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Physical Characterization of A Dystroferric Red Latosols Under Semideciduous Seasonal Forest

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ABSTRACT

Native forests, notedly belonging to Mata Atlântica biome, occupy a crescent highlight as reference in terms of original conditions in relation to actions of soil use and management. The current work aimed to evaluate and compare physical attributes of a typical dystroferric Red Latosol under the remaining of Semideciduous Seasonal Forest at campus of Federal University of Lavras, Minas Gerais state. The profile was sampled up to one meter deep. Results were submitted to variance analysis, multiple comparisons of means (Scott-Knott), correlation and linear regression tests. The profile was homogeneous, and particle density, texture, soil bulk density, total porosity and water holding capacity did not present significant variation up to one meter deep. The distribution of pores by size varied with depth and proportional alterations between macro and microporosity, and total porosity kept unchanged throughout the profile. It was observed a high water aggregates stability, which was correlated to the presence and high contents of organic matter. The profile presented low water holding capacity, signaling that this forest ecosystem is adapted to the condition of relative natural hydric stress during drought period in this region, which is typical of the occurrence area of Semideciduous Seasonal Forest.

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INTRODUCTION

The soil is a natural resource essential to the humanity, it may be considered renewable since it is accordingly used and conserved. Anthropic activities alter original ecosystems and commonly cause the degradation of original characteristics and properties of soil, since the models of use and management rarely contemplate sustainability (Resende *et al*., 1996).

The concept of soil quality includes the evaluation of characteristics, properties and processes related to its capacity to function as a component of a balanced ecosystem (Hillel, 1998; Silva *et al*., 2010). Therefore, soil quality may be defined as the capacity of a specific type of soil to support vegetal and/or animal production, to keep or improve air and water quality, and support human health and housing inside the limits of natural ecosystems, or managed by men. Thereby, efforts for conservation and protection of this natural resource and, consequently, of environmental quality, deserve the attention of the contemporary society (Karlen *et al*., 1997).

The characteristics, properties and processes of soil are sensible to management perturbations and are related to the productive capacity of the original or managed ecosystem. Among indicators of soil quality we can mention physical attributes, as structure, texture, bulk density, porosity and available water capacity. The structure refers to the shape and size of aggregates. The stability of aggregates describes the capacity of soil to keep its arrangement, it means, the strait relation between solid fraction and empty spaces which compose it, in relation to natural factors of the environment or external interventions. Texture influences several chemical, physical and biological attributes of soil. The water holding capacity measures the relative soil capacity to provide water. The porosity may be a sensible indicative of an inductive management of physical changes and imbalances between water and soil (Jong Van Lier, 2010).

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Considering different time scales, some physical attributes of soil are almost static (characteristics) and resistant to management practices, while others are dynamic and changeable (properties). But the set of physical attributes expresses the extent in which each property, characteristic or process is useful to measure soil quality, allowing its management in time or space. The challenge is the improvement of knowledge and understanding about this attributes in order to preview the dynamic behavior of soil processes and the impact of management practices on these processes. The capacity to face this challenge is fundamental on determining the sustainability of the use and management of soil and ecosystems (Schoenholtz *et al*., 2000).

Forests develop a particular role on forming and protecting soil due to the constant deposition and renewing of the organic litter on its surface (Fisher and Binkley, 2000). Therefore, the characterization of forest soils constitutes an important reference for the assessment of alterations caused by its use and management. In terms of forest ecosystems in Brazil, the typology Semideciduous Seasonal Forest highlights, it represents the main component of the threatened biome Mata Atlântica which original distribution involves continental regions under seasonal climate far from maritime influences (Veloso *et al*. 1991).

Thus, the profile of forest soils is commonly used as reference in works regarding the evaluation of quality and effects of the use and management of soil on its physical attributes (Martins *et al*., 2002; Silva *et al*. 2005; Centurion *et al*., 2007; Neves *et al*., 2007; Melloni *et al*., 2008).

This manner, the current study aimed to characterize and analyze physical attributes of the profile of soil under remaining of semideciduous seasonal forest.

