METER
ENVIRONMENT

SOIL MOISTURE SENSORS—HOW MANY DO YOU NEED?

Contributors

The number of soil moisture sensors installed at a research site can make the difference between proving a hypothesis or missing it entirely. How many sensors will produce the most complete soil moisture picture? No single answer captures all scenarios. Study objectives, accuracy requirements, scale, and site-specific characteristics all influence the number of sensors required. In addition, soil moisture is variable both spatially and temporally. Understanding the driving forces of this variability gives researchers insight into how to go about sampling.

UNDERSTANDING VARIABILITY CAN BE DIFFICULT

Within the area of a study site, soil moisture variability arises from differences in soil texture, amount and type of vegetation cover, topography, precipitation and other weather factors, management practices, and soil hydraulic properties (how fast water moves through the soil). Researchers should consider the variability in landscape features to get a sense of how many sample locations are necessary to capture the diversity in soil moisture.

Soil water content can vary over time as well, changing with precipitation, drought, irrigation, and evapotranspiration, and in predictable patterns associated with seasonal weather and the diversity of vegetation (Wilson et al., 2004). While this is an easy concept to grasp, it becomes more complex when considering the variability that arises from the interaction between temporal and spatial dynamics.

SOIL MOISTURE DATA OFTEN CHALLENGE ASSUMPTIONS

The following examples use simulated data to illustrate the effects of spatial and temporal differences on soil moisture content. In the first example, soil moisture content is simulated for the same study site under wet and dry conditions and calculated the probability density functions (PDFs). This example demonstrates that

the parameters describing the soil moisture PDFs are not static, but instead change through time depending on soil moisture conditions.

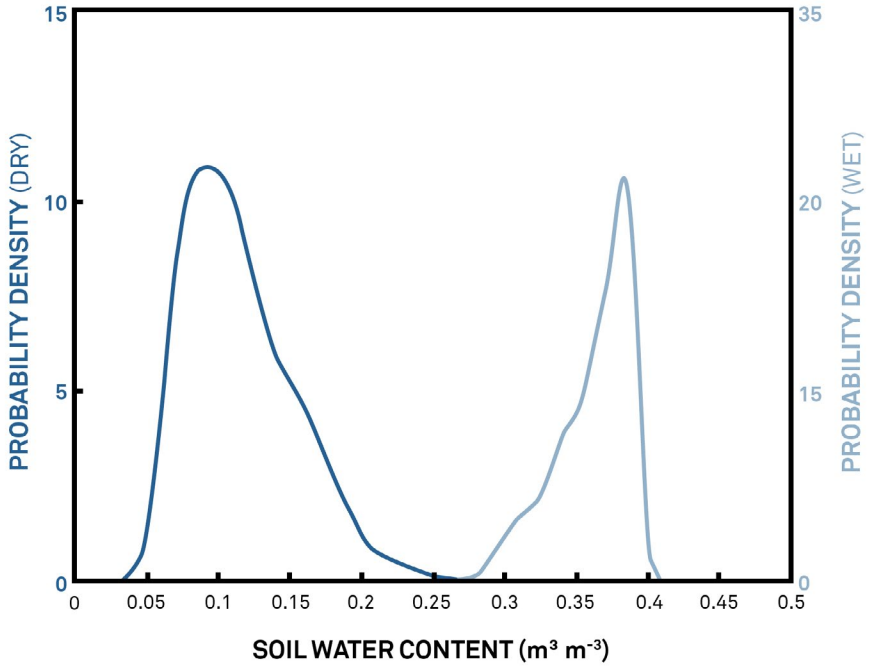

Figure 1. Probability density function (PDF) of soil moisture content from the same field under dry (dark blue) and wet (light blue) conditions

In the second example, soil water content is simulated for a single point in time when conditions were neither wet nor dry. The resulting PDF indicates that there is more than one "population" of soil moisture content within the study site (Figure 2). This could be caused by several factors. It may be that there are areas with different soil textures (e.g., drier sandy and wetter silt loam areas), that the study area includes low-lying topography and adjacent hillslopes, or that the study area has varying types of vegetation cover.

