A dataset of soil water measurements at multiple scales and depths on China's Loess Plateau

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1. Summary

This README gives an overview of the data set available at https://zenodo.org/records/21859310. The data set is described in full in the accompanying data description paper (Zhao et al., in review), submitted to *Earth System Science Data* (https://essd.copernicus.org). A DOI will be added here once it has been issued.

The data set contains in-situ soil water content (SWC) measurements made by the **Loess-Obs** network on the Loess Plateau of China since 2004. Volumetric SWC was measured with neutron probes at five nested spatial scales, at multiple depths within the 0–5 m profile, together with the soil, vegetation, terrain and climate attributes of the sampling points. In total it holds 167,883 SWC records from 523 sampling points and four experimental plots, spanning 2004 to 2019.

2. Background

Soil water is a critical component of the soil-plant-atmosphere continuum and drives the geophysical and biogeochemical processes of the Earth's critical zone. Quantifying its variation in space and time is essential to understanding hydrological and vegetation responses to climate change, particularly in arid and semi-arid regions. SWC data come from *in situ* measurement, remote sensing and model simulation, of which the first provides the reference against which the other two are calibrated and validated.

On the Loess Plateau of China, the loess reaches 350 m in thickness and the groundwater table lies well below the rooting zone, leaving vegetation dependent on water stored in the soil profile. Two thirds of the region is arid or semi-arid, and SWC is the primary factor limiting plant growth and the sustainability of the ecosystems established by restoration since 1999. The restored trees and shrubs are deep-rooted,

and the water that governs them lies several metres below the surface.

Observations at those depths remain scarce. Remote sensing does not detect deep soil water, single-site measurements lack spatial representativeness, and most published records cover only shallow depths, a single land use, or short periods. No single dataset has therefore covered the multi-scale behaviour of deep soil water on the plateau. Loess-Obs network was established in 2004 as the first operational soil water observatory there. It uses non-destructive neutron probes to measure the same profiles repeatedly, at five nested scales and to depths of 3.0 to 5.0 m, under a common protocol, an approach that is essential for acquiring *in situ* observations of deep soil water efficiently and over long periods.

3. Study area

The Loess Plateau lies in the upper and middle reaches of the Yellow River (33°41′–41°16′ N, 100°52′–114°33′ E) and covers about 640,000 km². It carries the world's thickest loess deposit, up to 350 m, and suffers severe soil erosion. The climate is a warm-temperate continental monsoon, with mean annual precipitation decreasing from 800 mm in the southeast to 150 mm in the northwest and mean annual temperature from 14.3 to 3.6 °C along the same gradient. Most rain falls as high-intensity storms between July and September. Vegetation cover has risen from 31.6% in 1999 to 64.2% in 2021 under large-scale restoration.

The plot, hillslope and local-landscape scales all lie in the Liudaogou watershed (6.9 km²; 110°21′–110°23′ E, 38°46′–38°51′ N) near Shenmu, Shaanxi Province, in the water-wind erosion crisscross region of the northern plateau. It is a semi-arid catchment of deep gullies and undulating loessial slopes, with a mean annual temperature of 8.4 °C and mean annual precipitation of 437.4 mm. The soil is a Calcaric Regosol developed from low-fertility loess, weakly cohesive, highly infiltrable and readily eroded.

4. The five scales

Loess-Obs network comprises five nested scales (Figure 1) of observation, from experimental plots 5 m wide to a transect 860 km long. Their sampling units, settings

and observation periods are summarised below (Table 1).

