

## Full Length Research Paper

## The effect of vegetation covers on the physical properties of a red latosol

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In this study, the physical properties of a red latosol were assessed under Cerrado (a Savannah like vegetation type) and under of *Eucalyptus grandis* cultivation. Two contiguous sites of 14 ha each showing similar original vegetation cover, slope, topographic position, soil type, and sun exposure (aspect) were selected. Systematically, 20 sampling points were distributed in each site, from which soil deformed samples were collected to determine soil texture and non-deformed soil samples were collected to determine apparent density, volumetric soil moisture, and penetration resistance. Based on this study's results, it was observed that by changing land cover of Cerrado vegetation to cultivation, *E. grandis* provided no significant changes, Scott-Knott test ( $\alpha = 0.05$ ) of soil penetration resistance, density, and volumetric moisture of the red latosol.

**Key words:** Cerrado vegetation, *Eucalyptus grandis*, land use, land cover change.

### INTRODUCTION

Anthropogenic pressure on the Cerrado biome has grown in recent decades due to the increase in population density in the region and the horizontal expansion of the agricultural frontier. The conversion of new areas into agricultural lands, pastures, and forestry causes destruction of large areas of native vegetation and major changes in the physical and biotic environment. In these regards, it is necessary to conciliate human needs with the conservation of natural resources by adopting alternative and more sustainable land uses. Hence, it is

fundamental to assess the impact of these land use changes caused by several anthropogenic uses as observed by Effgen et al. (2012), Tavares Filho et al. (2014), Effgen et al. (2015) and Stone et al. (2015).

Agricultural soils, such as those in originally dense vegetation in the Cerrado regions, represent an important rural frontier in Brazil. According to current legislation, these soils may suffer alterations in their use and occupation by converting them to agricultural lands, pastures or silvicultural sites. Therefore, they are subject

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to modifications in their physical and chemical attributes depending on the type of land use and management systems adopted. Its degradation effects are, therefore, a great environmental concern (Effgen et al., 2012, 2015; Stone et al., 2015). Furthermore, if soil degradation can be reversed, its qualities are maintained or improved using appropriate management methods; the sustainability of the agroecosystem may become a reality. Knowing soil quality under natural conditions and comparing these conditions to those resulting from different uses are essential to determine strategies for sustainable management.

Among the anthropic uses to which areas have been converted in the Cerrado biome is silviculture with crops of homogeneous eucalyptus (*Eucalyptus* species). By comparing *Eucalyptus* plantations to other land use types, such as pastures and agricultural lands, which are more commonly observed and encompasses much larger spatial and temporal scale, forestry is considered a more important economic activity at the national scenario and historically in the Cerrado region. There is a growing demand in wood products by industries such as energy (firewood, wood chips and charcoal), construction (shoring, plywood, structures, etc.), farmo-chemical production (oils, essences, resin, rubber, etc.), livestock (forage and wood), agriculture (mentoring, substrate, etc.), and in the environmental area (CO<sub>2</sub> sequestration) (Silva et al., 2010; Soares et al., 2017).

Silvicultural activities generally occur in a longer cycle in relation to agricultural and livestock activities. They generally promote less demanding species in regards to soil chemistry and physics, since they are less dependent on pesticides; they minimize the action of erosive agents; they require reduced soil preparation and a long cycle between planting-harvesting-planting; they have a high soil nutrient cycling potential throughout the cutting cycle by litter deposition (Pinto et al., 2016); their cultural practices are less intense and use fewer machines or devices while planting and cultivating; when properly managed, they have the potential to provide shelter for fauna, allowing the integrated promotion of natural resource production and conservation (Soares et al., 2017). The evaluation of alterations in soil caused by changes in land use and occupation can become an important parameter to evaluate the sustainability of newer approaches that meet human needs (Silva et al., 2010).

Physical properties of soil generally reflect the positive and negative impacts of management on soil conservation and on the quality of the ecosystem involved (Silva et al., 2010). Since the physical properties of soil are easily and rapidly obtained specially the soil apparent density and penetration resistance, they are important measurements for the *in situ* assessment of management quality, as well as of the economic and environmental viability of forest production. Many within the scientific community focus on the physical properties

of soils, since they evidence the negative impact of inadequate management through soil compaction. This can be aggravated by secondary problems and severely compromise the environmental quality of the production system (Effgen et al., 2015; Effgen et al., 2012).

