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Amazônia Ocidental (EMBRAPA-CPAA)**

**SHIFT Project ENV 45**

**BMBF No. 0339641 5**

**Water and nutrient fluxes as indicators for the stability of different  
land use systems on the Terra firme near Manaus**

**Annual Report 1997**

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#### 4) Single tree effects on soil organic matter

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#### ABSTRACT

Increasing the soil organic matter (SOM) contents is an important factor for improving soil fertility. Not only the amount of organic carbon in soil is ecologically important for SOM stability, but also its physical and chemical properties. The appropriate technique for the assessment of ecologically relevant soil pools can vary between soils, and information about this is lacking for oxisols in the Amazon basin. This work should identify soil pools which are sensitive to land-use changes in terra firme oxisols and yield easy to handle techniques for the evaluation of SOM properties. For this purpose, we have studied the influence of 10 different trees and annual crops on SOM properties on an oxisol near Manaus. A combination of aggregate and density fractionation was found to be most suitable for physical SOM characterisation. The particulate organic matter (POM, density less than  $1.6 \text{ g cm}^{-3}$ ) varied by one order of magnitude between sites and could be used as a sensitive indicator of land-use changes. The obtained results are extremely important for the evaluation of the sustainability of the investigated land-use systems and are the basis for soil ecological research on terra firme oxisols.

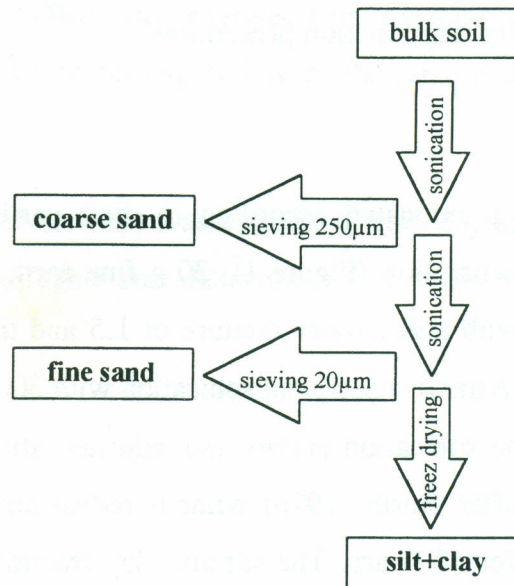
#### 1. INTRODUCTION

The terra firme oxisols near Manaus are characterized by severe nutrient limitation (Schroth et al., 1998). Increasing the soil organic matter (SOM) content is an important factor of improving soil fertility, first as a source of slowly releasing nutrients and secondly as means of enhancing the soil cation exchange capacity in order to reduce nutrient leaching (Coleman et al., 1989). Not only the amount of organic carbon in soil is ecologically important for SOM stability, but also its physical and chemical properties (Zech et al., 1997). Using particle size, aggregate and density fractionation methods (Tiessen and Stewart, 1983; Tisdall and Oades, 1982) together with the analysis of chemical SOM compounds (Degens, 1997), profound statements can be made about SOM stability and dynamics. The appropriate technique for the assessment of ecologically relevant soil pools can vary between soils, and information about this is lacking for oxisols of the

