard to silt- and clay-size fraction was also observed by Christensen (1987), Gregorich et al. (1989), Hassink (1995) but not by Bernhardt-Reversat (1987, 1988) in the case of tropical sandy soils under savannah or tree plantation.

The functionality index (FI-Cm, Equation (1)) of the particle size fractions of the two soils are presented in Figure 2. The plant debris fraction (f20 to 2000) appeared to be the functional pool for the sandy soil Ftl (FI% = 85.5) but not for the clayey soil Fi6 (FI% = 31.8). For this soil the functional pool was the organo-clay fraction f0 to 2 (FI % = 58.4). The difference in the functionality of the same fraction according to the type of soil might be attributed to the distribution of the total C within the fractions (textural effect) rather than to the differences of the descriptor values DV-Cm. For example, even if we applied the corresponding DV-Cm values of sample Fi6 to the Ftl fractions, the plant debris fraction (f20 to 2000) would have remained the functional pool for soil Ftl. Hassink (1995) also observed that DV-Cm did not differ significantly among size fractions in soils of different texture for temperate grasslands.

This emphasizes the fact that the only descriptor value seems insufficient to evaluate the role played by a given organic compartment for a given soil property; distribution of the property within the soils fractions must also be considered.

3. Comparisons between Nitrogen and Carbon Mineralization Functions

We only considered sample Fi6 for net N mineralization. The descriptor value DV-Nm varied in the order: f0 to 2 > f2 to 20 > f20 to 2000. This order differed from that of DV-Cm. The DV-Nm value increased as the C/N ratio of the fraction decreased (Table 2). A significant correlation between the N mineralization coefficient (equivalent to DV-Nm) and the C:N ratios of different particle size fractions, was observed for tropical sandy soils by Bernhardt-Reversat (1981), the low values of the sand-size fractions being attributed to nitrogen immobilization by presence of plant debris slightly decomposed. Similar observations were done by Sollins et al. (1984) and Barrios et al. (1996) with the existence of a negative relationship between "light fractions" (density <1.6 or 1.7) and equivalents of DV-Nm.

For sample Fi6, the comparison of the functionality index for Cm (FI-Cm) and Nm (FI-Nm) showed (Figure 2) that the FI% of the organo-clay fraction was largely more important for the nitrogen mineralization function than for the carbon mineralization one.

Finally, these two examples for LAC tropical soils showed that:

- the same fraction did not exhibit the same level of functionality according to the soil characteristics,
- the same fraction, for a given soil, did not exhibit the same level of functionality according to the type of the studied function.

C. Application to the Function of SOC Sequestration

In relation to the global greenhouse effect, more and more studies are concerned with the SOM potential for soil organic carbon sequestration (Cseq). The main purpose is to identify, for different bio-physical and socio-economical environments, the alternatives in soil use or land management that allow an increased storage of OC in soil. Another purpose is to identify which SOC pool is involved in the process of carbon sequestration. Those pools could be considered as functional pools when one discusses the function of carbon sequestration.

To illustrate this function, we studied by means of a synchronic approach in sub-Saharan Africa and in the Lesser Antilles, low activity clay (LAC) soils formerly cultivated under continuous annual crops (situation A) and later cultivated with a potential SOC sequestering system (situation B) during variable durations. For each site we considered a pair of plots.

The potential SOC sequestering systems studied (Table 1) were the following:

- spontaneous herbaceous or shrub fallows during 6 (site Fr3), 10 (site Fr7), 12 (site Fr2) and 21 (site Ps1) years after cultivation during 10 years or more with cereal, root crops and/or market gardening,
- artificial meadow during 10 years after 10 years of market gardening (site Fr4).

The relative increase in total SOC content in the 0 to 10 cm layer following these systems varied from 34 to 134% of the initial value under cultivation.

In order to study the SOM forms involved in the SOC variations observed, we conducted a particle-size fractionation of the different samples. The detailed results are presented in Table 3.

For the function of C-sequestration (Cseq) we defined the following descriptor values DV-Cseq:

- for each fraction i, $\text{DV-Cseq}_i = \Delta C_{i\,A\text{-}B} / C_{iA}$

with $\Delta C_{iA\text{-}B}$ representing the difference in the amount of carbon (g C kg^{-1} soil) in the fraction i between the situation A and B,

- for the sum of the fractions, $\text{DV-Cseq}_t = \Delta C_{tA\text{-}B} / C_{tA}$

with $\Delta C_{tA\text{-}B}$ representing the difference in the carbon amount (g C kg^{-1} soil) of the sum of the fractions between the situation A and B.

