Aggregate stability in soils cultivated with eucalyptus

Junior Cesar Avanzi[1], Lloyd Darrell Norton[2], Marx Leandro Naves Silva[3], Nilton Curi[3],
Anna Hoffmann Oliveira[3] and Mayesse Aparecida da Silva[3]

[1]Embrapa Pesca e Aquicultura, Quadra 103 Norte, Avenida JK, ACSO 01, Conjunto 01, Lote 17, Térreo, CEP 77015-012 Palmas, TO. E-mail: junior.avanzi@embrapa.br [2]United States Department of Agriculture, Agricultural Research Service, National Soil Erosion Research Laboratory, 275 South Russell Street, Purdue University, 47907-2077 West Lafayette, Indiana, USA. E-mail: norton@purdue.edu [3]Universidade Federal de Lavras, Departamento de Ciência do Solo, Caixa Postal. 3037, CEP 37200-000 Lavras, MG. E-mail: marx@dcs.ufla.br, niltcuri@dcs.ufla.br, anna.ufla@gmail.com, mayesse@gmail.com

Abstract – The objective of this work was to evaluate the aggregate stability of tropical soils under eucalyptus plantation and native vegetation, and assess the relationships between aggregate stability and some soil chemical and physical properties. Argisols, Cambisol, Latosols and Plinthosol within three eucalyptus-cultivated regions, in the states of Espírito Santo, Rio Grande do Sul and Minas Gerais, Brazil, were studied. For each region, soils under native vegetation were compared to those under minimum tillage with eucalyptus cultivation. The aggregate stability was measured using the high-energy moisture characteristic (HEMC) technique, i.e., the moisture release curve at very low suctions. This method compares the resistance of aggregates to slaking on a relative scale from zero to one. Thus, the aggregate stability from different soils and management practices can be directly compared. The aggregate stability ratio was greater than 50% for all soils, which shows that the aggregate stability index is high, both in eucalyptus and native vegetation areas. This suggests that soil management adopted for eucalyptus cultivation does not substantially modify this property. In these soils, the aggregate stability ratio does not show a good relationship with clay or soil organic matter contents. However, soil organic matter shows a positive relationship with clay content and cation exchange capacity.

Index terms: *Eucalyptus* sp., high-energy moisture characteristic curve, forest systems, tropical soils.

Estabilidade de agregados em solos cultivados com eucalipto

Resumo – O objetivo deste trabalho foi avaliar a estabilidade de agregados, em solos tropicais sob cultivo de eucalipto e vegetação nativa, e avaliar as relações entre a estabilidade de agregados e alguns atributos químicos e físicos do solo. Foram estudados Argissolos, Cambissolo, Latossolos e Plintossolo dentro de três regiões com cultivo de eucalipto, nos estados do Espírito Santo, Rio Grande do Sul e Minas Gerais. Para cada região, os solos com vegetação nativa foram comparados aos solos com preparo mínimo sob plantio de eucalipto. A estabilidade de agregados foi determinada por meio da técnica da curva característica da umidade em alta energia (HEMC), isto é, a curva de retenção de umidade na sucção muito baixa. Este método compara a resistência dos agregados à quebra em uma escala relativa de zero a um. Deste modo, a estabilidade de agregado em diferentes solos e práticas de manejo pode ser diretamente comparada. A razão de estabilidade de agregados foi maior que 50% em todos os solos estudados o que indica que o índice de estabilidade de agregados é alto tanto nas áreas com cultivo de eucalipto quanto naquelas com vegetação nativa. Isto sugere que o manejo do solo adotado para o eucalipto não modifica substancialmente este atributo. Nesses solos, a razão de estabilidade de agregados não mostra boa correlação com o conteúdo de argila ou de matéria orgânica. Entretanto, a matéria orgânica do solo mostra uma positiva correlação com o conteúdo de argila e com a capacidade de troca de cátion.