MATERIAL AND METHODS

This work was developed in a remaining of Semideciduous Seasonal Montana Forest with 5.8 ha, located at the Federal University of Lavras, Minas Gerais State; coordinates 21°13'40" S; 44°57'50" W and 925 m altitude, on typic dystroferric Red Latosol, very clayey texture (Dias and Oliveira-Filho, 1996). The regional climate is type Cwa with mean annual temperature of 20.4° C and mean annual precipitation of 1460 mm (Dantas *et al*., 2007).

The study of the vegetal cover on this area revealed 184 tree species distributed in 119 genera and 52 families, highlighting the species *Copaifera langsdorffii, Ocotea odorifera, Amaioua guianensis, Casearia arborea e Tapirira obtusa* (Oliveira-Filho *et al*., 1994). The area has never suffered clearcutting and has approximately the same geographic limits at least since 1920, but it suffered eventual interventions until 1986 for removal of wood, as well as opening trenches for soil studies.

The physical characterization of soil profile was made through four sampling points randomly selected, removing undisturbed soil samples with Uhland sampler and volumetric rings with 6.4cm of diameter and 2.54 cm high; and disturbed soil samples, both collected in seven layers: 0-3, 5-8, 10-13, 15-18, 20-23, 60-63 and 100-103 cm.

The following analysis were performed in laboratory: texture through the method of Bouyoucos (Embrapa, 1997); soil bulk density (Blake and Hartge, 1986a); particle density through the method of volumetric flask (Blake and Hartge, 1986b); total porosity (Danielson and Sutherland, 1986); distribution of macro and micropores in undisturbed soil samples through suction units at 60 cm high of a water column (Grohmann, 1960). Organic matter content was determined through humid oxidation (Embrapa, 1997).

The aggregate of stability in water was determined in soil samples of 25 g of aggregate with diameter from 4.76 to 7.93 mm obtained through the previously sieving of the soil samples. These aggregates were submitted to slow moistening and put in a set of sieves with diameters 5; 1.5; 0.75; 0.375; 0.1775 and 0.0525 mm, immerse in water and shaken in Yoder mechanical oscillator , with frequency of 32 cycles per minute and 4 cm of vertical amplitude during 15 minutes (Kemper and Rosenau, 1986). After sieving in water, the proportion of each aggregate class was calculated in relation to the total, proceeding with the calculus of mean geometric diameter (MGD) through the equation:

$$\mathbf{MGD = 10^{\frac{\sum_{i=1}^{n}[wi*\log(xi)]}{\sum_{i=1}^{n} wi}}}$$

Where: wi is the percentage of aggregates in different classes; xi is the mean value of each class (mm).

The water retention curve was determined in homogenized disturbed soil collected at the layers of 0 to 20 cm and from 60 to 100 cm, representing A and B horizons respectively, which were submitted to suctions of 0.002; 0.004; 0.006; 0.01; 0.033; 0.1; 0.5 and 1.5 MPa (Klute, 1986). The available water capacity (AWC) was calculated through the difference between soil moisture in the field capacity of 0.006 MPa (Reichardt, 1988) and in the permanent wilting point (PWP) of 1.5 MPa (Klein, 2008).

All analyzes were performed at the laboratory of Soil Physics of the Soil Science Department, Federal University of Lavras. The results were submitted to variance analysis, considering randomized design, with four repetitions. The means were compared statistically by Scott-Knott test, at 5% of significance.

Analyzes of Pearson simple linear correlation were performed by t test at 5% of significance.

Linear models were fitted for significant correlations, evaluated by t test (model significance) and by determination coefficient (fitted R²).

Data of soil water retention were analyzed considering the entirely randomized design in factorial scheme 7x2, it means, seven suction pressures and two horizons (A and B), with four repetitions.

Variance analysis and tests of multiple comparisons were performed using the statistical software SISVAR (Ferreira, 2008), and regression analysis were performed through the R software (R Development Core Team, 2011).

RESULTS AND DISCUSSION

Texture, soil bulk density, total porosity and particle density did not vary significantly in deep throughout the profile (Table 1). The mean observed values were 157 ± 8 g of sand; 99 ± 5 g of silt and 746 ± 8 g of clay by kilogram of soil; 0.93 ± 0.04 g cm^{-3}; 0.633 ± 0.014 m^{-3} and 2.53 ± 0.05 g cm^{-3}, for the bulk density, total porosity and particle density, respectively.