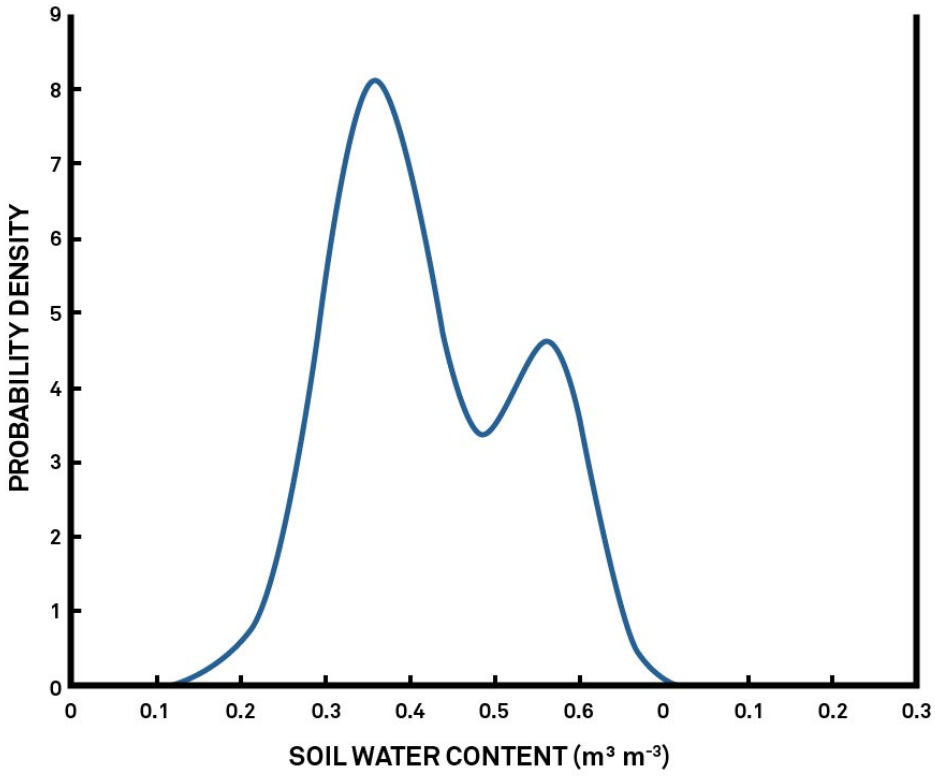

Figure 2. PDF for a snapshot in time at a location that has a heterogeneous landscape

The two simple examples above demonstrate the complex nature of soil moisture across time and space. Both examples suggest that an assumption of normality may not always be valid when working with soil water content in field conditions (Brocca et al., 2007; Vereecken et al., 2014).

HOW MANY SOIL MOISTURE SENSORS? IT DEPENDS.

If the objective is to determine the "true" mean soil water content for a study area, then the sampling scheme needs to account for the sources of variability described above. If the study area has hills and valleys, diverse types of canopy cover, and seasonal variations in precipitation, then sensors should be located in areas that represent the major sources of heterogeneity. If instead, the study site is fairly homogenous or the researcher is only interested in the temporal pattern of soil water content (e.g., for irrigation scheduling), then fewer soil moisture sensors may be required due to temporal autocorrelation in the data (Brocca et al. 2010; Loescher et al., 2014).

IN-SITU, CONTINUOUS MEASUREMENTS PROVIDE A SUPERIOR UNDERSTANDING OF SOIL WATER CONTENT

Soil water content is highly dynamic in time and space. It is labor intensive and difficult to capture all of these dynamics using spot sampling, although some researchers do choose to go this route. Like so many other areas of environmental science, some of the deepest insights into soil moisture behavior are emerging from studies using networks of in-situ sensors (Bogena et al., 2010; Brocca et al., 2010). For most applications, the use of in-situ, continuous measurements will provide you with a superior understanding of soil water content.

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REFERENCES

For a more in-depth treatment of “How many sensors do I need”, read the articles listed below.

Baroni, G., B. Ortuani, A. Facchi, and C. Gandolfi. “The role of vegetation and soil properties on the spatio-temporal variability of the surface soil moisture in a maize-cropped field.” Journal of Hydrology 489 (2013): 148-159. Article link.

Brocca, L., F. Melone, T. Moramarco, and R. Morbidelli. “Spatial-temporal variability of soil moisture and its estimation across scales.” Water Resources Research 46, no. 2 (2010). Article link.

Brocca, L., R. Morbidelli, F. Melone, and T. Moramarco. “Soil moisture spatial variability in experimental areas of central Italy.” Journal of Hydrology 333, no. 2 (2007): 356-373. Article link.

Bogena, H. R., M. Herbst, J. A. Huisman, U. Rosenbaum, A. Weuthen, and H. Vereecken. “Potential of wireless sensor networks for measuring soil water content variability.” Vadose Zone Journal 9, no. 4 (2010): 1002-1013. Article link (open access).

Famiglietti, James S., Dongryeol Ryu, Aaron A. Berg, Matthew Rodell, and Thomas J. Jackson. “Field observations of soil moisture variability across scales.” Water Resources Research 44, no. 1 (2008). Article link (open access).

García, Gonzalo Martínez, Yakov A. Pachepsky, and Harry Vereecken. “Effect of soil hydraulic properties on the relationship between the spatial mean and variability of soil moisture.” Journal of hydrology 516 (2014): 154-160. Article link.

Korres, W., T. G. Reichenau, P. Fiener, C. N. Koyama, H. R. Bogena, T. Cornelissen, R. Baatz et al. “Spatio-temporal soil moisture patterns–A meta-analysis using plot to catchment scale data.” Journal of hydrology 520 (2015): 326-341. Article link (open access).

Loescher, Henry, Edward Ayres, Paul Duffy, Hongyan Luo, and Max Brunke. “Spatial variation in soil properties among North American ecosystems and guidelines for sampling designs.” PLOS ONE 9, no. 1 (2014): e83216. Article link (open access).

Teuling, Adriaan J., and Peter A. Troch. “Improved understanding of soil moisture variability dynamics.” Geophysical Research Letters 32, no. 5 (2005). Article link (open access).

Vereecken, Harry, J. A. Huisman, Yakov Pachepsky, Carsten Montzka, J. Van Der Kruk, Heye Bogena, L. Weihermüller, Michael Herbst, Gonzalo Martinez, and Jan

Vanderborght. “On the spatio-temporal dynamics of soil moisture at the field scale.” Journal of Hydrology 516 (2014): 76-96. Article link.

Wilson, David J., Andrew W. Western, and Rodger B. Grayson. “Identifying and quantifying sources of variability in temporal and spatial soil moisture observations.” Water Resources Research 40, no. 2 (2004). Article link (open access).

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