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Agricultura Intensiva en la Islas del Caribe : posturas, coacciones y perspectivas

EFFECT OF LAND USE ON THE QUALITY AND QUANTITY OF ORGANIC MATTER IN DIFFERENT SOILS OF THE LESSER ANTILLES

CHOTTE J.L[(1)], ALBRECHT A[(1)], BROSSARD M[(2)] & FELLER C[(3)]

[(1)] Centre Orstom, BP 8006, 97259 Fort de France cedex. Martinique
[(2)] Orstom / CNRS, Centre de Pedologie Biologique, BP 5, 54501 Vandoeuvre les Nancy, France
[(3)] Centre Orstom, Laboratoire de Comportement des Sols Cultives, BP 5045, 34032 Montpellier cedex 1, France

ABSTRACT

The effect of different types of land use (banana or food crops vs pastured fallow or artificial meadow) on the quantity and the quality of soil carbon content was investigated on three types of soil of the Lesser Antilles (Andept, Ultisol, Vertisol). Organic carbon content of various particle size fractions of the 0- 10 cm layer of the Vertisol was determined by a physical soil fractionation method.

Soil organic matter content depended upon land uses and soil types. For the Andept, banana crops led to a soil carbon status (0-40 cm) that was higher than that of pastured fallow (13.3 and 12.6 kg $C.m^2$ respectively). In contrast, for the Ultisol and the Vertisol, organic matter content was lower under food crops than under pastured fallows or pastures, with a more pronounced variation for the vertisol. For this soil, the decrease of organic carbon content in the 0-10 cm layer was mainly due to a decrease in the 0-5 µm and >50 µm fractions identified as microbial metabolites and root exudates, and plant residues respectively.

Key words : Land uses, Lesser Antilles, Soil organic matter, Size fractions.

RESUME

L'effet comparé des cultures bananieres ou maraîchères et des jachères pâturées ou des prairies sur le stock de matiere organique est étudié pour trois types de sols (andosol, sol ferrallitique, vertisol) des Petites Antilles. La caracterisation par fractionnement granulométrique de la matière organique de l'horizon 0-10 cm du vertisol est utilisée pour préciser la nature des variations du stock.

Le stock de matière organique dépend du système de culture et du type de sol. Pour l'andosol, le statut organique est plus élevé sous bananes que sous jachère pâturée. Au contraire, pour le sol ferrallitique et le vertisol, le stock de matière organique de ces sols est plus faible sous cultures maraîchères que sous jachère pâturée et prairie. L'effet dépressif des cultures maraîchères sur le statut organique est le plus important sur le vertisol. Dans ce sol, la diminution du stock organique de l'horizon 0-10 cm est principalement due à la diminution des composés organiques d'origine microbienne, des exudats racinaires et des débris végétaux.
Mots cles : Fractions granulométriques, Matiere organique, Mode d'occupation du sol, Petites Antilles.

INTRODUCTION

The importance of organic matter on soil properties is well known. It influences plant productivity (Siband, 1974; Diatta, 1975), soil structure (Leprun, 1986; Albrecht, 1988) and the distribution of soil micro-organisms (Gray and Williams, 1971). In many ecosystems equilibrium levels of soil organic matter are determined by plant biomass production, stabilization and mineralization of organic compounds. When this equilibrium is changed by introduction of new agricultural practices, soil organic matter contents are modified. However, ranges of modifications depend upon climatic conditions, land uses, soil types, and soil texture. In Puerto Rico, Lugo *et al.* (1986) observed that decreases of soil organic carbon under cultivation were more important under moist climatic conditions than under dry conditions. One year after clearing a tropical rainforest, organic carbon content in the 0-15 cm layer of an ultisol was 25% lower than before clearing (Sanchez *et al.,* 1983). In a latosol from the Central Amazon, Cerri *et al.* (1991) measured a decrease of 25% of carbon content of the soil top layer (0-20 cm) in a two years old pasture installed following native forest burning. For many authors, effect of land uses on soil organic carbon content is more pronounced in heavy clayey soils than in sandy soils (Lugo *et al*., 1986; Feller *et al*., 1991.a).

The Lesser Antilles are characterized by a wide diversity of soils (Colmet-Daage and Lagache, 1965; Starck *et al.,* 1966) and by the coexistence of different land uses (De Guiran and Castellanet, 1988). This article presents studies conducted in three islands (Dominica, St-Lucia, and Martinique) to measure the effects of two land uses (10 years old herbaceous fallows or artificial meadow vs food crops for 10 years) on organic carbon content of three types of soil (Andept, Ultisol, Vertisol).

For 0-10 cm layer of the Vertisol, organic carbon content of particle size fractions was determined by a physical soil fractionation method (Albrecht *et al.,* 1986).

