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INFLUENCE OF SOIL PROPERTIES AND ENVIRONMENTAL CHARACTERISTICS IN WATER INFILTRATION IN URBAN AREAS

INFLUÊNCIA DAS CARACTERÍSTICAS AMBIENTAIS E DOS ATRIBUTOS DO SOLO NA INFILTRAÇÃO DA ÁGUA EM ÁREA URBANA

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ABSTRACT – This study investigated the influence of the environmental characteristics and soil properties on the soil infiltration rate in urban permeable area. The experiments were conducted at nine sampling points located in the urban perimeter of Campo Grande, capital city of Mato Grosso do Sul State, in the Brazilian Midwest. The infiltration rates were determined using a portable integrated rainfall and overland flow simulator. Each experiment was repeated three times, and a total of twenty-seven plots were collected. At the same time, environmental characteristics and soil physical properties, that may affect infiltration rate, were also evaluated. The relationship between the infiltration rate, the environmental plot characteristics and the soil physical properties was verified using a linear correlation matrix.
Keywords: Soil infiltration rate; Urban permeable area; Bulk density; Linear correlation; Integrated rainfall simulator.

RESUMO - Este estudo investigou a influência das características ambientais e das propriedades do solo na taxa de infiltração em áreas urbanas permeáveis. Os experimentos foram realizados em nove pontos de amostragem localizados no perímetro urbano de Campo Grande, capital do estado de Mato Grosso do Sul, no Centro-Oeste do Brasil. As taxas de infiltração foram determinadas usando um simulador de chuva portátil. Cada experimento foi repetido três vezes, com um total de vinte e sete amostras coletadas. Ao mesmo tempo, as características ambientais e as propriedades físicas do solo, que podem afetar a taxa de infiltração, também foram avaliadas. A relação entre a taxa de infiltração, as características ambientais da parcela e as propriedades físicas do solo foram verificadas usando uma matriz de correlação linear.
Palavras-chave: Taxa de infiltração; Área urbana permeável; Densidade; Correlação linear; Simulador de chuva.

INTRODUCTION

Soil infiltration is recognized as a basic ecological process that affects, not only surface runoff and soil erosion (Michaelides et al., 2009), but also the chemical transport route, the water quality of agricultural drainage and the uniformity and efficiency of surface irrigation (Rashidi et al., 2014). At the rate that the infiltration occurs is known as the infiltration rate, which continues to decrease and asymptotically approaches the saturated hydraulic conductivity. The infiltration rate, which is an important component of any hydrologic model, mainly depends on the characteristics of the soil (Osuji et al. 2010; Thompson et al. 2010) and influence the timing of overland flow (Viessman and Lewis, 1996). In addition, the infiltration rate and rainfall intensity define the runoff volume and influence the timing of overland flow.

Several factors can affect the infiltration rate such as hydraulic conductivity of the soil profile, porosity, texture, initial moisture content, degree of swelling of soil colloids, organic matter, vegetative cover and duration of irrigation or rainfall. Soil infiltration is directly dependent on the stability of soil structure (Herrick et al., 2006), bulk density (Anderson et al., 2008) and saturated hydraulic conductivity (Antigha and Essien, 2007). Gülser and Candemir (2008) affirm that the hydraulic conductivity is one of the most important physical properties determining infiltration rate. According Shrestha et al. (2005), physical changes in soil can alter the infiltration rates at reclaiming sites, when compared to the infiltration rates at undisturbed sites in the same area.

Some researchers (Olson et.al, 2013; Schwartz and Smith, 2016; Mohammadshirazi et al., 2017) investigated the uses and management of agricultural soils to restore the hydrological function of the soil and the environmental services of urban permeable areas. Parchami-Araghi et al. (2013) developmental studies for estimation of the infiltration process, in different soil classes in Iran. The authors conclude that the difficulty of the selected models explains the variability of infiltration process can be related to two reasons: the high variability of the infiltration process causes the inability of the applied independent variables for a reasonable explanation of its variation and the infiltration process is strongly affected by macro-pores and soil structure. Gregory et al. (2006) quantified the effect of compaction due to construction activities on infiltration rates and determined the effect of various levels of compaction on infiltration rates of sandy urban development sites in North Central Florida. They found that the infiltration rates in compacted soils were generally much lower than the design storm infiltration rate. This implies that construction activity in that region increases the potential for runoff and the need for large storm water conveyance networks. Yang and Zhang (2011) explored the water infiltration characteristics of urban soils with different degrees of compaction in Nanjing City, China and verified that the major factors affecting infiltration rates were related to the bulk density, total porosity, air-filled porosity, capillary porosity, and organic matter content. This study investigated the influence of the environmental characteristics and soil attributes on the soil infiltration rate in urban permeable area. The experiments were conducted at nine sampling points located in the urban perimeter of Campo Grande city, Mato Grosso do Sul State, Brazil.