This research hypothesized that land use conversion of Cerrado vegetation to silviculture with homogenous plantation of *Eucalyptus grandis* will significantly affect soil physical properties. Thus the study's objectives were to estimate changes in soil density, penetration resistance, and moisture as evidence of land use and land cover change in the study site.

## MATERIALS AND METHODS

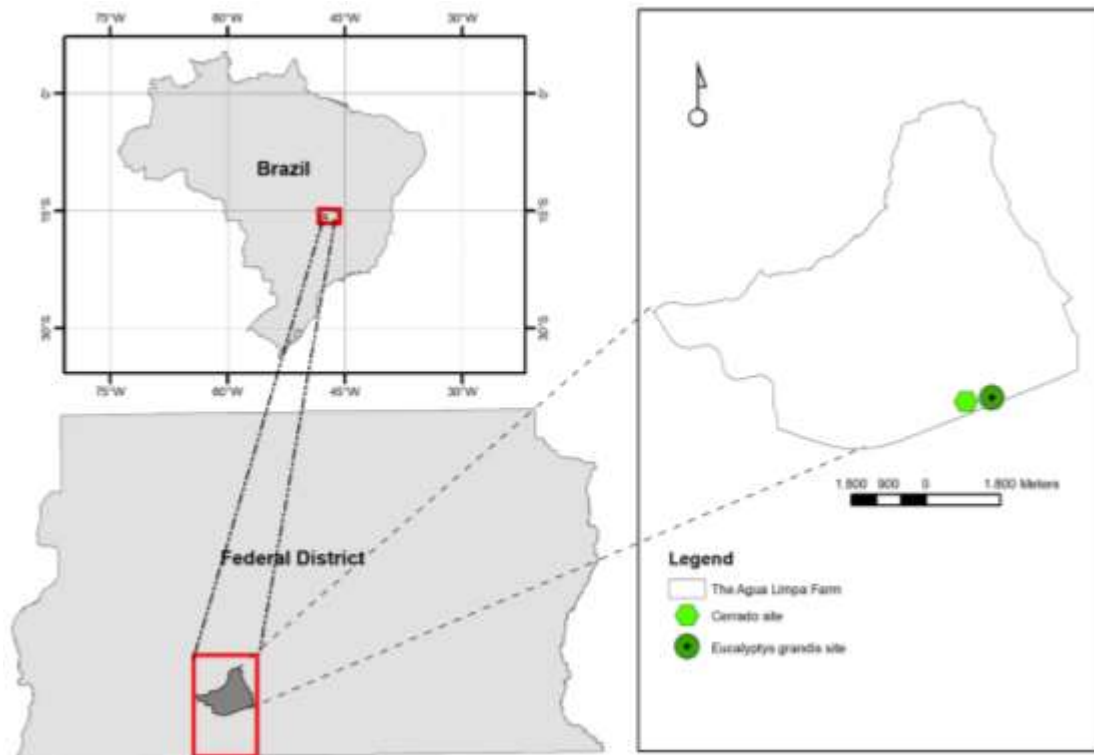
### Study area

This study was carried out at Água Limpa Farm (FAL) at the University of Brasília (UnB), located in the southwestern quadrant of the Federal District, 25 km from the center of Brasília-DF. Água Limpa Farm, with a total area of 4,250 ha, is located in the Hydrographic Microbasin of Ribeirão do Gama, a contributor to Paranoá River which is part of the Paranaíba River Basin. The relief is smoothly undulating and the altitude varies between 1,005 and 1,200 m above sea level. The studied areas are located in the watershed between the Capetinga and Taquara streams, both tributaries of Ribeirão do Gama, at coordinates latitude 15°58'23" South and longitude 47°54'31" West, SAD (South American Datum) datum 69, at an average altitude of 1150 m (Figure 1).

According to the Köppen climate classification, the climate of the region is "Aw" (Tropical seasonal savanna), with well-defined rainy and dry seasons. The rainy season begins in September or October and lasts until April or May, with an annual rainfall of 1,453 mm. The wettest months are November to March, when 75% of the annual precipitation occurs on average. The dry season usually begins in May and lasts until September. The months of June, July and August are the driest, constituting a period of water deficits for most soils. The mean annual temperature is 22°C, with a 27°C maximum and a 15.4°C minimum. September and October are the hottest months, with a monthly average of up to 25.6°C. June and July are the coldest months, with average temperatures of around 20°C. Relative humidity is high during the summer and over a few months of spring and autumn. During this period, the averages recorded range from 73 to 79%. Between June and September, these averages vary between 50 and 61%, although periods with relative humidity of less than 20% are frequent. The annual mean of this climatic variable is 67.3%. Average daylight per year is 2,417 h, always exceeding 125 h per month. Between April and September, the sun shines more than 200 h per month. November, December and January are the months with the less amount of daylight hours (Felfili and Silva Júnior, 1993).