MATERIAL AND METHODS

Geographical location, soil type, and land use

Field sites are located in three islands (Dominica, St-Lucia and Martinique) of the Caribbean region (Table I). The annual air temperature in this area averaged 26 °C and the main climatic difference between the three sites was annual rainfall and its seasonal distribution, with a more pronounced dry season in area of the Vertisol (V).

The soils (Andept, Ultisol, and Vertisol designated A, F, and V respectively) were representative of some typical soils of the Lesser Antilles.

For each soil, two different land uses (no crop for 10 years compared to a food crop for 10 years, abreviated as 1 and 2 respectively) were chosen only if soil depth, pedological features in the profile, position on the slope, surface clay content, and clay mineralogy were the same.

Soil sampling

Twelve replicates of soil, randomly distributed on the field site, were sampled with an auger from 0-10, 10-20, and 20-40 cm layers for each site. The twelve samples for each layer were mixed before analysis.

Soil organic matter fractionation

Soil organic matter was fractionated by a physical procedure according to ALBRECHT *et al.* (1986) (Figure 1). About 35 g of moist soil were put in a plastic flask and placed overnight in 200 ml of distilled water at 4 °C. The soil was then dispersed by addition of a solution of NaOH 0.1 N to reach pH 10. Particle size fractions >50 µm, 50-25µm, 5-25 µm, and 0-5 µm were then separated by wet sieving (>50 µm) and sedimentation (< 50µm) respectively.

Analytical process

Soil samples (unfractionnated and fractions) were air dried, sieved (2 mm) and ground (200 llm) before analysis. Total carbon was determined on sub-samples (20 mg) by gas chromatography in a CNS analyzer (Carlo Erba model Na 1500).

RESULTS

Soil organic content

Carbon content of the upper 40 cm layer were higher in the Andept (A) than in the other soils (11.3 and 12.6 kg C. m^{-2} in A. 1 and A.2 compared to 10.8 and 7.4 kg C. m^{-2} in F.1 and F.2, and 8.2 and 3.9 kg C. m^{-2} in V.1 and V.2 respectively) (Table I). The lowest value was measured for V.2 (3.9 kg C. m^{-2}).

For the Andept (A), soil organic carbon content (0-40 cm) under banana crop (A.2) was higher than under pastured fallow (A.1)

(12.6 and 11.3 kg C. m^{-2} respectively). For the two other soils (F and V) pastured fallow (F.2) or pasture (V.2) led to a carbon status higher than food crops. The highest difference between soil organic content under food crops and pasture was observed for the Vertisol (V). For this soil, carbon content (0-40 cm) was twice lowest under food crops (V.2) than under pasture (V.1). For the Ultisol (F), organic carbon status in the top layer (0-40 cm) under food crops (F.2) amounted to 68% of those under pastured fallow (F. l) (7.4 and 10.8 kg C. m^{-2} respectively).

For the Vertisol (V), the difference in carbon content between food crops and pasture reached 4.3 kg C. m^{-2} (8.2 - 3.9). The highest difference was measured in the 0-10 cm layer, where soil organic carbon content under food crops was 2.5 times lower than those under pasture (1.2 and 3.1 kg C. m^{-2} respectively). These differences amounted only to 1.7 and 2.0 in the 10-20 cm and 20-40 cm layer respectively.

Carbon content in the particle size fractions in the 0-10 cm layer of the Vertisol under pasture and food crops.

Carbon recovery after soil fractionation was equal to 97% and 98% in V.1 and V.2 respectively. Under pasture (V.1), organic carbon was more abundant in the fractions 0-5 µm and >50 µm (Figure 2). Carbon content of these fractions amounted to 1.6 kg C. m^{-2} and 0.9 kg C. m^{-2} respectively, wich represented 51% (= 1.6/3.1) and 29% (=0.9/3.1) of the carbon content of the unfractionated soil (= 3.1 kg C.m^{-2}). Carbon content of the fractions 5-25 µm and 25-50, um were about 0.2 kg C. m^{-2} respectively, which represented less than 20% of the carbon content of the total soil.

C/N ratios of the fractions were very different: less than to 10 for the fraction 0-5 µm, about 14 for the fractions 5-25 µm and 25-50 µm, and 20 for the fraction >50 µm.

Under food crops (V.2), organic carbon content was higher in the fraction 0-5, um (0.6 kg C. m^{-2}) which represented 50% (= 0.6/1.2) of the carbon of the unfractionated soil (1.2 kg C. m^{-2}). Carbon content in the fraction > 50 µm, 5-25 µm, and 25-50 ,um were 0.12, 0.20, and 0.15 kg C. m^{-2} respectively. Carbon content of these fractions amounted to 21% (=0.25/1.2), 16% (= 2/12), and 13% (=0.15/1.2) of the carbon of the unfractionated soil respectively.

