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Oxisolphysical attributes under different agricultural uses in Brazil

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Soil attributes are easily modified for different agricultural purposes, requiring the adoption of appropriate practices, according to the local particularities in order to maintain its production capacity. Given the above, this study aimed to assess soil physical attributes under different agricultural uses conditions in an Oxisol. The survey was conducted in Brazil with the following treatments: Cassava monoculture area, beans monoculture and native forest. Results were interpreted with multivariate analysis. Native forest differed from the other agricultural uses due to surface consolidation, lack of soil preparation practices and increased organic matter input, having higher water retention. The conclusion was that there were statistical irregularities in soil attribute tendencies. Different agricultural uses interfered in the physical attributes when compared to the native forest, which produced better results, followed by bean and cassava monocultures. The most significant physical attributes to distinguish agricultural uses were: Aggregation; weighted average diameter; soil density; particle density; total porosity; field capacity and available water.

Key words: Soil properties, density, porosity, water retention.

INTRODUCTION

Soils are three-dimensional, natural and dynamic bodies. They are formed on the Earth's surface through climate and organisms environmental factors action on the source material in function of relief, time action and

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spatial variation, according to these factors combination possibilities of these factors (Kämpf and Curi, 2012).

Under natural conditions the soil is in dynamic equilibrium and is resistant to changes (Goedert and Oliveira, 2007). However, human action has promotes attribute changes (Silva et al., 2007), causing soil natural fertility decline (Cordeiro et al., 2004), as its structure is easily changed. Thus, other properties are also degraded, such as soil density, micro, macro and total porosity, organic matter, water retention and infiltration in the soil profile (Reichert et al., 2009; Ferreira et al., 2010; Cunha et al., 2011).

Therefore, inappropriate land use causes changes in physical and hydraulic properties. The magnitude of these changes magnitude varies depending on the soil type, weather and agricultural crops management (Kay, 1990).

In general, arid and semiarid regions soils are naturally fragile because of their low water storage. In addition, plant root system growth is also physically limited in these soils (Cardoso, 2002), increasing its susceptibility to human action improper use practices.

Soil studies in Rio Grande do Norte state western region and in the municipality of Martins, RN state, are scarce. Therefore, physical attributes quantification is necessary to establish appropriate farming practices establishment, in order to seek better conditions in relation to the soil water dynamics, aeration and structure, which are dynamic attributes with spatial and temporal variability.

Given the above, this study aimed to assess soil physical properties under different agricultural uses in Martins, RN. Multivariate analysis was used as a tool to interpret results.

MATERIALS AND METHODS

Research was conducted in Martins, RN, Brazil. Martins is located in the Rio Grande do Norte state western meso region and in the Umarizalmicro region, in the following geographical coordinates: 6° 05´ 16´´ South, 37° 54´ 40´´ West. It is located in the Borborema plateau. However, its relief further comprises the Depressão Sertaneja, covering an area of 169.47 km². Climate is classified as tropical rainy (Aw) according to Köppen classification, with average rainfall of 1133.8 mm, whose rainy season is from January to June, the average annual temperature is of 25°C and subperennial forest vegetation type, which is associated with the Caatinga vegetation.

The following treatments were assessed: cassava monoculture (CASS), bean monoculture (BEAN) and native forest (NF).

The cassava monoculture area covered about 1 ha. The site was cleared in 2003. Plant residues were burned in small piles, with plowing and harrowing being conducted afterwards. These practices were always adopted before cassava planting, about once every two years. Sampling was performed after burning.

The bean monoculture area covered 1 ha, and like the cassava area, it was deforested in the same year (2003). Plant residues were burned and soil tillage was held afterwards through plowing and harrowing, the latter being held once a year, before sowing.

Through visual analysis by the farmer, cattle manure was applied to improve soil fertility. However, such practice was not performed during sampling.

