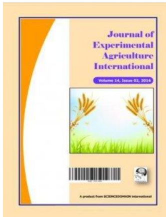

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Moisture Behavior to the Spatial Variability of Physical Attributes in Different Soil Management

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Authors' contributions

This work was carried out in collaboration between all authors, each one being responsible for one or more steps. Author CMG conducted the study, collected the analyzes in the field and did the statistical analysis of the data coming from his dissertation. Authors FBS and WDX were responsibles for the guidelines of the soils analyzes. Author CAGC was the supervisor of the master dissertation that originated the scientific article and responsible for the development of the project that originated the dissertation. Authors RRGF and ILNS formatted the article for publication, besides the reviewing the written article, ordering the text. All authors read and approved the final manuscript.

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ABSTRACT

The technique of temporal stability is used by several researchers to adequately represent the water content in the soil with reduced sampling effort from the identification of points on the field that reflects the average behavior of soil moisture. Therefore, the aim of this work was to analyze the moisture behavior to the spatial variation of density and particle size in a Hapludox under three different soil tillage systems (No-Till, Crop-Livestock Integration and Conventional Planting) in the municipality of Jataí, Southwest of Goias, Brazil. It was collected nine sampling points information

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for each handling system in three depth ranges (0 - 0.12 m, 0.12 to 0.24 m, 0.24 to 0.36 m). For this, it was used a portable type sensor TDR HydroSence model, rods with length 0.12 m. The determination and location of points for data collection were done by georeferencing, using a GPS system ("Global Positioning System"), GARMIN, MAP785 model. Bulk density and soil particle size (clay) were determinated according to the recommendation by EMBRAPA. The experimental area was composed of three sub-areas of approximately 1 ha each, cultivated with soybean (*Glycine max*) in the season 2013/2014 (first crop) with different soil management systems. Statistical analyzes were performed using analysis of variance and Pearson correction. The spatial variation was represented using the SURFER software. The results of variance analysis indicate statistical differences between values of bulk density and soil particle size between depths, between the different management and spatial distribution within each management. It was perceived spatial relationship between moisture and attributes studied for some depths and types of management, but there was little influence of physical attributes in the behavior of moisture to the soil and conditions studied.

Keywords: Soil physical attributes; soil water content; soil tillage systems; surfer.

1. INTRODUCTION

Water is the main factor determining the productivity of crops. During the whole development, the plant absorbs water and loses using the ground as a reservoir of water and nutrients. The amount of water consumed by a crop during its development varies with the spatial and temporal distribution of climate, the variety of culture and management of the agricultural system, which modifies the physical properties of the soil directly related to storage of water [1].

It is noteworthy that due to the large spatial variability of physical and water attributes become often onerous costs sampling and analysis of soil to represent the average of any attributes.

Soils are naturally heterogeneous and their properties vary continuously in space and time. Among the factors responsible for the variability, we can mention the processes of training, involving the physical and chemical characteristics, interactions with the biological system and anthropogenic interference.

The soil has higher variability in their attributes, both vertically and horizontally, resulting from the interaction of the processes that govern the factors of their formation [2]. Knowledge of the distribution of physical water soil attributes becomes a basic requirement when seeking to establish appropriate management practices for soil and crops, for failure to comply with these concepts will result in errors in sampling and soil management. This stems from the large spatial variation of soil attributes and meaning and direction of water flows [3].

Over the years, some authors have studied the temporal stability of soil moisture and concluded that specific sites can represent the mean values of moisture in a given area of study over a period of time and that the identification of these points is fundamental in planning of monitoring programs for hydrological and hydro agricultural variables, as it allows the reduction of costs related to the measurement of field data [4,5, 6,7,8,9,10,11,12].

Therefore, the aim of this work was to analyze the response of moisture to the spatial variation of density and particle size in a Hapludox under three different managements (Tillage, Crop-Livestock Integration and Conventional Planting) in the municipality of Jataí, southwest of Goiás, Brazil.

