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PHYSICAL DETERIORATION OF QUALITY AND SOIL AND WATER IN YOUR CONNECTION MASS REMOVALS

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ABSTRACT: The physical behavior of the soil and water based their management practices, especially in the strong slopes. The objective of this research was to evaluate the interrelationships between soil physical properties and water holding capacity of soils on different systems for urban use of San Juan de Pasto - Colombia and its impact on processes of mass removal. In 2013, we selected four areas contained in different slopes, which were built and are almost entirely urbanized twenty years ago, in two more places there is some kind of vegetation. Twenty seven soil samples were collected in the layers 0-45 cm, 45-100 cm and 100-145 cm depth, the resulting data determined as a result of water retention curves (WRCs), of soil in different seasons, which served to make correlations with variables such as bulk density, organic carbon content and clay content. It was found that the sealing of land use for asphalt roofing, resulted in higher values of soil density and soil with some vegetation cover type even at high slopes, resulted in lower bulk density, lower carbon organic and clay. Some canonical variables indicated dependence on moisture content of the soil density. The changes in the curves of water retention in the soil suggest a greater compaction of soils in areas with strong slopes, plus also mean a deterioration of physical and water of this quality, contributing to the increased likelihood of moving large amounts of land in a high slope slip.

Key Words: urban areas, slope, soil density, waterproofing, changes.

1. INTRODUCTION

The knowledge of certain physical properties of the soil is the basis for understanding the deterioration of physical properties thereof and its connection in mass removal. For its texture, particle size and other colloidal materials and clay, require a strict look at their behavior while time soon. For various voltages are applied to the compression and foundations and/or alleviated in the case of excavations for water drainage.

Soil also plays a key role in the regulation and distribution of surface and groundwater, since it favors the storage through infiltration or storm water runoff, the problem is that this dynamic is the ground support infrastructure and more so when these constructs are contained in strong slope, this soil property can be dangerous.

On the other hand the organic matter and other substances acting as cementing agent between individual particles, thus favoring the formation of agglomerates or aggregates in the soil. The structure of soil is created to adhere to other particles or water, modifying the physical properties of solid particles and pore spaces among the particles can be changed in a short time, thereby increasing the capacity of retaining water, accelerating the process favoring landslides and removals by weight.

The objective of this study was to evaluate the interrelationships between soil physical properties and water holding capacity of soils in different systems for urban use, obtaining the coefficients of the water retention of soils found (silty, clayey and muddy) in different systems for urban use and its impact on landslides of San Juan de Pasto - Colombia.

2. RETENTION OF SOIL MOISTURE

The water retention curve (WRCs) is essential in studies of soil quality in order to guide the practices of use and control. Modifications in the structure of the compression and associated loss of stability of aggregates that alter the pore size distribution of soil retention as well as the movement and availability of water.

The water retention curve (WRCs) is described by water content of the soil (θ) and matric potential (Ψ), with slow and steady decrease of these variables during soil drainage. The water content retained in a given structure and Ψ arises from the distribution of pore sizes (Beutler et al., 2005). The results of Rawls et al., (2003) show that, at high Ψ, the retention curve is influenced by structural pores associated with the effect of organic matter in the formation and stability of soil structure. Below Ψ, the particle size and mineralogical composition of the soil become more important due to the surface available for the adsorption of water (Gupta & Larson, 2007). Thus, the water retention curve (WRCs) allows dependency relationships between the coefficients of the mathematical equations that describe different properties of soil, such as clay content, the organic matter content, the specific surface area and density of the soil (Berg et al. 2004).

The Pearson correlations between soil physical properties and coefficients of descriptive equations of the soil water retention curve (WRCs) were made by Gupta and Larson (2007). This approach does not permit the direct and indirect effects of an independent variable with dependent variables. One way around these limitations is to use canonical correlations. According to Cruz et al., (2009), using this methodology is possible to estimate the maximum correlation between two groups of variables consisting of linear combinations (interrelations) of the different properties that are the.

Most studies describing the relationships between soil variables and coefficients of the retention curve in a wide range of soils. However, under the same soil, the different systems of use and management can promote changes in its structure and physical behavior of water in soil.