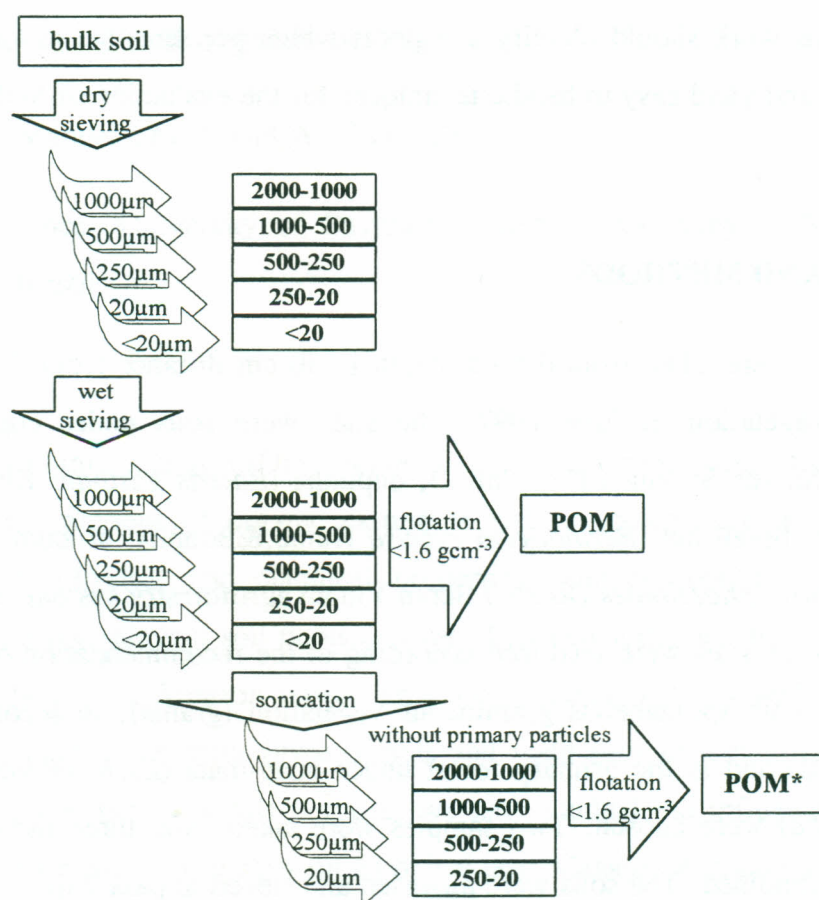
Amazon basin. This work should identify soil pools which are sensitive to land-use changes on terra firme oxisols and yield easy to handle techniques for the evaluation of SOM properties.

## 2. MATERIALS AND METHODS

The soil samples were taken from 0-5 cm depth in 50 cm distance from 8 different trees and two understorey vegetation in June 1997. The sites were soils under cupuacu (*Theobroma grandiflorum* (Willd. (ex Spreng.) K. Schum.), pupunha (*Bactris gasipaes* Kunth.) managed for palmito production, brazil nut (*Berthollecia excelsa* Humb.&Bonpl.), urucum (*Bixa orellana* L.) and pueraria (*Pueraria phaseoloides* (Roxb.) Benth.) in an agroforestry system, and under pupunha in monoculture. These sites were fertilized according to the recommendation of the EMBRAPA. Additionally, sites with spontaneous gramineous vegetation (grama), in secondary regrowth of *Vismia* spp. (vismia) and in the primary forest under mata-mata (*Eschweilera* spp.) und bacaba (*Oenocarpus bacaba*) were chosen. Two samples were taken from three individual trees of the same species and combined. The soils were air-dried and sieved to pass 2 mm.



**Figure 1:** Particle size fractionation procedure.



**Figure 2:** Aggregate and density fractionation procedures.

The soils were physically fractionated according to their particle size, aggregate size and density. For the particle size separation (Figure 1), 30 g fine earth were ultrasonically dispersed with an energy of  $200 \text{ J ml}^{-1}$  with a soil:water mixture of 1:5 and then sieved to yield the coarse sand fraction (2000-250  $\mu\text{m}$ ). After a subsequent sonication with  $300 \text{ J ml}^{-1}$ , the fine sand fraction 250-20  $\mu\text{m}$  was separated. The sonication energy was adjusted after preliminary experiments to ensure complete dispersion (after North, 1976) without redistribution of organic carbon. Both fractions were dried at  $40^\circ\text{C}$  for 48 hours. The silt and clay fractions ( $<20\mu\text{m}$ ) were not further separated and freeze dried. The mean recovery amounted to 87 %. Two different methods of aggregate fractionation were conducted in three parallels: dry and wet fractionation (changed after Angers and Giroux, 1996), the latter being combined with a density fractionation (Figure 2). First, 30 g soil was put on a cascade of sieves with 1000, 500, 250 and 20  $\mu\text{m}$  sieve openings, vertically shaken for 50 times, turned  $90^\circ$  and again shaken. Tests verified that after this procedure only aggregates larger than the respective sieve opening size remained on the sieves, and the recovery laid between 97 and 99 %. The separates were weighed. For the combined aggregate and density fractionation, aggregates from the dry fractionation were combined and

