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USDA LTAR Common Experiment measurement: Infiltration and percolation

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Abstract

Infiltration refers to water entering the soil from precipitation, condensation, irrigation, and surface flow (runoff). It is typically used to quantify water arriving at the root zone of plants (example application: plant water availability). Percolation, while verbally synonymous with infiltration, is typically used to quantify water leaving the root zone for deeper soil horizons (example application: agrochemical leachate). Both processes occur when the soil is near saturation, relying on the continuity of the water column for the downward movement of water.

Materials

Pan lysimeters have several manufacturers (e.g., Soil Moisture Equipment Co., Santa Barbara, CA, USA; Edaphic Scientific, Australia).

Passive- wicking lysimeters can be constructed in the laboratory (Gee et al. 2009) or commercially obtained (G3 Drain Gauge, METER Group, Pullman WA, USA).

A **fiberglass wick** in contact with the soil overcomes the soil water potential and wicks the water collecting inside the lysimeter.

Ceramic suction lysimeters (e.g., Soil Moisture Equipment Co., Santa Barbara, CA, Hanna Instruments Worldwide) actively collect water from the surrounding soil by having a low pressure, artificially created by a pump, that drives water from the soil via the ceramic cup into the lysimeter.

Weighing lysimeters can also collect infiltration; however, they are costly and require maintenance (Avila-Davila et al., 2021).

Selecting a method

1 The specific method chosen depends on whether the objective is to estimate infiltration/percolation rates or the actual collection of leachate for chemical analysis. Note that the estimation of groundwater pollution from surface pollutant sources entails both objectives. An example of the former objective is a pan lysimeter located underground that collects water trickling down (when soil is near saturation). This amount of water collected over a period of time is expressed on the basis of weight or volume, thus yielding an estimate of the infiltration rate at that soil depth/horizon. An example of the latter objective is a suction lysimeter that actively draws in and collects water from the unsaturated/vadose zone by means of a vacuum generated by pumping within the lysimeter. The leachate collected is subsequently analyzed for pollutants such as agrochemicals. An example of a device that can be used for both objectives is a passive-wicking lysimeter that collects water from the soil just above the lysimeter using a fiberglass wick. The dimensions of this wick are designed to passively overcome the capillary forces prevailing in soil. The water then trickles into a collection chamber from where it can be pumped out manually, or automatically by a pump triggered by a water level recorder.

Data collection

2 **Measurement.**
The amount of water collected is measured over a particular time interval of collection.

Note

- For instance, the G3 Drain Gage wicking lysimeter has a water level sensor inside the lysimeter with real-time water level data that can be aggregated over different intervals to obtain percolation rates.
- Other lysimeters are manually emptied using a pump (such as a peristaltic pump), and the volume is noted in a volumetric flask.

2.1 Perform sampling periodically or follow an intense rain event (typically 2-3 cm of rainfall).

3 **Site Maintenance.**
Lysimeters are typically installed underground with the top percolation collection area slightly underneath the root zone - typically 30 cm below the ground surface (but they can be installed at any depth depending on where leachate collection is needed or percolation is measured).

3.1 Use a post-hole digger, auger or shovel can be used to excavate the hole, evenly filling in the excavated soil and avoiding preferential flow paths for percolating water.

Note

In clay or loam soils, bentonite sand may be filled in to improve contact between the surrounding soil and lysimeter, thereby preventing preferential flow paths generated as a consequence of excavation. Manufacturers provide more information online.

3.2 Enclose the data cables and pump access/flush tubes with an electrical PVC conduit to protect against rodents, accidental abrasion by shovels or mowers, and moisture.

3.3 Maintain vegetation cover directly above the lysimeter to resemble the vegetation cover in the area, especially if the lysimeter is placed in a fenced enclosure in a grazed rangeland (to prevent trampling by cattle or feral hogs) that promotes grass growth.

Data processing and quality control

4 Automated lysimeters (such as the G3 Drain Gage) send real-time data to a data logger (such as Campbell Scientific or METER) that stores data in a text file.

Manually measured lysimeters necessitate some means for user data entry, such as a field notebook or phone-based app (example: ArcGIS Survey 123).

Note

- Please refer to the *Data Quality* section in the *USDA LTAR Common Experiment measurement: Best practices for collection, handling, and analyses of water quantity measurements* protocol (Baffaut, 2024).

4.1 The presence of soil moisture data (if available at the same location or a nearby location) serve to verify saturation conditions (typically approximately 0.4-0.5 water by volume fraction, or 40-50%, depending on soil type) and thereby help examine whether zero values for percolation are legitimate or arising from instrument failure.

Because percolation mainly occurs as rain events in near-saturated soil conditions, it is common for values to be zero for long periods of the dry season as well as parts of the wet season.

4.2 Saturated soils facilitate percolation because of the continuity of hydraulic pathways downward in the soil profile; such conditions exist intermittently over the wet season.

Note

- Heavy rainfall events early in the wet season (when the soils are dry or unsaturated) may or may not lead to percolation, as the soil resistance to infiltration results in higher fractions of incoming rainfall diverted as overland runoff.
- In due course, a relationship between rain events, soil moisture, and percolation can be established that can aid local hydrogeologic understanding and serve as quality control.

Data file formats and metadata

5 Text files or user-created spreadsheets/databases. Ancillary data are rainfall and soil moisture at various depths above the lysimeter placement. For example, soil moisture sensors at 5, 10, 20, and 50 cm can indicate if a rain event (or irrigation) results in a wetting front percolating downward in the soil profile, which can be captured by a lysimeter placed at a depth of 30 cm.

Note

A finer temporal resolution (such as 15 min for rain and soil moisture data) can aid a better dynamic understanding of percolation processes.

6 Recommendations on data storage and metadata: Follow the general recommendations in the *USDA LTAR Common Experiment measurement: Best practices for collection, handling, and analyses of water quantity measurements* protocol (Baffaut, 2024).

Recommendations for data collection

7 Table 1. Summary of recommendations for measuring infiltration/percolation.

A	B	C	D
Attribute	Preferred	Minimum	Comments
Spatial scale	Localized measurement		Percolation being a localized measurement, more installations give a better landscape-scale estimate. Funds permitting
Frequency	15 min	60 min	The finer the temporal resolution is, the better the understanding of coupled rainfall–runoff–percolation and plant water uptake processes

A	B	C	D
Covariate metrics	Precipitation and soil moisture		
Other	Evapotranspiration (ET) and runoff		These attributes complete the water balance, thereby constraining uncertainty in percolation estimates arising from spatial terrain/precipitation/soil type/land cover heterogeneity

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