TEXTURE, DENSITY AND HYDRAULIC CONDUCTIVITY OF SOME SOILS IN SAN LUIS PROVINCE, ARGENTINA

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Recibido 19 de octubre de 2000, aceptado 14 de mayo de 2001

As part of a study of plant water use and soil water balance in lowland areas of San Luis Province, we required information about the hydraulic conductivity of the soils. Measurement of hydraulic conductivity at many locations is time consuming and expensive. We therefore measured the conductivity at several sites representing a range of soils in the province, and used these measurements to develop pedotransfer functions to predict the hydraulic conductivity from other, more readily available information.

We described profiles and took samples from some lowland soils in the San Luis Province, representing clays through to sands. We measured hand textures, laboratory particle size, bulk density and hydraulic conductivity at a suction of 10 mm, using a steady state method. The hydraulic conductivities ranged from 0.016 to 35 mm/hr^{-1}. They were significantly correlated to the texture class as determined by hand texturing in the field, and to laboratory particle size measurements. Correlations were stronger with laboratory measured particle size than hand texturing in the field. The dry bulk density was similarly correlated, though the significance of the correlations was less. Therefore, both hand texturing and laboratory particle size analysis can be used for rough estimates of the hydraulic conductivity at 10 mm suction and the dry bulk density.

The best predictions, particularly of hydraulic conductivity, were given by a multiple regression involving the different size fractions. The best equation for hydraulic conductivity excluded a heavy clay soil, and had an R^2 of 0.818. An equation due to Rawls *et al.* (1992) predicted saturated hydraulic conductivities between 2 and 7 times greater than those measured (which, however, were at a suction of 10 mm). An equation due to Janes and Tyler (1984), developed specifically for soils similar to those investigated here, predicted values of the hydraulic conductivity at 10 mm suction that were similar to those measured in coarser soils but up to four times greater in finer soils. This equation had an R^2 of 0.748, and appears to be useful, though not as good as the best equation found in this study. The prediction equations (pedotransfer functions) given here are for use in the lighter textured soils of the lowland areas of San Luis Province.

Key words: Texture, Density, Particle size, Hydraulic conductivity, Correlation

INTRODUCTION

The hydraulic conductivity of soil is important in determining the water balance: that is, how much of the incident rainfall and irrigation ends up as runoff, how much as evapotranspiration and how much as deep drainage. The hydraulic conductivity is required as input in many water balance calculation methods and computer packages.

Measurement of the hydraulic conductivity is time consuming and expensive. It requires high quality sampling and measurement methods. It is, therefore, common practice to seek correlations or pedotransfer functions which permit prediction of the hydraulic conductivity from other properties that are more readily or cheaply measured. Many of the methods are based on correlations with soil texture (e.g., van Genuchten, Leij 1992).

Deposits of aeolian sand and loess dominate the lowland areas of San Luis Province. Smaller areas of outwash sands from the Sierras de San Luis occur in the northwest of the province, with heavier textured sequences associated with the river terraces and alluvial plains of the Conlara Valley. Soils within the province have been classified according to Soil Taxonomy as Entisols, Mollisols and Aridisols

(INTA 1998).

As part of a wider investigation into irrigation in San Luis Province, we needed to know the hydraulic conductivity of potentially irrigable soils in order to perform water balance calculations. We therefore conducted a pilot survey of hydraulic conductivity of some representative soils in the province. We also investigated the correlations between hydraulic conductivity, density and hand texturing in the field and laboratory measured particle size. We present the results in this paper.

MATERIALS AND METHODS

Sixteen sites were selected in different parts of the Province, with the aim of covering the main soil types in lowland areas that, in principle, might be irrigated. The sample sites were selected using prior soil information (e.g. INTA, 1998), satelite images interpreted for landform, and where ready access could be obtained. The general locations of the sites are shown in Figure 1, and also given in Table 1. At each site, the profile was described to a depth of 1.2 m, samples were taken for bulk density and the hydraulic conductivity at a suction of 10 mm was measured. The sites were visited from the 26th April to 3rd May 1999, which followed about 60 mm rain on the 24th April.