again put on the cascade of sieves but with the 20  $\mu\text{m}$  sieve removed. The cascade was installed in a Yoder apparatus in a water bath (Yoder, 1936). The aggregates were slowly wetted from below. This procedure could not completely exclude slaking and corresponded to the method wet sieving without prewetting of Gijsman (1996). They were separated using a 3 cm vertical displacement and 31 rpm for 30 min. The sieves were removed from the water bath and transferred into a pan with a sodiumpolytungstate (SPT) solution of  $1.6 \text{ g cm}^{-3}$ . The particulate organic matter (POM) which was lighter than  $1.6 \text{ g cm}^{-3}$  was washed with the SPT solution through a 250  $\mu\text{m}$  sieve to separate POM and SPT. All aggregate fractions and POM were washed several times with deionized water to remove the SPT. The aggregates which passed the 250  $\mu\text{m}$  sieve of the Yoder apparatus were poured through a 20  $\mu\text{m}$  sieve. The remaining fraction  $< 20 \mu\text{m}$  was flocculated with  $\text{MgCl}_2$  and allowed to settle before discarding the supernatant. All fractions were dried at  $40^\circ\text{C}$  for 48 hours and weighed (recovery 95 %). The aggregates were again fractionated in primary particles, POM\* and mineral matrix after sonication with the respective sieve and energy described above. Thus, the „true„ amount of aggregates could be determined excluding the mineral particles which would belong to the aggregate class because of their size alone. The primary particles were separated with the sieve of the respective size class, dried, weighed and discarded. POM\* was separated from the aggregates with the SPT solution as described above. POM\* and the remaining soil were thoroughly washed with deionized water, dried and weighed.

The mean weighted diameter (MWD) was calculated from dry and wet aggregate separates in order to get a parameter of aggregate size distribution from each sample (Kemper and Rosenau, 1986):

$$MWD = \sum_{i=1}^n \bar{x}_i w_i$$

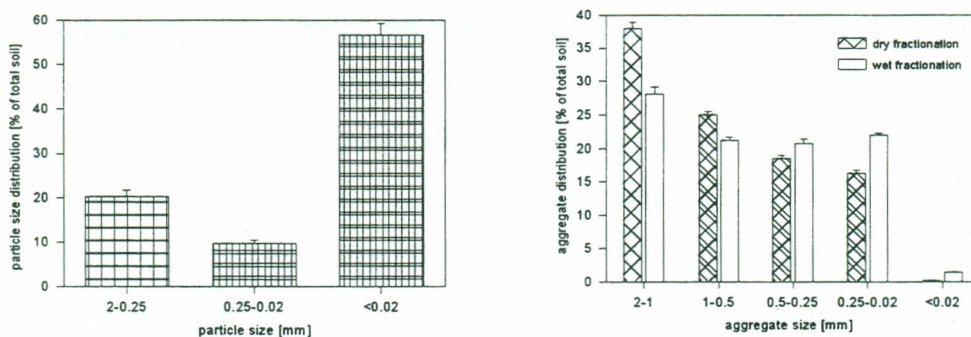
The MWD and the ratio of MWD from wet and dry aggregate fractionation ( $MWD_{\text{wet}}/MWD_{\text{dry}}$ ) was taken as a measure of aggregate stability.