METHODOLOGY

Study area

The present study was developed in permeable areas of the city Campo Grande, capital of the Brazilian State of Mato Grosso do Sul, which is located on the watershed divide of the Paraná and Paraguay basins. The urban area of the city is located in the geographic coordinates 20º26'34" South latitude and 54º38'47" West longitude.

The Geotechnical Chart of the City of Campo Grande (Planurb, 1991) was used as a basis to guide the location of the tests and obtain variability of soil properties. The Geotechnical Chart has five units that express a higher expectation of the occurrence of a given set of characteristics, such as lithology and pedology, according to the Brazilian System of Soil Classification, of the units can be highlighted: Unit I – Basalt and intertrap Arenite of Serra Geral Formation, witch originates LV, an oxisol; Unit II - Arenites of Caiuá Formation that originate RQo, an entisol; Unit III – Intertrap Arenite of Serra Geral Formation, witch originate LV, an oxisol, and LVA, an oxisol; Unit IV – Recent Alluvial Deposit which corresponds a alluvial and hydromorphic soils; and he Unit V which corresponds of the headwater drainage area. The Units IV and V were not considered in this study, because the soils of Unit IV are normally saturated and with a little thickness seated on basalt, and Unit V is superimposed over the others.

The experiments were conducted at nine sampling points located in the urban perimeter of Campo Grande city, MS, Brazil. The sampling points are located in permeable surface with distinct uses: parks, squares and lots without construction of public or private property. Each experiment was repeated three times, and a total of twenty-seven plots were collected (Figure 1).

Infiltration and soil characteristics

The initial and final infiltration rates were evaluated in 27 plots at different locations, after removal of the vegetation cover. The experimental plots with dimensions 0,70 meters wide by 1 meter in length towards the slope received the precipitation of the portable rainfall simulator (Alves Sobrinho et al., 2008). The plots were pre-wetted 12 hours before the field tests were started in order to standardize the humid conditions.

The rainfall intensity applied at the experimental plots varied from 62 to 118 mm.h^{-1}, this variation was necessary to surface runoff occur in different soils in the plots and to obtain a stable infiltration rate in the experiments, considering