2. MATERIALS AND METHODS

2.1 Experiment Location

The experiment was conducted in an experimental area at the Federal University of Goiás (UFG), Regional Jataí, in the southwest of the State of Goiás - Brazil (Fig. 1), 17º 52 '53 "S latitude and 51° 42' 52" W longitude, with 700 m of altitude, located in a climatic region type Cw, tropical savanna, mesothermal, with well-defined dry and rainy season, according to Kopen rating. The average annual rainfall varies around 1600 mm [13]. The studied soil was classified as Hapludox, according to the classification of EMBRAPA [14].

2.2 Experiment Area

The experimental area was composed of three sub-areas of approximately 1 ha each, cultivated with soybean (*Glycine max*) in the season 2013/2014 (first crop) with different soil management systems (Fig. 1, b and c).

Subareas have been cultivated over the years with soybean in the first crop and maize (*Zea mays*) and sorghum (*Sorghum bicolor*) in the second (off-season) in no-tillage (NT) since the year 2008 (subarea 1) in crop-Livestock Integration system (ILP), consorting soybean crops and pasture since 2009 (subarea 2) and conventional tillage (CONV) associated with the use of harrowing at the time of planting. Each subfield is divided into a regular grid containing nine cells measuring 30 x 30 m each (Figs. 1, b, and c) considering the center of each cell as the reference point for sampling.

The nine points were used to maintain the same experimental conditions for the treatments, with the same slope, even soil, and the same environmental conditions.

