S1 Calculation methods

S1.1 Geostatistal methodology for analyzing spatial variability in soil water content

Geostatistical analysis is pivotal for exploring spatial variability in variables, with the semivariance function being a cornerstone. This function operates on the principle that spatial properties tend to be more similar at nearby locations than distant ones (Nielsen and Wendroth, 2003). The semivariogram for a lag distance (h) can be calculated as follows:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N} [Z(x_i) - Z(x_i + h)]^2 \tag{S1}$$

where γ(h) denotes the semivariance, N(h) represents the number of sample pairs of variable Z within the interval h, and Z(x) and Z (x + h) are the values of Z at positions x and x + h, respectively. The γ(h) at h = 0, known as the nugget (C_0), represents the field and experimental (or random) variability that remains undetected within a specific sampling scale (Zhao et al., 2017). As h increases, γ(h) typically rises, eventually approaching a constant value (C_0 + C) over a given separation distance (A). The C_0 + C (sill) represents the total variance of the variables. The nugget-to-sill ratio, $C_0/(C_0 + C)$, serves as a parameter to describe the spatial dependence of Z. Generally, a $C_0/(C_0 + C)$ ratio below 0.25 indicates strong space dependence, while a $C_0/(C_0 + C)$ ratio above 0.75 indicates weak space dependence. Ratios falling between 0.25 and 0.75 indicate moderate space dependence (Cambardella et al., 1994). The geostatistical model that provided the best fit was selected to derive parameters for assessing the spatial variability of soil water content (SWC). In this study, the spherical function model was identified as the optimal fit.

S1.2 Methodology for assessing the temporal stability of soil water content

In this study, three indices were used to assess the temporal stability of SWC at each sampling point. These indices comprise the standard deviation of relative difference (SDRD, $\sigma(\delta_{ik})$; Vachaud et al., 1985), the mean absolute bias error (MABE; Hu et al., 2010), and the index of temporal stability (ITS; Jacobs et al., 2004). Lower values of all three indicate stronger temporal stability. A detailed comparison of these and other indices is given by Hu et al. (2012). The relative difference in SWC (RD, δ_{ijk}) at the *i*th point and *k*th depth for the *j*th sampling time is defined as follows:

$$\delta_{ijk} = \frac{SWC_{ijk} - \overline{SWC_{jk}}}{\overline{SWC_{jk}}} \tag{S2}$$

where SWC_{ijk} represents the SWC at point *i* and depth *k* for sampling time *j*, $\overline{SWC_{jk}}$ represents the areal mean SWC at depth *k* for time *j* across all sampling points.

The temporal mean relative difference (MRD, $\overline{\delta_{ik}}$) and SDRD ($\sigma(\delta_{ik})$) for each sampling point are calculated as follows:

$$\overline{\delta_{ik}} = \frac{1}{M}\sum_{j=1}^{M}\delta_{ijk} \tag{S3}$$

and

$$\sigma(\delta_{ik}) = \sqrt{\frac{1}{M-1}\sum_{j=1}^{M}(\delta_{ijk} - \overline{\delta_{ik}})^2} \tag{S4}$$

where M is the number of measurement campaigns.

By rearranging equation (S2), the mean SWC at the *k*th depth of the *j*th measurement campaign can be expressed as follows:

$$\overline{SWC_{jk}} = \frac{SWC_{ijk}}{1+\delta_{ijk}} \tag{S5}$$

The areal mean was estimated by the indirect method, in which the measurement at a single point is corrected by its temporal mean relative difference. Given a constant offset $\overline{\delta_{ik}}$ for a temporally stable point, the estimated mean SWC ($\overline{SWC_{jk}}'$) is calculated as follows:

$$\overline{SWC_{jk}}' = \frac{SWC_{ijk}}{1+\overline{\delta_{ik}}} \tag{S6}$$

The bias error of mean SWC (φ_{ijk}) can thus be expressed as follows:

$$\varphi_{ijk} = \frac{\overline{SWC_{jk}}' - \overline{SWC_{jk}}}{\overline{SWC_{jk}}} \tag{S7}$$

