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Use of the Rawls Pedotransfer Functions for Predicting Soil Water Retention of a Zimbawean Soil

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Abstract: Several regression equations have been developed to estimate points on the moisture characteristics curve from soil composition and bulk density. Pedotransfer functions developed from different locations have not been used in other locations because of differences in particle size analysis, classification, differences in pedality and in clay size minerals of he clay fraction. Rawls regression equations for predicting moisture contents at -1500 and -60 kPa from soil composition and bulk density were used to predict Romwe catchment moisture contents and compared with measured moisture contents at the same potentials. A significant correlation between measured and predicted moisture content were realised. The Rawls equations overpredicted catchment soil moisture content at the two potentials as indicated by slopes of 1.269 and 1.311 and constants of +3.837 and +5.069 at -1500 and -60 kPa, respectively. This study shows that, in the absence of measured data on the moisture characteristic curve, the Rawls empirical equations can be used to predict soil moisture contents at given potentials, provided a 'local calibration factor' is used to take account of any systematic under or over estimation.

Key words: Soil moisture, soil water potential, empirical equations

INTRODUCTION

Measurements of the relationship between matric potential and water content is very costly and time consuming given the variability in soils within short distances[1]. Most laboratories in developing countries do not have the equipment to measure the soil moisture characteristic curve and this is a major limitation in irrigation scheduling. However, data on soil particle analysis is available in most cases.

Several pedotransfer functions have been developed to predict the moisture release curve from the knowledge of texture, organic matter and bulk density[2-6]. These methods, offer a relatively simple means of characterising soil moisture content at certain potentials at the field or catchment scale without the necessity of collecting huge quantities of soil to be processed by costly, time consuming analytical methods. Pedotransfer functions provide a first estimate that can be most useful for planning and evaluation purposes while field or laboratory measurements are essential if accurate data is required. Rawls[6] reported multiple linear regressions between water content and clay, sand, silt and organic matter at ten matric potentials, with regression coefficients values ranging from 0.80 to 0.87 for major USDA soils. Gupta[4] also developed multiple regression equations to predict water content from sand, silt, clay, organic matter and bulk density at 12 potentials of Miossouri soils.

Attempts to use empirical equations developed elsewhere have not been successful. The failure has been attributed to differences in analytical techniques between laboratories, sampling procedures and type and size of samples[7,8]. The objective of this study was to evaluate the suitability of two of the regression equations developed by Rawls[4] for predicting Romwe catchment soils' water content at -1500 and -60 kPa.

MATERIALS AND METHODS

Study site: The Romwe catchment that is situated in Southern Masvingo is 4.6 km^2 in area. Three soil types dominate in this catchment, mainly due to differences in parent material[9]. Light grey coloured, sandy soils formed from the more granitic gneiss are found on the Southern side of the stream. These are described as Fersiallitic soils (II 5P) according to the Zimbabwean soil classification system[10]. In many locations, a thick clay layer at 0.7 m in depth underlies the light textured surface horizons. In the Northern side of the stream, Fersiallitic, red clays with granular micro-structure (III 5E) predominate and are derived from the more mafic pyroxene gneiss. The third and least extensive soil type are small areas of Vertisols (II 3E). These occur as the lower members of the catenal sequence to the north of the stream.

Fourteen pits, selected at random within the Romwe catchment were dug and horizon delineation was based on colour and observable textural and structural differences. Forty-one soil samples from three or more layers within each of the 14 pits, provided the data set for examining the relationship between moisture content measured and that predicted using the Rawls[4] equations at -1500 and -60 kPa. Particle size analysis on the soil samples was done by the Institute of Soils and Chemistry (Harare). Soil cores for bulk density determination were taken from three faces of a pit at positions where soil samples for particle size analysis were taken using a core sampler of volume 1.67.5 m^3. The soil samples were put in tins and dried in an oven for 48 h at 105°C and then reweighed.

The pressure chamber method was used to determine the gravimetric moisture content at -1430 and -60 kPa following the technique by Black[11]. A saturated paste of each of the 41 samples was prepared and replicated twice in the rings that were placed on a ceramic plate. The samples were left to equilibrate until there was no significant amount of water increase in the burettes collecting the outflow. This was achieved after nine days. After equilibration, samples were transferred into weighed aluminium foil. The weight of the wet soil plus the foil was determined, and the samples dried at 105°C for 48 h before reweighing. Moisture content was expressed as HO_2 g/100 g of soil.

Moisture contents at -1500 and -60 kPa suctions were predicted using the Rawls[4] Eq. 1 and 2 and compared with that measured as above. Although the suctions are not quite the same at -1430 and -1500 kPa, there should not be much effect on the minor discrepancy between the suctions at such high suctions, where changes in water content with potential are small. Rawls[4] equations were chosen because the data set from which the equations were developed contained a wide range of clay (mean 18% and range 0.1-94%), silt (mean 26% and range 0.1-93%) and sand (mean 56% and range 0.1-99%). The Romwe soils contained the following ranges of soils; clay (mean 23% and range 4-50%), silt (mean 10% and range 3-33%) and sand (mean 67% and range 34-91%):

At -1500 kPa

$$\theta = 0.0260+0.005C+0.015OM \quad (1)$$

At -60 kPa

$$\theta = 0.2065+0.0016S+0.004C+0.0275OM \quad (2)$$

Where, C, S and OM are clay, sand and organic matter, respectively.