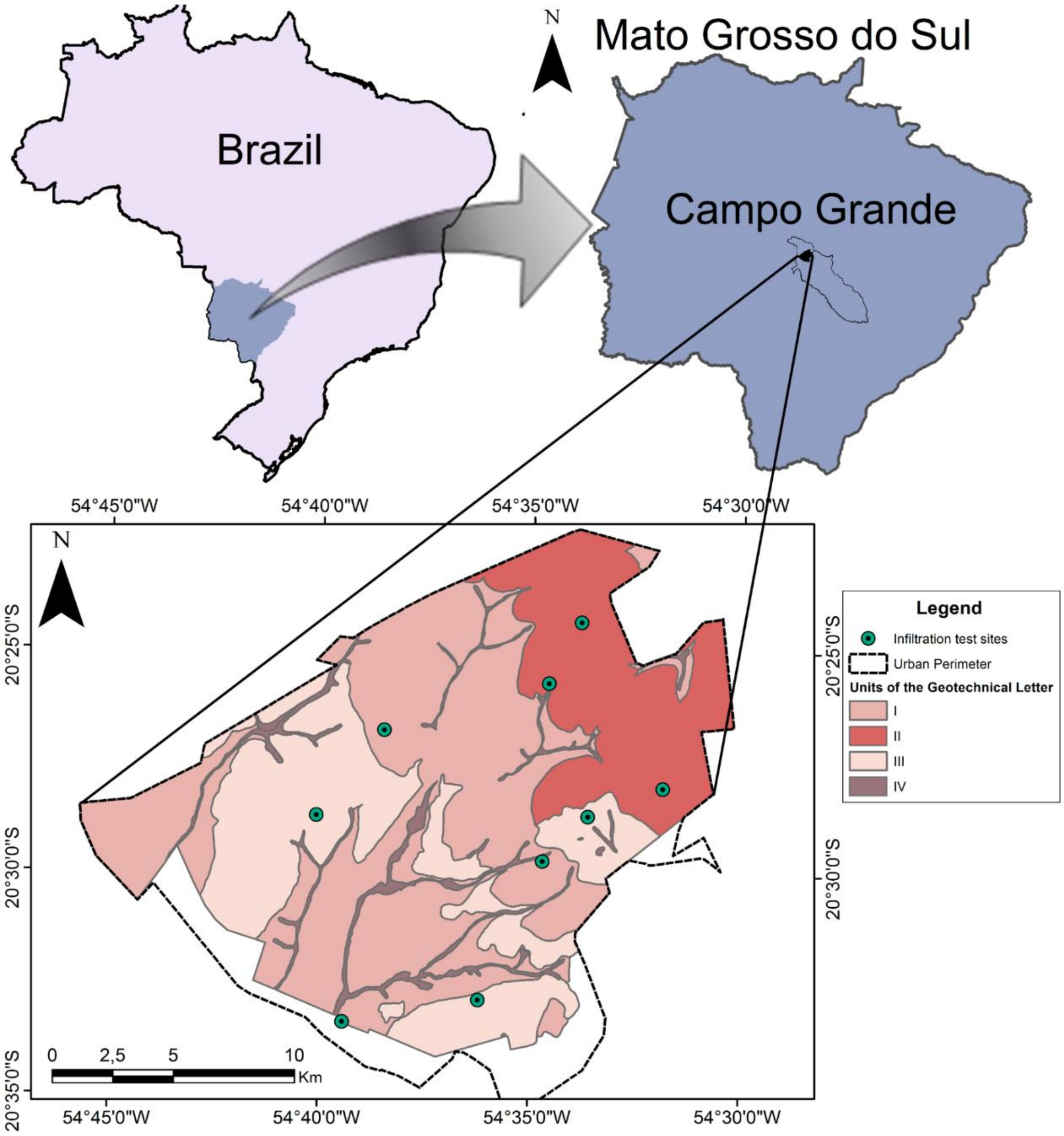

Figure 1. Location of the urban perimeter, sampling points and Geotechnical Chart Units of the City of Campo Grande - MS (Planurb, 1991).

the limitation of the flow volume collected by the available equipment. The rainfall intensity was calibrated before each simulation using a calibration plate that covers the useful area of the experiment.

After checking the beginning of the runoff, 31 samples were taken with a duration of 1 minute, with an equal interval between collections. The total duration of the experiment was 61 minutes. The final infiltration rate (Tf) was considered the arithmetic mean of the last four observations during the infiltration test, i.e., the mean of the values obtained at 54, 56, 58 and 60 minutes after the beginning of the flow.

Sampling and soil analysis

Samples were collected in the experimental plots in order to understand some factors that affect water infiltration into the soil. In order to determine the bulk density, undisturbed samples were collected with volumetric rings at depths of 0-15 cm and 15-30 cm. Deformed samples were collected from the superficial horizon (0-15 cm) for the following analyzes: Organic matter, through oven drying at 105ºC and subsequent burning at 440ºC (ABNT, 1996); texture analysis, performed by the pipette method after chemical dispersion with NaOH in 1mol/L and physical dispersion by mechanical stirrer at 14000 rpm; particle density, determined through a volumetric flask, with a sample of fine earth dried in an oven and ethyl alcohol, according to Embrapa (1997) recommendations. The total porosity, which is the fraction of the soil in volume, not occupied by solids, was obtained through the relation between the bulk density and particle density.

In addition to the rainfall intensity, the environmental characteristics of the plots were verified. The slope of the plot (in the direction of higher slope) was determined using a level ruler. To obtain the initial and final soil moisture, a humidity probe with Time Domain Reflectometry (TDR) technology was used.

Statistical Analysis

Descriptive statistical analysis based on the Units of Geotechnical chart was performed. For each variable studied, the parameters maximum, mean, minimum, standard deviation (SD) and coefficient of variation (CV). The normality of the data was assessed using the Shapiro-Wilk test at a significance level of 0,05%. The null hypothesis were accepted that the texture (with the exception of the coarse sand), bulk density, particle density, organic matter, total porosity, slope and initial and final soil moisture, initial and final infiltration rate of the plots, initial and final infiltration rate of the evaluated sites do not have a normal distribution.