Termos para indexação: *Eucalyptus* sp., curva característica de umidade em alta energia, sistemas florestais, solos tropicais.

Introduction

Eucalyptus plantations play an important role in the economy of several countries. In Brazil, this crop covered about 4.3 million hectares in 2008, with an increase of 7.3% compared with 2007 (Associação Brasileira de Produtores de Floresta Plantada, 2009). Despite the large cultivated area, little is known about how management system of this cultivation affects soil properties.

Many soil physical and chemical properties and agriculture management practices can affect aggregate stability (Levy & Mamedov, 2002; Levy et al., 2003; Norton et al., 2006; Ruiz-Vera & Wu, 2006). The interaction between aggregation and clay content and its mineralogy have been reported by Reichert & Norton

(1994), Levy & Mamedov (2002), Lado et al. (2004), Denef & Six (2005), Norton et al. (2006) and Ruiz-Vera & Wu (2006). Under fast wetting, an increase in clay content inside aggregates also increases the extent of differential swelling and the volume of entrapped air that, in turn, can increase aggregate slaking. Therefore, an increase in clay content in the soil might have two opposite effects on seal formation: an increase in aggregate stability and a reduction in seal formation, and an increase in aggregate slaking, upon wetting, and an increase in soil susceptibility to sealing (Lado et al., 2004). Thus, an increase in clay content does not always result in increased stability, since clay type is an important factor in aggregation (Reichert & Norton, 1994).

Aggregation by iron oxides is evident in Oxisols formed from the Tertiary age sediments in Brazil. This indicates that remobilization of iron during soil formation is essential for iron acting in aggregation. These findings suggest that the mode of formation and iron mineralogy affect aggregation (Muggler et al., 1999). In Brazilian Oxisols, the presence of Al-oxides (gibbsite) conferred a good correlation with aggregate stability, conversely, kaolinite showed a strong negative relationship (Ferreira et al., 1999).

Soil organic matter (OM) is expected to be the primary binding agent in 2:1 clay-dominated soils because polyvalent-organic matter complexes form bridges between the negatively charged clay platelets. In contrast, soil OM is not the only binding agent in oxides and 1:1 clay dominated soils (Six et al., 2000b). The electrostatic interaction between kaolinite, oxides, and vermiculite seem to result in soil stability and not as dependent on soil OM content as soils dominated by 2:1 clays. Due to the binding of particles by electrostatic interactions, soil OM does not have to function as critical binding agent (Six et al., 2000a). This is supported by the observation of aggregate size in kaolinitic soil (Six et al., 2000b). For the more weathered kaolinitc soils (1:1 type clay minerals), soil OM and biological processes played only a partial role in the binding of aggregates (Denef & Six, 2005).

The interaction of soil chemical and physical properties suggests that aggregate stability is a complex group of processes (Levy & Mamedov, 2002; Levy et al., 2003). In addition, soil management and type of vegetation can also change soil aggregation,

because of different organic compounds that are deposited in the soil.

The high-energy moisture characteristic (HEMC) method has been recognized to be a useful method for determining aggregate stability of arid and humid zone soils with different stability levels (Pierson & Mulla, 1989; Levy & Miller, 1997; Levy & Mamedov, 2002; Levy et al., 2003; Norton et al., 2006), and has been also noted for its ability to detect small differences in aggregate stability (Pierson & Mulla, 1989).

The objective of this work was to evaluate the aggregate stability of tropical soils under eucalyptus plantation and native vegetation, and analyze the relationships between aggregate stability ratio and some soil chemical and physical properties.