3. MATERIALS AND METHODS

Soil samples were taken from four sites in San Juan de Pasto city, located in the Nariño State in southern Colombia (Figure 1). According to the soil classification Pinto (2004) identified three types of soils; silty, clayey and muddy (Figure 2), where we sampled the four areas of the city in a different slope, containing buildings over the last 20 years. (Table 1)

Figure 1. A1 - Location San Juan de Pasto city. B2 – Digital Globe images, Landsat, U.S. C3 - Sampling points, A - Urban area, slope 31%, B - Urban area, slope 60%. C - Urban area, slope 42%, D - Urban area, slope 64%.
Source: Modified from DigitalGlobe images, Landsat, U.S. Geological Survey, 2014.

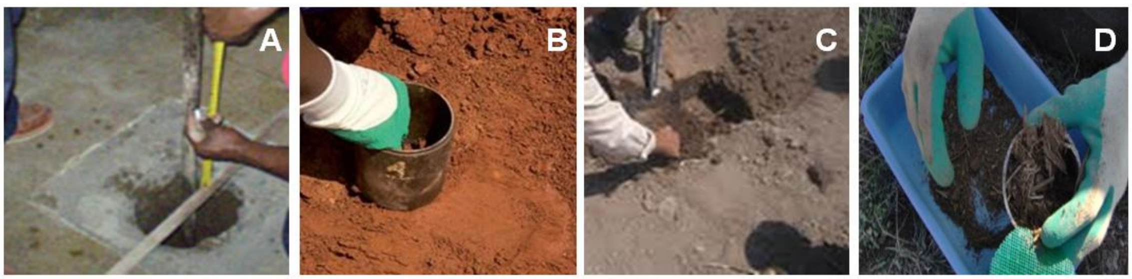

Figure 2. Muddy soil (A and D), clay soil (B), silty soil (C)

3.1 Sampling Points

Once defined the four sampling sites, 27 samples were taken in two different seasons, totaling 55 soil samples in 2013, sampling was performed in January during the rainy season, in August in the summer. Sampled the layers 0-45 cm, 45-100 cm and 100-145 cm deep and samples were collected in bags thick and sturdy polypropylene material to maintain the quality and moisture of the soil samples. The time to pick up the samples varied between 08:00 and 10:00 AM always in the morning, trying to maintain moisture for subsequent transfer to the soil laboratory at the University of Nariño, to further determine the result of water retention curves.

Table 1 - Sampling Points and slopes

Point	Elevation	Longitude	Latitude	Description
A	2567	1° 12' 16.053" N	77° 15' 10.341" W	Urban area with a slope of 31%, with wooded banks and lawns.
B	2613	1° 12' 6.168" N	77° 15' 18.374" W	Urban area with slope very strong 60% with wooded banks and lawns and ornamental plant species.
C	2563	1° 11' 39.600" N	77° 16' 27.588" W	Urban area with a slope of 42%.
D	2622	1° 11' 35.893" N	77° 16' 41.184" W	Urban area with slope very strong of 64%.

Four sampling sites were selected in different slopes. If they took samples in the 0 – 45 cm, 45-100 cm and 100-145 cm depth, where a block has been removed from the ground 10 cm^3 and ground beside one metal ring deformed sample (0.05 m diameter and height). The soil blocks were manually crushed to further perform the separation of aggregates between 2 and 4 mm diameter, which were used for desorption of water at low (Ψ).

After properly prepared the undisturbed soil samples were saturated by gradual elevation of a water slide in trays until about 2/3 of the height of the samples. The water retention curve (WRCs) the soil was determined by applying the Ψ -10, -20, -40, -60 and -80 hPa, using a voltage table and Ψ of -250, -500, -1000, -2000, -4.000 and -15.000 hPa by means of pressure applied on porous plates (Klute, 2006).

In the undisturbed samples were applied to the Ψ -10, -20, -40, -60, -80, -250, -500 and -1000 hPa. In Ψ -2.000, -4.000 and -15.000 hPa, we used aggregates with a diameter between 2-4 mm. The saturation of the aggregates was performed directly on the porous plate inside the chamber Richards, for 24 hours and by capillarity. After the samples are put into the balance Ψ applied, they were weighed and placed in an oven at 105 ° C ± for determination of moisture based on mass (θg).