The native forest area was used as a reference to compare with the other agricultural uses. The vegetation is of subperennial type, consisting of broad-leaved trees, with relatively slender and dense trunks, which is typical of tropical rainy climate zones. The most commonly found species are: *Psiium firmum*, *Talisia esculenta*, *Enterolobium contortisiliquum*, *Pithe colobium* polycephalum, *Sideroxylon obtusifolium*, Helicostylistomenosa, *Hymenaea courbaril*, *Dipteryx odorata*, *Mimosa sepiaria*, *Copaifera langsdorffii,* among others.

Agricultural uses textural classification was: sandy clay to native forest (NF), cassava monoculture (CASS) and bean monoculture (BEAN). Two soil profiles were opened in a representative area of the study sites. Soil samples with deformed structure in their respective horizons were collected for physical analysis, as well as diagnostic horizons identification and classification, according to the Brazilian Soil Classification System (Donagema et al., 2011; Santos et al., 2013).

Profile 1 showed a textural classification ranging from sandy clay on A and BA horizonsto clay in the Bw horizon. Profile 2 ranged between sandy clay in the A horizon to clay in the Bw horizon. Both were classified as Oxisol.

In order to assess soil physical properties, four representative points in each area were sampled to collect disturbed and undisturbed samples, in depths from 0.00 to 0.30 m. Subsequently, two representative profiles of the areas under study were opened for soil classification of soil, according to methodology described by the manual of methods and soil analysis (Donagema et al., 2011).

In order to collect soil samples with undisturbed structure an Uhland type device was used, with cylindricalmetal sampler dimensions of 0.05 m diameter and 0.05 m height was used. Physical attributes, retention curve, soil density, total porosity, macro and microporosity were assessed. Eight samples were collected by point and 32 samples were collected for each area under study, totaling 128 samples. After collection, samplers were coated with aluminum foil and taken to the laboratory with care, in order to maintain the soil structure and moisture.

Deformed structure samples collection were carried out in four representative points of each area, with three repetitions, totaling 48 samples, Collection was conducted with the aid of a straight shovel, with samples being transferred to properly labeled plastic bags. Subsequently, samples were used to determine textural classification and particle density.

Textural classification (granulometric analysis) carried out by pipette method using chemical dispersant (sodium hexametaphosphate). Soil density (SD) was determined by volumetric ring method and particle density (PD) was determined by volumetric flask method, using alcohol. These determinations were performed following Embrapa soil analysis methods manual (Donagema et al., 2011).

In order to determine aggregation and average diameter, wet screening method was used. Five samples of 25 g for each agricultural use were used, with a sample being used for moisture determination (correction factor). Each sample was transferred to a filter paper disk located on the upper sieve (2.00 mm) and spread over the entire filter paper surface. Moistening was conducted through capillarity (4 min) in a four sieves set with the following mesh diameters: 2.00; 1.00; 0.50 and 0.25 mm.After the required time, the filter paper was removed. Sieve sets agitation was performed in avertical oscillation apparatus (42 oscillations/min) during four minutes inside barrels with water. Fractions retained on each sieve were transferred to beckers that were previously treated and identified, and sent to an oven at 105°C for 24 h. After dry

Table 1. Physical attributes analysis of variance (ANOVA) under different agricultural uses: cassava monoculture (CASS), bean monoculture (BEAN) and native forest (NF).

VS	DF	MS									
		AGREG	WAD	SD	PD	TP	MICRO	MACRO	FC	PWP	AW
Between AU	2	6.92^{ns}	0.02**	0.01^{ns}	0.001^{ns}	91.58*	43.00^{ns}	47.58^{ns}	0.01^{ns}	0.001*	0.005^{ns}
WithinAu	9	1.70	0.001	0.01	0.01	12.39	15.81	13.83	0.002	0.0001	0.002
CV (%)		14.04	13.30	6.70	2.94	8.45	30.01	13.20	19.18	7.64	36.85

VS – variation source; AU - agricultural uses; CV - coefficient of variation; DF - degrees of freedom; MS - mean square; AGREG. - Aggregation; WAD – weighted average diameter; SD - soil density; PD - particle density; TP; total porosity; MICRO - microposity; MACRO - macroporosity; FC - field capacity; PWP – permanent wilting point; AW - available water; ** Significant difference indicator of p≤0.01; * Significant difference indicator of p≤0.05; ns - not significant.

matter obtainment and sand content (sodium hexametaphosphate) deduction, water stable aggregates (aggregation) percentage and weighted average diameter (WAD) were determined for each class. WAD was obtained through Equation 1, proposed by Castro Filho et al. (1998).

$$\mathrm{WAD} = \sum_{i=1}^{n} \left(xi\ wi \right) \qquad (1)$$

Where: WAD–weighted average diameter, mm; xi–classes average diameter, mm; wi - each class proportion in relation to the total.