The profile description was based on hand augering to a depth of 1.2 m using a 75 mm diameter auger. The sites were described according to McDonald *et al.* (1990) and the soil profiles were classified according to Soil Taxonomy (Soil Survey Staff 1998). Soil texture was estimated by hand using the method of Northcote (1979).

At each site, undisturbed samples were obtained in thin walled brass sampling rings, 75 mm diameter and 75 mm long. All samples were trimmed so that the soil was flush with the ends of the rings. At 15 of the sites, the profile description indicated that the soil was fairly uniform with depth, and so for a pilot survey we considered it sufficient to take samples at one depth only, about 30 mm beneath the surface. At the other site, the soil became finer textured with depth, so samples were obtained at two depths, 30 mm and 600 mm. At each depth at each site, four samples were obtained: two were immediately placed in plastic bags for weighing in the laboratory to obtain densities and particle size analysis; the other two were used for hydraulic conductivity measurement. Ideally, more samples would be required to provide measures of variability amongst samples, but this was outside the scope of this pilot survey.

The dry bulk density was estimated by oven drying the samples for two days at 55°C. No oven was available at the preferred temperature for dry-

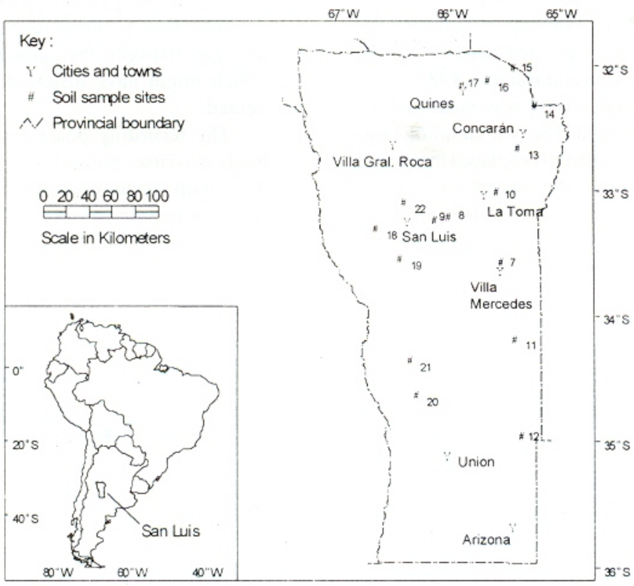

Figure 1. Map of site locations in San Luis Province. The inset map shows the location of San Luis Province in South America..

Figura 1. Ubicaciones de las muestras de suelos en la Provincia de San Luis. El mapa recuadrado muestra la ubicación de la Provincia de San Luis en América del Sur.

Table 1. Site locations, texture class, particle size, hydraulic conductivity at 10 mm suction and dry bulk density of the soils studied. Note that at site 18, both the soil was sampled near the surface and at 65 cm depth.

Tabla 1. Ubicaciones de los sitios, clase de textura del perfil, tamaño de las partículas, conductividad hidráulica a 10mm succión y densidad aparente seca a granel de los suelos en estudio. Nótese que en el sitio 18 se tomaron muestras del suelo cerca de la superficie y a 65 cm de profundidad.