### Experimental design

The experiment was carried out in two adjacent areas with Red Clay Oxisol (EMBRAPA, 2013, 2011). Both of them were originally covered by Cerrado vegetation (Felfili and Silva Júnior, 1993). The first area has a natural vegetation cover, properly preserved Cerrado vegetation, with no history of recent fires, invasive plants or other signs of anthropic actions. This area represents the original form of the savanna physiognomy characterized by its soil cover. It is covered with a herbaceous layer composed mainly of grasses and a wood layer spaced of arboreal and shrub elements



**Figure 1.** Studied area at Água Limpa Farm (FAL), University of Brasília (UnB), spatially located in the southwestern of the Federal District, Brazil.

(Ribeiro and Walter, 1998). Its tree cover varies from 10 to 60%, while its density ranges between 600 and 1200 wood plants (DAP at 30 cm of soil greater than 5 cm) per hectare (Felfili and Silva Júnior, 1993).

The second area was deforested and converted to a homogeneous forest stands of *Eucalyptus grandis* in 2009. The forest site was 7 years old at time of this study. Conventional soil preparation using a 26" harrow was adopted previously for *Eucalyptus* plantation. The spacing used for planting was 3 m × 3 m (1,111 plants/ha).

A plot of 1 ha (100 m × 100 m) was demarcated for data collection in each area. Four sets of undisturbed soil samples made of 8 pieces of 2.5 cm high were sequentially collected up to 20 cm deep for the verification of apparent density of the soil and volumetric humidity. This was collected with Uhland type sampler in rings of 80 cm<sup>3</sup> of internal volume. Twenty deformed soil samples were randomly collected in each plot, using a 2" Dutch type test, to a depth of 20 cm in order to perform the particle size analysis of soil particles for texture determination. The method used to determine soil granulometric composition is described in EMBRAPA (2011). The samples were analyzed and the results used to determine soil texture through the textural triangle method; thus classified as clay textured.

Penetration resistance in each plot of up to 30 cm depth was evaluated using Stolf impact penetrometer ( $M = 3,985$  kg,  $A = 1,2767$ cm<sup>2</sup> and  $m = 3,506$  kg) up to a depth of 30 cm in each plot. The calculation of penetration resistance was performed as described by Stolf et al. (2014).

$$RP = \left[ \left( \frac{Mgh}{10A} \right) \times \left( \frac{M}{M+m} \right) \times N \right] + \frac{(M+m) \times g}{A} \quad (1)$$

where RP is the penetration resistance (kgf.cm<sup>-2</sup>); M is the impact mass (kg); g is the gravity acceleration (m.s<sup>-2</sup>); h is the mass displacement height of impact (m); A is the penetration cone base area (cm<sup>2</sup>); N is the necessary impacts to penetrate soil by 1 dm (impacts\*dm<sup>-1</sup>); and m is the penetrometer body mass (kg).

The acceleration of gravity (g) was calculated according to the methodology proposed by Lopes (2008) for correction of the 15.973° latitude and the 1150 m altitude at the experiment site. The value found was  $g = 9.7842$  ms<sup>-2</sup>. For the transformation of RP in kgf.cm<sup>-2</sup> to MPa the RP result is multiplied by  $g \times 100^{-1}$  (0.09784).

A regular mesh of resistance to the penetration in the studied areas was obtained with the data taken from the field.

### Statistical analysis

The edaphic variables under a vegetative Cerrado vegetation cover and *E. grandis* cultivation were compared using the Scott-Knott test at a 5% probability level. This test was chosen because of its power and robustness for non-parametric distributions, as was recommended by Borges and Ferreira (2003) in comparison with other statistical tests. The statistical software SISVAR of the Federal University of Lavras (Ferreira, 2009) was used to perform the mean contrast test. This software is of public domain and was freely downloaded at the Federal University of Lavras (UFLA) website.