For TP, macroporosity and microporosity determination, tension table was used. For microporosity, a tension of 6 kPa was used. Macroporosity was calculated through the difference between total porosity and microporosity.

The graphical relation between matric potential and soil water content is calledsoil water characteristic curve, or moisture retention curve, that is, matric potential (φm) x water content (θ). For retention curve obtainment, tensions of 0; 2; 6; 10; 33; 100; 300; 500 and 1500 kPa were used. In the application of 0; 2; 6 and 10 kPa tensions, the tension table was used. Low tension cameras were used for 33 and 100 kPa, and high tension cameras were used for 300; 500 and 1500 kPa.

Soil water retention curves adjustment was made based on van Genuchten's equation (1980), (Equation 2) using the SWRC software, developed by Dourado Neto et al. (1990). The equation considers the matric potential (φm) as an independent variable, and water content (θ) as dependent variable:

$$\theta = \theta_r + \frac{\theta_s - \theta_r}{\left[1 + \left(\alpha . |\varphi_m| \right)^n \right]^m} \qquad (2)$$

Where: θr -residual water content, $m^3\ m^{-3}$; θs- saturated water content, $m^3\ m^{-3}$; |φm|- matric potential, kPa α, m, n –Equation empirical parameters.

As it is a theoretical parameter that varies between 10 kPa (sandy soils) and 33 kPa (clay soils), field capacity value (FC) was determined according to the textural classification. Permanent wilting point (PWP) was obtained with 1500 kPa tension, and available water (AW) was obtained through the difference between FC (at 10 kPa tension) and PWP.

Soil physical attributes average values under different agricultural uses (NF, CASS and BEAN) were interpreted through ANOVA, which was performed with Tukey's test (p<5%), descriptive analysis (average, minimum, maximum, variance, standard deviation and coefficient of variation) In addition, multivariate statistical analysis tool was used in Principal Component Analysis (PCA), using the GENES program.

Soil physical attributes were measured in different unit systems, with data standardization being necessary, since variance is influenced by the attributes in the measurement units in question. Correlation matrix was established after data standardization, in order to verify the percentage and the degree of importance of these correlations, with values that were higher or equal to 0.7 being considered.

RESULTS AND DISCUSSION

Through soil physical attributes analysis of variance under different agricultural uses (AU analysis of variance, it was shown that there was no statistical difference for AGREG, SD, PD, MACRO, MICRO, FC and AW there was no statistical difference. WAD statistically differed at1% probability and TP and PWP were statistically different (p<0.05) (Table 1). These differences are probably due to soil structural arrangement being a dynamic, functional, functional and complex property that is easily modified property by land use (Carneiro et al., 2009; Kämpf and Curi, 2012).

Evaluating SD, PD, TP and PWP attributes coefficients of variation (CV) showed low values (CV lower than 10%); as for aggregation, WAD, MACRO and average FC, CV was between 10 and 20%. For MICRO and AW, CV was very high (higher than 30%), according to Pimentel (2009).

The correlation matrix obtained with the physical attributes studied in the different agricultural uses (NF, CASS, BEAN), in the municipality of Martins-RN were highly correlated (values above 0.7), showing interrelation in the different agricultural uses (Table 2). High and positive correlations between aggregation (AGREG), weighted average diameter (WAD) and microporosity (MICRO) were found.

High positive correlations were found between SD and TP for MACRO, FC and AW (except for TP, in which high

Table 2. Soil physical attributes correlation matrix obtained by principal component analysis (PCA) under different agricultural uses (CASS, BEAN and NF).