Site	Location		Soil Type (Soil Survey Staff, 1998)	Profile texture class	Depth of top of sample, cm	Sand > 0.125 mm	Fine sand 0.05 – 0.125 mm	Silt 0.002 – 0.05 mm	Clay < 0.002 mm	Hydraulic conductivity, mm/hr, at 10 mm suction		Dry bulk density, g/cm³	
	Longitude	Latitude								Replicate 1	Replicate 2	Replicate 1	Replicate 2
07	-65.4528	-33.6012	Typic Haplustoll	VFSaL	3	11.7	56.4	25.0	6.9	11.29		1.13	1.29
08	-65.9414	-33.2449	Typic Haplustoll	VFSaL	3	16.5	52.7	23.8	7.0	1.27	3.02	1.12	1.08
09	-66.0728	-33.2678	Typic Haplustoll	FSaL	2	12.3	49.8	32.7	5.2	3.37	5.40	1.06	1.05
10	-65.4947	-33.0453	Entic Haplustoll	SiL	2	14.9	19.8	60.4	4.9	0.24	0.52	1.40	1.41
11	-65.3161	-34.2182	Typic Ustipsamment	FSa	3	58.6	34.5	3.7	3.2	35.65	18.02	1.45	1.29
12	-65.2490	-34.9889	Pachic Haplustoll	FSaL	2	47.1	26.9	21.4	4.6	0.96	3.72	1.24	1.22
13	-65.3006	-32.6949	Pachic Haplustoll	SaCL	3	29.0	16.2	49.2	5.6	0.20	0.18	1.35	1.40
14	-65.1453	-32.3447	Entic Haplustoll	ClL	3	22.7	10.2	61.0	6.1	0.28	0.16	1.25	1.28
15	-65.3440	-32.0516	Mollic Ustifluvent	SiL	3	2.2	3.7	82.8	11.3	3.36	2.03	1.09	0.93
16	-65.5792	-32.1515	Typic Ustipsamment	LSa	3	64.0	10.2	18.3	7.5	1.05	4.42	1.51	1.47
17	-65.8146	-32.1950	Entic Haplustoll	SaL	3	49.2	12.4	23.4	15.0	0.50	1.05	1.31	1.38
18	-66.6191	-33.3387	Typic Torriortent	Sa	2	60.7	23.2	8.8	7.3	7.68	15.46	1.60	1.57
18A	-66.6191	-33.3387	Typic Torriortent	SaL	65	53.4	23.9	16.6	6.1	7.97	4.26	1.53	1.52
19	-66.3954	-33.5824	Typic Torriortent	FSaL	3	45.8	26.9	25.3	2.0	2.16	2.61	1.39	1.43
20	-66.2444	-34.6698	Typic Torripsamment	FSa	3	67.1	17.5	12.7	2.7	10.99	8.29	1.24	1.25
21	-66.2986	-34.3906	Typic Torripsament	LFSa	3	22.8	39.8	31.7	5.7	5.48	1.91	1.40	1.38
22	-66.3555	-33.1303	Typic Ustortent	SaL	16	48.0	18.0	29.8	4.2	3.52	1.66	1.34	1.36

ing of 105°C. but since most of the soils were relatively coarse grained, we considered that the overestimation of dry weight would not be too great. After drying, the samples were weighed to ±0.1 g. The dry bulk density was calculated as the dry weight of soil divided by the enclosed volume of the sampling ring.

The soil from the density samples was then further subsampled for laboratory particle size analysis. Particle size was measured using the method described by Gee and Bauder (1982).

The hydraulic conductivity was measured using a constant head method. The two sampling rings with the soil samples included were placed in a plastic bowl that contained about 10 mm of water in the bottom. The samples were allowed toabsorb water until water appeared on the upper surface. Usually, this happened within about half an hour. The samples were then placed upon a small platform of soil in the bowl: the platform was formed from disturbed soil obtained when the samples were taken, and so was at least as permeable as, if not slightly more permeable than, the undisturbed soil in the core. The top surface of the platform was about 10 mm higher than the level of the water (see Figure 2). This means that at the bottom of the sample, the potential of the water was 10 mm of suction. A thin layer of sandy or silty soil (chosen to be at least as permeable as, or slightly more permeable than the soil samples themselves) was spread on the top of the samples to promote full contact between the sample and a disc permeameter. One disc permeameter of the suction type described by Perroux and White (1988) was then placed on top of each of the two samples (Figure 2). The disc permeameters were set at 10 mm suction, using the principle of the Mariotte bottle to maintain the suction (Figure 2). The fall in the level of water in the measuring chamber of the permeameters was recorded at intervals, until it was judged that a steady state had been reached. The test was then stopped.

The 10 mm suction was chosen because this excludes flow in the larger pores. Thus, flow down any gap between the sample and the brass ring, which might have distorted the results, was prevented.

The recording phase took from about 1 to 2 hours in coarser grained soils (these were the majority) but up to about 12 hours in the heavier textured soils. In the coarser grained soils, the tests were

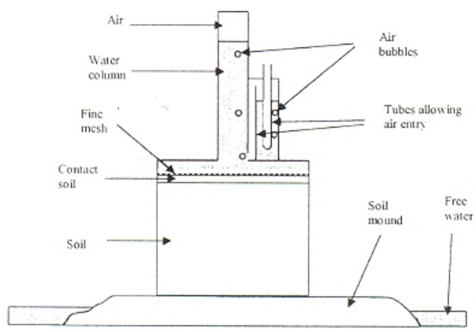

Figure 2. Schematic diagram of the equipment for measuring the hydraulic conductivity.

