MOISTURE-RETENTION CURVES OF THE SUGARCANE CULTIVATED SOILS IN PERU

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ABSTRACT

The soil moisture-retention curves were determined for the Peruvian cane-growing area with a sampling density of one point per 1,600 ha. Samples were obtained from every 30 cm down to the depth of 90 cm.

The obtained mathematical model expressed the water potential in the soil as a function of its moisture content and the saturation percentage (Arany number, $K_A$). The saturation % is a commonly used characteristic in the Peruvian cane sugar industry and can be determined easily. The regression analysis showed a correlation coefficient ($R^2$) of 0.76.

INTRODUCTION

Because of water deficit in the coastal valleys of Peru where the cane-growing areas are situated, it is imperative to maximize the use of the existing water resources. To attain this objective, a technical tool was designed to serve as a decision element for those in charge of irrigation scheduling. This tool is used by the "Moisture Control Service" (Eppink2) and is based on the moisture-retention curves or moisture characteristic curve which express the relation between content and the water potential of the soil. The soil-water potential also expressed as soil-water tensions, indicates the degree of water availability to the plant (Forsythe4). The moisture characteristic curves as functions of the physio-chemical properties of soils were described by different researchers, such as Wilcox12 which established correlations between the field capacity ($-0.33$) and the wilting point ($-15.0$) with percentages of sand, clay, colloids, moisture equivalent and settling volume as the best. The relation is as follows:

$$
\sigma_{15.0} = 0.92 + 0.317 \ e_q + 18.5
$$

where: $e_q$ is the moisture equivalent.

Petersen et al8 studied the influence and bulk density of the different contents of sand, silt and clay in the retaining capacity of soils. For $\sigma_{0.33}$, a closer correlation with the bulk density was found. Likewise, a closer correlation with the percentage of clay was found for $\sigma_{15.0}$. The available water shows a negative correlation with both sand and clay, but a positive one with silt.
The relation of percentages of fine sand, silt, clay, organic matter and calcium carbonate to the bulk density, field capacity, wilting point and available water were studied by Shaykewich and Zwarich\textsuperscript{10} found that the predicting equations of the bulk density, field capacity and wilting point were reliable.

Salter and Williams\textsuperscript{9}, Zawadzki\textsuperscript{14} and Maclean and Yager\textsuperscript{6}, studied the relations between the percentage of clay and moisture of 2 pF and 4.2 pF. Osty\textsuperscript{7} obtained a regression equation to estimate the moisture content at 3 pF with a determination coefficient of 0.95 based on the percentage of clay, fine silt, coarse silt, fine sand and coarse sand. With a determination coefficient of 0.73 it can be estimated from the percentage of clay and organic matter only.

Correlations between the moisture content at different tensions and the texture of soils of the Chicama Valley, were made by Husz\textsuperscript{5}. Chanduvil found a relation between the moisture content and its corresponding water potential at 12 atmospheres as a function of the percentage of clay.

The objective of the present work is to find a mathematical model that may relate the soil water potential with the Arany number ($K_A$) and the soil moisture content which are characteristics easily determined.

MATERIALS AND METHODS

The study was performed on fields of the twelve Agrarian Cooperatives of Production that are associated with the Central de Cooperativas Agrarias de Produccion Azucarera del Peru (CECOAAP) which comprises approximately 80,000 ha. The sampling density used was at the rate of one point (pit) per 1,600 ha at three depths (0-30, 30-60 and 60-90 cm).

The selection of fields in each Cooperative was carried out with the collaboration of the Field Superintendent who with their experience helped to locate sampling points where soils of different textures can be found.

Undisturbed samples were obtained for determining both bulk density and retention curves, whereas disturbed samples were obtained to determine the Arany number.

The determination of moisture contents at tensions of 0.1, 0.8, 2.0, 5.5 and 15.0 bars were made with four replications by means of the pressure ceramic plates. The determination of the Arany number was made according to the method proposed by the ICIA, Eppink\textsuperscript{2}.