Therefore, the functionality index, FI-Cseq calculated with equation (1), is given for each fraction by the formula:

$$\text{FI-Cseq}_i = 100 \cdot \Delta C_{iA\text{-}B} / \Delta C_{tA\text{-}B}$$

Table 3. Characteristics (C,N) of the particle-size fractions and their descriptor values (DV) and functionality index (FI) for the function of C sequestration

Fraction	Characteristics	Site / situation (A or B)									
		Fr3		PS1		Fr2		Fr7		Fr4	
(μm)		A	B	A	B	A	B	A	B	A	B
Clay content (g 100 g^{-1} soil) (mean value of A and B)			7.6		8.5		19.7		53.1		65.5
20–2000	mass (g 100 g^{-1} soil)	85.0	86.9	86.0	86.4	69.4	71.1	23.7	27.2	10.7	13.5
	C (g kg^{-1} fraction)	13.0	62.5	12.9	33.0	29.7	55.8	145.6	291.9	143.9	565.7
	C (g lg^{-1} soil)	1.1	5.4	1.1	2.8	2.1	4.0	3.5	7.9	1.5	7.6
	C/N	19.7	14.5	12.0	13.1	19.5	20.1	24.6	33.1	19.3	31.8
	DV-CseqC (g ΔC kg^{-1} CsoilA)		3.9		1.6		0.9		1.3		3.9
	FI-Cseq (%)		72.9		59.1		29.4		45.1		31.6
2–20	mass (g 100 g^{-1} soil)	4.4	4.6	3.0	3.6	7.7	8.8	17.2	13.9	13.5	18.4
	C (g kg^{-1} fraction)	41.1	64.6	22.3	33.3	38.4	61.1	13.9	22.8	47.5	41.6
	C (g kg^{-1} soil)	1.8	3.0	0.7	1.2	3.0	5.4	2.4	3.2	6.4	7.7
	C/N	15.2	10.9	10.6	10.6	18.1	19.6	13.5	16.5	13.5	16.6
	DV-Cseq		0.7		0.8		0.8		0.3		0.2
	FI-Cseq (%)		20.1		17.6		37.2		7.9		6.4
0–2	mass (g 100 g^{-1} soil)	8.9	6.4	8.7	8.4	20.7	18.6	52.2	53.9	67.0	63.9
	C (g kg^{-1} fraction)	23.1	38.6	23.1	32.0	20.6	34.5	23.9	31.8	15.7	35.1
	C (g kg^{-1} soil)	2.0	2.5	2.0	2.7	4.3	6.4	12.5	17.1	10.5	22.4
	C/N	9.2	8.4	9.9	9.0	10.7	11.8	10.7	10.6	8.5	10.7
	DV-Cseq		0.2		0.3		0.5		0.4		1.1
	FI-Cseq (%)		7.0		23.3		33.4		46.9		61.9
H_2O	~~mass~~ (g 100 g^{-1} soil)	0.5	0.7	0.8	0.8	1.2	1.2	7.5	5.8	11.3	5.6
Sum	mass (g 100 g^{-1} soil)	102.5	98.0	98.5	99.2	99.1	99.7	100.6	100.8	102.5	101.4
	C (g kg^{-1} soil)	5.0	10.9	3.8	6.7	9.3	15.8	18.3	28.2	18.5	37.7
	C/N	14.0	12.7	10.6	10.7	13.9	15.5	12.3	13.8	10.3	13.4
	DV-Cseq		1.2		0.8		0.7		0.5		1.0
	FI-Cseq (%)		100.0		100.0		100.0		100.0		100.0

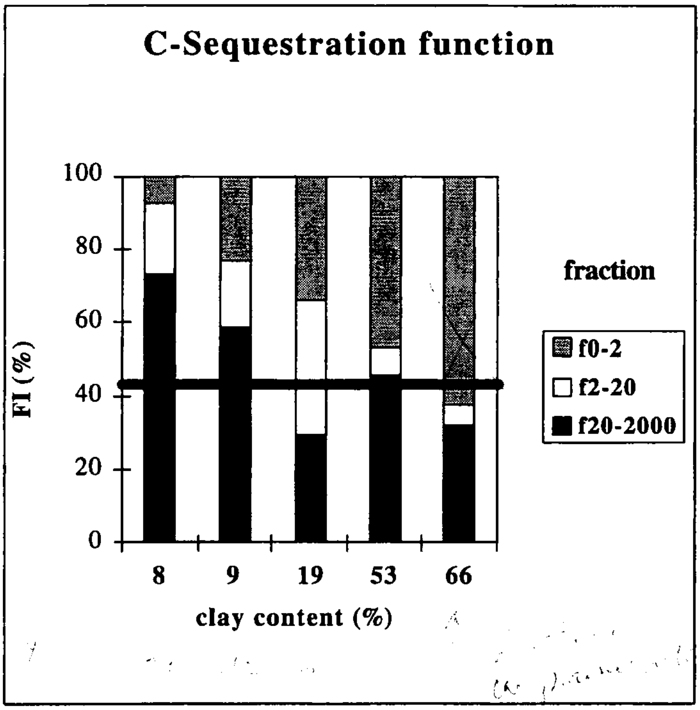

Figure 3. Functionality Index (FI) for the C sequestration function.