Soil bulk density was calculated as Blake & Hartge (1999). After drying the undisturbed samples, the soil was removed from the rings, sieved in a sieve with 2 mm diameter mesh. In these samples, we determined the content of soil organic carbon, using the indirect method by wet oxidation of C (Walkley & Black), and particle size, by the hydrometer method. The water retention curve (WRCs) of the soil was described mathematically by the function proposed by van Genuchten (1980), Equation [1] as described;

$$\theta = \theta r + \{(\theta s-\theta r)/[1+(\alpha\Psi)^{n}]^{m}\} \quad [1]$$

Where;

θ is the water content of the soil (kg kg-1);
θs is the saturation water content (kg kg-1);
θr is the residual water content (kg kg-1);
Ψ is the matric potential (hPa); and
α (hP a-1) n are the coefficients of the equation.

Adopted the restriction [m+1-(1/n)] the equation to fit the data. The coefficients *θs, θr, α* and *n* of the equation of van Genuchten (1980) were estimated by the method of nonlinear least squares, using the routine "PROC NLIN" (SAS, 2001). The comparison of the variables: density, organic carbon content and soil clay content were made adopting the confidence interval of the mean of 95% (p = 0.05), as Morettin & Bussab (2003).

The multicollinearity test and analysis of canonical correlations were performed by the software GENES (Cruz, 2009) in accordance with the recommendations of Cruz and Carneiro (2007), the group of soil properties (group I: Organic carbon content of soil, clay content and bulk density) and the group of coefficients of van Genuchten (group II equation: *θs, θr, α* and *n*).

The multicollinearity mothers was poor, with condition number of (CN ≤ 0.062 ≤ 2.06) and the variance inflation factor (VIF ≤ 1.55 ≤ 8.62) for the four study sites.

Before submitting the data to the analysis of canonical correlations in the software GENES (Cruz, 2007) took place prior testing data normality of variables (n=27), essential for linear mathematical models (Vieira, 2009). The confidence level of 0.01 for the Shapiro-Wilk test was adopted, corresponding to the lowest confidence level used for the coefficients of the canonical correlations. The content of soil organic carbon and clay content in four places, non-normal distribution of the original data, respectively, with probabilities of 0.0084 and 0.0096 for the Shapiro-Wilk test, using the procedure "PROC UNIVARIATE" (SAS, 2003). The content of soil organic carbon and clay content in four places, non-normal distribution of the original data, respectively, with probabilities of 0.0084 and 0.0096 for the Shapiro-Wilk test, utilizandose the procedure "PROC UNIVARIATE" (SAS, 2003). Using the procedure "PROC UNIVARIATE "(SAS, 2003). After arcsine transformations of the root of the levels of soil organic C divided by 10 and natural logarithm of clay content was obtained normal distribution of 0.0771 and 0.0184, respectively. The other variables showed normal distribution of the original data, with probabilities 0.0197 to 0.9226 by the Shapiro - Wilk test. Thus, the two transformed variables and the other variables were subjected to analysis of variance, given the assumption of normal distribution for all variables (Vieira, 2009).

For 27 sets of data from each of the variables and the state of the soil, the confidence intervals of the mean were calculated: Equation [2]

$$IC = X \pm t\,[(n-1)(1-\alpha/2)]\,\frac{s}{\sqrt{n}} \qquad [2]$$

Where:

IC is the confidence interval of the mean;

X is the arithmetic mean;

t is the value of the normal distribution tabulated according to the number of data (n) minus one degree of freedom (n-1) and the degree of confidence to 95% (α = 0.05); and
s is the standard deviation of the samples (Schlotzhauer & Littell, 1997).

4. RESULTS AND DISCUSSION

The average content of soil organic C to areas with a slope of 60% and 64% was significantly higher than the soil in areas with slopes of 31% and 42% respectively (Table 2), compared to lower the rate of return and decomposition of organic matter, soils with higher slopes has more ability to capture and retain water (Sanchez, 2008).