	AGREG.	WAD	SD	PD	TP	MICRO	MACRO	FC	PWP	AW
AGREG.	1.00									
WAP	0.99	1.00								
SD	-0.06	0.08	1.00							
PD	-0.88	-0.79	0.42	1.00						
TP	0.09	0.22	0.99	0.29	1.00					
MICRO	0.77	0.85	0.59	-0.45	0.70	1.00				
MACRO	-0.67	-0.57	0.78	0.86	0.68	-0.05	1.00			
FC	0.13	0.29	0.99	0.29	1.00	0.74	0.64	1.00		
PWP	0.64	0.77	0.59	-0.22	0.69	0.90	0.04	0.74	1.00	
AW	-0.10	0.05	1.00	0.47	0.98	0.56	0.80	0.96	0.63	1.00

AGREG. - Aggregation; WAD – weighted average diameter; SD - soil density; PD - particle density; TP; total porosity; MICRO - microposity; MACRO - macroporosity; FC - field capacity; PWP – permanent wilting point; AW - available water.

positive correlation was found for MICRO). These correlations can be justified due to SD and TP not being limiting factors for other attributes, with soil density values ranging from 1.14 to 1.28 g cm^{-3} and total porosity ranging between 37 and 47% (Table 3). According to Borges et al. (1997), SD values above 1.62 g cm^{-3} were partial obstacles for root growth while working in an Oxisol with medium texture at the *Triângulo Mineiro* region.

In the native forest, higher AGREG, WAD, SD, TP, MACRO, FC and AW average values were found (Table 3), what can be attributed to its surface higher consolidation due to tillage practices absence and higher organic matter input provided higher average values. Data tendency is in accordance with Corrêa (2002), who found increased aggregates and weighted average diameter innative forest, with reduction as intensive land use practices were carried out. Different agricultural management practices interfered in aggregates formation because it modifies soil organic matter dynamics (Zanatta et al., 2007) and conditions for microorganism activity (Vargas and Scholles, 2000).

Considering the principal component 1 (PC1), which showed 55.26% of total data variation, physical attributes that had the highest weights (in module) were: soil density (SD), total porosity (TP), field capacity (FC) and available water (AW). In CP2, which explained 41.46% of data explanation, the largest eigenvectors were: Aggregation (AGREG.), weighted average diameter (WAD) and particle density (PD) (Table 4).

In the graphic representation (Figure 1), the two first principal components scores (PC1 and PC2) were considered for groups' interpretation. Two different groups were formed; the first refers to cassava (CASS) and beans (BEAN) monoculture, indicating that practices adopted in these areas have not contributed to physical attributes differentiation. Analyzing the second group, native forest (NF), it differed from the first group (CASS and BEAN), being higher regarding soil physical properties. Albuquerque et al. (2005), Souza et al. (2005), Carneiro et al. (2009), Corrêa et al. (2010) obtained similar results, as agricultural use has changed soil physical properties, when compared to the native vegetation area.

Assessing soil water retention curve under different agricultural uses (NF, CASS and BEAN), which was adjusted according to the mathematical model proposed by Van Genuchten (1980), (Figure 2) the different agricultural uses showed uniformity, except for cassava monoculture, at 0 to 100 kPa tensions, which were below the others, due to lower total porosity (Table 3).

Water retention process occurs in unsaturated soils as a result of capillarity. Adsorption forces operating in the soil matrix vary depending on the texture, mineralogy, depth, structure, porosity, organic matter and agricultural uses (Libardi, 2005; Reichardt and Timm, 2004).

Viscosity is a property that reflects the ease with which the molecules or particles slide over the other, being directly proportional to the volume of the particles varying with the temperature. It is affected by solutes type and concentration of solutes (Reichardt and Timm, 2004).

Native forest (NF) showed higher water retention, total porosity, field capacity and available water. This can be justified by OM increase due to vegetation cover maintenance, soil non-disturbance and iron aluminumoxides presence, which give higher aggregate stability. Results obtained by (Roth et al., 1991; Bertol et al., 2000; Giarola et al., 2002) corroborate with this study. Soil and agricultural crops management modify the soil structure, and consequently, its physical properties, such

Table 3. Physical attributes descriptive statistics under different agricultural uses: native forest (NF), cassava monoculture (CASS) and bean monoculture (BEAN).