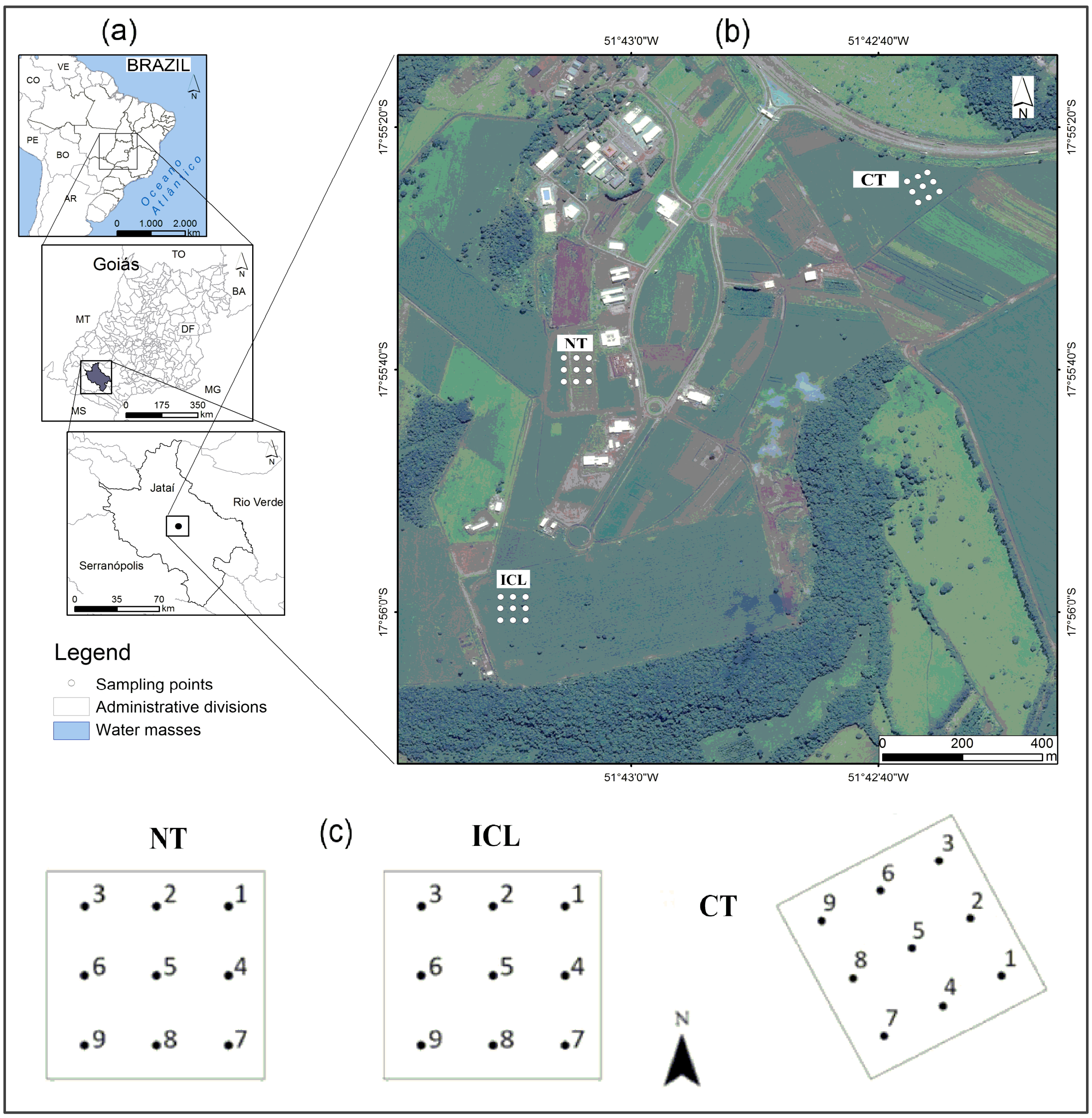

Fig. 1. Experiment location (State System of Geoinformation of Goiás - SGEI, 2014) (a); satellite image of the study area (Google Earth, 20/04/2014) (b); Sketching and distribution of the sampling points in the study areas (c). NT: No-tillage; ICL: integrated crop livestock; CT: conventional tillage

2.3 Sampling and Data Collection

The determination and location of points for data collection were done by georeferencing, using a GPS system ("Global Positioning System"), GARMIN, MAP785 model.

On predetermined points, it was collected the straw (crop residues deposited on the soil surface) using an arc with an internal area of 1.0 m², released randomly near the sampling point. Immediately after sampling the straw at each point, it was made monitoring of soil moisture. Moisture data were collected on nine points on each soil management system (NT, ICL and CT) at depths from 0 to 0.12, from 0.12 to 0.24 and 0.24 to 0.36 m, between the months of November 2013 and February 2014, with instantaneous readings every 14 days, by means of an equipment type TDR (time domain reflectometry). At the same points, deformed samples were collected for determination of soil organic matter (SOM). This portable Time Domain Reflectrometry (TDR) type sensor, "HydroSence" (CD620, CS620), 0.12 m long rod manufactured by Campbel Scientific, provided instantaneous readings of soil water content based on volume, providing monitoring of layers 0.12 m depth. Four repetitions were made, collected randomly within a radius of 1 m from the reference point.

For calibration of the TDR sensor, a methodology similar to Abbas et al. [15] was adopted. 270 deformed soil samples were collected at five of the nine points of each management system, with 4 replicates per point (20 replicates per depth analyzed), collected randomly within a radius of 1 m from the point, at three depths.

With the predetermined points, it was held to monitor the soil moisture, as well as the removal of undisturbed soil samples collected in containers volumes known for determining the density and deformed sample for determining of soil particle size (clay), as recommended by EMBRAPA, [14].

3. RESULTS AND DISCUSSION

3.1 Area Characteristics

Although Schneider et al. (2008) [16] mention that the continuing existence of the pattern of the water content in the soil can be influenced by the topography, the relief of the areas used in the study (the gently rolling plan) significantly reduces the interference of relief in the spatiotemporal pattern of moisture soil in these areas, significantly reducing the influence of the topography in the temporal analysis of soil moisture (Fig. 2).

As the topography, vegetation also had little influence in the comparative analysis of soil moisture between the three types of soil management (NT, ICL and CT), since the plantation was carried out with the same crop (soybean) and on the same date for both.

3.2 Soil Characteristics

It was determined the soil pH (H_2O), which showed values close to 5.47 for all conditions.

