CHAPTER 3

DATA REQUIREMENTS OF COMMON STAKEHOLDERS FOR SOIL MOISTURE DATA

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Learning Outcomes

Understanding current and potential stakeholder needs should inform network planning and data quality and assurance goals.

In this chapter, data quality needs for several common stakeholders have been summarized from the perspective of soil moisture measurement units and depths, accuracy, ancillary data, time span, and latency of data.

Stakeholders require several different categories of information (Table 2) associated with each measurement of soil moisture to make the best use of data. As one example, soil moisture data needs to be expressed in units that can be related to drought intensities when used for drought monitoring purposes. The U.S. Drought Monitor (USDM) methodology that uses a percentile approach for magnitude category thresholds to express the rarity of an event is based on an assessment of numerous drought indicators and related datasets (Svoboda et al., 2002, *Table 1*). The drought data and indicators, including soil moisture, need to be expressed as percentiles, or units that can be related to historical percentiles, to be most effective for drought monitoring purposes. To convert raw volumetric values into a meaningful percentile equivalent, a multi-year period of record is needed to provide an adequate historical context. If the length of the record is too short to provide such a historical context, then the data ideally should be expressed in terms that have meaning to vegetation. For example, is the amount of water in the soil sufficient to meet the needs of the crops or ecosystem vegetation? Or is it below some threshold whereby the plants will experience some level of drought-related stress?

Another use of soil moisture data is in the field of digital soil mapping. Soil moisture dynamics are closely related to soil development and spatial variability. US soil survey has relied on topographic maps or digital elevation models that represent only water surface redistribution over the landscape but that are used to infer properties and processes for subsurface. However, recent advancements with distributed hydrological models that simulate soil moisture trends over time and with depth show that, when validated with soil moisture *sensor* data, these models can be used to map soils and properties across surface (2D), depth (1D), and time (1D), which provides a 4D approach to soil mapping (4DSM) (Owens et al., 2024; Libohova et al., 2024) (Figure 1).

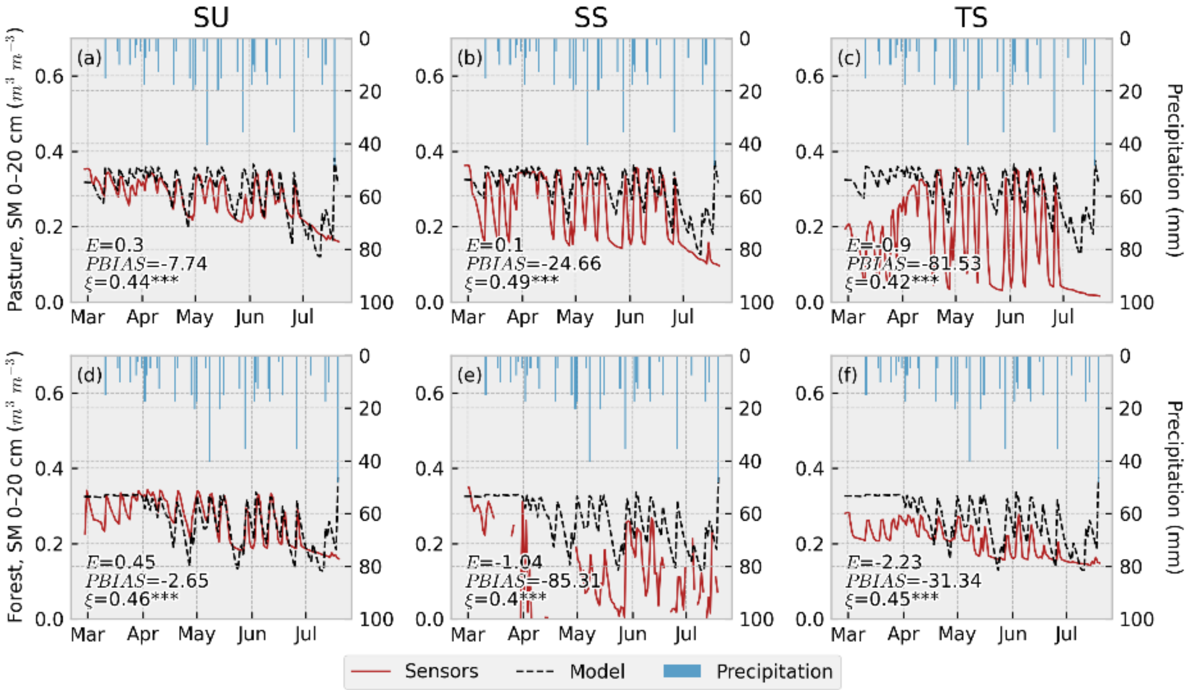

Figure 1. A comparison between soil moisture content (SM) from sensors and simulated (model) for depth 0–20 cm by a Distributed Hydrology Model (DHM) for two catchments under pasture and forest. Sensors are located at the summit (SU), sideslope (SS), and toeslope (TS) of each catchment. Figure Credit: Libohova et al., 2024.