The clay content of the topsoil in the samples was also reduced in soil with high compression that was the lower slope (Table 2). According to Cardoso et al. (2007), an intensive compacting soil for subsequent urbanization reduces the thickness of the surface horizon, soil organic matter and, therefore, increases the degree of dispersion of clay. Related to clay content in soils sampled (Table 2) the preservation of these data indicates contained in compressed and glued to the other particles of sand particles selective, allowing the absorption of a certain quantity of water contained in the soil when necessary.

The equation of van Genuchten (1980) explains that over 99% of the water retention of soil ($R^2 > .99$), with F values were highly significant ($p < 0.01$) for all samples. The coefficients θs, θr, α e *n* were statistically significant, because they did not show null values in its confidence limits, as recommended Glantz & Slinker (2000).

There was similarity coefficients α e *n* for soils in urban areas with a slope of 31% and very strong slope of 60% (Table 3) with average values of θr and θs that were statistically superior over lower values of bulk density and with higher organic C content. These results corroborate those cited by Silva et al., (2005), who observed a decrease in soil porosity by mechanical compression resulting physical and urban processes.

The largest value of n was obtained in the soil (Figure 3) soil from urban area with very strong slope of 60%, indicated a higher water retention due to a higher total porosity and large pore size variation between Ψ of -10 to -100 hPa and -1000 to -15,000 hPa. There was a slight superiority of water retention between -1000 and -100 hPa, attributed to differences of n values resulting from a greater frequency of smaller pores having sizes in this range of Ψ.

The curves of water retention (WRCs) in soils showed higher water retention in soils with slopes greater compared to soils of lower slopes, as it estimated a higher density in these soils, due to the distribution of pores that retain water in Ψ greater than -100 hPa, evidenced by the strong reduction of θs en these soils (Table 2 and 3, Figure 3). These characteristics explain higher water retention resulted in which changes in the physical quality of the soil (Dexter, 2004).

Table 2. Descriptive analysis and normal distribution Shapiro-Wilk (W and p <W) for the variables organic carbon content, bulk density and clay content in the four sampling sites in the San Juan de Pasto city.

sampling sites	Minimum	Media[(1)]	ICM[(2)]	Maximum	CV(%)[(3)]	W	P < w
Organic carbon content of soil (g kg^{-1})							
A	3.35	7.48b	0.81	9.87	26.51	0.9208	0.0222
B	4.72	12.12a	1.08	17.59	23.44	0.9102	0.2339
C	4.14	9.74a	0.86	13.30	21.27	0.9731	0.0410
D	5.99	13.21a	1.02	19.11	24.35	0.9041	0.2812
Density of soil (Mg m^{-3})							
A	2.88	1.43c	0.03	1.64	3.67	0.9441	0.3211
B	1.96	1.46c	0.03	1.52	4.39	0.9675	0.2521
C	2.35	1.81b	0.01	1.76	1.87	0.9457	0.3424
D	2.07	1.88a	0.02	1.84	2.51	0.9524	0.5232
Clay content (g kg^{-1})							
A	140.00	185.60b	11.56	240.00	15.09	0.9457	0.2006
B	170.00	207.20a	7.86	250.00	9.19	0.9441	0.1920
C	180.00	210.00a	10.72	250.00	12.37	0.9231	0.0091
D	170.00	206.20a	9.34	240.00	13.21	0.9420	0.4002

(1) Means followed by the same letter in the column to the same variable do not differ statistically by the confidence interval of the mean of 95% (p = 0.05). (2) Confidence interval of the mean of 95% (p = 0.05). (3) Coefficient of variation. A - Urban area with a slope of 31%; B - Urban area with a very strong 60% slope; C - Urban area with a slope of 42%; D - Urban area with very strong slope of 64%.