Materials and Methods

The areas chosen for this study represent the dominant soils used for eucalyptus cultivation in three Brazilian states: Espírito Santo, Rio Grande do Sul and Minas Gerais. Soil classifications are according to Santos et al. (2006) and the corresponding nomenclature, in parentheses, are according to soil taxonomy (Soil Survey Staff, 1999). In Espírito Santo state, the soils selected were classified as Plintossolo Háplico distrófico-FX (Phinthaquox), Argissolo Amarelo distrófico-PA1 (Hapludult), and Argissolo Amarelo moderadamente rochoso-PA2 (Hapludult), which represent more than 80% of soils from the Coastal Plain region. In the South of Brazil the Argissolo Vermelho eutrófico-PVe (Rhodudalf) and Argissolo Vermelho-Amarelo distrófico-PVA (Hapludult) are the main soils, while the Cambissolo Háplico distrófico-CXbd (Dystrudept) represents the shallow soils there. In the Rio Doce Valley, center-east earn of Minas Gerais state, the samples were collected in a Latossolo Vermelho distrófico-LV (Haplustox) and in a Latossolo Vermelho-Amarelo distrófico-LVA (Haplustox), which are the main soils there. Espírito Santo soils were developed from Tertiary age sediments above Precambrian crystalline rocks; in Rio Grande do Sul, soils were formed from granites, being lesser developed pedogenetically due to the subtropical climate; and, in Minas Gerais, they were developed from granitic gneisses of the Precambrian age. For each region, the soils under native vegetation were studied in order to compare them with soils under minimum tillage cultivated with eucalyptus.

Soil samples were taken from the superficial horizons (0–10 cm) from the soils above described. For each place and soil, three soil samples were collected in the treatments with eucalyptus cultivation, in plots of 12 x 24 m, to characterize the particle-size-distribution using the hydrometer method, total porosity (Dane & Topp, 2002), cation-exchange capacity (CEC) using the sodium acetate procedure, organic matter (OM) content by potassium dichromate oxidation and ferrous sulfate titration (Claessen, 1997), iron extracted by dithionite-citrate-bicarbonate (Fe_d), ammonium oxalate (Fe_o), and sulfuric attack (Fe_s) according to Claessen (1997). Through sulfuric attack silicon, aluminum, titanium and phosphorus were extracted. The molecular ratios SiO_2/Al_2O_3 and $SiO_2/(Al_2O_3 + Fe_2O_3)$ were calculated according to Claessen (1997), using Si, Al and Fe from sulfuric attack extraction. The mean geometric diameter (MGD) of stable aggregates was determined by wet sieving (Dane & Topp, 2002) of air-dried aggregates for sizes from 4.75 to 8.00 mm. The soil losses (A_{USLE}) and the erodibility (K factor) were obtained by USLE-plots from previously studies performed by Martins (2005), and Oliveira (2006, 2008).

Aggregate stability was determined for soils under eucalyptus and native vegetation using the high-energy moisture characteristic (HEMC) method (Pierson & Mulla, 1989) modified by Levy & Mamedov (2002). In this method, the wetting process of the aggregates is accurately controlled, and the energy of hydration and entrapped air are the only forces responsible for aggregation breakdown.

Aggregate stability was obtained by quantifying differences in the moisture characteristic curve (MC) between fast and slow wetting (Figure 1A). For a given wetting rate, a structural index (SI) is defined as the ratio of the volume of drainable pores (VDP) to modal suction (Pierson & Mulla, 1989; Levy & Mamedov, 2002). The modal suction (MS) corresponds to the matric potential (ψ, J kg^{-1}) at the peak of the specific water capacity curve ($d\theta/d\psi$), where θ is the water content (kg kg^{-1}) (Figure 1B). The VDP is the area under the specific water capacity curve and above the dotted baseline (Figure 1B). The stability ratio (SR = $SI_{fast\ wetting}/SI_{slow\ wetting}$), was used to compare the resistance of aggregates to slaking on a relative scale from zero to one. Since the SR is a dimensionless value, soil samples of different size fractions and soil

classes can be compared if identical wetting rates and sample handling procedures are used for each sample (Pierson & Mulla, 1989).

