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L.-S. Koutika · Th. Choné · F. Andreux · C.C. Cerri

Carbon decomposition of the topsoils and soil fractions under forest and pasture in the western Brazilian Amazon basin, Rondônia

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Abstract The topsoils of two sites, comprising natural forest and 4- and 20-year-old pastures, respectively, were selected in Rondônia to evaluate the changes of soil organic matter due to pasture establishment. These changes were evaluated by measuring the proportions of the C and N associated with clay and silt fractions, and by the C decomposition (CD) rate of the whole topsoils and their size fractions. The topsoils studied had large proportions of C and N associated with fine fractions, especially with clay fractions. The CD rate of the silt fractions was higher than that of the clay fractions under the two forest topsoils and under the 20-year-old pasture. The CD rate of the silt fractions under forest vegetation at each site was significantly higher than that of the silt fractions under pasture vegetation at the same site. The CD of clay fractions followed the same trend as the silt fractions, showing an improvement in the stability of C associated with clay and silt fractions under pasture vegetation.

Key words Carbon decomposition · Forest · Pastures · Topsoils · Rondônia

L.-S. Koutika (✉) · T. Choné
CNRS, Centre de Pédologie Biologique, 17 rue N-D des pauvres, B.P. 5, F-54501 Vandoeuvre-les-Nancy, France

Th. Choné · F. Andreux
Université de Bourgogne, Centre des Sciences de la Terre, 6 Boulevard Gabriel, F-21000 Dijon, France

C.C. Cerri
Universidade de São Paulo, CENA, CP 96 13416000 Piracicaba, SP, Brazil

Present address:
L.-S. Koutika, IITA, Cameroon, c/o Lambourn and Company, 26 Dingwall Road, Croydon CR9 3EE,
e-mail: l-s.koutika@iccnet.cm/L.KOUTIKA@CGIAR.OR

Introduction

Agricultural expansion into the tropical forest zone has been responsible for at least 50% of deforestation in the last two decades (Myers 1991). A report published by FAO/UNEP in 1981 showed that shifting agriculture accounted for only 35% of deforestation in Latin America against 70% in Africa and 50% in Asia. Moreover, deforestation caused by pasture establishment is more pronounced in South America, including the Brazilian Amazon basin (Alvim 1982; Fearnside 1985; Hecht 1992). The State of Rondônia has a surface area of 234 044 km^2, and is one of the states of Brazil with the highest deforestation rate. In Rondônia, the proportion of land cleared by deforestation greatly increased, from 0.3, to 23.7%, between 1975 and 1988 (Huguet 1990). Numerous changes in soil properties occur in the pasture systems of deforested land, such as a temporary improvement in chemical properties (Hecht 1981; Diez et al. 1991), a decrease in soil porosity (Eden et al. 1991; Chauvel et al. 1991; Koutika et al. 1997), and a decrease in the quantity of soil organic matter (SOM) (Desjardins et al. 1994). However, an increase in SOM under pasture has also been reported for central Amazonia (Choné et al. 1991), eastern Amazonia (Koutika et al. 1997), and western Amazonia (Feigl et al. 1995; Moraes et al. 1996). The effects of pasture establishment in Rondônia on SOM quantity and quality have been studied (Piccolo et al. 1994a,b; Feigl et al. 1995; Moraes et al. 1996). Piccolo et al. (1994a) did not find any increase in N content, but argued that the variation in nitrification and mineralization rates was strongly related to patterns of land-use changes, which therefore influenced total N pools. Moreover, Piccolo et al. (1994b) found that the conversion of forest to pasture was accompanied by major changes in soil N sources. Using the lignocellulose index, Feigl et al. (1995) found an improvement in SOM quality in the topsoils due to pasture establishment. A significant increase in soil C content after the removal of original vegetation for pasture creation was found in the soils of two chronosequences (Moraes et al. 1996). Changes in SOM quality occurring under pasture as compared to forest were estimated using ^{13}C (Choné et al. 1991; Desjardins et al. 1994; Feigl et al. 1995; Koutika et al. 1997). However, other information about the change in SOM from forest to pasture could be obtained from studying C decomposition (CD) of the whole soil and its size fractions (Koutika et al. 1999). The aim of this study was to estimate the changes in C that have occurred in the topsoils of the pasture and forest systems in Rondônia. These changes were evaluated from the C and N proportions in the fine, silt- and clay-size fractions of the soil, and by studying the decomposition rate of C of the whole topsoils and their respective fine fractions using a laboratory incubation technique.