Carbon and nitrogen were analysed by dry combustion with an automatic C/N-Analyser. The lignin content and its stage of oxidative degradation was determined in the the bulk soil, the particle size fractions and all aggregate and POM fractions with combined parallels using alkaline CuO oxidation (Ertel and Hedges, 1984). 500 mg of soil or 50 mg of POM were oxidized with CuO and 2 M NaOH for 2 hours at  $170^\circ\text{C}$  under a  $\text{N}_2$  atmosphere. The oxidation products were

analysed as trimethylsilyl derivatives by capillary gas chromatography (OV-1 column) with a FID detector. The amounts of lignin were calculated as the sum of the phenolic compounds (vanillyl, syringyl and cumaryl compounds, V+S+C). The acid to aldehyde ratio (ac/al) was taken as an indicator of the degree of microbial degradation of the lignin (Ertel and Hedges, 1984). Non-cellulosic (NCS) and cellulosic (CS) sugars were determined with the MBTH method (Beudert, 1988) after sequential acid hydrolysis according to Miltner (1997). Statistical analyses were performed using linear regression (STATISTICA 5.0).

### 3. RESULTS AND DISCUSSION

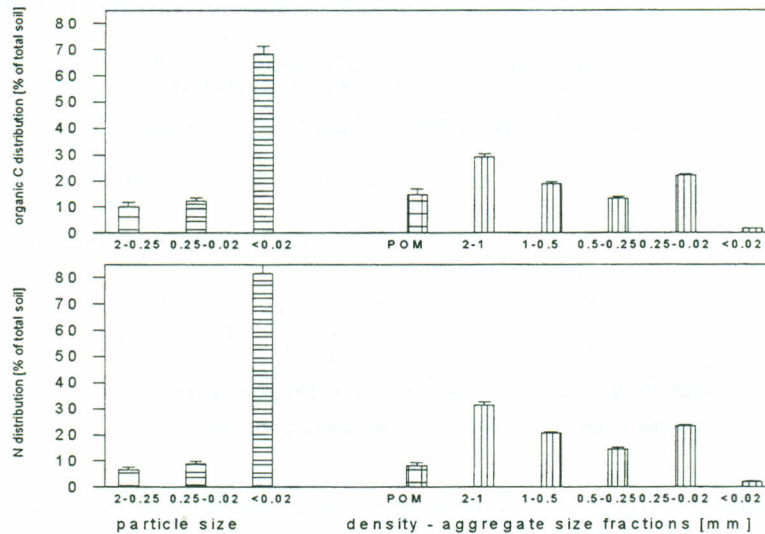
Most of the particles had clay and silt sizes, whereas only 21 and 11 % of the soil constituted of coarse and fine sand, respectively (Figure 3). When the aggregates were not disrupted but dry sieved, however, more than 80 % of the soil was larger than 250  $\mu\text{m}$  (21 % in the coarse sand fraction) and 38 % in the 1-2 mm class (Figure 3). Even with wet sieving, the aggregates larger than 250  $\mu\text{m}$  amounted to 70 %. The aggregate stability seemed to be very high in these soils compared to e.g. a Neubois silty loam from Canada (Angers and Giroux, 1996). Higher aggregate stability was described from an oxisol from Colombia, which had only 10 % of total soil in the fraction  $< 250 \mu\text{m}$  (Gijsman, 1996).



**Figure 3:** Particle (left) and aggregate size distribution of dry and wet fractionation without removal of primary particles (right) as percentages of the whole soil from means of all sites ( $n=10$ ); means and standard errors.

The carbon and nitrogen distribution across particle, density and aggregate fractions accentuates this pattern (Figure 4): 70 % of the organic C was found in clay and silt size separates, only 10 % in the coarse sand. When an aggregate fractionation was performed,