These results indicate a physical uniformity of these attributes in soil profile. The high porosity and low soil bulk density indicate good conditions of structure, aeration and drainage, which may be related to the high clay and organic matter content, thus configuring the porous and massive aspect *in situ* and granular structure type ground coffee, typical characteristics of dystroferric Red Latosol (Embrapa, 2006). According to Camargo and Alleoni (1997), the characteristic value of bulk density of the Latosols is approximately 0.95g cm^{-3}.

Table 1: Summary of variance analyzes results for the studied characteristics and physical properties of dystroferric Red Latosol.

Variation factor	DF	Mean square				
		OM	MGD	Sand	Silt	Clay
Depth	6	9.1007*	0.1379*	247.6190^{ns}	184.5238^{ns}	984.5238^{ns}
Error	21	0.7029	0.0323	151.1905	163.0952	321.4286
	VC	15.14	3.76	7.82	12.91	2.40
		BD	TP	Macro	Micro	PD
Depth	6	0.0055^{ns}	0.0008^{ns}	0.0049*	0.0020*	0.0108^{ns}
Error	21	0.0026	0.0004	0.0013	0.0003	0.0043
	VC	5.53	3.21	11.85	5.33	2.58

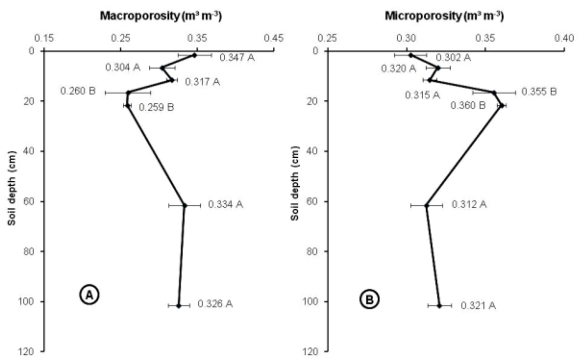

Fig. 1: Macroporosity (A) and microporosity (B) of dystroferric Red Latosol profile. Means followed by the same letter did not differ at 5% of significance by Scott-Knott test.

DF: degrees of freedom; VC: variation coefficient (%); OM: Organic matter content; MGD: mean geometric diameter; BD: Soil bulk density; TP: total porosity; Macro: macroporosity; Micro: microporosity; PD: Particles density; * significant at 5% by F test; ^{ns} not significant at 5% by F test.

Despite total porosity did not alter significantly throughout the profile, alterations were observed on pore size distribution regarding depth, with reduction of macroporosity and proportional increase of microporosity, since total porosity kept unchangeable in the profile (Figure 1). The presence of a dense layer between 10 and 25 cm was observed, what also was reported by Silva *et al*. (2005).

Considering that Hillel (1998) proposed 0.30 to 0.60 m³ m-3 of total porosity and the minimum 0.06 to 0.20 m³ m-3 of macropores as adequate condition, it was possible to verify that the studied profile presented satisfactory values regarding the soil porosity.

The simple linear correlation analysis showed significant relation among variables of the soil porosity (Table 2), which fitted statistic models are presented on Figure 2. An inverse behavior among bulk density, total porosity and macroporosity was observed. Clear trends may be observed, like the decrease of soil bulk density followed by an increase on total porosity, macro and microporosity. Moreover, there is a dynamic balance in the transformation of macro in micropores (Figures 1 and 2D), and vice versa, over the composition of total porosity throughout the profile, since total porosity did not vary significantly in depth, according to what was reported previously.

