SOIL QUALITY PARAMETERS OF A XANTHIC FERRALSOL IN THE AMAZON BASIN

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Decline in the productivity of tropical soils under continuous cultivation, even with supplementary fertilisation, is well documented. It confirms that productivity of tropical land use agricultural systems is not only dependent on the stock of nutrients in the soil or the availability of commercial fertilisers, but it is also dependent on the maintenance of the soil structure. A better understanding of the processes affecting the soil following forest conversion to agriculture systems is very important to define which land use systems may maintain the agriculture potential of the clayey Ferralsols in the central Amazon.

The present study was conducted to investigate alterations in soil properties as affected by plant-soil interaction and specific soil management. Three land use systems were investigated. They were i) a conventional monoculture of peach palm (*Bactris gasipaes*); ii) a monoculture of cupuaçu (*Theobroma grandiflorum*) and iii) a complex agroforestry association with peach palm, cupuaçu, Brazil nut (*Bertholletia excelsa*) and annatto (*Bixa orellana*). The soil was covered by *Pueraria phaseoloides* in all systems except the peach palm monoculture. Adjacent areas of primary and secondary forest were investigated for comparison. The study was carried out at the experimental station of Embrapa–Amazônia Ocidental in Manaus, Brazil. The soil is a clayey Xanthic Ferralsol. The climate is classified as Aw (Köppen classification). Disturbed soil samples were collected at ≈ 40 cm far from the trunks. The conventional sieve-pipette sedimentation method was used (EMBRAPA, 1997). Additionally, water dispersible clay was measured by repeating the above described texture analysis, except that the chemical dispersion agent was excluded then indexes of flocculation (IF) were calculated. The soil pH and the cations calcium (Ca^{2+}), magnesium (Mg^{2+}) and aluminium (Al^{3+}) were extracted by N KCl and determined by atomic absorption spectrometry (EMBRAPA, 1997).

RESULTS

The high flocculation indexes indicate that most clay particles in field conditions are flocculated (Table 1). As a consequence of this flocculation and the structured aggregates present in the Ferralsols, these soils behave like sand in terms of water infiltration near saturated conditions but behave like clay soils at higher tensions with respect to infiltration rates and water holding capacity.

Table 1 does not show significant differences for IF between treatments, however, a highly significant difference between the blocks was found (Figure 1). In the blocks C and B the effect of liming and previous fertilisation promoted clay particle deflocculation near the soil surface. A similar effect on clay particle deflocculation by liming was reported by Roth and Pavan (1991).

Table 1 Exploratory analysis indexes of flocculation [%] data set evaluated on different land use system in a clayey Ferralsol in the Central Amazon – Brazil.

Land Use System	Specie	mean	SE of mean	Median	Maximum	Minimum
Agroforestry	Cupuaçu	73.60a	2.49	72.60	69.87	78.33
Agroforestry	Annatto	74.97a	7.35	76.23	61.66	87.01
Agroforestry	Brazil nut	75.41a	4.85	78.37	65.93	81.93
Agroforestry	Peach palm – F	75.72a	2.69	74.96	71.50	80.71
Agroforestry	Peach palm – P	69.80a	7.39	75.33	55.17	78.90
Agroforestry	Pueraria	75.46a	4.71	79.82	66.04	80.52
Monoculture	Cupuaçu	72.13a	4.02	72.49	64.99	78.91
Monoculture	Grasses and pueraria	70.11a	5.96	64.64	63.68	82.01
Monoculture	Peach palm – F(m)	73.11a	8.22	76.07	57.63	85.63
Monoculture	Peach palm – F(mb)	74.68a	1.68	75.65	71.41	76.97
Monoculture	Peach palm –P(m)	73.98a	1.65	74.68	70.84	76.41
Monoculture	Peach palm –P(mb)	68.32a	4.10	70.39	60.41	74.16
Fallow	Vismia	75.23a	6.87	80.12	61.66	83.91
Average		73.27	1.26	74.96	55.17	87.01

m = monoculture; b = between the palms; F = Peach palm for fruits production; P = Peach palm for palm heart production.
Means followed by the same letters within the column, do not differ by Tukey's test (a < 0.05).