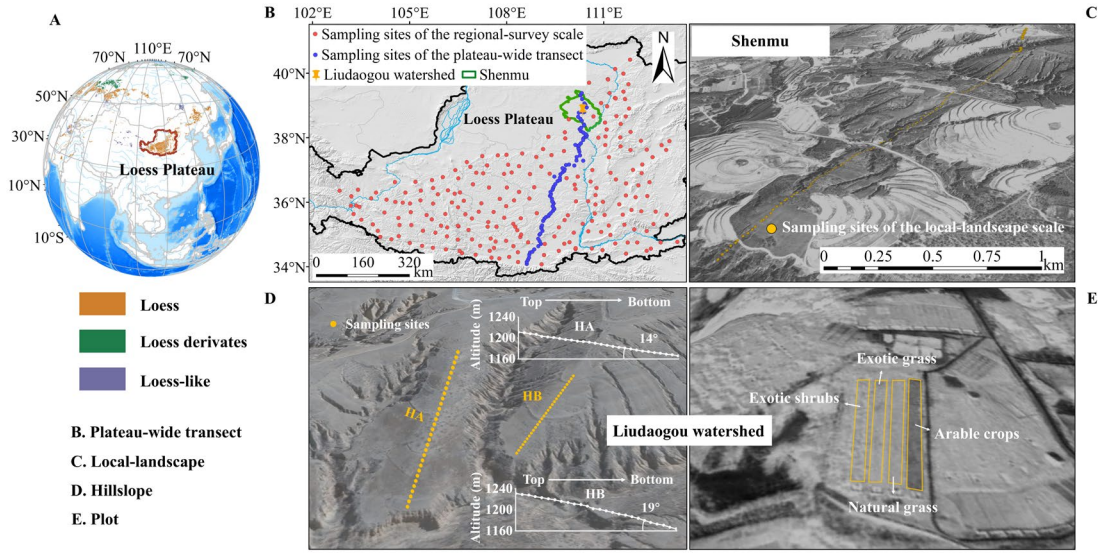

Figure 1 Distribution of sampling points at 5 spatial scales. A shows the global distribution of loess and the location of the Loess Plateau of China; B shows the sampling points at the regional-survey scale (red points) and along a plateau wide transect (blue points) in the Loess Plateau; C shows the sampling points along a local-landscape transect; D shows the sampling points on the hillslope A (HA) and the hillslope B (HB); and E shows the four long-term experimental plots.

Table 1 Overview of the five observation scales of Loess-Obs.

Scale	Sampling units	Setting	Period
Plot	4 plots of 61 × 5 m, 11 access tubes each	A 12° northwest-facing slope, Liudaogou watershed	2004–2019
Hillslope	31 points on HA, 28 on HB, at 10 m spacing	Two hillslopes, Liudaogou watershed	2004–2016
Local-landscape transect	135 points at about 10 m spacing, 1.34 km	East to west across the Liudaogou watershed	2012–2013
Plateau wide transect	86 points at about 10 km spacing, 860 km	South to north across the Loess Plateau	2013–2016
Regional-survey	243 points at about 40 km spacing	The typical loess region of the Loess Plateau	2015

The four **plots** were established in 2003 to compare land uses under otherwise identical conditions. They carry exotic shrubland (*Caragana korshinskii*), exotic grassland (*Medicago sativa*), natural grassland (*Stipa bungeana*, long fallow) and arable cropland in a millet and soybean rotation. Each plot is walled to prevent water moving between plots, and the archived values are the mean of its eleven access tubes.

The two **hillslopes** are separated by a deep gully and have received different restoration strategies. HA is the gentler and more heterogeneous of the two. It has a gradient of 14°, is 300 m long, and carries grassland, apricot forest and millet farmland. HB is steeper and uniform. It

has a gradient of 19°, is 270 m long, and consists entirely of abandoned fields of alfalfa and bunge needlegrass with no trees or farmland.

The **local-landscape transect** runs over both hillslopes and gullies rather than staying on one landform, and so spans the transitions between them. The **plateau wide transect** follows the climatic gradient from the semi-humid southeast to the semi-arid northwest, across which mean annual precipitation decreases from 627 to 407 mm and mean annual temperature from 12.3 to 6.8 °C. The **regional-survey** is the only scale sampled in two dimensions rather than along a line, and the only one measured once rather than repeatedly.

5. Data format and data set structure

The data set is organised as one archive per scale, each holding the data tables for that scale, a metadata file and a data dictionary. The file <scale>_meta.json is the cover sheet, giving the space and time coverage, site setting, time reference system, calibration equation and remarks on the measurements and their quality control. The file <scale>_attributes.csv holds one row per sampling unit, with its identifier, position and static attributes. The remaining tables hold the measurements in long format, one row per sampling unit and depth layer, and per date where dates were recorded. The file variables.csv defines every column in the archive and should be read first. The contents of each archive are listed in Table 2.