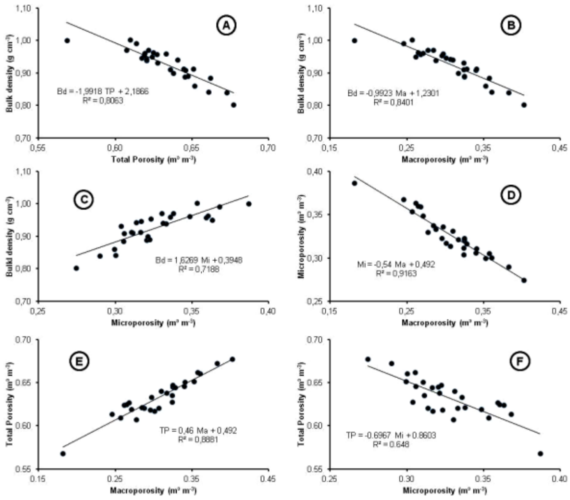

Fig. 2: Relation among attributes of soil porous complex: soil bulk density and total porosity (A), and macroporosity (B) and microporosity (C); microporosity and macroporosity (D); total porosity and microporosity (E) and macroporosity (F).

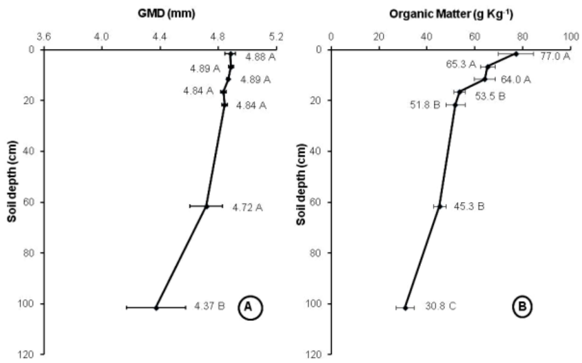

Fig. 3: Mean geometric diameter of aggregates (A) and organic matter content (B) in the dystroferric Red Latosol profile. Means followed by the same letter did not differ at 5% of significance by Scott-Knott test.

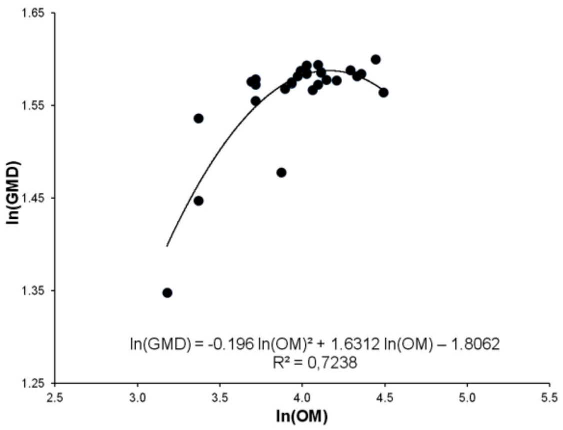

Fig. 4: Relation between mean geometric diameter (MGD in mm) and organic matter content (OM in g kg^{-1}) in the dystroferric Red Latosol profile. Significant at 1%; variation coefficient of 2.8%; standard error of the estimative equal to 0.132mm.

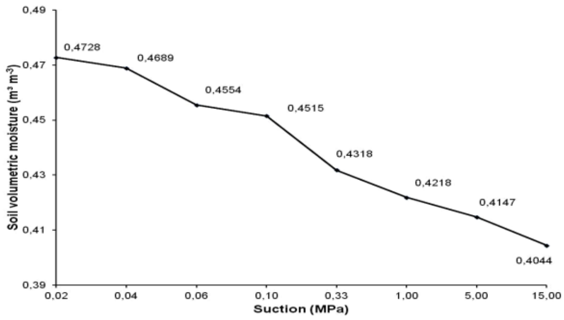

Fig. 5: Mean retention water curve for the dystroferric Red Latosol profile.

Argenton *et al*. (2005) also observed pattern of correlations similar to that found in the present work, it means, harrow and direct relationship among total porosity, macroporosity and soil bulk density, and low relations with microporosity. Mean geometric diameter (MGD) and organic matter content varied with depth in the profile (Figure 3). Correlation analysis detected significant and positive correlation between organic matter content and MGD (Table 1), and a linearized parabolic model related to these two variables was fitted (Figure 4).

Table 2: Linear correlation among characteristics and properties of dystroferric Red Latosol.