Materials and methods

Experimental site and soils

Two sites were selected, one at the fazenda (ranch) Ouro Preto and the other one at the fazenda Nova Vida, located in Rondônia. Nova Vida is located along highway BR 364, about 250 km south of Porto Velho, the state capital. Ouro Preto is located about 90 km south-west of the fazenda Nova Vida. At these sites the mean annual temperature is 25.6 °C and mean precipitation is 2200 mm, with the dry period from June to August (Bastos and Diniz 1982). The soils are red-yellow latosols that developed on tertiary sediments belonging to the Xingu formation. The vegetation cover is a natural forest designated as Ouro Preto forest (OPF) and Nova Vida forest (NVF). The pasture at Ouro Preto (OPP) has been cultivated for 20 years with *Brachiaria decumbens*; the pasture at Nova Vida (NVP) has been planted with *Brachiaria brizantha* for 4 years. Composite soil samples were prepared from 40 samples taken with an auger from a 200×200-m cross-shaped transect. All samples were air-dried, sieved at 2 mm, and homogenised manually prior to analysis.

Standard soil analyses

On 0–2 mm air-dried soil samples, particle-size fractionation was carried out using the Na-resin dispersion method described by Rouiller et al. (1972). The following fractions were obtained: sand (50–2000 μm), silt (2–50 μm), and clay (0–2 μm). C and N contents of the whole soil (2-mm sieve), and of fine-particle-size fractions (silt and clay) were determined by combustion, using a Carlo Erba NA 1500 Autoanalyzer.

Incubation experiments

Five grams each of sieved (0–2 mm) soil, clay, and silt fractions were reinoculated and moistened with soil solution (soil:liquid ratio, 1:1000, w/w) to 80% of the field capacity (3.2 kPa for the whole soil and silt and 1.8 kPa for clay), and incubated for 100 days at 28 °C in tightly closed 250-ml flasks. There were three replicates for each soil sample and fraction. During the incubation, soil moisture was maintained by placing a plastic tube with 5 ml distilled water in each flask. The air in the flasks was sampled periodically with a 1-ml syringe, and flasks were opened for 10 min every fifth day to allow for an exchange of gases. Measurements of CO_2 were carried out using an infrared LCA-2 ADC analyzer. The amounts of CO_2 released (or CD rate) were expressed in mg kg^{-1}.

Statistics

Statistical analyses were conducted to determine the difference in CD between the topsoils and their fractions, using Wingz software. The variance of CD under forest and pastures topsoils was tested at each measurement.

Results

All the topsoils contained more than 60% sand fraction (Table 1), with clay as the second main component. The clay contents varied between 16.5% (NVF) and 22.6% (OPP). The sand/clay ratios were higher than 2 in all the topsoils, but were higher in topsoils under forest than under pasture. The C contents were higher in the topsoil under pasture at both sites, while N contents were similar under all the topsoils. Consequently, only a slight and not significant increase in C/N ratio values could be observed under pasture (11.6–11.8) as compared to forest (10.5–11.2; Table 1). The C and N contents of the silt and clay fractions were significantly higher than those of the whole soils (Table 2). Proportions of C associated with the silt fraction in the whole soil varied between 22.9% and 30%, and those of N ranged from 19.9% to 24.1%. Proportions of C and N associated with the clay fraction in the whole soil were about twice as high as those of the silt fraction: from 46.6% to 52.4% of C and from 55.2% to 64.6% of N were associated with the clay fraction. In contrast, C associated with the sand fraction ranged from 20.9% to 28.3%, whereas the proportion of N associated with the sand fraction barely exceeded 20%.