After completion of the analysis of variance and test "Scott-Knott" the 5% significance, realized a statistical difference between the mean values of soil attributes evaluated in this study. Different letters placed after the average values of the attributes (Table 1) represent these differences.

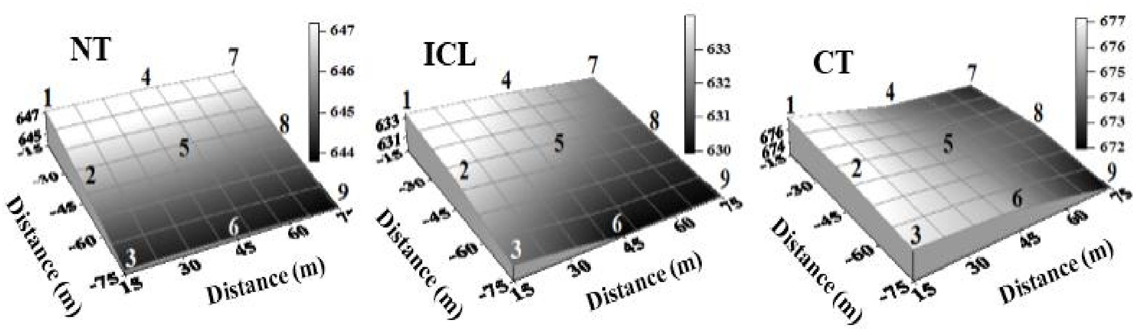

Fig. 2. Topography in the study areas. NT: No-tillage; ICL: integrated crop livestock; CT: conventional tillage

The increased stability in CT probably occurred due to the frequent disturbance of the three depths under review. Higher values of soil density in layers close to the soil surface, in NT and ICL systems indicate a greater degree of compression in these layers (Table 1), which can be attributed to traffic historical of agricultural machinery in soil slightly upturned to over the years, confirming effects observed by Costa et al. [17] and Assis et al. [18]. In ICL, such compaction becomes more pronounced due to animal trampling [19].

Table 1. Characteristics of the studied Latosol (ANOVA and test "Scott-Knott," α = 0.05)

Attribute	Parameter	NT-A	NT -B	NT -C	ICL-A	ICL-B	ICL-C	CT-A	CT-B	CT-C
Bulk Density ($g\ cm^{-3}$), (n = 9)	Average	1.26a	1.19b	1.17b	1.32a	1.22a	1.14b	1.24a	1.26a	1.27a
	Maximum	1.44	1.37	1.32	1.38	1.37	1.25	1.37	1.39	1.38
	Minimum	1.09	0.99	1.02	1.14	1.09	0.99	1.07	1.14	1.09
	Standard deviation	0.10	0.12	0.11	0.07	0.10	0.08	0.10	0.08	0.09
	Variation coeficient	7.98	10.23	9.69	5.46	7.98	6.92	7.69	6.23	6.73
	S. Error	0.03	0.04	0.04	0.02	0.03	0.03	0.03	0.03	0.03
Organic Matter (%), (n = 36)	Average	3.1b	2.7c	2.2d	3.4a	3.3a	2.6c	3.5a	3.4a	2.7c
	Maximum	3.61	3.59	2.97	4.10	4.04	3.56	4.05	3.61	3.25
	Minimum	2.56	2.27	1.69	2.71	2.48	1.80	2.56	2.47	2.23
	Standard deviation	0.24	0.25	0.32	0.40	0.37	0.38	0.40	0.37	0.36
	Variation coeficient	7.8	9.38	14.48	11.96	11.15	14.74	11.60	12.29	13.40
	S. Error	0.04	0.04	0.05	0.07	0.06	0.06	0.13	0.12	0.12
Clay (%), (n = 9)	Average	45.1c	44.3c	48.2b	43.1c	46.8b	48.3b	57.6a	58.0a	58.9a
	Maximum	49.32	50.16	52.74	48.59	50.48	53.12	64.85	63.19	63.84
	Minimum	42.19	36.31	44.21	35.12	39.96	44.19	52.06	47.83	54.16
	Standard deviation	2.83	4.64	2.74	4.42	3.36	3.10	4.87	5.37	3.78
	Variation coeficient	6.27	10.46	5.68	10.25	7.17	6.43	8.45	9.25	6.42
	S. Error	0.94	1.55	0.91	1.05	1.12	1.03	1.62	1.79	1.26
Silt (%), (n = 9)	Average	28.5a	29.4a	25.1b	32.0a	27.8a	26.5b	26.2b	26.3b	23.0b
	Maximum	34.30	3.69	30.14	38.51	30.68	30.66	32.53	33.16	28.97
	Minimum	24.34	22.65	19.97	25.73	23.52	22.47	17.72	22.43	13.02
	Standard deviation	3.40	5.00	3.17	3.91	2.33	2.86	4.57	4.16	4.84
	Variation coeficient	11.92	17.01	12.64	12.23	8.39	10.77	17.47	15.83	21.08
	S. Error	1.13	1.67	1.06	1.30	0.78	0.95	1.52	1.39	1.61
Sand (%), (n = 9)	Average	26.4a	26.3a	26.7a	25.0a	25.4a	25.2a	16.3b	15.7b	18.1b
	Maximum	29.11	29.35	29.76	26.86	29.36	25.93	18.76	19.23	25.18
	Minimum	21.38	20.92	24.55	17.25	22.00	24.26	14.18	13.07	14.61
	Standard deviation	2.27	2.99	1.68	2.96	2.62	0.57	1.50	1.95	2.99
	Variation coeficient	8.60	11.35	6.26	11.85	10.33	2.27	9.22	12.40	16.51
	S. Error	0.76	1.00	0.56	0.99	0.87	0.19	0.50	0.65	1.00