## RESULTS

Tables 1, 2 and 3 show that according to the Scott-Knott test at 5% probability level, there were no significant

**Table 1.** Grain size composition of red latosol on Cerrado vegetation and *Eucalyptus grandis* crops.

Soil cover	Granulometric composition (g.kg <sup>-1</sup> )		
	Area*	Silt*	Clay*
Cerrado vegetation	250 <sup>a</sup>	175 <sup>a</sup>	575 <sup>a</sup>
<i>Eucalyptus grandis</i>	225 <sup>a</sup>	200 <sup>a</sup>	575 <sup>a</sup>

\*Results followed by the same letter in the same column did not differ statistically according to the Scott-Knott test with a 5% probability level.

**Table 2.** Statistical moments of the soil's volumetric moisture in the 0-20 cm deep layer of red latosol on Cerrado vegetation and *Eucalyptus grandis* crops.

Soil cover	Volumetric moisture (cm.cm <sup>-3</sup> )				CV (%)
	Mean*	Standard deviation	Minimum	Maximum	
Cerrado vegetation	0.28 <sup>a</sup>	0.02	0.23	0.34	8.37
<i>Eucalyptus grandis</i>	0.28 <sup>a</sup>	0.03	0.18	0.33	10.55

\*Results followed by the same letter in the same column did not differ statistically according to the Scott-Knott test with a 5% probability level.

**Table 3.** Apparent density according to the sampled depths of red latosol in the Cerrado vegetation and *Eucalyptus grandis* plantation.

Depth (cm)	Apparent density (g.cm <sup>-3</sup> )		
	Cerrado vegetation*	<i>Eucalyptus grandis</i> *	CV (%)
0 - 2.5	0.87 <sup>a</sup>	0.92 <sup>a</sup>	10.91
2.51 - 5	1.04 <sup>a</sup>	1.08 <sup>a</sup>	9.55
5.01 - 7.5	0.99 <sup>a</sup>	1.14 <sup>a</sup>	2.26
7.51 - 10	1.05 <sup>a</sup>	1.15 <sup>a</sup>	3.11
10.01 - 12.5	1.09 <sup>a</sup>	1.15 <sup>a</sup>	4.31
12.51 - 15	1.11 <sup>a</sup>	1.16 <sup>a</sup>	7.19
15.01 - 17.5	1.06 <sup>a</sup>	1.18 <sup>a</sup>	4.45
17.51 - 20	1.10 <sup>a</sup>	1.16 <sup>a</sup>	5.81
Mean	1.04 <sup>a</sup>	1.12 <sup>a</sup>	3.18

	Penetration resistance (MPa)		
	Cerrado vegetation*	<i>Eucalyptus grandis</i> *	CV (%)
0 - 10	1.15 <sup>a</sup>	1.30 <sup>a</sup>	13.01
10 - 20	1.93 <sup>a</sup>	2.17 <sup>a</sup>	12.13
20 - 30	2.44 <sup>a</sup>	2.51 <sup>a</sup>	10.09
Mean	1.84 <sup>a</sup>	1.99 <sup>a</sup>	11.73

Results followed by the same letter in the same column did not differ statistically according to the Scott-Knott test with a 5% probability level.

differences in variables texture, volumetric moisture, apparent density and resistance to penetration, in red latosol on Cerrado vegetation and *E. grandis* crops.

The two study sites showed the same soil type and granulometric composition, which indicates homogeneity in edaphic conditions.

The Cerrado vegetation is composed of herbaceous,

shrub and small tree stratus, with open canopy, unique and great species diversity. The *E. grandis* plantation showed only one stratum, even-aged stand, homogenous, arboreal with closed canopy. Despite of the large structural differences in the vegetation between the two studied sites, there were no statistically significant differences in soil volumetric moisture.

Heavy machines were used to convert (clean and prepare) land cover from Cerrado vegetation to *E. grandis* plantation. Consequently, an increase in apparent density and soil penetration resistance were expected. Based on the results, the expected soil physical changes were not observed.

## DISCUSSION

As shown in Table 1, there were no statistical differences between the soil textures of the two areas thus, showing that one silvicultural cycle (7 years) is not enough to differentiate soil textures between these two types of uses. In fact, the change in granulometric composition of soil is only evidenced on a much longer time scale, from decades or even centuries, as described by Anjos and Liesenberg (2002).

Soil volumetric moisture did not differ statistically in the 5% probability level by the Scott-Knott test in the studied areas. The mean depth at 0 to 20 cm for the Cerrado vegetation and *E. grandis* plantations was  $0.28 \text{ cm}^3$ . During the 30 days prior to collection, 50.5 mm of accumulated rain were recorded for the Federal District. The results are to be interpreted in terms of soil texture (57.5% clay), which contributes to a higher water retention (Resende et al., 2007), so that roots, requires higher osmotic pressure to absorb water. The volumetric moisture content in the soil coincides with the values (28%) observed by Carneiro et al. (2009) in a Cerrado vegetation under similar soil conditions in the southwest of the state of Goiás.