Table 3. Descriptive analysis and normal distribution, Shapiro-Wilk (W and p <W) for the coefficients of the water retention curve (WRCs) at oursampling sites of the city of San Juan de Pasto.

sampling sites	Minimum	Media[(1)]	ICM[(2)]	Maximum	CV(%)[(3)]	W	P < w
α (hPa^{-1})							
A	0.016	0.028a	0.02	0.052	38.76	0.9765	0.3842
B	0.006	0.024a	0.02	0.042	31.21	0.9542	0.3902
C	0.004	0.012b	0.02	0.027	23.34	0.9554	0.3642
D	0.002	0.011b	0.02	0.018	23.98	0.9587	0.3313
θs (kg kg^{-1})							
A	0.265	0.380a	0.016	0.523	12.38	0.9793	0.2076
B	0.211	0.261a	0.008	0.421	10.07	0.9432	0.4967
C	0.167	0.161b	0.006	0.214	14.39	0.9452	0.7436
D	0.145	0.170b	0.005	0.291	7.45	0.9421	0.7001
θr(kg kg^{-1})							
A	0.063	210.00a	11.56	240.00	15.09	0.9457	0.2006
B	0.058	206.20a	7.86	250.00	9.19	0.9441	0.1920
C	0.072	207.20a	10.72	250.00	12.37	0.9231	0.0091
D	0.093	185.69b	9.34	240.00	13.21	0.9420	0.4002
n							
A	1.5321	1.725b	0.060	2.002	9.01	0.9456	0.2006
B	1.4786	1.681b	0.066	2.008	10.19	0.9523	0.3920
C	1.7390	2.311a	0.103	2.821	12.72	0.9630	0.2091
D	1.6349	2.602a	0.121	2.728	12.98	0.9505	0.2202

(1) Means followed by the same letter in the column to the same coefficient do not differ statistically by the confidence interval of the mean of 95% (p = 0.05). (2) Confidence interval of the mean of 95% (p = 0.05). (3) Coefficient of variation. A - Urban area with a slope of 31%; B - Urban area with a very strong slope 60%; C - Urban area with a slope of 42%; D - Urban area with very strong slope of 64%.

The canonical correlations explained 0.91, 0.90, 0.93 and 0.94 of the correlations between variables of Groups I and II of the first canonical pair ($p < 0.01$) for the 4 sampled soils. (Table 4). The canonical correlations between variables in Groups I and II also explained the cause and effect of negative dependence on θs with soil density, confirming the importance of soil structure on water retention. The bulk density influences both the porosity and the pore distribution of larger diameter, modifying the characteristics of the soil water retention Ψ in the range of -10 to -100 hPa (Figure 3), according to Rasiah & Aylmore (2002).

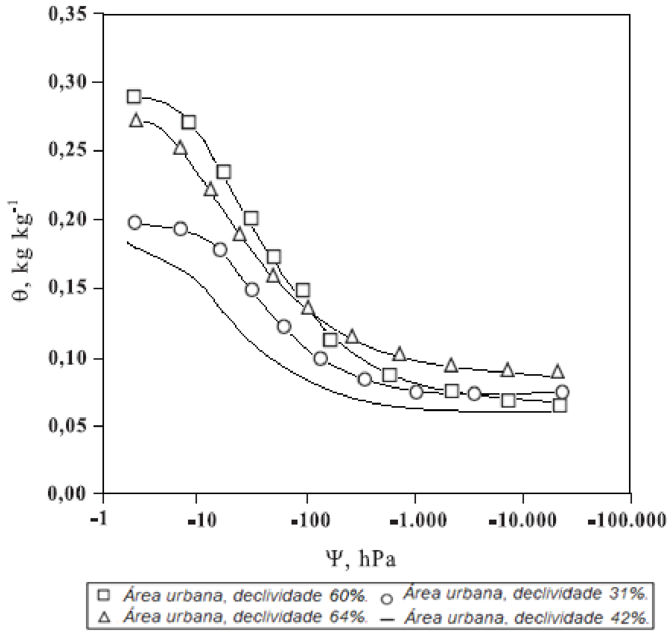

Figure 3. Retention curves of soil water to the soil sampled in four locations in the city of San Juan de Pasto.

The second pair of canonical variables in Groups I and II showed a correlation coefficient of 0.63, 0.71, 0.73 and 0.72 ($p < 0.05$, $p < 0.10$ and $p < 0.05$), respectively, for the soil of urban area with a slope of 42%, urban area with a slope of 31%, urban area with very strong slope of 64% and urban area with very strong slope of 60% (Table 4). The positive correlation of the levels of soil organic C with θr in soils demonstrates the importance of organic matter to retain water, attributed to the high specific surface of organic matter (Felton, 2005).