	OM	BD	TP	Micro	Macro	PD	MGD	Clay	Sand	Silt
OM	1									
BD	-0.15	1								
TP	-0.10	-0.95*	1							
Micro	-0.16	0.88*	-0.81*	1						
Macro	0.04	-0.96*	0.94*	-0.96*	1					
PD	-0.59*	0.10	0.10	0.06	0.01	1				
MGD	0.60*	-0.07	-0.13	-0.01	-0.06	-0.41	1			
Clay	-0.14	0.13	-0.06	-0.03	-0.02	0.21	-0.22	1		
Sand	0.53*	-0.22	0.07	-0.14	0.12	-0.40	0.16	-0.53*	1	
Silt	0.05	0.05	-0.08	0.10	-0.09	0.14	0.19	-0.55*	-0.13	1

DF: degrees of freedom; VC: variation coefficient (%); OM: Organic matter content; MGD: mean geometric diameter; BD: Soil bulk density; TP: total porosity; Macro: macroporosity; Micro: microporosity; PD: Particles density; * significant at 5% by t test.

MGD values (Figure 3A) were relatively high. but coherent for soils under native forests in comparison to the obtained for soils under other types of vegetal cover. Martins *et al*. (2002) observed MGD of 4.7 mm under forest. and from 2.04 to 2.72 mm under eucalypt, pine and rubber.

This high MGD suggests that these large aggregates is provided by the native forest ecosystem, possibly to the protection and continuous process of cycling and incorporation of organic matter to the soil, conditioning the observed physical properties, notedly those related to bulk density, porosity and aggregate of stability (Leroy *et al*., 2008). Santos *et al*. (2006) observed bulk density values for forest soil between 0.85 and 0.95 g cm^{-3}; Argenton *et al*. (2005) found values between 0.65 and 0.90 g cm^{-3}; Centurion *et al*. (2007) found 1.08 g cm^{-3}; and Martins *et al*. (2002) found 1.03 g cm^{-3}. Regarding porosity of soil under native forest, Martins *et al*. (2002) found 0.44 m^3 m^{-3} of micropores and 0.18 m^3 m^{-3} of macropores; Giarola *et al*. (2007) reported macropores between 0.10 and 0.15 m^3 m^{-3} and micropores between 0.45 and 0.52 m^3 m^{-3}; Centurion *et al*. (2007) found values equal to 0,286 m^3 m^{-3} of macropores and 0,295 m^3 m^{-3} of micropores; Argenton *et al*. (2005) observed macroporosity between 0.20 and 0.35 m^3 m^{-3} and microporosity between 0,38 and 0,50 m^3 m^{-3}.

Analyzing variance of individual points and also mean water retention curves, significant differences on moisture retention between the A and B horizons were not observed, demonstrating again the physical uniformity condition of the soil profile. The mean water retention curve is shown on Figure 5.

From data of water retention curve of the profile, and considering the field capacity of 0.006 KPa and permanent wilting point of 1.5 KPa, the mean value of water holding capacity (AWC) of the profile up to one meter deep was 0.051 m^3 m^{-3}. Beutler *et al*. (2002) also found several values of AWC between 0.046 and 0.052 m^3 m^{-3} for latosols under native forest cover. The value of mean AWC is low, according to Costa *et al*. (2006), who proposes 0.13 m^3 m^{-3} as adequate value.

Thus, considering the low soil AWC and the regional tropical climate type Cwa with dry winters and rainy summers (Dantas *et al*., 2007), it is possible to infer that during the season of prolonged drought, vegetation is submitted to a significant hydric stress, confirmed by the partial deciduous condition of trees, typical of semideciduous seasonal forest.

According to Veloso *et al*. (1991), the occurrence of semideciduous seasonal forest is ecologically conditioned by climatic seasonality characterized by a period of intense summer rain followed by a prolonged drought period during winter (4 to 6 months), configuring from 20% and 50% deciduous trees of the forest.

Conclusions:

The profile of typical dystroferric Red Latosol under Semideciduous Seasonal Forest cover was homogeneous, with a little variation on its characteristics and physical properties. Particles density and texture, besides soil bulk density, total porosity and water retention, did not present significant variation up to one meter deep.

The pore size distribution varied with depth, with proportional alterations between macro and microporosity, keeping unaltered the total porosity of the profile.

The presence of large stable aggregates were detected in water (MGD > 4.5mm), which was correlated to the presence and high organic matter contents.