Table 2 Contents of the data set.

Archive	File	Rows	Description
Plot.zip	plot_attributes.csv	4	Plot identifier, position, land use, dominant species and management regime
	plot_swc.csv	12,400	SWC, 4 plots × 25 layers × 124 campaigns. Profile 0–4.0 m, in 0.1 m layers to 1 m and 0.2 m layers from 1.0 to 4.0 m. Each value is the mean of the eleven access tubes of the plot
	plot_meta.json	n/a	Metadata for the plot scale
	variables.csv	13	Data dictionary for this archive
Hillslope_A.zip	hillslope_A_attributes.csv	31	Point identifier, position along the transect, coordinates and elevation
	hillslope_A_swc.csv	14,260	SWC, 31 points × 20 layers × 23 campaigns. Profile 0–3.0 m, in 0.1 m layers to 1.0 m and 0.2 m layers from 1.0 to 3.0 m
	hillslope_A_soil_properties.csv	62	Particle size and organic carbon for 0–0.1 and 0.1–0.2 m. Bulk density

			and saturated hydraulic conductivity for 0–0.1 m
	hillslope_A_meta.json	n/a	Metadata for hillslope A
	variables.csv	21	Data dictionary for this archive
Hillslope_B.zip	hillslope_B_attributes.csv	28	Point identifier, position along the transect, coordinates and elevation
	hillslope_B_swc.csv	57,568	SWC, 28 points × 112 campaigns. Profile 0–3.0 m, in 20 layers from 2004-08-26 to 2013-03-18 and in 16 layers from 2013-04-16 to 2016-10-14
	hillslope_B_soil_properties.csv	28	Particle size, organic carbon, bulk density and saturated hydraulic conductivity for a single 0–0.2 m layer
	hillslope_B_vegetation.csv	28	Litter mass and aboveground biomass, one row per point
	hillslope_B_meta.json	n/a	Metadata for hillslope B
	variables.csv	25	Data dictionary for this archive
Local_landscape_transect.zip	local_landscape_transect_attributes.csv	135	Point identifier, landform, coordinates and elevation
	local_landscape_transect_swc.csv	38,880	SWC, 135 points × 16 layers × 18 campaigns. Profile 0–3.0 m, in 0.1 m layers to 0.2 m and 0.2 m layers from 0.2 to 3.0 m
	local_landscape_soil_properties.csv	135	Particle size, organic carbon, bulk density and saturated hydraulic conductivity for a single 0–0.2 m layer
	local_landscape_transect_vegetation.csv	135	Aboveground biomass, one row per point
	local_landscape_transect_meta.json	n/a	Metadata for the local-landscape transect
	variables.csv	23	Data dictionary for this archive
Plateau_wide_transect.zip	plateau_wide_transect_attributes.csv	86	Position, terrain, land use, planting density, climate and NDVI
	plateau_wide_transect_swc.csv	38,700	SWC, 86 points × 25 layers × 18 campaigns. Profile 0–5.0 m in 0.2 m layers
	plateau_wide_transect_soil_properties.csv	946	Particle size and organic carbon over eleven layers to 5.0 m. Bulk density, saturated hydraulic conductivity, field capacity and saturated water content over the top three layers

	plateau_wide_transect_meta.json	n/a	Metadata for the plateau wide transect
	variables.csv	31	Data dictionary for this archive
Regional-survey.zip	regional_survey_attributes.csv	243	Position, terrain, land use, vegetation characteristics, climate and NDVI
	regional_survey_swc.csv	6,075	SWC, 243 points × 25 layers, one survey. Profile 0–5.0 m in 0.2 m layers
	regional_survey_soil_properties.csv	2,916	Particle size over eleven layers to 5.0 m. Bulk density, saturated hydraulic conductivity, field capacity and saturated water content over the top three layers. Wilting point for 0–0.4 m
	regional_survey_meta.json	n/a	Metadata for the regional-survey
	variables.csv	34	Data dictionary for this archive

6. Licence and citation

When using these data, please cite both the dataset and the data description paper:

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