Soil Water Potential

Soil water potential can be derived from a soil water content sensor using ICT International's SMM Soil Moisture Meter. A mathematical relationship between soil water potential and soil water content for a particular soil type is derived using established laboratory techniques. The equation derived from this relationship can be entered into the SMM Soil Moisture Meter as a script. Soil water content sensors are installed in the field, such as the MP406 or MP306. The SMM Soil Moisture Meter then outputs data as both water content and water potential. This article provides a background to this technique, why a user will want to know soil water potential versus soil water content, and expands on the methodology to simultaneously measure soil water content and water potential with the SMM Soil Moisture Meter.

Soil water content is a well-established and wide-spread measurement. Soil water content is measured with ICT International's MP406 or MP306 volumetric water content sensors. These sensors are commonly used by scientific researchers, irrigators, agriculturalists and education institutions around the world. However, only measuring soil water content limits the amount of information available from the soil environment.

MP306

MP406

The major limitation of soil water content data is the reliance on soil physical properties. That is, depending on the type of soil being measured, for example in a sandy or a clay soil, the same water content value carries a vastly different meaning. For instance, a 20% volumetric water content measurement on a sandy soil indicates a moist to saturated soil. A value of 20% recorded on a clay soil, on the other hand, indicates a near dry soil. Therefore, a user needs to have an intimate knowledge of the soil physical properties where they are measuring water content in order to gain meaningful information.

The reason why a value of 20% carries a different meaning for a sandy soil and a clay soil is related to the texture, structure and porosity. It more useful to have a tool which can measure soil water independently of these variables. What is needed is a universal technique that works irrespective of soil physical characteristics. Fortunately, the measurement of soil water potential is the universal technique.

The measurement of soil water potential is the measurement of the amount of energy available in the soil to do work. Or, to put it more intuitively, it is the amount of energy required for a plant to perform work in order to extract moisture from soil. Soil water potential is expressed by a number of different units. In soil science the most common units are kilopascals (kPa), megapascals(MPa), bar or centibar. Table 1 outlines the equivalency between these units of meaurements.

Using kPa, the more negative the number then the greater amount of work a plant needs to do in order to extract moisture from soil. In agriculture, it is assumed that -33 kPa is field capacity (the optimal moisture potential for plants) and permanent wilting point is -1500 kPa (the point of plant mortality). Importantly, these values of field capacity and wilting point are assumed to be the same for all soil types (field capacity and wilting point does vary depending on the plant species under consideration, but this is a story for another day).

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Table 1. A comparison of water potential units commonly used in soil science.

	Kilopascals (kPa)	Megapascals (MPa)	Bars	Centibars
	-1	-0.001	-0.01	-1
	-10	-0.01	-0.1	-10
Field Capacity	-33	-0.033	-0.33	-33
	-100	-0.1	-1	-100
	-1000	-1.0	-10	-1000
Wilting Point	-1500	-1.5	-15	-1500

In order to derive soil water potential data from soil water content data there needs to be a mathematical or statistical relationship between these two variables. Fortunately, there exists a relationship between soil water potential and soil water content. Once this relationship is determined, it is a simple matter of algebra to derive soil water potential from a soil water content value.

The relationship between soil water potential and soil water content is known by a few different titles including: moisture release curve; water characteristic curve; water retention curve; and capillary pressure-saturation relation, among others. This article will not describe this method in detail. However, the moisture release curve is a well-established technique in soil science and detailed methodology can be found in Dane and Hopmans (2002). Also, you can find more information by contacting ICT International.

Figure 1 is an example relationship between soil water content and soil water potential derived from a pressure plate extractor. Curve A is a theoretical curve from a sandy soil and Curve B is a theoretical curve from a clay soil. The mathematical relationships for these curves are:

Curve A Sandy Soil: Soil Water Potential $= 5343 \times$ Soil Water Content $^{-1.852}$

Curve B Clay Soil: Soil Water Potential $= 6 \times 10^{7} \times$ Soil Water Content $^{-4.228}$

Note that these are demonstration curves only and the values presented above can vary depending on your soil type. The important point from Figure 1 is a strong mathematical relationship can be derived between soil water potential and soil water content. Once a reliable equation has been derived, the relevant parameters can be entered as a script into the SMM Soil Moisture Meter.