The relationship between the initial and final infiltration rate, the environmental plot characteristics (rainfall intensity, slope and initial and final soil moisture) and the soil properties (texture, bulk density, particle density, organic matter and total porosity) was verified using a linear correlation matrix.

RESULTS AND DISCUSSION

According to Ogunkunle (1993) classification, the results of descriptive statistical analysis of infiltration rate and environmental plot characteristics (Table 1) with coefficient of variation with below 15% were considered with low variation, between 15% and 35% of moderate variation, and above 35% high variation.

In the three soil classes, the particle density, because it is a very stable physical attribute and related to the soil source material, was the property that presented lower variability (CV<4%). Particle density values higher than 3,0 $g.cm^{-3}$ in the LV, an oxisol, with clayey texture. According to Ferreira (2010), this fact is explained by the presence of iron oxides in LV, an oxisols, such as magnetite (specific mass of the order of 5,2 $g.cm^{-3}$), which contributes to the increase of the density of the particles and the quartz (specific mass of the order of 2,65 $g.cm^{-3}$), which contributed to the reduction of the values of the particle density in RQo, an entisol.

The coefficients of variation of the results obtained for Unit I, comprising LV, an oxisol, indicated large variations occurred for final infiltration rate (CV:59,72%), silt content (CV:55,53%), organic matter content (CV:46,66%) and clay content (CV:35,90%). The results to initial infiltration rate, slope, fine and course sand contents and final soil moisture presented moderate variation (15% < CV < 35%), and the others are considered of low variability (CV < 15%). The following classes were found with respect to texture: clay loam, sandy clay loam and sandy loam.

The largest variations for Unit II, comprising RQo, an entisol, with a sandy texture (sand, loamy sand and sandy loam), are related to the silt content (CV:44,97%) and to the clay content (CV:37,13%). The variations occurred in the final infiltration rate, slope, organic matter and course sand were moderate.

About the results obtained for Unit III, comprising LV and LVA, both oxisols, the organic matter content (CV:98,75%), clay (CV:79,44), silt (CV:70,77), course sand (CV:44,79) and the final infiltration rate (CV: 38,83) presented a high variation. This was mainly due to the fact that the sites sampled had two distinct textural classes: Clay and loamy sand. In this Unit, the initial infiltration rate, the rainfall intensity, the fine sand, the initial and the final soil moisture, the total porosity and the slope) presented coefficient of variation classified as moderate.

A large variation of the soil properties was observed within the same unit of the geotechnical chart. A greater heterogeneity was observed in the texture, organic matter and final infiltration rate. Elhakeem and Papanicolaou (2009) highlight that scale is an important factor in characterizing the heterogeneity of landscape attributes and the geotechnical chart used in this study has soil clusters and pedological sketch in scale of 1: 60.000.

The strong negative correlation between organic matter and the initial infiltration rate might be connected to the hydrophobicity of the organic matter (Table 2). Ferreira et al. (2015) found a positive linear correlation between organic matter content and hydrophobicity severity (r = 0,308 for surface and 0,345 for subsurface soil). Capriel et al. (1995) affirm that

Table 1. Descriptive statistical analysis by sampling classes.