Substituting equations (S5) and (S6) into equation (S7):

$$\varphi_{ijk} = \frac{\delta_{ijk} - \overline{\delta_{ik}}}{1+\overline{\delta_{ik}}} \tag{S8}$$

The absolute bias error (ABE) and the MABE are defined as follows:

$$ABE_{ijk} = \frac{|\delta_{ijk} - \overline{\delta_{ik}}|}{1+\overline{\delta_{ik}}} \tag{S9}$$

and

$$MABE_{ik} = \frac{1}{M}\sum_{j=1}^{M}\frac{|\delta_{ijk} - \overline{\delta_{ik}}|}{1+\overline{\delta_{ik}}} \tag{S10}$$

MABE quantifies the error of the indirect estimate. Its numerator is the same as that of SDRD, the deviation of each relative difference from its temporal mean. Its denominator, one plus the MRD, is less than one at points drier than the areal mean and greater than one at wetter points. MABE is therefore inflated at dry points and reduced at wet points, and the two indices rank points differently to a degree that grows with the range of MRD (Hu et al., 2012).

The ITS is calculated as follows:

$$ITS_{ik} = \sqrt{\overline{\delta_{ik}}^2 + \sigma(\delta_{ik})^2} \quad \text{(S11)}$$

ITS combines the bias and the precision of a point in a single value. Time-stable points were identified as those with MABE < 5% and ITS < 10%.

S1.3 Methodology for calculating soil water storage and plant-available water storage

The calculation of soil water storage (SWS, mm) for the 0–1.0 m, 1.0–5.0 m and 0–5.0 m soil layers are performed as follows:

$$SWS_{i(0-1.0\,m)} = 200 \times [SWC_{i(0-0.2\,m)} + SWC_{i(0.2-0.4\,m)} + SWC_{i(0.4-0.6\,m)} + SWC_{i(0.6-0.8\,m)} + SWC_{i(0.8-1.0\,m)}] \quad \text{(S12)}$$

$$SWS_{i(1.0-5.0\,m)} = 200 \times [SWC_{i(1.0-1.2\,m)} + SWC_{i(1.2-1.4\,m)} + SWC_{i(1.4-1.6\,m)} + \cdots + SWC_{i(4.6-4.8\,m)} + SWC_{i(4.8-5.0\,m)}] \quad \text{(S13)}$$

$$SWS_{i(0-5.0\,m)} = 200 \times [SWC_{i(0-0.2\,m)} + SWC_{i(0.2-0.4\,m)} + SWC_{i(0.4-0.6\,m)} + \cdots + SWC_{i(4.6-4.8\,m)} + SWC_{i(4.8-5.0\,m)}] \quad \text{(S14)}$$

where *i* represents the *i*th point; SWC represents volumetric soil water content (cm^3 cm^{-3}), 200 is the thickness of each measured layer in mm.

The plant-available water storage (PAWS, mm) is defined as:

$$PAWS_{i(0-0.4\,m)} = SWS_{i(0-0.4\,m)} - SWS_{i-WP} \quad \text{(S15)}$$

$$SWS_{i(0-0.4\,m)} = 200 \times [SWC_{i(0-0.2\,m)} + SWC_{i(0.2-0.4\,m)}] \quad \text{(S16)}$$

$$SWS_{i-WP} = 400 \times SWC_{i-WP} \quad \text{(S17)}$$

where the $PAWS_{i(0-0.4\,m)}$ represents the PAWS at a depth of 0–0.4 m at the *i*th point; the $SWS_{i(0-0.4\,m)}$ represents the measured SWS at a depth of 0–0.4 m at the *i*th point; the SWS_{i-WP} is the SWS at the wilting point at the *i*th point; and the SWC_{i-WP} is the wilting point at a depth of 0–0.4 m at the *i*th point (cm^3 cm^{-3}). 400 is the thickness of measured layer in mm. The $PAWS_{i(0-0.4\,m)}$ was set to zero when $SWS_{i(0-0.4\,m)}$ was less than SWS_{i-WP}.

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