Once the aggregates had been saturated (either slowly or rapidly), a MC curve [$\theta = f(\psi)$], at a matric potential (ψ) range of 0 to -3.0 J kg^{-1}, was obtained using a hanging water column. To accurately calculate VDP and MS, modeling of MC curves was carried out with modified van Genuchten model (Pierson & Mulla, 1989). The aggregate stability mean was submitted to Scott-Knott test at 5% probability.
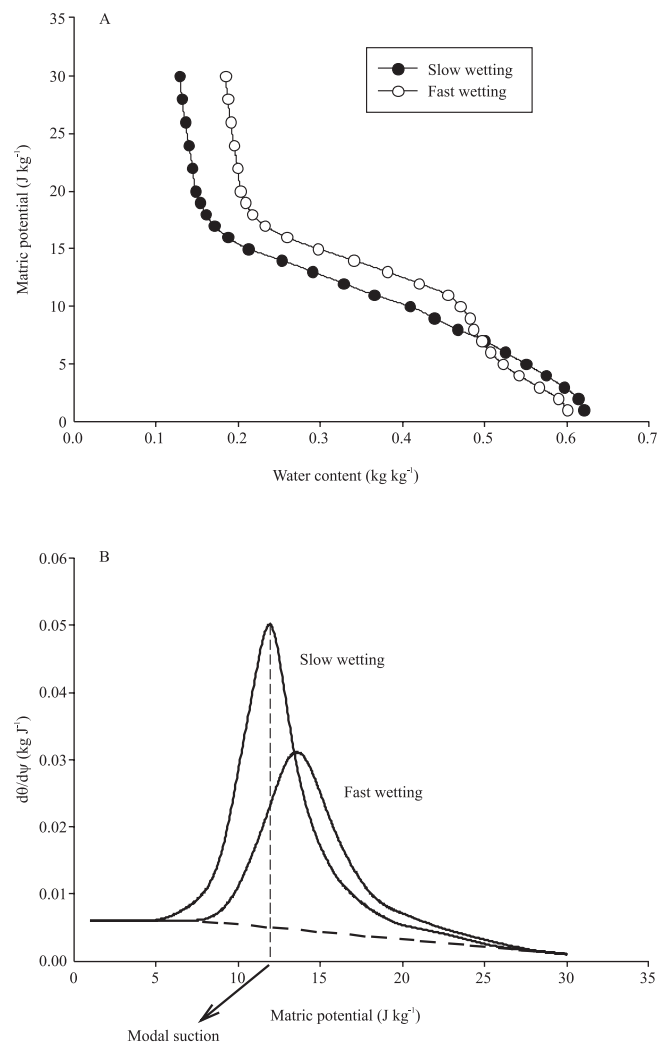

Figure 1. Schematic representation of (A) moisture release and (B) specific water capacity curves for fast and slow wetting. The dashed line in (B) represents soil shrinkage line for slow wetting.

Results and Discussion

Through the SiO_2/Al_2O_3 molecular ratio (Ki), it can be inferred that the soils are in the advanced process of silica removal, since every soil showed a molecular ratio less than 2.2 (Table 1). The Minas Gerais Oxisols had the least SiO_2/Al_2O_3 molecular ratio values. These soils also showed the smallest value of $SiO_2/(Al_2O_3 + Fe_2O_3)$ (Kr) molecular ratio. The lowest values for CEC are expected in such soils, because they are highly weathered and leached; however, these soils showed the highest CEC values. This fact can be atributed to the relatively high organic matter content, which is the most important factor for negative charge in soils with predominance of 1:1 clay minerals. In addition, the highest clay content was also found on soils from this region (Table 2).

The iron extraction by sulfuric attack (Fe_s) ranged from 16 to 77 g kg^{-1} (Table 1). These relatively low values of Fe_2O_3 are probably due to the parent material dominated by granitic gneiss rocks. The small Fe_o/Fe_d ratio is expected in tropical soils due to the removal of silica and oxidation of organic matter, favoring the more stable iron oxides (Fe_d) (Kämpf & Curi, 2000).