Figura 2. Diagrama esquemático del equipo para medir la conductividad hidráulica.

done in the field while the profiles were being described. This was impractical for the finer grained soils, so the tests were performed in a room. The temperature of the room was not controlled but, since it was neither heated nor cooled, the temperatures at which the indoor tests were conducted were within the range at which the outdoor tests were conducted.

Multiple regression was used to develop pedotransfer functions. The method was to take a proposed pedotransfer equation such as the following which relates the logarithm of the calculated hydraulic conductivity ($\log(k_{-10mm})_{calc}$)at a suction of 10 mm to the sand (*Sa*), fine sand (*FSa*), silt (*Si*) and clay (*Cl*) percentages:

$$\log(k_{-10mm})_{calc} = a + b.Sa + c.FSa + d.Si + e.Cl \quad (1)$$

and adjust, using a minimization algorithm, the coefficients (a, b, c, d and e) such that an objective function, F

$$F = \sum \left(\log(k_{-10mm})_{obs} - \log(k_{-10mm})_{calc}\right)^2 \quad (2)$$

is minimized. Correlation coefficients and R^2 were calculated according to standard formulae (e.g., Snedecor and Cochran, 1967). Significance levels of the correlation coefficients were taken from Table A11 of Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

The results of a typical pair of hydraulic conductivity tests are given in Figure 3, which shows the readings of water volume (interpreted as the depth of water to infiltrate the sample) as a function of time. The early phase, up to about 20 minutes, does not show a linear relation between the cumulative inflow and time. During this phase, the water in the sample was coming into equilibrium with the imposed flow. The flow then entered a second phase in which there was a linear relation between the cumulative inflow and time. During this phase, the flow was at a steady state, with a suction of 10 mm throughout the column and the downward flow of water was due to gravity only. The slope of the line in the steady state is the *velocity of flow*. Darcy's Law relates the velocity of flow, v, to the hydraulic conductivity, k, and the potential gradient, i:

$$v = ki \quad (3)$$

Since the potential gradient due to gravity alone is unity, $v = k$.

The profile classes and hand textures are given in Table 1. Results of the laboratory particle size analyses are also shown in Table 1. The soils ranged from sands to clays, with most being medium to coarse textured. The densities and hydraulic conductivities are also shown in Table 1.

For many soils, hydraulic properties including hydraulic conductivity and porosity have been successfully related to other, more readily measured soil properties including particle size (e.g., Rawls, Brakensiek 1989; Tietje, Hennings, 1996; Goncalves *et al.* 1999). Since the soils we dealt with in San Luis were generally young and not highly structured, simple correlations between hydraulic properties and particle size information might be reasonably expected.

The dry bulk density can be used to calculate the porosity, from which the saturated water content can be estimated.

The relationship between the hydraulic conductivity and field texture class is shown in Figure 4. Hydraulic conductivity is sometimes considered to be simply related to some point of the cumulative size distribution (Lambe, Whitman 1969). Figure 5 shows the relationship between hydraulic conductivity and the size which 20% of the particles are smaller than, estimated from the laboratory particle size analysis. This 20% passing size was estimated by interpolating the relationship between linear percent passing and logarithm

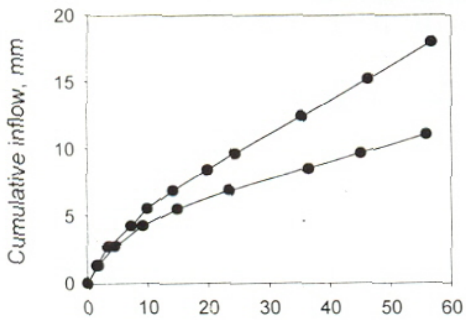

Figure 3. Results of hydraulic conductivity tests at site 18. The two lines show the results of the two replicate samples.