	Maximum	Minimum	Range	Mean	SD	CV (%)
			Unit I			
CS	34,34	22,78	11,55	27,87	4,55	16,32
FS	44,29	18,61	25,67	35,68	11,86	33,26
Si	19,77	5,06	14,71	11,13	6,18	55,53
C	37,74	16,12	21,62	25,32	9,09	35,90
BD	1,85	1,55	0,30	1,68	0,09	5,62
PD	3,23	2,96	0,27	3,09	0,10	3,27
TP	50,77	37,52	13,25	45,74	4,80	10,50
OM	8,71	2,62	6,09	5,11	2,39	46,66
S	10,51	5,24	5,27	8,60	1,84	21,36
Θ_i	46,31	31,94	14,37	38,27	5,13	13,42
Θ_f	49,92	32,67	17,25	41,41	6,22	15,03
RI	89,14	62,00	27,14	72,82	9,41	12,92
Tin	84,17	42,06	42,11	60,53	12,51	20,67
Tf	30,00	3,14	26,86	14,23	8,50	59,72
			Unit II			
CS	52,55	30,33	22,22	42,04	8,74	20,79
FS	46,32	38,05	8,27	42,83	3,24	7,57
Si	6,76	1,41	5,35	4,41	1,98	44,97
C	16,59	6,86	9,73	10,71	3,98	37,13
BD	1,93	1,76	0,18	1,80	0,06	3,17
PD	2,94	2,83	0,11	2,88	0,03	1,04
TP	39,89	33,05	6,84	37,51	1,96	5,23
OM	2,81	1,62	1,19	2,15	0,48	22,59
S	10,51	5,24	5,27	8,07	1,85	22,95
Θ_i	33,21	26,28	6,93	30,29	2,61	8,61
Θ_f	34,53	28,17	6,36	32,38	2,38	7,34
RI	107,14	80,64	26,50	92,73	10,72	11,56
Tin	97,17	76,36	20,81	85,87	9,30	10,83
Tf	49,29	20,86	28,43	35,10	10,04	28,60
			Unit III			
CS	49,39	13,46	35,93	33,26	14,90	44,79
FS	45,91	28,00	17,90	38,27	7,44	19,43
Si	18,86	3,89	14,97	8,82	6,24	70,77
C	42,71	8,27	34,44	19,65	15,61	79,44
BD	1,87	1,41	0,46	1,66	0,19	11,50
PD	3,21	2,95	0,26	3,06	0,10	3,39
TP	56,06	38,00	18,06	45,59	7,74	16,97
OM	12,50	1,09	11,41	5,32	5,26	98,75
S	8,75	5,24	3,51	7,77	1,20	15,40
Θ_i	43,62	30,09	13,53	35,63	6,05	16,98
Θ_f	44,78	33,22	11,56	38,07	5,02	13,20
RI	108,00	66,00	42,00	90,64	18,73	20,66
Tin	102,00	59,11	42,89	86,43	19,72	22,81
Tf	83,63	30,00	53,63	48,85	18,97	38,83

SD: standard deviation, CV: coefficient of variation, CS: course sand (%), FS: fine sand(%), Si: Silt(%), C: Clay(%), BD: bulk density ($g.cm^{-3}$), PD: particle density($g.cm^{-3}$), TP: total porosity (%),OM: organic matter(%),S: Slope(%), Θ_i : Initial soil moisture($m^3.m^{-3}$), Θ_f: Final soil moisture ($m^3.m^{-3}$), RI: rainfall intensity ($mm.h^{-1}$), Tin: initial infiltration rate ($mm.h^1$); Tf: final infiltration rate($mm.h^1$).

Table 2. Linear correlation matrix

	CS	FS	Si	C	BK	PD	TP	OM	S	Θi	Θf:	RI	Tin	Tf
CS	1													
FS	0,259	1												
	(0,192)													
Si	-0,960	-0,260	1											
	(0,000)													
C	-0,966	-0,366	0,926	1										
	(0,000)	(0,060)	(0,000)											
BK	0,823	0,387	-0,769	-0,807	1									
	(0,000)	(0,046)	(0,000)	(0,000)										
	(0,000)	(0,070)	(0,000)	(0,000)	(0,000)									
PD	-0,742	-0,501	0,751	0,778	-0,737	1								
	(0,000)	(0,008)	(0,000)	(0,000)	(0,000)									
TP	-0,821	-0,388	0,799	0,820	-0,926	0,891	1							
	(0,000)	(0,046)	(0,000)	(0,000)	(0,000)	(0,000)								
OM	-0,930	-0,387	0,906	0,948	-0,741	0,721	0,727	1						
	(0,000)	(0,046)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)							
S	0,187	-0,113	-0,208	-0,126	0,311	-0,071	-0,286	-0,029	1					
	(0,349)	(0,575)	(0,297)	(0,530)	(0,114)	(0,725)	(0,148)	(0,885)						
Θi	-0,860	-0,371	0,823	0,856	-0,864	0,722	0,846	0,752	-0,221	1				
	(0,000)	(0,057)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,268)					
Θf:	-0,771	-0,507	0,783	0,813	-0,850	0,795	0,887	0,692	-0,191	0,920	1			
	0,000	(0,007)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,334)	(0,000)				
RI	0,844	0,511	-0,803	0,854	0,786	-0,641	-0,693	-0,867	0,163	-0,784	-0,717	1		
	(0,000)	(0,006)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,417)	(0,000)	(0,000)			
Tin	0,789	0,445	-0,750	-0,805	0,687	-0,567	-0,585	-0,858	-0,056	-0,696	-0,617	0,913	1	
	(0,000)	(0,020)	(0,000)	(0,000	(0,000)	(0,002)	(0,001)	(0,000)	(0,780)	(0,000)	(0,001)	(0,000)		
Tf	0,498	0,452	-0,498	-0,527	0,418	-0,364	-0,314	-0,560	-0,073	-0,526	-0,459	0,764	0,819	1
	(0,009)	(,019)	(0,009)	(0,005)	(0,030)	(0,062)	(0,111)	(0,002)	(0,717)	(0,005)	(0,016)	(0,000)	(0,000)	