The results of physical characterization of the soils showed different textural classes (Table 2). The soils corresponded to the following textural classes: clay (LV and PVe), sandy clay (PA2 and LVA), sandy clay loam (PA1 and CXbd), and sandy loam (FX and PVA). Silt content ranged from 28 to 206 g kg^{-1}, which can produce surface sealing in bare soils when the content is high and greatly reduces the infiltration capacity. The high content of fine sand and very fine sand can also help to formate surface sealing, reducing infiltration

Table 1. Chemical and mineralogical soil properties[1] of the superficial horizon from representative soils cultivated with eucalyptus.

State[2]	Soil[3]	CEC (cmol$_c$ dm^{-3})	OM	Fe$_o$	Fe$_d$	Fe$_s$	SiO$_2$	Al$_2$O$_3$	TiO$_2$	P$_2$O$_5$	Fe$_o$/Fe$_d$	Fe$_d$/Fe$_s$	Ki	Kr
			---------------------------------- (g kg^{-1}) ----------------------------------											
	FX	9.1	31	2.81	12.15	28	72	70	20.6	0.19	0.231	0.434	1.79	1.42
ES	PA1	3.9	14	1.52	13.23	34	98	87	22.4	0.11	0.115	0.389	1.77	1.41
	PA2	8.3	33	1.63	16.44	40	158	153	22.4	0.28	0.099	0.411	1.76	1.51
	PVe	8.4	41	2.73	49.68	53	159	140	9.9	0.34	0.055	0.937	1.92	1.59
RS	CXbd	10.4	36	2.91	27.52	53	103	82	17.5	0.88	0.106	0.519	2.15	1.52
	PVA	6.5	19	1.59	11.62	16	33	26	5.16	0.05	0.137	0.726	2.19	1.56
MG	LV	11.4	42	3.18	63.44	69	177	235	13.6	0.19	0.050	0.919	1.28	1.08
	LVA	11.6	34	1.82	44.68	77	116	173	16.6	0.50	0.041	0.580	1.14	0.89

[1]CEC, cation exchange capacity; OM, organic matter; Fe$_o$, iron extracted by ammonium oxalate; Fe$_d$, iron extracted by dithionite-citrate-bicarbonate; Fe$_s$, iron extracted by sulfuric attack; Ki, SiO$_2$/Al$_2$O$_3$ molecular ratio; and Kr, SiO$_2$/(Al$_2$O$_3$ + Fe$_2$O$_3$) molecular ratio. [2]ES, Espirito Santo; RS, Rio Grande do Sul; MG, Minas Gerais. [3]FX, Plintossolo Háplico distrófico (Phinthaquox); PA1, Argissolo Amarelo distrófico (Hapludult); PA2, Argissolo Amarelo moderadamente rochoso (Hapludult); Pve, Argissolo Vermelho eutrófico (Rhodudalf); CXbd, Cambissolo Háplico distrófico (Dystrudept); PVA, Argissolo Vermelho-Amarelo distrófico (Hapludult); LV, Latossolo Vermelho distrófico (Haplustox); LVA, Latossolo Amarelo-Vermelho distrófico (Haplustox).

Table 2. Soil physical properties of the superficial horizon from representative soils cultivated with eucalyptus[1].