Figura 3. Resultados de ensayos de conductividad hidráulica en el sitio 18. Las dos líneas muestran *los resultados de las dos muestras replicadas.*

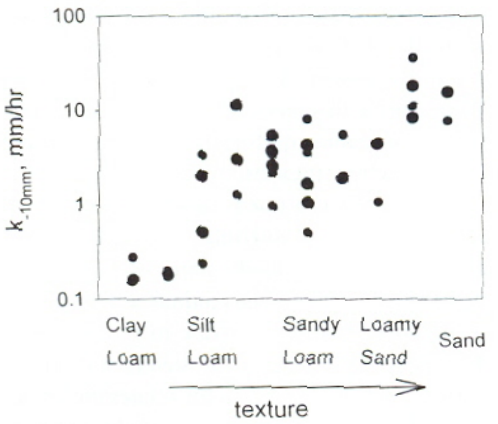

Figure 4. Relationship between hydraulic conductivity at a suction of 10 mm and hand texture class.

Figura 4. Relación entre conductividad hidráulica a succión 10mm y textura de suelo (en campo).

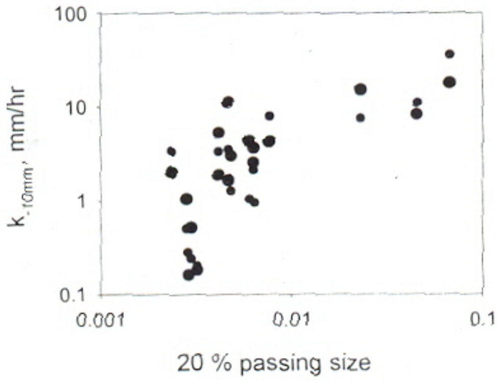

Figure 5. Relationship between hydraulic conductivity at a suction of 10 mm and the 20 % passing size.

Figura 5: Relación entre conductividad hidráulica a una succión de 10mm y tamaño de partícula de referencia, de la cual 20% fue de menor tamaño (20% passing size).

of particle size. The figures show that the hydraulic conductivity was greater in the coarser soils, as expected. Table 2 shows the correlation between the logarithm of the measured hydraulic conductivity and the field texture class, and between the logarithm of the hydraulic conductivity and the 50 %, 20 % and 10% passing sizes. All the correlations were significant at the 0,1% probability level. The 10% passing size is sometimes used in civil engineering soil mechanics as a predictor of saturated hydraulic conductivity, using a formula known as the Hazen equation (Lambe, Whitman 1969). However, in the present data, the most significant correlation was that with the 20% passing size. Percentiles of the par-

Table 2. Correlations amongst the logarithm of hydraulic conductivity at 1cm suction, dry bulk density, texture and particle size. D_{50}, D_{20} and D_{10} are the 50 %, 20 % and 10 % passing sizes. NS indicates that a correlation was not statistically significant.

Tabla 2. Correlación entre el logaritmo de conductividad hidráulica a 10 mm succión, densidad aparente seca a granel, textura y tamaños de las partículas de referencia, de las cuales 50%, 20% y 10% fueron de menor tamaño: 50%, 20% y 10% "passing sizes" correspondientes a D_{50}, D_{20} y D_{10}. NS significa que la correlación no es estadísticamente significativa.

Variables	Correlation coefficient	Significance level
$Log(k_{-10}) / Log(D_{50})$	0.612	0.001
$Log(k_{-10}) / Log(D_{20})$	0.721	0.001
$Log(k_{-10}) / Log(D_{10})$	0.554	0.001
$Log(k_{-10})$ / Texture class	0.593	0.001
$Log(k_{-10})$ / clay %	0.230	NS
Density / $Log(D_{50})$	0.452	0.01
Density / $Log(D_{20})$	0.291	NS
Density / $Log(D_{10})$	0.237	NS
Density / Texture class	0.449	0.01
$Log(k_{-10})$ / Density	0.085	NS

ticle size distribution have generally not been used in developing pedo-transfer functions in soil science, though Campbell (1985) used the geometric mean particle size. Bristow *et al.* (1999) developed this further to use clay percentage alone in the estimation of water retention curves and hydraulic conductivity. Clay percentage was tested with the San Luis data but was not significantly correlated to hydraulic conductivity (Table 2), and did not lead to useful predictions of hydraulic conductivity.

