

Field, laboratory and estimated soil-water content limits

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Abstract

For the purpose of irrigation scheduling, estimates of soil-water content limits are determined using field or laboratory measurements or empirically-based regression equations. In this study the field method involved measuring simultaneously the soil-water content (using a frequency domain reflectometer with the PR1 profile probe that relies on changes in the dielectric constant of soil), and soil-water potential (using Watermark granular matrix sensors and tensiometers) at three depths (100, 300 and 600 mm) from a 1 m² bare plot. A retentivity relationship was developed from these measurements and the drained upper limit was estimated to be 0.355 m³·m⁻³ when the drainage from the pre-wetted surface was negligibly small. The lower limit, corresponding to -1 500 kPa, was estimated to be 0.316 m³·m⁻³. In the laboratory, soil-water content and soil matric potential were measured on undisturbed soil samples taken from the edge of the bare plot. The undisturbed soil samples were saturated and exposed to different matric potentials between -1 and -1 500 kPa. A retentivity relationship was then developed from these measurements. The laboratory method realized a drained upper limit value of 0.390 m³·m⁻³ at -33 kPa and a lower limit value of 0.312 m³·m⁻³ at -1 500 kPa. A regression equation, which uses the soil bulk density and the clay (<0.002 mm) and silt (0.002 to 0.05 mm) percentage to estimate the soil-water content at a given soil-water potential, realised a drained upper limit value of 0.295 m³·m⁻³ at -33 kPa and a lower limit value 0.210 m³·m⁻³ at -1 500 kPa. Comparisons were made between field, laboratory and regression equation methods of estimating the upper and lower soil-water content limits. The field-measured soil-water content was statistically different from the laboratory-estimated and regression equation estimates of soil-water content. This was shown from a paired *t*-test, where the probability levels for the laboratory and regression equation methods were 0.011 and 0.0005 respectively at the 95 % level of significance. Field method soil-water content comparisons with the laboratory method resulted in a linear regression coefficient of determination of 0.975 with a root mean square error (RMSE) of 0.064 m³·m⁻³. By contrast, field method comparisons with the regression equation method showed a coefficient of determination of 0.995 with an RMSE of 0.035 m³·m⁻³. The frequency domain reflectometry method used for monitoring soil-water content has been shown to be useful in this case of relatively homogenous soils supporting perennial crops.

Keywords: soil-water content limits, Watermark granular matrix sensor, tensiometer measurements, PR1 soil-water profile probe dielectric method

Introduction

The field-measurement of soil-water content is of paramount importance in irrigation science and irrigation management. It affects irrigation system design, irrigation system management, crop selection and crop management. There are, however, very few practical field methods for measuring or estimating soil-water content. Accurate measurement of the lower limit and the drained upper limit is required to estimate the available water reserve of a soil and these limits are critical inputs required by soil-water balance models (Ritchie, 1981). Both the lower limit and drained upper limits can be measured in the field or laboratory or they can be estimated using empirical equations based on easily measured soil properties such as soil texture, soil bulk density and soil organic matter content. The field-measured lower limit is taken as the soil-water content at which plants were practically dead or dormant as a result of the soil-water deficit (Ratliff et al., 1983). The lower limit could also be measured using *in situ* soil psychrometers (Savage et al., 1996). The drained upper limit is taken as the soil-water content at which drainage from a pre-wetted soil practically ceases or when the soil-water content decrease is about 0.001 to 0.002 m³·m⁻³·d⁻¹ (Ratliff et al., 1983).

In the laboratory, the most common procedure for estimating the drained upper limit and lower limit is to extract water from a disturbed or undisturbed soil sample using the soil-water extraction apparatus (Richards and Weaver, 1943). The lower limit is estimated using the apparatus at a soil matric potential of -1 500 kPa (Richards and Weaver, 1943). The water content at a matric potential of -33 kPa is used as an estimate of the drained upper limit for moderately coarse and fine-textured soils, whereas -10 kPa is used for coarse-textured soils (Colman, 1947; Jamison and Kroth, 1958).

Field or laboratory measurement of the relationship between soil-water potential and soil-water content is expensive, difficult, and often impractical (Saxton et al., 1986). Thus, for many purposes, general estimation is often based on more readily available information such as soil texture, soil bulk density and soil organic matter, thereby reducing the time and cost of laboratory and field measurements. Many researchers (Brooks and Corey, 1964; Gupta and Larsen, 1979; Mottram et al., 1981; Rawls and Brakensiek, 1982; Cosby et al., 1984; Schulze et al., 1985; Hutson, 1986; Saxton et al., 1986; Ritchie et al., 1999) have developed regression equations to estimate the soil-water potential and water content relationships from soil texture, soil bulk density and soil organic matter. Mottram et al. (1981), for example, developed regression equations for the top- and sub-soil of 31 soil types at Mkuzi (KwaZulu-Natal, South Africa) based on the soil texture clay (< 0.002 mm) and silt (0.002 to 0.05 mm), organic matter and bulk density. The lower limit was estimated at a matric potential of -1 500 kPa and the upper limit

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