n = sample size; S. Error = mean standard error; NT: no-tillage; ICL: integrated crop livestock; CT: conventional tillage; A = 0 – 0.12 meters; B = 0.12 – 0.24 meters; C = 0.24 – 0.36 meters; Means followed by the same letter on the line, do not differ statistically

Analyzing Table 1 and Fig. 3, it is noted a tendency toward greater stability of density values along the soil profile in CT system, since the three layers of this system are equal to each other, while in other systems the first layers showed higher density values also represented by a greater homogeneity in color pattern between the three layers of CT system, compared to other systems.

Also in Table 1 and in Fig. 4, it is possible to see similarities between the NT and ICL systems as the clay content in the three analyzed layers and growing trend with soil depth, unlike CT system, that is statistically different when presenting higher values of clay content at all depths evaluated compared to previous systems, with mean values close to 58%.

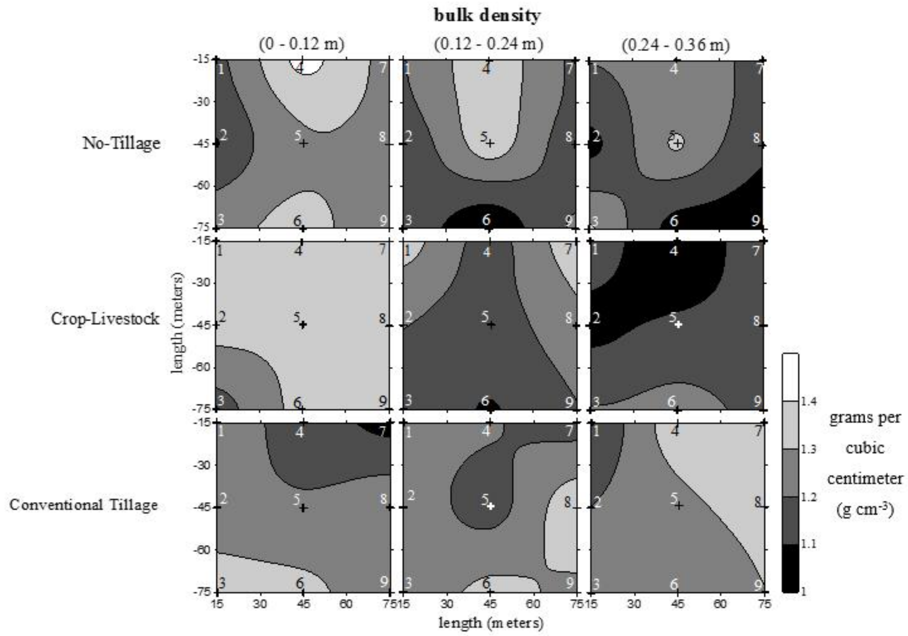

Fig. 3. Spatial distribution of density (g cm^{-3}) soil in three management systems and three depths