As the soil carbon content of the surface horizons of tropical LAC clay soil is generally strongly correlated with the clay content (Feller and Beare, 1997), we shall present the results in relation to soil texture.

1. Mass and Carbon Balances of the Fractionation Procedure

The mass balance (Sum × 100 / NF Soil) of the fractionation procedure varied between 98.0 and 102.5%. With the exception of sample PS1-Am6 with a low carbon balance of 70.2%, the other samples exhibit an acceptable carbon balance in the range of 84.4 to 103.9%.

2. Functional Pools for Carbon Sequestration

Results are presented in Table 3 and summarized for FI in Figure 3. The descriptor value DV-Cseq for the sum of the fractions varied from 0.5 (grass fallow 10 years) to 1.2 (bush fallow 6 years). The value for the 10-year artificial meadow (site Fr4) was relatively high (1.0). For each sample, the DV-Cseq for the fractions generally varied in the order : f20 to 2000 > f2 to 20 = f0 to 2, except for the artificial meadow of site Fr4, which displayed a relatively high value for f0 to 2. All situations gathered, the DV-Cseq of the 20 to 2000 µm fraction was 1.8 (site Fr2) to 5.9 (site Fr3) times higher than that of the 0 to 2 µm fraction.

However, if we consider the functionality index FI, it appeared (Figure 3) that the type of functional pools (FI > 50%) depended also on the texture.

- the plant debris compartment (20 to 2000 µm fraction) for sandy to sandy-clay soils (sites Fr3 and PS1) with clay content less than 20%,
- the organo-clay (0 to 2 µm fraction) for clayey soils with a clay content higher than 50%.

But none of the soil fractions with an intermediate clay content of ca. 20% (site Fr2) exhibited an FI% higher than 50.

Finally, whatever the samples, the organo-silt complex never appeared as a functional pool for C-sequestration.

Different results were published about the benefits of tree plantation, agroforestry or planted pastures on C-sequestration for the tropical and subtropical zones, which seem to confirm this trend. In the Congo the positive effect of a eucalyptus plantation on SOC content of a sandy soil was attributed to >50 µm fractions (Bernhard-Reversat, 1991). Harmand (1998) and Harmand and Nitji (1998) showed in North Cameroon for an LAC sandy soil (% clay = 5) that the positive effect of different legume or non-legume tree species, and especially *Acacia polyacantha*, was mainly due (64%) to > 50 µm fractions. Lehman et al. (1998) studied for a sandy loam plinthic acrisol with 12% clay and with a litter bag experiment of 120 days, the increase in C content for different agroforestry systems including tree legume leaves inputs). For *Calliandra calothyrsus*, the increase was mainly due (near 100%) to the 20 to 2000 µm fraction. However, with *Senna siamea*, this increase only represented 21 % for the 20 to 2000 µm against 49 and 28% for the 2 to 20 and 0 to 2 µm fraction, respectively. Quiroga et al. (1996) showed that for different sandy to loamy soils (Argentina, 0 to 20 cm horizon, % clay from 5 to 25%) the positive effect of a crop-pasture (4 years crops with conventional tillage and 4 years pasture) rotation on C-sequestration as compared to continuous cropping cultivation was mainly due (ca. 66%) to fraction 50 to 2000 µm. Guggenberger et al. (1995) observed that pastures with *Digitaria decumbens* following native savannah in Columbia allowed an increase of C content in the A horizon of an oxisol with 40% clay. The increase due to 20 to 2000 µm fraction was only 21% versus 52 and 27% for the 2 to 20 and 0 to 2 µm fraction, respectively.

IV. Conclusion

The approach of SOC functional pools and quantification of the functionality was only applied here to three types of function: short-term mineralization of carbon, short-term mineralization of nitrogen and pluriannual term of C-sequestration. These examples already showed that:

- for a given soil, the functional pool and the functionality intensity will depend on the function studied,
- for a given function, a particle-size fraction can be considered as a functional pool for a specific soil but not for another, and the importance of soil texture was emphasized,
- the plant debris fraction (20 to 2000 µm) seems to play an important role in the functioning of coarse textured soils, compared to the organo-clay fraction in fine textured soils. For the functions studied, the organo-silt complex (2 to 20 µm fraction) does not appear as an important functional pool.

Therefore, the particle-size fractionation seems to be an interesting approach to identify functional SOC pools, as long as the texture is taken into consideration for the quantification of the functionality. This approach has to be extended to other SOM functions (cationic and anionic exchange, organic molecules sorption, aggregation, etc.). And different land uses, potentially interesting for C-sequestration, must also be studied in different tropical environments.

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ASSESSMENT METHODS FOR SOIL CARBON

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