Indicators such as Nash-Sutcliffe efficiency (E) (Nash and Sutcliffe, 1970), percent bias (PBIAS) (Onyutha, 2021), and the Chatterjee's correlation coefficient (ξ) (Chatterjee, 2021) can be used to compare simulated and observed data (Figure 1). Hydrological models informed by soil moisture data offer the advantage of producing high resolution soil moisture maps that can fill the gaps between sensors. Such applications require numerically accurate soil moisture data.

The data requirements and data needs of the various stakeholders that participated or were represented in the working group meetings for this document are listed in Table 2. This table can be used by network operators to consider example needs of data users for planning their soil moisture data collection efforts. However, *each data user is different*, and early engagement with a network's direct intended users can help support alignment with user needs and suitability of future data for its intended applications.

Table 2. Stakeholder requirements. (In cases where information was unavailable for a particular category, the field was marked by a '-')

Application	Data Latency	Depth (m)	Units	Agencies/Organizations	Critical Data Need
Flood / Stream forecasting	< 3 hours	-	-	U.S. Army Corp of Engineers (USACE), National Weather Service (NWS) River Forecast Centers	Low latency
Crop Water Demand, crop forecasting	Daily to Weekly	0 - 1	m^3/m^3	National Agricultural Statistics Service (NASS)	Soil Water Content (SWC) at field capacity and SWC at wilting point[5] for the entire soil profile; historical anomalies
Drought monitoring	Daily to Weekly	Root zone and/or below	Moisture percentiles	United States Department of Agriculture (USDA), National Oceanic and Atmospheric Administration (NOAA), National Drought Mitigation Center (NDMC), State Climate Offices, Agriculture and Agri-Food Canada (AAFC)	Long-term datasets for statistical comparisons, Soil Water Content (SWC) at field capacity, and SWC at wilting point
Validation datasets for models and RS	Weekly	0-1	m^3/m^3	Broader Research Community, AAFC	Numerically accurate soil moisture data

[5] Refer to the Metadata Guidance document for definition of wilting point.

Application	Data Latency	Depth (m)	Units	Agencies/Organizations	Critical Data Need
Precision agriculture	Hourly	0-2	m^3/m^3	AAFC	Spatially distributed soil moisture information, SWC at field capacity, and SWC at wilting point
Planting/Harvesting guidance	Daily	0.1	m^3/m^3	USDA	Spatially distributed near-surface soil moisture information. Collocated with temperature.
Trafficability (for forestry applications too, not limited to agriculture)	Daily	0-0.2	% capacity for soil type	Department of Defense, USDA, US Forest Service	Spatially distributed near-surface soil moisture information
Fire management/ forecasting	Daily	0.05/0.1/0.2	% Plant Available Water or m^3/m^3	State Forest Services / Weather Forecast offices	Soil Water Content (SWC) at field capacity and SWC at wilting point
Understanding ecosystem ecology processes (e.g., plant water status, species distribution, etc.)	NRT to daily depending on ecosystem type/research question	Plant rooting depths, permafrost layer	m^3/m^3	Long-Term Ecological Research (LTER) Network, NEON, USFS, individual researchers	Soil Water Content (SWC) at field capacity and SWC at wilting point
Water table recharge	Monthly	> 1	mm, m^3/m^3	United States Geological Survey (USGS), AAFC	Long-term datasets
Forest management/ forest harvesting	Weekly	0.05/0.1/0.2 2/4/8 inches	m/m, % field capacity	U.S. Forest Service	Long-term datasets

Application	Data Latency	Depth (m)	Units	Agencies/Organizations	Critical Data Need
Forest health (disease/pests) monitoring	Weekly-Monthly	0-2	m^3/m^3	USDA (FS, APHIS)	Long-term datasets; Minimum Soil Water Content (SWC) requirements of indigenous vegetation
Climatology (drought, etc.)	Monthly	0-1			Long-term datasets
Weather forecasting	Sub-daily	0.05		NWS/ECMWF	Low latency
Carbon cycle modeling/monitoring			m^3/m^3, kPa		SWC at field capacity and SWC at wilting point
Biogenic volatile organic compounds	Daily	0.05-0.1	m^3/m^3	EPA, Texas Commission on Environmental Quality	
Preferential flow and solute transport	15 min-30 min	0-1	m^3/m^3		High-frequency data
Wastewater and application	Monthly	-	mm		Spatially distributed soil moisture information
Freeze/Thaw	Hourly	.1	By occurrence	USDA	Co-located with soil temperatures
Landslides	-	-	-	Department of Transportation	Low latency
Atmospheric process/land-atmosphere interaction studies	-	Near-surface, root zone	m^3/m^3	DOE Atmospheric Radiation Measurement (ARM) user facility	Co-located with (representative of conditions at) atmospheric measurements
Mapping soils and properties with depth and over time	Daily to Weekly	0-2m	m^3/m^3	United States Department of Agriculture/ Natural Resources Conservation Service/Agriculture Research Service.	Spatially distributed soil moisture information at variable depth intervals. Numerically accurate moisture data. Soil characteristics of full profile.