CS: course sand (%), FS: fine sand(%), Si: Silt(%), C: Clay(%), BD: bulk density (g.cm^{-3}), PD: particle density(g.cm^{-3}), TP: total porosity (%),OM: organic matter(%),S: Slope(%), Θ_i : Initial soil moisture(m^3.m^{-3}), Θ_f: Final soil moisture (m^3.m^{-3}), RI: rainfall intensity (mm.h^{-1}), Tin: initial infiltration rate (mm.h^1); Tf: final infiltration rate(mm.h^1)

the soil texture influences the composition of the soil organic matter and amount of microbial biomass, is the organic matter of sandy soils more hydrophobic and clay stabilizing the microbial biomass. Bronik and Lal (2005) affirm that in Oxisols, non-crystalline aluminum hydroxides are capable of protecting organic matter from microbial decomposition and stabilizing aggregates. Such affirmations are evidenced by the strong positive correlation of the organic matter with the clay content (0,948, p < 0,001) and negative correlation with the course sand (-0,930, p < 0,001).

There was no significant correlation between slope and the infiltration rate. This result might be due to the small variation of the slope of the plots, which varied from 6 to 11%, which reflects the relief in the city of Campo Grande, with predominance of smooth and undulating areas (0-12%).

A negative correlation was found between initial infiltration rate and initial soil moisture (-0,696, p < 0,001). As shown by Huang et al. (2013), the initial soil moisture increase reduces the infiltration of water into the soil, once decreases soil water potential and water suction. Throughout the infiltration process the water suction decays and becomes almost zero, the infiltration rate stabilizes over time. In such condition, the movement of water in the soil occurs by gravity through the macroporos and preferentially flows and the moisture remain constant corresponding to the saturation, considered in this work, close to final soil moisture.

In addition, initial and final soil moisture has a high positive correlation with the silt and clay contents e negative with course sand. According to Yang and Zhang (2008), silt and clay have a stronger effect on the water suction than sand, even when the pore sizes are similar. Gregory et al. (2006) did not find a relationship between soil moisture and final infiltration rate. Thus, it is believed that the other correlations found between final moisture and initial and final infiltration rates are due to the influence of texture on the retention and movement of water in the soil.

By the influence of soil water potential and water suction a high correlation between precipitation and the initial infiltration rate was obtained (0,913, p < 0,001). Furthermore, in this study, the rainfall intensity was adjusted in order to obtain the final infiltration rate. Huang et al. (2013) found no significant difference in the increase of soil moisture for different rainfall intensities. Hawke et al. (2006) found alterations in the hydraulic conductivity and soil water potential relationship only when the rainfall intensity coincided with textural disruption of the soil. However, Abu-Awwad (1997) e Foley and Silburn (2002), argue that the increased of rainfall intensity might reduce the saturated hydraulic conductivity of the soil through the formation of the surface sealing. No information was obtained on the surface sealing in the plots due to the limitations of the equipment used in this study.

The lowest values of total porosity were found in sandy soils, while the highest values were obtained in clayey soils. There was a strong negative correlation (-0,821, p < 0,001) of this attribute with the coarse sand content. In porosity, two categories are considered regarding pore size, macroporosity and microporosity. The reduction of particle size leads to the reduction of macroporosity, which is responsible for water movement in the profile and increase of microporosity, which favors the retention of water in the soil. Considering the classes of soil, in LV, the microporosity exerts greater influence on the composition of the total porosity, while in RQo, the greatest influence is exerted by macroporosity. However, the total porosity is higher in LV, as demonstrated by Carneiro et al. (2009), where the soil had total porosity of 54%, with microporosity of 37%. Also in this study, for the RQo under pasture, the total porosity found was 34% and macroporosity 25%.