In the OPF soil the CD of the silt fraction was 38.2 mg kg^{-1}, while that of the clay fraction was

Table 1 Characteristics of the topsoils studied

Topsoils	Texture				C and N contents		
	Clay (%)	Silt (%)	Sand (%)	Sand/clay ratio	C (%)	N (%)	C/N ratio
Ouro Preto forest	17.3	11.2	67.5	3.9	1.45	0.13	11.2
Ouro Preto pasture	22.6	11.6	62.2	2.9	1.62	0.14	11.6
Nova Vida forest	16.5	11.1	72.0	4.4	1.26	0.12	10.5
Nova Vida pasture	21.1	8.0	68.5	3.2	1.53	0.13	11.8

Table 2 C and N contents, and C and N associated with particle size fractions

Topsoils	C and N contents of clay fractions			C and N associated with clay in the soil		C and N contents of silt fractions			C and N associated with silt in the soil		C and N contents of sand fractions			C and N associated with sand in the soil	
	C (%)	N (%)	C/N ratio	C (%)	N (%)	C (%)	N (%)	C/N ratio	C (%)	N (%)	C (%)	N (%)	C/N ratio	C (%)	N (%)
Ouro Preto forest	3.9	0.47	8.4	46.6	62.5	3.9	0.28	13.9	30.0	24.1	0.50	0.025	20.0	23.3	13.3
Ouro Preto pasture	3.5	0.40	8.8	48.8	64.6	3.2	0.24	13.9	22.9	19.9	0.73	0.034	21.5	28.3	15.5
Nova Vida forest	3.9	0.47	8.4	51.1	64.6	3.1	0.23	13.5	27.3	21.3	0.37	0.023	16.1	21.6	14.1
Nova Vida pasture	3.8	0.34	9.0	52.4	55.2	5.1	0.38	13.4	26.7	23.4	0.46	0.040	11.5	20.9	21.4

32.2 mg kg^{-1} (Fig. 1). In the OPP soil the CD of the silt fraction was 21.5 mg kg^{-1}, and that of the clay fraction 28.3 mg kg^{-1}. In the NVF soil the CD of the silt fraction was 40.1 mg kg^{-1}, and that of the clay fraction 28.2 mg kg^{-1}. In the NVP soil there was no significant difference between the CD of the silt fraction (20.0 mg kg^{-1}) and of the clay fraction (21.1 mg kg^{-1}). During 35 days of incubation, the CD was significantly higher in the whole topsoil than in the corresponding silt and clay fractions under the two pasture sites (Fig. 1). In OPF soil, the CD of the silt fraction was always higher than that of the whole topsoil and clay fractions. In NVF soil, the CD of the silt fraction was always significantly higher than that of the clay fraction. In both sites, the CD of the clay and silt fractions was significantly higher under forest than under pasture (P>99% for the Ouro Preto site and P>99.9% for the Nova Vida site).

Discussion

Rondônia topsoils studied had a typical sandy texture. Even though clay and silt contents were close to 20%

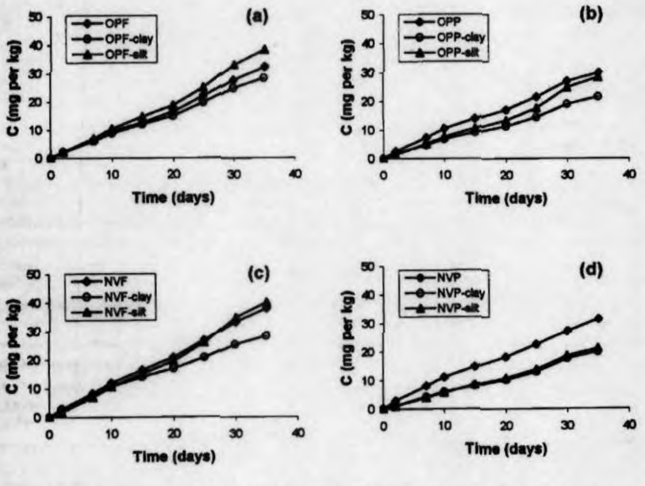

Fig. 1 C decomposition of the whole topsoils, and their fractions during incubation for 35 days at 28 °C: **a** under forest at Ouro Preto (*OPF*), **b** under pasture at Ouro Preto (*OPP*), **c** under forest at Nova Vida (*NVF*), **d** under pasture at Nova Vida (*NVP*)