Physical attributes	**Management**	**Descriptive analysis**					
		Md	**Min**	**Max**	**s^2**	**s**	**CV**
AGREG. (%)	NF	10.00	8.89	11.18	0.90	0.95	9.48
	CASS	10.09	7.38	11.44	3.38	1.84	18.2
	BEAN	7.77	6.68	8.62	0.82	0.91	11.7
WAD (mm)	NF	0.26	0.23	0.29	0.00	0.03	10.4
	CASS	0.24	0.21	0.29	0.00	0.04	14.8
	BEAN	0.15	0.12	0.17	0.00	0.02	14.4
SD (g cm^{-3})	NF	1.28	1.25	1.31	0.00	0.02	1.91
	CASS	1.16	1.09	1.3	0.01	0.10	8.36
	BEAN	1.22	1.11	1.35	0.01	0.10	8.22
PD (g cm^{-3})	NF	2.53	2.39	2.61	0.01	0.10	3.80
	CASS	2.52	2.43	2.60	0.00	0.07	2.78
	BEAN	2.55	2.48	2.59	0.00	0.05	1.96
TP (%)	NF	47.00	0.45	0.49	0.00	0.02	3.65
	CASS	37.00	0.33	0.42	0.00	0.04	10.8
	BEAN	41.00	0.35	0.45	0.00	0.04	10.4
MICRO (%)	NF	17.00	0.16	0.19	0.00	0.02	8.96
	CASS	13.0	0.09	0.22	0.00	0.06	48.9
	BEAN	10.00	0.07	0.13	0.00	0.03	24.4
MACRO (%)	NF	30.00	0.28	0.3	0.00	0.01	3.39
	CASS	24.00	0.20	0.28	0.00	0.03	13.6
	BEAN	31.00	0.25	0.38	0.00	0.05	17.7
FC (cm^3 cm^{-3})	NF	0.29	0.26	0.31	0.00	0.02	8.45
	CASS	0.21	0.16	0.27	0.00	0.05	26.6
	BEAN	0.24	0.17	0.28	0.00	0.05	23.2
PWP (cm^3 cm^{-3})	NF	0.14	0.13	0.14	0.00	0.01	3.64
	CASS	0.12	0.11	0.13	0.00	0.01	6.80
	BEAN	0.11	0.10	0.13	0.00	0.01	11.20
AW (cm^3 cm^{-3})	NF	0.15	0.12	0.18	0.00	0.03	18.10
	CASS	0.09	0.03	0.15	0.00	0.06	64.80
	BEAN	0.13	0.07	0.17	0.00	0.05	37.30

AGREG. - Aggregation; WAD – weighted average diameter; SD - soil density; PD - particle density; TP; total porosity; MICRO - microposity; MACRO - macroporosity; FC - field capacity; PWP – permanent wilting point; AW - available water; NF - native forest; CASS – cassava monoculture; BEAN - bean monoculture; Md - mean; Min - minimum; Max - maximum; s^2 - variance; s - standard deviation; CV - coefficient of variation.

as density, porosity (Faria et al., 1998; Pires et al., 2012) and soil water retention (Ramos et al., 2013). Therefore, management based on monoculture, compared to native forest, negatively influenced on physical and hydraulic attributes (Table 3 and Figure 2). In Brazil Portela et al. (2001), among others, Cintra et al. (2009), found modifications in soil pores quantity and quality. The soils of both studies were classified as Oxisol in water retention, in a tableland ecosystem soil under different land use.

Conclusions

Different agricultural uses influence soil physical attributes mean values. The most significant physical

Table 4. Soil physical attributes eigenvectors analyzed with the main components.