The correlations between total porosity and initial and final infiltration rate were not significant. This could be due to the textural variation and the consequent variation of the micro and macro porosity of the data, which were not measured and affected the result of the total porosity. Klinke Neto et al. (2017) found a correlation of 0,53 the saturated hydraulic conductivity and macroporosity, being this the best result found among all attributes studied (texture, bulk density, total porosity, macroporosity and microporosity). Analyzing the spatial variability of the data, for the LVA soil class, the same authors found anisitropy only for the data of saturated hydraulic conductivity, macroporosity and total porosity.

Similarly to what occurred in the correlation between total porosity and infiltration rates, the textural variation observed in the different soil classes LV, RQo, and LVA led to a misunderstanding in the correlations between bulk density and initial and final infiltration rates. For being an attribute that reflects the arrangement of the soil particles, the soil density is a reflection of the porous system. As previously described, sandy soils have greater macroporosity, which leads to higher infiltration rates. However, lower total porosity leads to higher bulk density values. The opposite occurs in clayey soils, which leads to a positive correlation between bulk density and initial and final infiltration rates. This can be confirmed by the strong positive correlation (0.823) between bulk density and course sand content and negative (-0,807) between bulk density and clay content.

Thus, it is observed that the increase of bulk density is related to soil texture and not to compaction. For the same texture, the increase of bulk density would be an indication of compaction, while the reduction of the pore space would lead to lower values of infiltration rate. Therefore the correlation between soil density and infiltration rate should be negative, thus reflecting soil compaction.

In this study, samples of the same soil class, identical texture and different levels of compaction were not collected. It should be noted that if a larger number of samples had been collected, a grouping through the texture could initially have been performed. Next, the bulk density and infiltration rate analysis of the pooled data would be performed. This would allow to evaluate the influence of compaction on the infiltration rate, disregarding the influence of textural variation. However, in this study, the bulk density results were influenced by the textural variation of the soils sampled and, therefore, soil compaction could not be evaluated. The correlation between bulk density and infiltration rate reflected the influence of the textural composition.

The data of bulk density and total porosity did not reflect the soil structure and neither the compaction of it, which is an important factor that affects the infiltration in urban areas. Yang and Zhang (2011) explored the water infiltration characteristics of urban soils with different degrees of compaction and identified that the amount of macropores is very important for hydraulic conductivity. In that study, the authors conclude that many factors affected the final infiltration rate of the soil; however, the degree of compaction was the most important factor.

Gülser et al. (2016) realized studies to determine changes in spatial variability of some physical properties of Vertic Haplustoll on a small-scale part of cultivated fields, in Turkey, by geostatistical method. In this study, the authors found a strong correlation (-0,905, p < 0,001) between the saturated hydraulic conductivity and the clay content). Papanicolaou et al. (2015) conducted studies in the southeastern part of the Iowa state and suggested that the soil texture dominated the infiltration process in soils with a higher sand content (>15%), whereas bulk density dominated the infiltration process in soils experiencing the effects of compaction due to agricultural activity. Thus, it is important to point out that there is a consensus in the understanding that soil structuring modifies the manifestations of its textural composition. According to Brandão et al. (2003), unlike what happens in temperate soil conditions, the soil structure may exert a much more significant influence on the rate of infiltration than the texture.

CONCLUSIONS

The textural variation between different soil classes and the different manifestation of this variation in bulk density and total soil porosity prevent such attributes from being used as indicative of soil structure and compaction.

In order to analyze the influence of compaction on the infiltration rate, a greater number of samples of the same soil class, the same textural class, and different levels of compaction are required, besides the macroporosity.

The correlations between bulk density and total porosity with infiltration rates were not significant. The textural variation between the different soil classes, and the different manifestation of this variation in bulk density and total porosity, prevented these attributes from being used as indicative of soil structure and compaction.

It is not recommended to analyze the influence of soil attributes considering the grouped set of different soil classes, since the chemical and textural manifestations differ from each other. Thus, only the influence of texture on soil infiltration rates is evident.

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