Various studies (e.g., those summarized in Tietje, Hennings 1996) have found that multiple regression using different fractions of the particle sizes gave reasonable predictions of the hydraulic conductivity. We therefore regressed the logarithm of the hydraulic conductivity against the sand (*Sa*), fine sand (*FSa*), silt (*Si*) and clay (*Cl*) percentages using equation (1).

The coefficients of the regression are shown in Table 3 and the observed versus predicted values of $\log(k_{-10mm})$ are shown in Figure 6. The R^2 of the regression was 0.416, which is worse than that of the relationship with the 20% passing size. However, it is clear from Figure 6 that two points are significantly different from the rest. These two points are the duplicate hydraulic conductivity measurements at site 15, which had the finest particle size distribution of any site. This material had a hydrau-

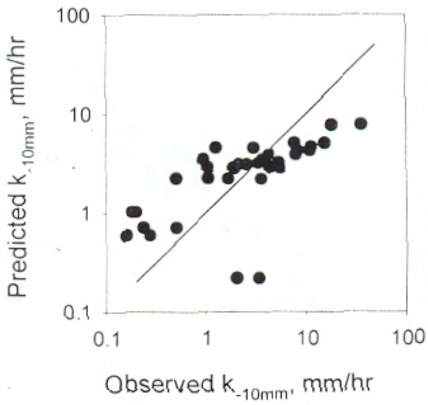

Figure 6. Relationship between measured and predicted hydraulic conductivity using equation 2. The 1:1 relationship is shown by the line.
Figura 6. Relación entre conductividad hidráulica anticipada y medida usando la ecuación 2. La línea muestra la relación 1:1.

lic conductivity greater than might be expected from particle size alone. Although it was the heaviest soil based on laboratory particle size measurements, the hand texturing results did not indicate this. This suggests that the clay may have been structured into small aggregates, resulting in a hand texturing class somewhat lighter than indicated by the particle size analysis. Many studies of hydraulic conductivity conclude that soil structure has an important influence (e.g., Bristow *et al.* 1999;

Table 3. Coefficients of multiple regression equations for predicting hydraulic conductivity at 1cm suction and dry bulk density from particle size sand (*Sa*), fine sand (*FSa*), silt (*Si*) and clay (*Cl*) percentages.
Tabla 3. Coeficientes de ecuaciones de regresión múltiple para anticipar conductividad hidráulica a 10mm succión y densidad aparente seca a granel a partir de porcentajes de tamaño de partícula de arena *(Sa)*, de arena fina *(Fsa)*, de limo *(Si)* y de arcilla *(Cl)*.

Equation	a	b	c	d	e	R^2
All sites $Log(k_{-1}) = a + b.Sa + c.FSa + d.Si + e.Cl$	-6.02	0.068	0.074	0.051	0.061	0.416
Heavy clay site removed $Log(k_{-1}) = a + b.Sa + c.FSa + d.Si + e.Cl$	-6.02	0.072	0.082	0.042	0.024	0.818
All sites Density = a + b.Sa + c.FSa + d.Si + e.Cl	-0.10	0.017	0.012	0.013	0.010	0.412

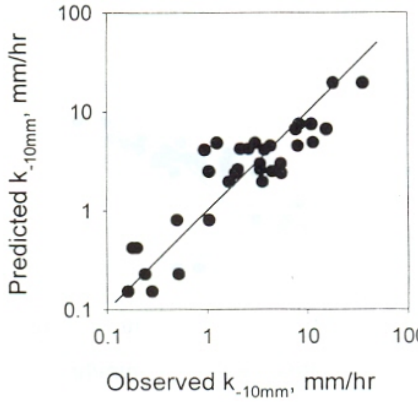

Figure 7. Relationship between measured and predicted hydraulic conductivity with site 15 omitted. The 1:1 relationship is shown by the line.

Figura 7. Relación entre conductividad hidráulica anticipada y medida sin el sitio 15. La línea muestra la relación 1:1.