The C/N ratio was lower for the fraction 0-5 µrn (=8), the highest for the fraction > 50 µm (=18) and about 14 for the fractions 5-25 µm and

25-50 µm.

DISCUSSION

Our objectives were to measure the effect of two different land uses (no cultivation for 10 years and fallow or pasture since then vs food crops for 10 years) on the organic carbon content of three soils representative of some of typical soils of the Lesser Antilles (Andept, Ultisol, Vertisol) and to determine for the 0-10 cm layer of the Vertisol the soil organic matter content in various particle size fractions.

For the Andept, banana led to higher soil organic carbon status than a ten-year old pastured fallow. For the Ultisol and the Vertisol, soil organic carbon content under food crops were lower than under pastured fallow or pasture. The Vertisol seemed very affected by land uses. Its carbon content (0-40 cm layer) under food crops was almost half than that under pasture. These results suggest that effects of land use on soil organic carbon content depend upon soil types (ALBRECHT *et al.*, 1992). Furthermore, modifications of soil properties due to variations of soil carbon content varied. Decrease of soil carbon content did not influence soil phosphate fixing capacity (Brossard *et al.*, 1988), maize productivity, and ^{15}N-urea uptake by plants (CHOTTE *et al.*, 1991), even if nitrogen mineralized under controlled conditions was positively correlated to carbon content (CHOTTE *et al.*, 1993.b). In the Lesser Antilles, food crops induce, excepted for the Andept, a decrease of soil organic matter content, but carbon contents are still higher than those measured in African soils (FELLER, 1993) where plant productivity and fertilizer efficiency depend upon soil carbon status (MARQUETTE, 1986). Also, aggregate stability (ALBRECHT, 1988), earthworm (BAROIS *et al.*, 1988), and microbial biomasses (CHOTTE, 1993; unpublished data) were positively related to soil organic matter content in some Caribbean soils.

For the Vertisol, the soil organic carbon content of the 0-10 cm layer under food crops (V.2) was half than under pasture (V.2) (1.2 kg C. m^{-2} and 3.1 kg C. m^{-2} respectively). The comparison of organic carbon content of the particle size fractions isolated by a physical fractionation method suggested that only two fractions were affected by the type of land use (Figure 3). The difference of the carbon content of the particle size fractions 0-5 µm and >50 ,um isolated from the Vertisol under food crops (V.2) and pasture (V.1) amounted about to 1.0 kg C . m^{-2} and 0.6 kg C. m^{-2} respectively, which represented 52% (=1.0/1.9) and 31% (=0.6/1.9) of the 0-10 cm layer carbon content decrease due to food crops (1.9=3.1-1.2) respectively. C/N values, chemical composition, and microscope observations indicated that these fractions are partly composed of microbial metabolites and/or root exudates, and plant residues respectively (TIESSEN and STEWA1T, 1983; FELLER *et al.*, 1991.b; CHOTTE *et al.*, 1993.a). The importance of these two fractions as "active fractions" is now well established (TIESSEN and STEWART, 1983; CHOTTE, 1988; MARTIN *et al.*, 1990; FELLER, 1993).

CONCLUSION

Land uses in the Lesser Antilles lead to different soil organic matter content depending upon soil types. Soil carbon status of the Ultisol and the Vertisol under food crops are lower than under pastured fallow or pasture, and the differences are mainly due to microbial metabolites, root exudates, and plant residues.
Successfull land management should conserve these organic compounds as abundant as possible.

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Table I: Location, soil type, and land use

Island	Soil Type	Symbol	Location	Annual Rainfall (mm)	Land use	Symbol
Dominica	Andept*	A	Grand Fond	5400	no crop for 10 years pastured	A.1
	*Andosol***		Grand Fond	5400	fallow since then banana crop for 10 years	A2
St-Lucia	Ultisol*	F	Dugard	2000	no crop for 10 years pastured	F1
	*Sol ferrallique***		Roblot	2400	fallow since then banana crop for 10 years	A.2
Martinique	Vertisol*	V	Sainte-Anne	1300	no crop for 10 years and	V.1
	*Vertisol***		Sainte-Anne	1300	*Digitaria decumbens* since then food crops for 10 years	V.2