RESULTS AND DISCUSSION

The relationship between measured soil moisture and that predicted using Rawls[4] regression Eq. 1 and 2

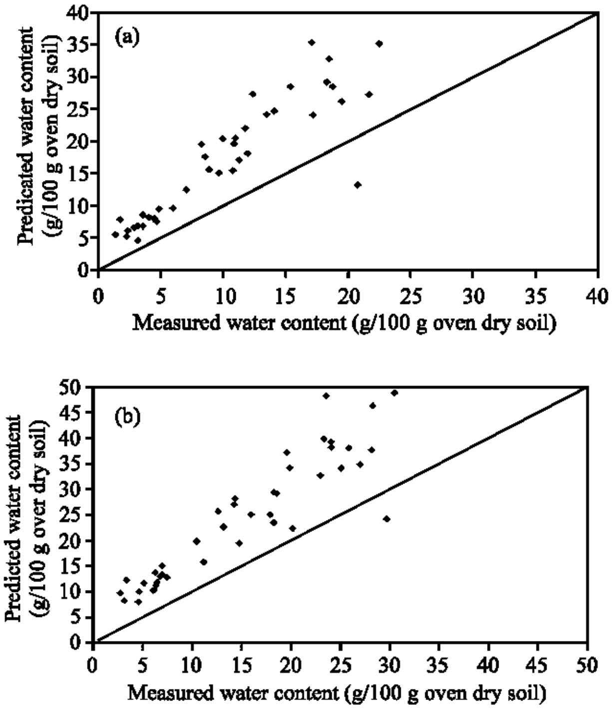

Fig. 1: Relationship between measured water content and that predicted by Rawls *et al.*[4] empirical equations at (a)-1500 and (b)-60 kPa suctions

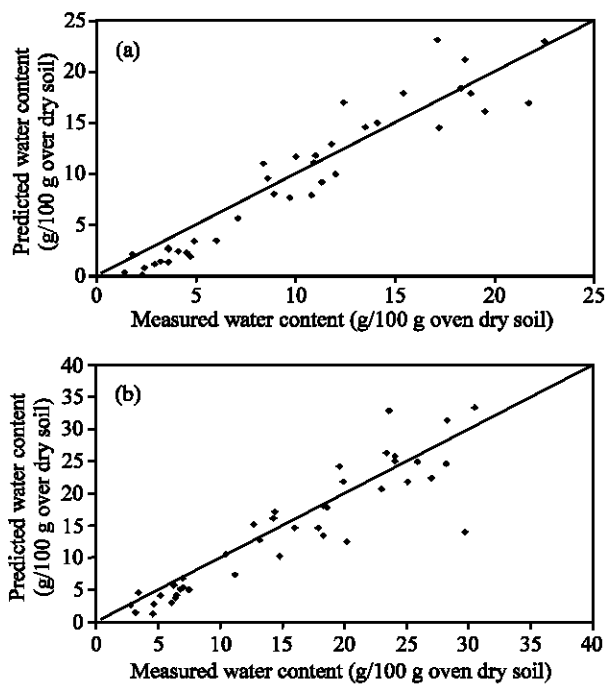

Fig. 2: Relationship between measured water content and that predicted by Rawls *et al.*[4] equations (with calibration factors) at (a)-1500 kPa and (b)-60 kPa suctions

are presented in Fig. 1. Both correlations are significant at the 95% level with coefficients of determinations of 0.834 and 0.809 at -60 and -1500 kPa, respectively. However, the Rawls[4] equations overestimated gravimetric water content as indicated by the slopes of 1.269 and 1.311 and constants of +5.069 and +3.837 at -60 and -1500 kPa, respectively.

Figure 2 shows the relationships between measured soil moisture and that predicted by Rawls[4] equations after applying correction factors. The relationships between measured and predicted soil moisture contents improved after applying these correction factors (x0.788 and -5.068) and (0.763 and -3837) which gave coefficients of determinations of 0.834 and 0.809 and slopes of 1 and 0.999 at -60 and -1500 kPa, respectively. The constants were reduced to-1.076 and -0.910, respectively.

At -60 and -1500 kPa, Rawls[4] equations over predicted soil moisture by 27 and 30%, respectively. The finding that these empirical equations developed by Rawls[4] over predicted water content is consistent with Campbell's[7] observation that even though the correlation fits the data with which they are developed quite well, they give relatively poor fit to data from other studies. The differences in the moisture predicted by Rawls[4] equations and that measured in the laboratory might be emanating from the differences in the ranges of soils used, differences in mineralogy or textural diameters used as was found by Williams[12]. Good agreement was observed between measured soil moisture and that predicted by empirical equations developed by Mugabe[13] for the Romwe catchment soils.

However, the observed water contents and the equations used to predict moisture content were well correlated. This suggest that measurements on a few soil samples from the Romwe catchment could be used to calibrate the Rawls[4] equations for the Romwe catchment soils, by finding multiplication and subtraction/addition factors.

In this experiment, the validity of only two equations out of the ten developed by Rawls[4] was assessed. The Rawls[4] equations for predicting soil moisture at -60 and -1500 kPa had almost similar calibration factors of 0.788 and 0.763. Since the calibration factors at low (-1500 kPa) and a high (-60 kPa) potentials compared quite well it might be expected that the rest of the ten pedotransfer functions developed by Rawls[4] can be successfully used to predict Romwe catchment soil moisture at those suctions. This study shows that, in the absence of measured data on the moisture characteristic curve, the Rawls[4] empirical equations can be used to predict soil moisture at given potentials provided local calibration factors are used to take account of any systematic under or overestimation.

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