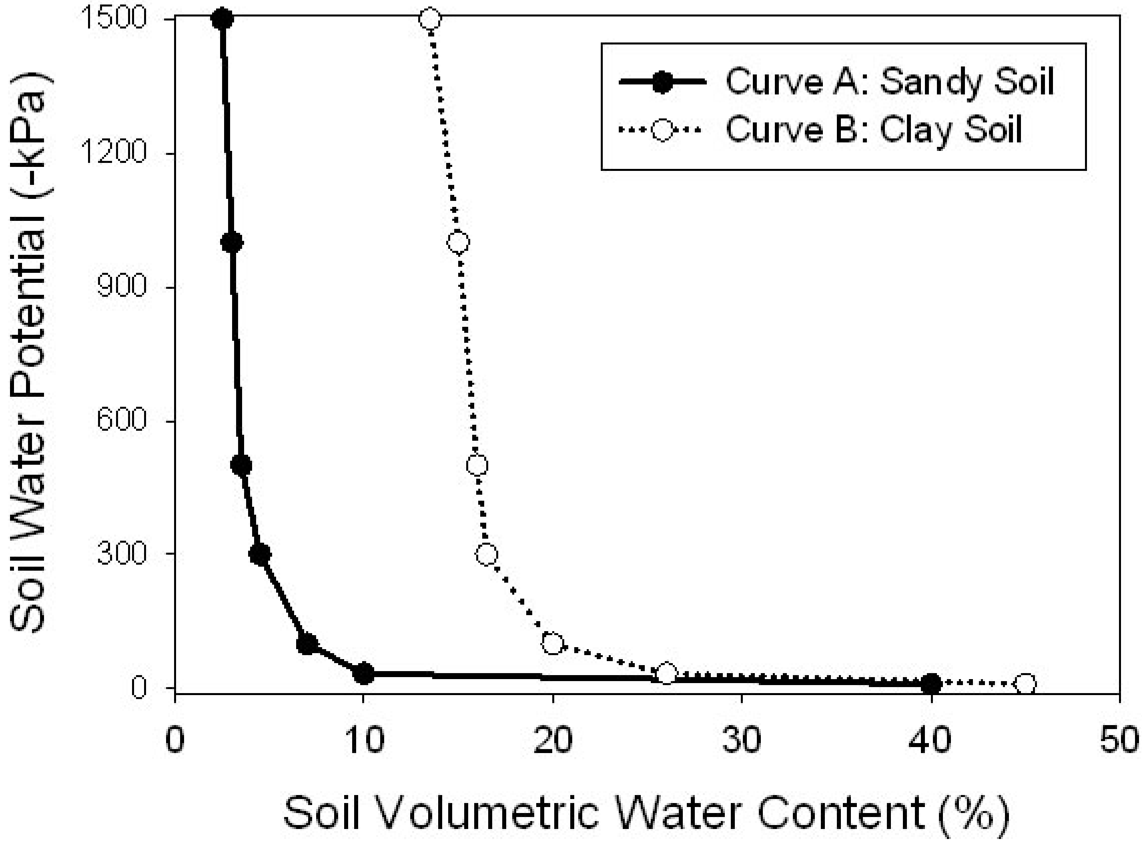

Figure 1. A hypothetical moisture release curve for a sandy soil (Curve A) and clay soil (Curve B).

ICT International's SMM Soil Moisture Meter has a 10 sensor capacity. These 10 sensors can be real sensors installed in the field, or a number of real sensors and correlated virtual sensors. For now, let's assume there are 5 x MP406 Volumetric Water Content sensors, installed at a depth of 10cm, at 5 locations across a field. The 5 x MP406 sensors are installed in channels 1 to 5 on a SMM Soil Moisture Meter. The MP406 sensors are giving output data as volumetric water content (%). A moisture release curve has been derived for this soil and, coincidentally, it is the same equation as Curve A above. The SMM Soil Moisture Meter has the flexibility to handle scripts and a script for the equation for Curve A above is entered. Channel 6, via the script, is now assigned as a virtual sensor, correlated with Channel 1, and its output data is soil water potential (kPa). Channel 7, also via a script, is now assigned as a virtual sensor, correlated with Channel 2, and its output data is also soil water potential (kPa). Channels 8 to 10 are also assigned as virtual sensors correlated with channels 3 to 5 respectively. Now the SMM Soil Moisture Meter is simultaneously recording soil water content and soil water potential data at 5 locations in this hypothetical cotton field.

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On another field, a researcher has 10 x MP406 sensors connected to a SMM Soil Moisture Meter. These are installed at 5 locations and 2 depths (10cm and 50cm). The 10cm depth is a sandy soil and the 50cm depth is a clay soil corresponding to the equations of Curve A and Curve B in Figure 1. In this instance, all 10 channels of the SMM Soil Moisture Meter are dedicated to the MP406 sensors. The researcher can choose to monitor soil water content data and then later, after the data has been downloaded from the SMM, apply the equations of Curve A and Curve B to his data in an Excel worksheet.

Alternatively, the researcher can use the script feature in the SMM Soil Moisture Meter to direct each channel to log soil water potential data. The script can be easily adapted to record soil water potential data instead of soil water content data. Additionally, for peace of mind, the SMM Soil Moisture Meter can simultaneously log raw millivolt data from each MP406 sensor. Since the raw data is also being recorded, the researcher can back calculate soil water content data. If a new moisture release curve is generated and the equations of Curve A or Curve B need to be altered, the researcher can also back calculate the results from the SMM Soil Moisture Meter.

In summary, through ICT International's SMM Soil Moisture Meter, soil water potential can be measured with a soil water content sensor. A moisture release curve needs to be generated in order to derive a mathematical relationship between soil water content and water potential for a particular soil type. This mathematical equation can be either directly entered into the SMM Soil Moisture Meter and data output generated via a virtual channel, or data output can be generated direct on a sensor channel. At all times, raw millivolt data can be recorded so any alterations can be applied to the measured data from the field.

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Reference

Dane, JH and Hopmans JW (2002). Water retention and storage. In: Methods of Soil Analysis, Part 4 Physical Methods (Editor-in-Chief SSSA: WA Dick). Pp 671 – 720. Soil Science Society of America, Inc, Madison, Wisconsin, USA.