* USDA Soil Taxonomy

** *French Soil Classifications CPCS, 1967*

Table II: Soil organic carbon and nitrogen content

Site	Layer (cm)	Carbon ‰	Carbon kg.m^{-2}	Nitrogen ‰	Nitrogen kg m^{-2}	C/N
A.1	0*10	95.5	4.0	9.8	0.4	9.7
	10*20	80.9	3.7	8.4	0.4	9.6
	20*40	44 9	3.6	4.0	0.3	11.2
total	0*40		11.3		1.1	
A.2	0*10	107.7	4.5	10.7	0.4	10.1
	10*20	80.4	3.7	7.7	0.4	10.4
	20*40	55 3	4 4	5.3	0.4	10.4
total	0*40		12.6		1.2	
F.1	0* 10	27.0	2.9	2.0	0.2	13.5
	10*20	23.5	2.8	2.0	0.2	11.5
	20*40	21.2	5.1	1.6	0.4	13.3
total	0*40		10.8		0.8	
F.2	0*10	19.0	1.7	2.2	0.2	8.6
	10*20	1 9.4	1.8	2.1	0.2	9.2
	20*40	16.4	3.9	1.9	0.5	8.6
total	0*40		7.4		0.9	
V.1	0*10	31.2	3.1	3.1	0.3	10.2
	10*20	18.4	1.9	2.1	0.2	8.7
	20*40	15.3	3 2	2.0	0.4	7.6
total	0*40		8.2		0.9	
V.2	0* 10	11.8	1.2	1.7	0.2	7.0
	10*20	9.4	1.1	1.5	0.2	6.4
	20*40	8.3	1.6	1.6	0.3	5 4
total	0*40		3 9		07	

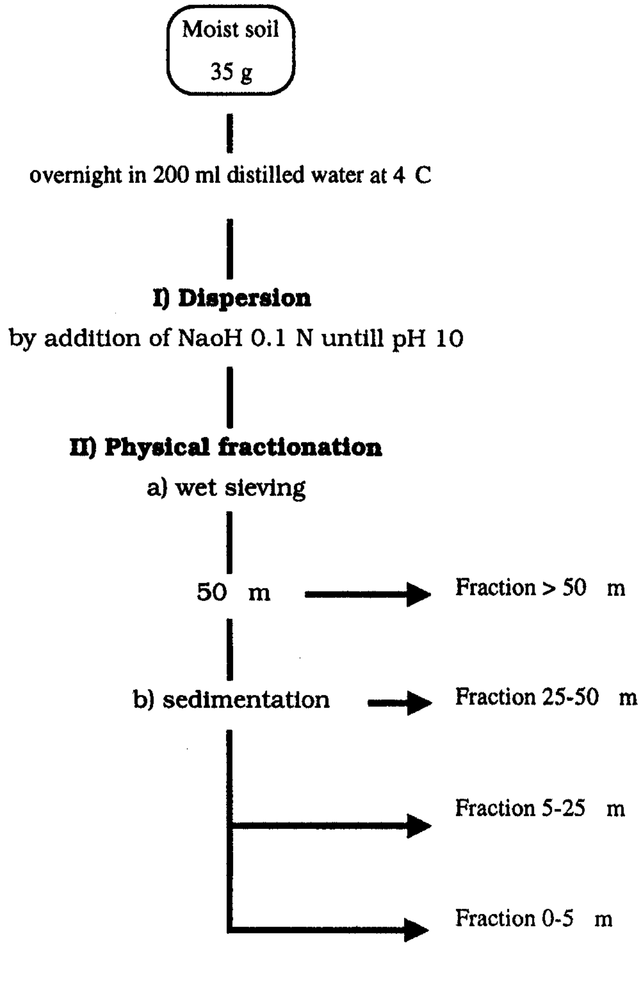

Figure 1: Flow chart for soil organic matter fractionation

Figure 2: Carbon distribution (kg . m^{-2}) in the particle size fractions in the 0-10 cm layer of the Vertisol (V) under pasture (V.1) and food crop (V.2).

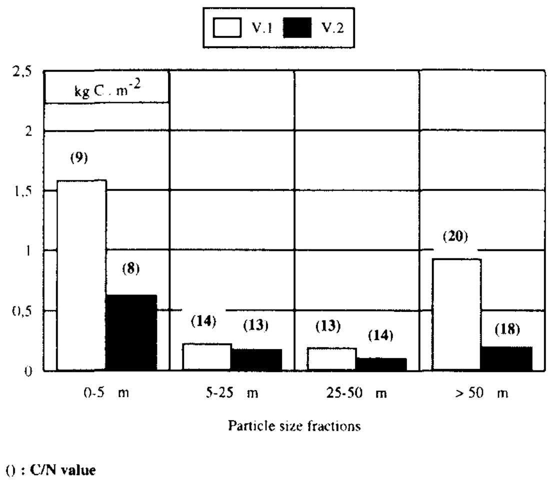

Figure 3: Variation (V.2 - V.1) of organic carbon content in the particle size fraction in the 0-10 cm of the Vertisol.