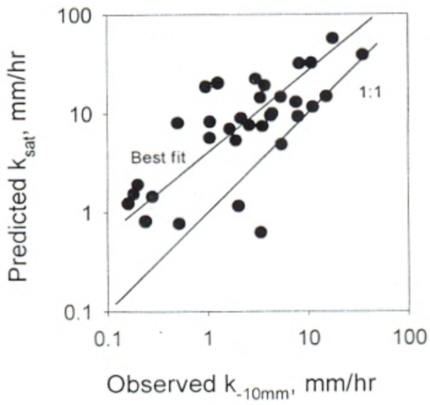

Figure 8. Relationship between measured k_{-10mm} and predicted k_{sat} using equation (2) of Rawls *et al.* (1992). The lines show the 1:1 relationship and the best fit regression between the observed and predicted values.

Figura 8. Relación entre k_{-10mm} medido y k_{sat} anticipado usando la ecuación (2) de Rawls *et al.* (1992). Las líneas muestran la relación 1:1 y la línea de mejor ajuste entre los valores anticipados y observados.

Cresswell *et al.* 1999), which might explain why this soil differed from the rest. Omitting this site from the regression using equation (2) leads to a better fit. The coefficients of the regression are shown in Table 3 and the observed versus predicted values of $\log(k_{-10})$ are shown in Figure 7. The R^2 of the regression was 0,818, indicating that equation (2) is a reasonable predictor of the hydraulic conductivity when restricted to exclude the heaviest soils.

Rawls and Brakensiek (1989, 1992) provided an empirical regression equation for predicting the saturated hydraulic conductivity from the sand and clay fractions and the porosity. The equation (equation [2] of Rawls and Brakensiek 1992) involves 13 coefficients. Applying this equation to the data in Table 1 results in the predicted hydraulic conductivities shown in Figure 8. The predicted values of k_{sat} were between 2 times greater than the measured k_{-10mm} in the coarser soils and 7 times greater in the finer soils. The difference might be due to the difference between k_{sat} and k_{-10mm}. The R^2 of the regression between k_{sat} predicted using the Rawls, Brakensiek (1992) equation and the measured k_{-10mm} was 0,666. It appears, therefore, that the Rawls and Brakensiek equation, while it predicts values strongly correlated (the significance of the correlation is greater than P=0,001) to the measured data, is not as useful as equation (2).

Janes and Tyler (1984) developed an equation relating hydraulic conductivity to sand and silt percentages and bulk density. The equation was based on soils considered to be without structure effects, and with a range of particle sizes similar to those studied here. The equation is:

$$\log k = \left[-0.016\,Sa + 0.013\,Si\right]\psi^{0.5} + 0.044\,Sa - 0.61\,BD \qquad (4)$$

in which k is in cm/day, ψ is the water potential in kPa, Sa and Si are sand and silt percentages, and BD is the bulk density. Evaluating this for a water potential of -10 mm yielded the results shown in Figure 9. In coarser soils the predicted values agreed with the observed, whereas in finer soils the predicted values overestimated the measured values by a factor of about four. The R^2 of the regression between k_{-10mm} predicted using Janes and Tyler (1984) and the measurements was 0.748. This equation, therefore, appears useful for these soils, but not as good as equation (2).

The prediction of hydraulic conductivity at 10 mm suction developed here appears useful for the relatively unstructured sandy and silty soils of the lowland areas of San Luis Province. The heavier soils are explicitly excluded.

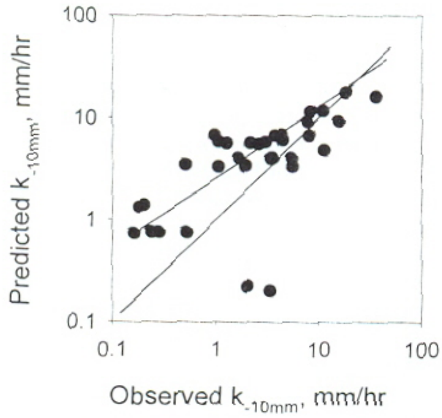

Figure 9. Relationship between measured k_{-10mm} and predicted k_{-10mm} using equation (3) (from Janes. Tyler, 1984). The lines show the 1:1 relationship and the best fit regression between the observed and predicted values.

Figura 9. Relación entre k_{-10mm} medido y k_{-10mm} anticipado usando la ecuación (3) (Janes, Tyler, 1984). Las líneas muestran la relación 1:1 y la línea de mejor ajuste entre los valores anticipados y observados.

The relationships have not been tested on other soils or in other locations.