Based on the results obtained in the laboratory, the water potential ($Y$), as a function of moisture content in vol. % ($\theta$) and the Arany number ($K_A$) can be expressed in the following mathematical model:

\[
y = \frac{7 (1 - \left(\frac{\theta}{\mu}\right)^{0.8})^6}{1 + \left(\frac{\theta}{\mu}\right)^{0.8}}
\]
where: \( \mu = \) soil porosity

\( b \) and \( c = \) constants

Constants \( b \) and \( c \) are then calculated obtaining 3.6 and 2.4, respectively. Finally, the mathematical relation of \( t, \mu \) and \( v \) was determined.

RESULTS AND DISCUSSION

As a result of the laboratory analysis, it was found that the Arany number of the samples was between 23 and 130. This corresponds to textures which range from sandy to clay according to the USDA. The bulk density varied between 1.10 and 1.70 g/cm\(^3\). It was also observed to slightly vary with depth. This was in accordance with a report by Vasquez et al\(^{12}\). The salinity level of samples was low, with a maximum value of 1,000 mmhos/cm of electrical conductivity in the extract, which resulted from the exclusion of this variable in the final model. Likewise, both organic matter and calcium carbonate contents were low.

The results of the regression analysis as shown in the general model are as follows:

\[
\mu = 100 - 37.736848 \left[ 1.2916 + 0.2442 \ e^{- \frac{(X - 23)^2}{a_1}} \right]
\]

\[
V = 0.78 + 0.4075 \ \frac{(X - 23)^2}{13.375} \ e^{- \frac{(X - 23)^2}{13.375}}
\]

\[
t = 0.60 + 11.70 \ e^{- \left[ \frac{(X - 23) / (10.3 - (X - 23) / (10.7))^{0.5}}{a_1} \right]}
\]

where: \( i = 1, 2, 3 \), indicators of depths 0-30, 30-60, and 60-90 cm, respectively

\( a_1 = 24.1 139 \) magnitude of constants

\( a_2 = 24.9731 \) base of natural logarithm

\( x = \) saturation percentage

Since the final model is only a function of \( X \) its application is reliable if it has high correlation (\( R^2 = 0.76 \)).

Figure 1 shows the retention curves generated according to the model based on the first depths where observations on the quantity of available moisture on the different types of soil, conforms with that of Stakman and Harst\(^{11}\), Husz\(^5\), and Eppink\(^2\).

Though it was true that water retention phenomenon plays a very important role, the porosity has an indirect relation to the saturation percentage (Vasquez
FIGURE 1. Moisture retention curves for different soil textures. Moreover, it was intended that the results be obtained from easy routine determination so that they may have practical application.

CONCLUSIONS

The general model found in this work gives grounds for confidence at $R^2 = 0.76$. Besides it is very practical since it is a function of only one soil physical characteristic ($K_F$) the determination of which is only routine.

It is possible to determine the soil moisture-retention curve by means of a mathematical model derived from the function of the saturation percentage or the Arany number ($K_A$) which is the best index of soil texture.

The textural range under study included all the soils of the Peruvian cane-growing area.

The soil’s organic matter content, electrical conductivity and calcium carbonates were low.

The bulk density of studied soil varied between 1.10 and 1.70 g/cm$^3$.

REFERENCES

1. Chanduvi, F. (1964). El contenido de humedad del suelo a 12 atmosferas de presión con relación a las constantes hídricas y con el análisis textural. Tesis Ingeniero Agrícola, Universidad Nacional Agraria "La Molina"

3. ________, (1973). La relacion entre la Cifra Arany y el limite superior de plasticidad segun Atterberg. Saccharum ICIA No. 1


Las curvas de retención de humedad en el suelo, fueron determinadas para el área cañera del Perú, con una densidad de muestreo de un punto cada 1,600 ha, obteniéndose muestras cada 30 cm hasta, la profundidad de 90 cm.

El modelo matemático obtenido expresa el estado energético del agua en el suelo, en función de su contenido de humedad y el porcentaje de saturación (Cifra Arany, K_A); por ser esta última una característica muy usada en la industria azucarera peruana y de fácil determinación rutinaria. El análisis de regresión arrojo un coeficiente de determinación ($R^2$) de 0.76.