The data analyses did not indicate a significant statistical difference between *E. grandis* and the Cerrado vegetation. It may be inferred that in the local biomass and evapotranspiration conditions, *E. grandis* did not modify the soil water regime in the 0 to 20 cm layer.

The mean values of apparent density were statistically the same in the soil under Cerrado vegetation and *E. grandis* at 5% level of significance according to the Scott-Knott test. For a red latosol in either type of soil cover, soil density did not reach the value determined as limiting for root development of  $1.33 \text{ g.cm}^{-2}$  proposed by Klein et al. (2009), at any depth.

The apparent density in the first sampled layer (0 to 2.5 cm depth) was about 20% lower in both types of soil cover. This can be attributed to higher organic matter content in the soil surface and/or to greater difficulties while sampling in more superficial layers given the greater root density. Dedecek and Gava (2005) attributed the recovery of apparent density in the 0 to 10 cm layer to of soil drying-wetting cycles. According to the authors, the cycles reorganize soil particles in order to recover the original density in the layer directly in contact with machines' wheels by the action of organic matter and biological activity thus restoring the physical properties of the soil after 7 years of *Eucalyptus* growth.

In the present study, the physical properties of soil remained the same in the 0 to 30 cm layer as there were no significant differences found between the Cerrado vegetation and the 7-year-old *E. grandis* cultivation. This result is similar to that obtained by Dedecek and Gava (2005), Oliveira et al. (2008) and Effgen et al. (2015).

The mean apparent density observed at 20 cm depth in the Cerrado vegetation and *E. grandis* crop was 1.04 and  $1.12 \text{ g.cm}^{-3}$  each. Apparent density increased with soil depth in both soil covers up to 12.5 cm, and remained stable at the maximum depth of 20 cm. This was probably due to the gradual decrease in organic matter content in the soil. Further studies are needed to prove this hypothesis.

The mean apparent density did not differ statistically between the two soil used at the 5% level in the soil under Cerrado vegetation or *E. grandis* crops as can be observed in Table 3.

The study of penetration resistance up to 30 cm can identify impediments to root development in areas of greater fine roots concentration, since they are responsible for the absorption of water and nutrients used by the plants both in the Cerrado vegetation and *E. grandis* crops. In both types of soil cover penetration, resistance increased with depth increment, exceeding 2 MPa in the 20 to 30 cm layer. This is considered by many authors as restrictive for root development of large tree species.

The occurrence of the same phenomenon in the Cerrado vegetation area discards the hypothesis that an increase in penetration resistance takes place in deeper soil layers due to the traffic of machines used for planting of *E. grandis*. It is therefore considered a natural situation in this environment.

The average resistance to penetration in the 0 to 10 cm, 10 to 20 cm and 20 to 30 cm depth layers did not differ statistically at 5% level of significance according to the Scott-Knott test between soil cover types. The averages in the 0 to 10 cm layer were 1.15 and 1.30 MPa, respectively for the Cerrado vegetation area and *E. grandis* crops (Table 3). Penetration resistance greater than 2 MPa implies restrictions of root development occurring in the superficial layer of the soil. Values surpassing this criterion were observed in the 20 to 30 cm soil depth in both studied areas.

The effects of land preparation using heavy machinery adopted for the cultivation of *E. grandis* compared to the undisturbed Cerrado vegetation did not cause significant soil impacts at the three analyzed soil depths. The study results suggest that silvicultural activity in latosols is an alternative land use that causes lesser impacts to soil physical properties compared to those subject of agricultural croppings (Dedecek and Gava, 2005; Oliveira et al., 2008; Tavares Filho et al., 2014; Effgen et al., 2015; Stone et al., 2015). However, complementary and spatially larger studies should be conducted to achieve more detailed results in this regard.

## Conclusion

There were no significant differences (Scott-Knott test at  $\alpha=0.05$ ) between the edaphic variables of grain size or granulometry, humidity or moisture, density and penetration resistance assessed in a medium-textured red latosol under a vegetative Cerrado cover and *E. grandis* plantation. It indicates that changing land cover from Cerrado vegetation to *E. grandis* plantation did not substantially impact the assessed soil physical properties of red latosols in the study sites. Further studies, however, should be conducted to better understand broader soil impacts by forestry plantations in the Cerrado region.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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