The general profile condition, characterized as porous massive, provided low water holding capacity (0.051 m^3 m^{-3}), suggesting that this forest ecosystem is adapted to the relative condition of natural hydric stress during the drought period in the region, typical of the occurrence area of Semideciduous Seasonal Forest.

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REFERENCES

Argenton, J., J.A. Albuquerque, C. Bayer, L.P. Wildner, 2005. Comportamento de atributos relacionados com a forma da estrutura de Latossolo Vermelho sob sistemas de preparo e plantas de cobertura. Revista Brasileira de Ciência do Solo, Viçosa, 29: 425-435.

Beutler, A.N., J.F. Centurion, Z.M. Souza, I. Andrioli, C.G. Roque, 2002. Retenção de água em dois tipos de Latossolos sob diferentes usos. Viçosa: Revista Brasileira de Ciência do Solo, 26 (3): 829-834.

Blake, G.R., K.H. Hartge, 1986a. Bulk density. In: Klute, A. (ed.). Methods of soil analysis. 2 ed. Madison: American Society of Agronomy, 1: 363-375.

Blake, G.R., K.H. Hartge, 1986b. Partycle density. In: klute, a. (ed.). Methods of soil analysis. 2 ed. Madison: American Society of Agronomy, 1: 377-382.

Camargo, O.T., L.R.F. Alleoni, 1997. Compactação do solo e o desenvolvimento das plantas. Piracicaba: ESALQ/USP.

Centurion, J.F., O.S. Freddi, R.G. Aratani, A.F.M. Metzner, A.N. Beutler, I. Andrioli, 2007. Influência do cultivo da cana-de-açúcar e da mineralogia da fração argila nas propriedades físicas de Latossolos Vermelhos. Viçosa: Revista Brasileira de Ciência do Solo, 31: 199-209.

Costa, E.A., W.J. Goedert, D.M.G. Sousa, 2006. Qualidade de solo submetido a dois sistemas de cultivo: preparo convencional e plantio direto. Brasília: Pesquisa Agropecuária Brasileira, 41(7): 1185-1191.

Danielson, R.E., P.L. Sutherland, 1986. Porosity. In: Klute, A. (ed.). Methods of soil analysis. 2 ed. Madison: American Society of Agronomy, 1: 443-461.

Dantas, A.A.A., L.G. Carvalho, E. Ferreira, 2007. Classificação e tendências climáticas em Lavras, MG. Lavras: Ciência e Agrotecnologia, 35(5): 2163-2171.

Dias, H.C.T., A.T. Oliveira-Filho, 1996. Fenologia de quatro espécies arbóreas de uma Floresta Estacional Semidecídua Montana em Lavras, MG. Lavras: Cerne, 2(1): 66-88.

Embrapa, 1997. Centro Nacional de Pesquisa de Solos. Manual de métodos de análise de solos. 2.ed. Rio de Janeiro: Embrapa.

Embrapa, 2006. Centro Nacional de Pesquisa de Solos. Sistema brasileiro de classificação de solos. 2.ed. Rio de Janeiro: Ministério da Agricultura e do Abastecimento.

Ferreira, D.F., 2008. Sisvar: um programa para análises e ensino de estatística. Lavras: Revista Symposium, 6: 36-41.

Fisher, R.F., D. Binkley, 2000. Ecology and management of forest soils. 3.ed. New york: John Wiley & Sons.

Giarola, N.F.B., C.A. Tormena, A.C. Dutra, 2007. Degradação física de um Latossolo Vermelho utilizado para produção intensiva de forragem. Viçosa: Revista Brasileira de Ciência do Solo, 31: 863-873.

Grohmann, F., 1960. Distribuição do tamanho de poros em três tipos de solo do estado de São Paulo. Campinas: Bragantia, 73(2): 319-328.

Hillel, D., 1998. Environmental soil physics. San Diego: Academic Press.

Jong Van Lier, Q., 2010. Física do solo. Viçosa: Sociedade Brasileira de Ciência do Solo.