State[2]	Soil[3]	Clay	Silt	Sand	Textural classes[4]	VCS	CS	MS	FS	VFS
		-------------- (g kg^{-1}) -----------------				------------------------ (g kg^{-1}) ------------------------				
	FX	188	87	725	SL	69	146	211	225	75
ES	PA1	269	28	703	SCL	70	175	217	187	54
	PA2	394	72	534	SC	175	128	102	96	34
	PVe	419	206	375	C	50	66	98	122	39
RS	CXbd	288	188	525	SCL	63	109	142	146	65
	PVA	125	159	716	SL	71	232	232	140	42
MG	LV	598	71	331	C	20	74	132	86	20
	LVA	425	109	466	SC	83	94	144	122	22

[1]VCS, very coarse sand; CS, coarse sand; MS, medium sand; FS, fine sand; and VFS, very fine sand. [2]ES, Espirito Santo; RS, Rio Grande do Sul; MG, Minas Gerais. [3]FX, Plintossolo Háplico distrófico (Phinthaquox); PA1, Argissolo Amarelo distrófico (Hapludult); PA2, Argissolo Amarelo moderadamente rochoso (Hapludult); PVe, Argissolo Vermelho eutrófico (Rhodudalf); CXbd, Cambissolo Háplico distrófico (Dystrudept); PVA, Argissolo Vermelho-Amarelo distrófico (Hapludult); LV, Latossolo Vermelho distrófico (Haplustox); LVA, Latossolo Amarelo-Vermelho distrófico (Haplustox). [4]SL, sand loam; SCL, sand clay loam; SC, sand clay; C, clay .

capacity and increasing runoff and, consequently, increasing water and soil losses (Le Bissonnais & Bruand, 1993).

Results for stability ratio (SR) performed using the HEMC technique are presented in Figure 2. The soils showed a stability ratio from 0.59 for the FX to 0.85 for the PA2, both under eucalyptus plantation. All the soils had a stability ratio greater than 50%, suggesting a high level of aggregate stability (Levy & Miller, 1997). This observation indicated that aggregate stability breakdown, due to fast wetting, did not result in a loss of more than 50% of the drainage pores (Levy & Miller, 1997).

Native vegetation was used as reference to non managed soil. Thus, the effect of management practices would be expressed. However, through statistic analysis (Scott-Knott, $\alpha=0.05$) soils did not show difference in SR between land uses (eucalyptus and native vegetation) and even among soil classes. This suggests that soil management adopted for eucalyptus cultivation did not substantially modified this property. The non plowing of the soil within eucalyptus grove areas, during seven-year production cycle, besides

Figure 2. Aggregate stability ratio of soil samples under eucalypt cultivation and native vegetation in Brazil. FX, Plintossolo Háplico distrófico (Phinthaquox); PA1, Argissolo Amarelo distrófico (Hapludult); PA2, Argissolo Amarelo moderadamente rochoso (Hapludult); PVe, Argissolo Vermelho eutrófico (Rhodudalf); CXbd, Cambissolo Háplico distrófico (Dystrudept); PVA, Argissolo Vermelho-Amarelo distrófico (Hapludult); LV, Latossolo Vermelho distrófico (Haplustox); LVA, Latossolo Amarelo-Vermelho distrófico (Haplustox).

soil preparation only at the eucalyptus planting time should also contribute for the eucalyptus stability ratio remaining similar to native vegetation, where both systems provide elevated SR values.

The comparison of soil stability ratios by the HEMC method indicated that aggregate stability in tropical soils are very stable, since Oxisols (very weathered soils) were statistically equal to the Inceptisols (less weathered soils) (Figure 2).

Studies performed by Mamedov et al. (2010) for aggregate stability of smectitic, illitic and kaolinitic soils showed that kaolinitic soils had the greatest stability ratio values (0.61–0.78), probably due to presence of oxides (Muggler et al., 1999; Six et al., 2000b). The SR values reported by these authors were similar to those found in our study (Figure 2). Kämpf & Curi (2003) reported kaolinitic as the most abundant in clay mineral of the Brazilian soils; this information can help to explain the high stability ratio found.