The relationship between the dry bulk density and field texture class is shown in Figure 10, whereas Figure 11 shows the relationship between dry bulk density and the median size (50 % passing size) estimated from the laboratory particle size analysis. The figures show that the dry bulk density was greater in the coarser soils, as expected. Table 2 shows the correlation between the measured dry bulk density and the field texture class, and between the dry bulk density and the 50%, 20% and 10% passing sizes. The correlations between dry bulk density and field texture class and the 50% passing size were both significant at the 1% probability level, but the other correlations were not significant.

A multiple regression equations similar to (2) but with density in place of $\log(k_{-10mm})$ resulted in slightly greater correlations than those with a single particle size index alone. The result is shown in Table 3. The R^2 of the regression was 0.412, indicating that equation (2) is a fair predictor of the dry bulk density. In the case of density, the omission of site 15 led to a worsening of the R^2 so, unlike the case for hydraulic conductivity, this result is not shown.

There was no correlation between hydraulic conductivity and density. As would be expected, therefore, the addition of density to the multiple regression equations used to predict hydraulic conductivity resulted in no improvement to the quality of the predictions.

CONCLUSIONS

For some lowland soils in the San Luis Province, representing clays through to sands, the hydraulic conductivity at a suction of 10 mm varied from 0.016 to 35 mm hr^{-1}. The hydraulic conductivity was significantly correlated to the

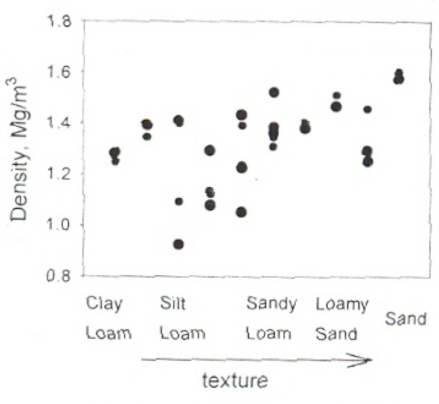

Figure 10. Relationship between dry bulk density and hand texture class .

Figura 10. Relación entre densidad aparente seca a granel y textura de suelo (en campo).

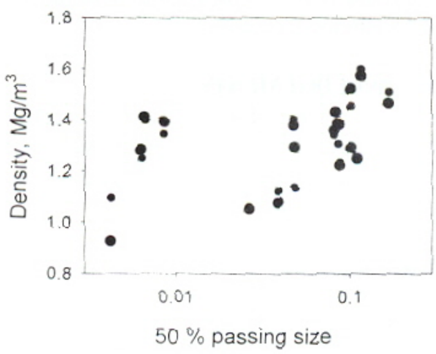

Figure 11. Relationship between dry bulk density and the 50 % passing size.

Figura 11. Relación entre densidad aparente seca a granel y tamaño de partícula de referencia, de la cual 50% fue de menor tamaño (50% passing size).

texture class as determined by hand texturing in the field, and to laboratory particle size measurements. The dry bulk density was similarly correlated, though the significance of the correlations was less. Therefore, both field texturing and laboratory particle size analysis can be used for rough estimates of the hydraulic conductivity at 10 mm suction and the dry bulk density.

The best predictions, particularly of hydraulic conductivity, were given by a multiple regression involving the different size fractions. The best equation had an R^2 of 0.818, but the heaviest soil had to be omitted from the regression. An equation due to Rawls *et al.* (1992) predicted k_{sat} between 2 and 7 times greater than that expected, and had a smaller R^2 of 0,666, and so appears less useful. An equation due to Janes and Tyler (1984), developed specifically for soils similar to those investigated here, predicted values of k_{-10mm} that were similar to those measured in coarser soils but up to four times greater in finer soils. This equation had an R^2 of 0,748, and appears to be useful, though not as good as the best equation found in this study.

This pilot study has led to rough, but useful means of predicting hydraulic conductivities for lowland soils in San Luis. It does indicate that there are good prospects for developing general relationships between the hydraulic properties and the particle size and other readily measured soil properties of these soils. Future work should include more of the heavy soils so that robust relationships can be extended to them.

ACKNOWLEDGEMENTS

This work was done as part of a study funded by the San Luis government. We gratefully acknowledge permission to publish the work.

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