Soil physical properties	Principal components	
	1	2
AGREG.	0.09	0.48
WAD	0.15	0.46
SD	0.41	-0.13
PD	0.09	-0.46
TP	0.42	-0.06
MICRO	0.33	0.30
MACRO	0.24	-0.40
FC	0.42	-0.04
PWP	0.34	0.24
AW	0.40	-0.15
Eigenvalue	5.29	4.20
Explanation (%)	55.26	41.46
Accumulated explanation (%)	41.46	96.72

AGREG. - Aggregation; WAD – weighted average diameter; SD - soil density; PD - particle density; TP; total porosity; MICRO - microposity; MACRO - macroporosity; FC - field capacity; PWP – permanent wilting point; AW - available water.

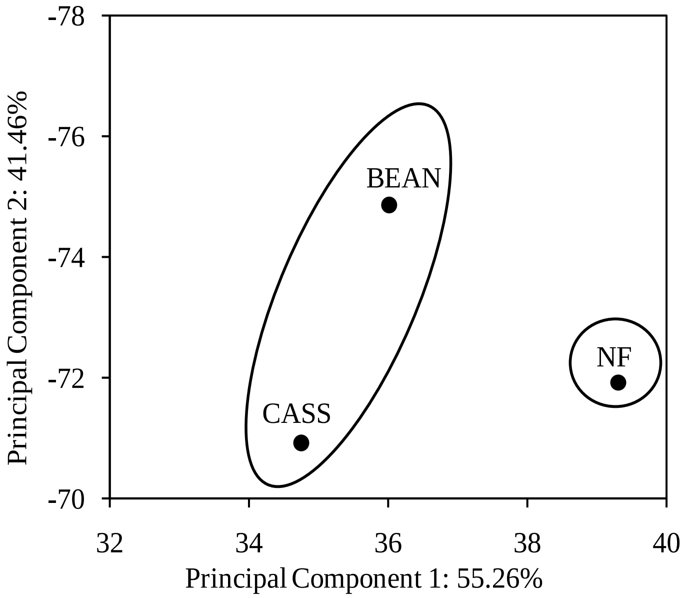
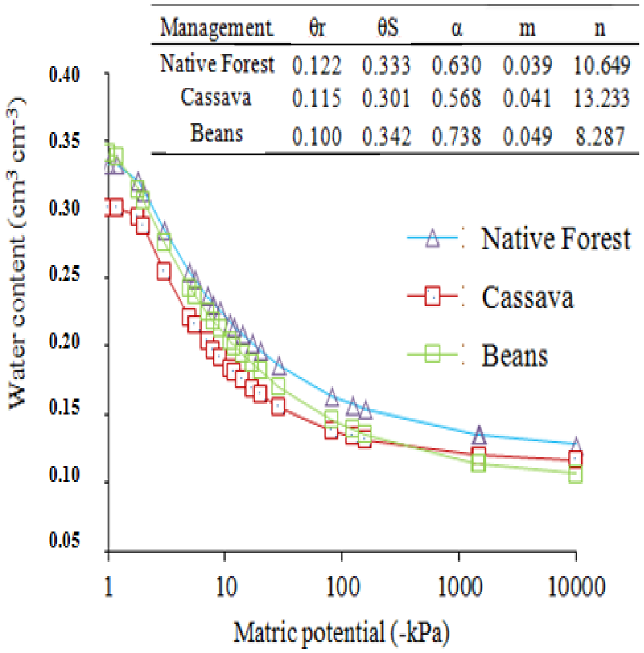


Figure 1. Scores graphical representation in the different agricultural uses: cassava monoculture (CASS), bean monoculture (BEAN) and native forest (NF), obtained with soil physical attributes.



Management	θr	θS	α	m	n
Native Forest	0.122	0.333	0.630	0.039	10.649
Cassava	0.115	0.301	0.568	0.041	13.233
Beans	0.100	0.342	0.738	0.049	8.287

Figure 2. Soil water retention curve of an Oxisol under different agricultural uses: cassava monoculture (CASS), bean monoculture (BEAN) and native forest (NF).

attributes to distinguish agricultural uses were: aggregation; weighted average diameter; soil density; particle density; total porosity; field capacity and available water. Native forest obtained better results, followed by cassava and beans monoculture. Soil water characteristic curves showed uniformity among different agricultural uses with higher water retention in the native forest.

Conflict of Interests

The authors have not declared any conflict of interests.

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