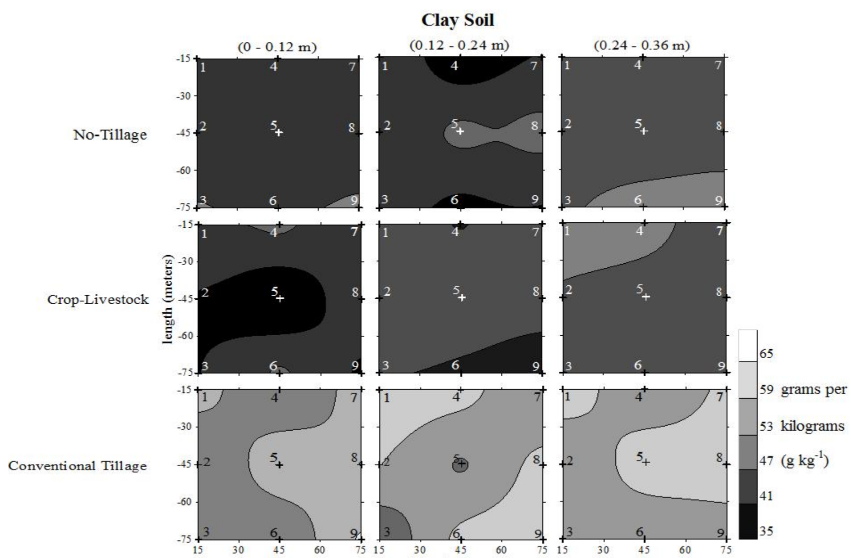

Fig. 4. Spatial distribution of soil clay content in three management systems and three depths

Table 2. Correlation coefficient of "Pearson" between soil moisture and variables investigated for the three types of management in different soil depths

Management system	Depth	Bulk density	Clay
NT	A	0.29	-0.14
	B	-0.24	-0.16
	C	-0.23	0.22
ICL	A	-0.14	-0.20
	B	0.03	0.64**
	C	-0.52**	-0.16
CT	A	0.13	-0.35
	B	-0.35	-0.56**
	C	-0.79**	0.09

*** Significant to 1% (ANOVA); A = 0 to 0.12 m; B = 0.12 to 0.24 m; C = 0.24 to 0.36 m; NT: no-tillage; ICL: integrated crop livestock; CT: conventional tillage*

Similar to Gao & Shao [11], the correlation coefficient of "Pearson" was used to examine the dependence of the water content in the soil (WCS) in relation to the soil properties to NT, ICL and CT at three different depths (Table 2).

The physical attributes analyzed showed a spatial relationship with moisture in two soil management systems (ICL and CT), with two events in each system. The increase in density caused a reduction of soil moisture in depth from 0.24 to 0.36 m for both, ICL and to CT. However, to the clay, there was both a positive (ICL-B) and negative (CT-B) relation. Note also that greater depths favor greater influence of these attributes on the variation of soil moisture in ICL and CT systems (Table 2).

4. CONCLUSION

Although there was some significance between the analyzed variables, it can be considered that there was little influence of physical attributes on the behavior of moisture to the studied soil and conditions.

For the systems of integrated crop livestock and conventional tillage, the greater the depth, the greater the influence of bulk density and clay on soil moisture.

Bulk density and clay reduced with depth in no-tillage and integrated crop livestock systems, and clay was higher in no-tillage and integrated crop livestock systems compared to conventional tillage.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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