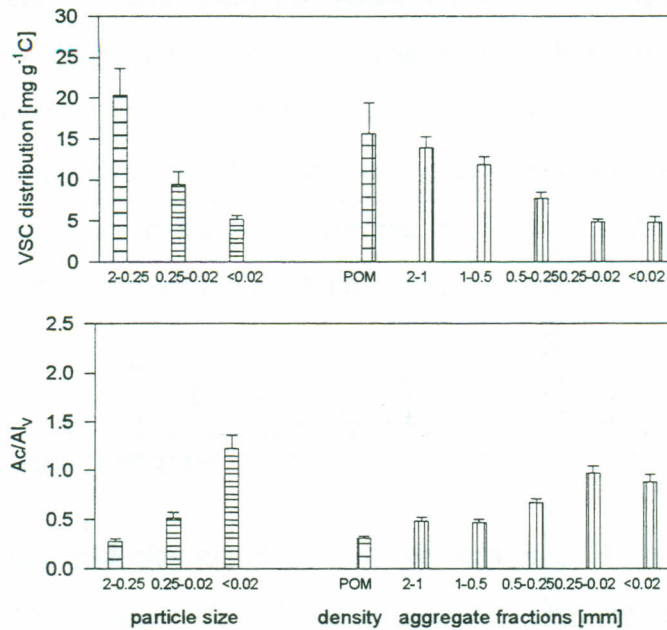
however, less than 2 % of the total soil carbon was found in the fraction  $<20 \mu\text{m}$ , but more than 80 % in aggregates from 0.02-2 mm. In the particulate organic matter (POM), 15 % of the soil organic carbon was found.



**Figure 4:** Organic carbon (above) and nitrogen (below) distribution in particle size, aggregate and density fractions as percentages of the whole soil from means of all sites ( $n=10$ ); means and standard errors.

The lignin distribution (Figure 5) revealed that the coarse sand and POM mainly consisted of labile organic matter i.e. weakly decomposed and humified organic matter. High VSC contents indicate low degradation and low Ac-to-Al ratios indicate low oxidation of intact lignin (Ertel and Hedges, 1984). The coarse sand and POM were expected to be the fractions which react first after land-use changes which was indeed verified for the investigated soils. But also the aggregates 1-2 mm showed relatively high VSC contents compared to POM.

The POM and the coarse sand fraction generally varied more between sites than other soil fractions (Table 1). The differences between sites could be more sensitively assessed by POM stocks, which varied by one order of magnitude, than bulk soil carbon analyses. Although POM constituted only of 15 % of the total soil organic carbon, it was significantly ( $p < 0.001$ ) related to total soil organic carbon. This indicated not only that the effects of trees on SOM was sensitively reflected by POM carbon contents but also that SOM replenishment was related to POM in a functional sense. However, there was no significant relation between the carbon in the coarse sand and bulk soil carbon ( $p < 0.05$ ). Thus, the POM fraction was a better indicator for SOM changes than the coarse sand in terra firme oxisols at our site.



**Figure 5:** VSC-lignin (above) and Ac-to-Al ratios (below) in particle size, aggregate and density fractions (n=10); means and standard errors.

**Table 1:** Coefficients of variation (CV [% standard deviation of mean]) of the carbon and nitrogen contents in particle size, density and aggregate size separates as indicators of the sensitivity of the respective soil pools towards land-use changes (n=10).

Soil pools (fraction [ $\mu\text{m}$ ])	Carbon	Nitrogen
bulk soil	18	10
<i>particle size fractions:</i>		
coarse sand (2000-250)	67	49
fine sand (250-20)	45	46
silt+clay (<20)	17	16
<i>density fraction:</i>		
particulate organic matter	64	59
<i>aggregate size fractions:</i>		
2000-1000	12	16
1000-500	20	14
500-250	25	18
250-20	16	9
<20	21	20



#### 4. CONCLUSIONS

The POM fraction is an important indicator of the effects of different organic inputs on SOM properties. It could be used for assessing the effects of land-use or single-tree effects on SOM. The investigation of different stages of humification and the chemical properties of POM should be intensified. The relationship between aggregation and SOM is only poorly understood and should be continued in future research, as it may give important information about SOM stabilization. The relation between soil organic matter and nutrient availability and the effects of single-trees on the terra firme oxisols is not understood up to now. The soil nutrient availability in different soil pools should be looked at in the future.

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