Several studies have been reported the relationships between SR and clay content (Levy & Miller, 1997; Levy & Mamedov, 2002; Levy et al., 2003; Norton et al., 2006; Ruiz-Vera & Wu, 2006), however, the soils studied here did not show a strong SR and clay contet relationship (Table 3). Furthermore, Lado et al. (2004) and Norton et al. (2006) reported that aggregate stability increased with an increase in clay content, due to high aggregation ability of clayey soils, whereas, for tropical soils the trend was less pronounced, probably due to the presence of a large amount of oxides (Six et al., 2000b). For kaolinitic soils associated with iron oxides, the mineralogical effect may overshadow the long-term land use effects (Norton et al., 2006).

The eucalyptus plantation in Espírito Santo soils showed the extreme values of aggregate stability ratio (Figure 2). The lowest SR was found for the FX, which had the greatest amount of iron in noncrystalline forms (highest Fe_o/Fe_d ratio) (Table 1), and low clay content (Table 2). Moreover, the FX soil was classified according to textural class as a sand loam, with high content of fine sand and very fine sand (Table 2). These combinations contributed to generate the lowest SR. In fact, the removal of the Fe-oxides played a very high disaggregation in Oxisols and Inceptisols (Pinheiro-Dick & Schwertmann, 1996). This way, iron oxides confirmed their participation on soil aggregation (Muggler et al., 1999). Aggregation in Oxisols on Tertiary sediments, in Minas Gerais, seems
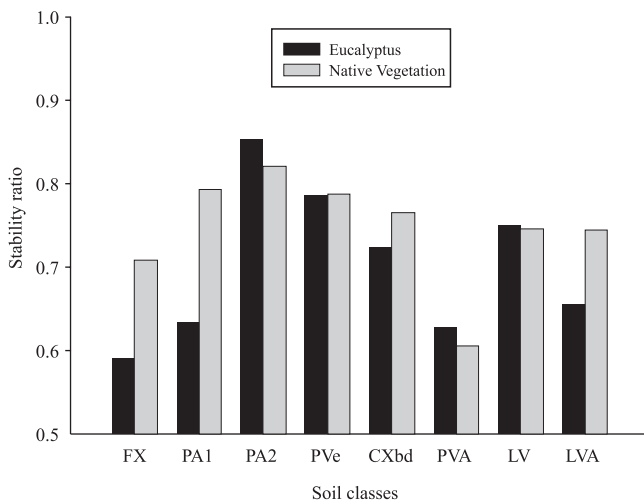
to be strongly influenced by iron oxides (Muggler et al., 1999). Usually, the clay fraction of Oxisols is composed predominantly by kaolinite, gibbsite, goethite and hematite, which form are extremely stable (Lima & Anderson, 1997).

Studies performed under a rainfall simulator showed that soils with the highest clay content produced low runoff and a low sediment concentration (Mamedov et al., 2002) due to large size of the entrained particles (Mamedov et al., 2002; Lado et al., 2004). Thus, a combination of low runoff and low sediment concentration in runoff resulted in lesser soil losses. Nevertheless, soil loss data, obtained through USLE-plots under natural rainfall data compiled from Martins (2005), and Oliveira (2006, 2008), which encompassed the studied area, did not show a correlation with clay content (Table 3). In addition, soil loss showed a weak relationship with silt content, which can affect surface sealing in bare soils causing runoff and then soil losses (Le Bissonnais & Bruand, 1993).

Despite not finding a relationship between SR and soil losses, a negative and weak correlation between SR and soil erodibility (K factor) can be noticed (Table 3). For kaolinitic soils (1:1 minerals), the trend between soil loss and SR was not as significant; furthermore, soil loss was more related to clay dispersibility (Levy & Miller, 1997), whereas, the same authors reported a linear relationship for soils with 2:1 clay minerals.