and 10%, respectively, about one half of soil C and N were associated with the clay fractions, and one third with the silt fractions. These results were in accordance with previous findings, showing that clay-size fractions are the most humified part of SOM (Turchenek and Oades 1979; Andreux and Correa 1981). The proportions of N associated with the clay and silt fractions in the sandy soils were higher that those of other soils located in the eastern Brazilian Amazon basin, which were either sandy (Desjardins et al. 1994), or had more than 80% clay (Koutika et al. 1999). This was indicative of a better SOM humification rate in Rondônia, due to more contrasting local climatic conditions, particularly a longer dry season. As a result, lower C/N ratios were found in the clay fractions than in the respective whole soils. These results also confirmed several earlier findings showing the greatest incorporation and accumulation of organic materials in the clay-size fractions, and the influence of texture on organic-matter incorporation (de Boissezon et al. 1973; Van Veen and Kuikman 1990; Desjardins et al. 1994). The incubation experiment showed that CD was higher under forest vegetation than under pasture, indicating an increase in biological stability of C from the forest to the pasture systems. This trend was confirmed by a higher CD of the silt fraction under forest compared to that under pasture. This increase in the biological stability of C under pasture probably resulted from a change in the SOM quality due to the incorporation of C derived from pasture, as found in several other studies (Choné et al. 1991; Feigl et al. 1995; Koutika et al. 1997). This was also consistent with findings of Moraes et al. (1996) showing a fast decline in forest C following deforestation of the Nova Vida soil, and the incorporation of about 25% and 50% of C derived from pasture in the 0- to 30-cm layer, after 4 years and 20 years, respectively.

The CD of the silt fractions under forest remained higher than those of the clay fractions under forest and pasture. This result again confirmed the higher lability of C under forest as compared to pasture, and showed a higher biological stability of C in the clay fraction under both types of vegetation. These results were in agreement with our results on soils of the eastern Amazon basin, which showed the prevalent contribution of the silt-size fractions to CD during the first 40 days of incubation, compared to that of the clay fractions (Koutika et al. 1999). In Rondônia, pasture establishment seems to have induced a decrease in the CD of organic material associated with clay, i.e. an increase in the biological stability of C of the finer fraction. Since the total soil C content had increased, it could be considered that pasture establishment resulted in an improvement of SOM quality. This was in agreement with results of Feigl et al. (1995) on a chronosequence of the same area. In contrast, in eastern Brazilian Amazonia, in addition to an increase in stored C (Koutika et al. 1997), pasture induced a depletion in SOM quality due to an increase in CD and an increase in the proportion of macroorganic matter (Koutika et al. 1999).

Finally, in this study, experiments to measure the CD of the silt and clay fractions yielded sensitive indices of the change in the nature of SOM occurring in the topsoils after pasture establishment. These results supplemented quantitative information obtained from other soil analyses, especially ^{13}C isotopic methods (Andreux et al 1990; Feigl et al. 1995; Moraes et al. 1996; Koutika et al. 1997). The incubation method showed no difference between the two sites, probably due to their proximities and similarities, while strong differences were found with soils from other locations in the Amazon basin (Koutika et al. 1999). It should be noted that when the parent material was relatively rich, and local climatic conditions sufficiently contrasting, the changes that occurred in SOM under pasture vegetation resulted in an improvement in SOM quality and other properties associated with it (Feigl et al. 1995; Moraes et al. 1996). This study confirmed that conditions which favoured an improvement in SOM quality were met only in Rondônia. In other places of the Amazon basin, depletion of SOM was observed (Desjardins et al. 1994; Koutika et al. 1997, 1999).

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