Karlen, D.L., J.J. Mausbach, J.W. Doran, R.G. Cline, R.F. Harris, G.E. Schuman, 1997. Soil quality: a concept, definition, and framework for evaluation. Madison: Soil Science Society of American Journal, 61: 4-10.

Kemper, W.D., R.C. Rosenau, 1986. Aggregate stability and size distribution. In: Klute, A. (ed.). Methods of soil analysis. 2 ed. Madison: American Society of Agronomy, 1: 425-442.

Klein, V.A., 2008. Física do solo. Passo Fundo: Universidade de Passo Fundo.

Klute, A., 1986. Water retention: laboratory methods. In: Klute, A. (ed.). Methods of soil analysis. 2.ed. Madison: American Society of Agronomy, 1: 635-686.

Leroy B.L.M., H.M.S.K. Herath, S. Sleutel, S. De Neve, D. Gabriels, D. Reheul, M. Moens, 2008. The quality of exogenous organic matter: short-term effects on soil physical properties and soil organic matter fractions. Soil Use and Management, 24(2): 139-147.

Martins, S.G., M.L.N. Silva, N. Curi, M.M. Ferreira, 2002. Avaliação de atributos físicos de um Latossolo Vermelho distroférrico sob diferentes povoamentos florestais. Lavras: Cerne, 8(1): 32-41.

Melloni, R., E.G.P. Melloni, M.I.N. Alvarenga, F.B.M. Vieira, Avaliação da qualidade de solos sob diferentes coberturas florestais e de pastagem no sul de Minas Gerais. Viçosa: Revista Brasileira de Ciência do Solo, 32(6): 2461-2470.

Neves, C.M.N., M.L.N. Silva, N. Curi, E.L. Cardoso, R.L.G. Macedo, M.M. Ferreira, F.S. Souza, 2007. Atributos indicadores da qualidade do solo em sistema agrossilvopastoril no noroeste do estado de Minas Gerais. Piracicaba: Scientia Forestalis, 74(2): 45-53.

Oliveira-Filho, A.T., J.R.S. Scolforo, J.M. Mello, Composição florística e estrutura comunitária de um remanescente de Floresta Semidecídua Montana em Lavras, MG. São Paulo: Revista Brasileira de Botânica, 17(2): 167-182.

Development Core Team, R., 2011. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing.

Resende, M., Ker, J., A.F.C. Bahia Filho, 1996. Desenvolvimento sustentado no cerrado. In: Alvarez V.V.H.; Fontes, L.E.F.; Fontes, M.P.F. (eds). O solo nos grandes domínios morfo-climáticos do Brasil e o desenvolvimento sustentado. Viçosa: SBCS/UFV/DPS, 169-199.

Reichardt, K., 1988. Capacidade de campo. Viçosa: Revista Brasileira de Ciência do Solo, 12: 211-216.

Santos, M.L., M.P. Carvalho, R.M.A. Rapassi, C.T. Muraishi, A. Maller, F.A. Matos, 2006. Correlação linear e espacial entre produtividade de milho (*Zea mays* L.) E atributos físicos de um Latossolo Vermelho distroférrico sob plantio direto do cerrado brasileiro. Maringá: Acta Scientiarum Agronomy, 28(3): 313-321.

Silva, R.R., M.L.N. Silva, M.M. Ferreira, 2005. Atributos físicos indicadores da qualidade do solo sob sistemas de manejo na bacia do alto do Rio Grande – MG. Lavras: Ciência e Agrotecnologia, 29(4): 719-730.

Silva, A.P., C.A. Tormena, M.S. Dias Junior, S. Imhoff, V.A. Klein, 2010. Indicadores da qualidade física do solo. In: Jong van Lier, Q. Física do solo. Viçosa: Sociedade Brasileira de Ciência do Solo.

Schoenholtz, S.H., H. Van Miegroet, J.A. Burger, 2000. A review of chemical and physical properties as indicators of forest soil quality: challenges and opportunities. Madison: Forest Ecology and Management, 138: 335-356.

Veloso, H.P., A.L.R. Rangel Filho, J.C.A. Lima, 1991. Classificação da vegetação brasileira adaptada a um sistema universal. Rio de Janeiro: IBGE; Departamento de Recursos Naturais e Estudos Ambientais.