The soil OM did not show a relationship with SR (Table 3), as was found by Levy & Mamedov (2002) and Levy et al. (2003). Kaolinitic soils have variable charges and a coexistence of both positively and negatively charges. If oxides, rather than soil OM, are the dominant agents in aggregate stabilizability

in weathered soils (Ferreira et al., 1999), the relation between soil OM and macroaggregation might not be as strong as the soils with dominant 2:1 clays (Six et al., 2000b). In addition, in tropical soils where the clay fraction is dominated by 1:1 minerals and oxides, a decrease of soil OM levels results in a smaller decrease of soil stability, in comparison to soils dominated by 2:1 minerals (Six et al., 2000a). Furthermore, the OM lack of correlation with aggregate stability does not imply that soil OM is unimportant in clayey soils structure, but its importance is at a different structure level (Reichert & Norton, 1994). The absence of a relationship between aggregate stability and organic matter content, found in our study, could be linked to the fact that in tropical soils other nonevaluated soil properties, as mineralogy and soil structure, may have a greater impact on aggregate stability and, hence, overshadow the effects of soil organic matter.

Besides stability ratio, soil OM can be influenced by several soil properties. Soil OM showed a positive relationship with clay content (Table 3). Clay particles can generate organic-mineral complexes, which results in an increased accumulation of organic matter. Thus, as clay content increases, both soil surface area and organic matter increase (Scott et al., 1996).

In weathered soils, the main contribution for CEC is due to soil OM, in most cases soil OM in studied soils was more than 3% (Table 1), which can generate a large number of negative charges. A significant relationship was found between soil OM and CEC (Table 3). This way, good management practices that protect soil OM are extremely important to keep or improve soil fertility in these environments. The aforementioned correlation was greater than between CEC and clay

Table 3. Pearson correlation matrix of soil properties under eucalyptus plantation in Brazil[1].

	SR	MGD	TP	K factor	A_{USLE}	CEC	OM	Clay	Silt	Sand
SR	1.00									
MGD	0.20	1.00								
TP	0.03	-0.28	1.00							
K factor	-0.56	0.47	-0.65	1.00						
A_{USLE}	0.33	0.03	-0.52	0.45	1.00					
CEC	0.24	-0.15	0.81**	-0.37	-0.20	1.00				
OM	0.59	0.13	0.51	-0.36	0.22	0.84**	1.00			
Clay	0.63*	0.39	0.56	-0.87*	-0.02	0.57	0.71**	1.00		
Silt	0.17	-0.61	-0.02	-0.10	0.69*	0.25	0.37	-0.15	1.00	
Sand	-0.68*	-0.14	-0.54	0.84*	-0.26	-0.66*	-0.85***	-0.92***	-0.26	1.00

[1]SR, stability ratio; MGD, mean geometric diameter; TP, total porosity; K factor, soil erodibility; A_{USLE}, soil loss from USLE-plots; CEC, cation exchange capacity; OM, organic matter. *, **, ***, significant at 10, 5 and 1% respectively.

content (Table 3). This fact strengthens the information that in soils dominated by 1:1 clay minerals and Al- and Fe-oxides, soil OM can be more important than clay content for explaining CEC context. Levy & Miller (1997) found a direct linear relationship between stability ratio and CEC. Thus, the researchers reported that aggregate stability depends not just on clay content, but also on clay type, with differences expressed in the CEC. Reichert & Norton (1994) also observed that aggregate stability was positively related to CEC for soils with 1:1 clay minerals and oxides, and negatively related with 2:1 clay mineral soils, suggesting that for the latter soils, increasing CEC may decrease aggregate stability due to an increased amount of hydrated cations and degree of swelling and dispersion, however for the studied soils, we did not find any relationship between CEC and SR (Table 3).

Conclusions

1. All the soils evaluated have a high level of aggregate stability determined by the high-energy moisture characteristic technique and do not show any difference between either, eucalyptus cultivation or native vegetation.

2. The aggregate stability of soils is stable and wheathered soils (Oxisols) have a aggregate stability similar to that of less wheathered soils (Inceptisols).

3. The soil organic matter does not show a relationship with the aggregate stability ratio but shows a positive relationship with clay content and cation exchange capacity; and the cation exchange capacity shows no relationship with the aggregate stability ratio.

Acknowledgements

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