A significant dependence on θr with the interaction of clay content and soil organic C in areas with slopes of 64 and 60%. The magnitude of the coefficients of clay content (0.91 for each soil areas with slopes of 64 and 60%). In relation to soil organic carbon soil (-0.60 and -0.79, respectively) which shows that θr was dependent on both the combination of higher clay and lower levels of soil organic carbon. The antagonistic interrelationships between the levels of soil organic C and clay content is attributed to the higher efficiency of organic carbon in soil on θr (Rawls et al., 2003).

This assertion is supported by the values in this study were higher clay content of the soils of urban areas with slopes of 42 and 64% (Table 2).

The soils of the urban area with a slope of 42% differed from the soils of other areas for presenting the third canonical pair with canonical correlation coefficients of 0.55 ($p < 0.10$) between the variables in groups I and II (table 4). The third canonical pair revealed that the coefficient n was dependent on the interaction between soil organic carbon and clay content of the soil. These results confirm the effect of organic carbon in soils θr.

The contribution of A canonical correlation analysis between soil properties and the coefficients of the soil water retention curve (WRCs), indicated that the use of these soils should be guided by the density reduction and removal of soil organic carbon.

Table 4. Canonical correlations and canonical pairs (ג n) for the soils on four sites sampled in the city of San Juan de Pasto, estimated between primary components, for varying amounts of soil organic carbon, clay content and soil bulk density (group I) and secondary (group II), for the coefficients of the van Genuchten equation (θs, θr, α and n)

Variable or coefficient	Urban areas with slopes in %											
	42			31			64			60		
	ג1	ג2	ג3	ג1	ג2	ג3	ג1	ג2	ג3	ג1	ג2	ג3
Group I												
Organic Carbon Content	-0.32	0.52	-0.82	-0.49	-0.45	0.67	0.06	-0.60	0.69	0.21	-0.79	0.73
Clay content	-0.03	0.44	0.97	0.21	0.99	0.04	-0.43	0.91	0.64	-0.57	0.91	0.16
Density of Soil	0.96	0.33	0.07	0.91	-0.26	0.37	-0.97	-0.22	-0.08	-0.94	0.42	-0.08
Group II												
α	-0.40	-0.23	0.59	-0.46	-0.09	-0.92	-0.55	0.24	0.66	-0.59	0.41	0.18
θs	-0.98	-0.08	0.13	-0.96	0.17	-0.17	-0.90	-0.30	0.29	-0.91	-0.46	0.23
θr	-0.33	069	-016	0.03	0.78	0.41	-0.28	0.74	0.40	-0.66	0.46	0.17
n	-0.39	0.26	-0.74	-0.23	0.02	0.70	-0.24	0.03	-0.70	-0.22	0.22	-0.77
Dc(1)	0.91	0.63	0.56	0.90	0.71	0.26	0.93	0.73	0.39	0.94	0.72	0.32
Significance (2)	***	**	*	***	*	ns	***	*	ns	***	**	ns

(1) canonical correlation coefficient. (2) ns (not significant), * ($p < 0.10$), ** ($p < 0.05$) and *** ($p < 0.01$).

5. CONCLUSIONS

1. The process of compressing, prepare and remove the upper layers of soil with organic carbon contents for subsequent construction and urbanization should be strict and intensified in areas of higher slope because of the four sites sampled, the highest values of retention water, organic carbon and clay resulted in the two areas of greatest slope, demonstrating an existing susceptibility in urban areas contained in pending high and the potential for future mass removals, depending on the geology and the type of soils in the city of San Juan de Pasto.

2. The first pair of canonical variables indicated dependence on θs with respect to density, and the second pair distinguished soils verifying the dependence of θr in relation to clay content and soil organic carbon. Determining that needs a certain amount of clay to keep the constraint on the ground, thereby preventing removal by mass.

3. Concentrations of organic carbon contained in the soil and the density of the soil in strong slopes, can generate large changes in a short time on the water retention curve (WRCs), optimizing the soil for possible water uptake when need be and enhancing saturation and subsequently and removing landslide.

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