Deflocculation after liming is explained by substitution of Al^{3+} by Ca^{2+} and Mg^{2+} on the exchange complex. The ions of Al^{3+} had a greater flocculation power in the original soil conditions, because they are tightly absorbed and compress the electrical double layer (Jury et al., 1991). In the original conditions, i.e., when the soil is covered by primary forest, the clay particles on clayey Ferralsols near Manaus are almost totally flocculated (Teixeira, et al., 1997). This is a consequence of the low pH and its relations with the surface charge of the clay colloids. The experiment was limed in November/December 1996 with 2.1 Mg ha^{-1} of dolomitic lime, which was broadcast in the plots. Soil sampling was conducted on block A before the application of lime, whereas blocks B and C were sampled in January 1997. Figure 1 shows higher values of Ca^{2+}, Mg^{2+} and pH and reduced levels of Al^{3+} for block C. It was probably caused by a more intense use of lime and fertiliser in the previous experiments in those areas. The reduced levels may present near bacabas and matá-matás in the primary forest (Table 2) represent the original levels of these parameters. In the secondary forest the plots were not limed or fertilised during the present experiment, the levels of Ca^{2+} and Mg^{2+} where not so high (Table 2), but confirms an anterior different use of the site. This fact is reflected in a highly significant effect of blocks for the chemical parameters (Figure 1) Variability between blocks clearly does not affect differences between treatment means, since each treatment appears the same number of times in every block. Nevertheless, significant treatment effects were found for pH, Al^{3+} and Ca^{2+}. An important implication of the results is the fact that certain management practices, which improve soil fertility, may be detrimental to soil structure (i.e., liming reduced intra-aggregate bonds by eliminating most positive charges). Fortunately, the origin of the inter-aggregate bonding is non-electrostatic in these Ferralsols, but are principally due to the activity of roots and earthworms (Chauvel, 1982). This fact tends to reduce the detrimental consequences of such changes in the functionality of the soil structure. Therefore, the most visible effects of the collapse of the soil structure, which are normally an expressive reduction of bulk density, could not be observed yet. Conversely, a increase in pH and higher concentration of mineral nutrients in the soil may result in more intense biological activity and the formation of polysaccharides, which promote aggregation and as a probable consequence, the opposite effect would be observed some time later, showing that the deflocculation of clay in the Ferralsols following liming was a temporary phenomenon. Further investigations are necessary to confirm or refute the hypothesis of a better aggregation on a long-term basis from the increase of pH and reduction of Al^{3+}.

CONCLUSIONS

While laboratory measurements of particle size distribution using the classical method with chemical agent of dispersion provided no different results, the flocculation indexes of clay particles indicated changes in the natural aggregation of the clay particles correlated with the reduction of Al level and an increase of the levels of Ca, Mg and pH. The monitoring of chemical parameter and the index of flocculation, which are cheaply and easily evaluated, can be used as indicators of stability of the soil structure of clayey Ferralsols. It is a crucial factor for the sustainability of land use systems on the strongly aggregate clayey Ferralsols that their structure remains stable.

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Table 2 Soil chemical characteristics evaluated on different land use systems in a clayey Ferralsol - Brazil.

Land Use System	Specie	ph	Ca^{2+}§	Mg^{2+}§	Al^{3+}
			$cmol_c\ dm^{-3}$		
Agroforestry	Cupuaçu	4.50 c	1.41 ab	1.10 a	0.99 abc
Agroforestry	Annatto	3.97 abc	0.46 a	0.33 a	1.75 bc
Agroforestry	Brazil nut	4.33 abc	2.26 ab	0.84 a	0.68 ab
Agroforestry	Peach palm – F	4.20 abc	1.49 ab	0.93 a	0.73 ab
Agroforestry	Peach palm – P	4.13 abc	0.97 ab	0.55 a	1.06 abc
Agroforestry	Pueraria	4.17 abc	1.44 ab	1.25 a	1.17 abc
Monoculture	Cupuaçu	4.40 bc	1.61 ab	1.07 a	0.53 a
Monoculture	Grasses and pueraria	3.80 abc	0.50 ab	0.30 a	1.63 abc
Monoculture	Peach palm – F(m)	4.17 abc	0.90 ab	0.68 a	0.95 abc
Monoculture	Peach palm – F(mb)	4.27 abc	0.67 ab	0.41 a	1.36 abc
Monoculture	Peach palm –P(m)	4.07 abc	1.69 ab	1.20 a	0.74 ab
Monoculture	Peach palm –P(mb)	4.57 c	1.51 ab	1.07 a	0.68 ab
Fallow	Vismia	3.77 a	0.19 b	0.18 a	1.95 c
Primary forest	*Escheweilera sp*	3.86	0.05	0.08	1.61
Primary forest	*Oenocarpus bacaba*	3.79	0.04	0.08	1.85

m = monoculture; b = between the palms; F = Peach palm for fruits production; P = Peach palm for palm heart production.§ - Original means (statistical analysis was carried out with transformed data). Means followed by the same letters within the column, do not differ by Tukey's test (a < 0.05). Primary forest data were not include in the statistical analysis..

Figure 1 Graphical means of a) indexes of flocculation [%], b) concentration of aluminium [$cmol_c\ dm^{-3}$] c) concentration of calcium [$cmol_c\ dm^{-3}$] and d) concentration of magnesium [$cmol_c\ dm^{-3}$] evaluate in a clayey Ferralsol in the central Amazon. Error bars represent the standard error of mean.