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USDA LTAR Common Experiment measurement: Rainfall

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Abstract

Rainfall includes any moisture falling from the atmosphere in liquid form. Rainfall is often called precipitation, but precipitation includes liquid water as well as a solid water such as snow fall. The rainfall measurement protocol addresses the measurement of only liquid precipitation. The snow metrics measurement protocol describes how to measure snowfall. The total amount of rainfall reaching the ground in a given period is described as a depth over a given area, assuming no loss by evaporation, plant interception, or runoff. Rainfall is an essential input, with much of the world relying on it for agricultural production. There is evidence that rainfall patterns and intensity are changing, which affects the sustainability of agroecosystems and soil erosion rates. Rain gauges are the most effective method for measuring liquid precipitation. The recommended method for measuring rainfall is through a network of recording rain gauges, which measure the time and amount of liquid precipitation. Alternatively, catch gauges are applicable, but they will typically not yield the time and rate of rainfall, and thus, they are not recommendable. The area and spatial variability of rainfall will determine how many gauges are needed. Generally, more rain gauges distributed within a given region are preferable, although geographical and economic constraints can limit gauge density and placement. Recently, automated methods for determining optimum rain gauge placement within a region have been published (Di et al. 2020).

1. Data collection

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1 **Equipment**

Measure precipitation and record rainfall timing with an electronic weighing rain gauge because of reduced error (Hansen et al. 2001, Keefer et al. 2008). These instruments are available from several manufacturers (e.g., OTT Hydromet, Kemptem, Germany; Texas Electronics, Dallas, TX, USA; Hydrological Services, Australia).

Note

For recommendations on placement, refer to the "Placement and site maintenance" section in the *USDA LTAR Common Experiment measurement: Best practices for collection, handling, and analyses of water quantity measurements* protocol (Baffaut et al., 2024).

1.1 In addition, specific recommendations for rain gauge placement include choice of site, prevention of evaporative loss, and consideration of wind and splashing effects (Brakensiek et al. 1979).

1.2 Gauges with windshields are highly recommendable to reduce gauge undercatch. Place a gauge so that no obstructions, such as trees, fences, and buildings, are closer to the gauge than twice, preferably four times, the height of the obstruction.

Note

Do not place gauges on sharply sloping ground. Preferably, place gauges over short grass or other natural surfaces.

1.3 In sites with considerable bird activity, such as wetlands and along water courses, install bird protectors on the rim of the rain gauge to prevent birds from perching and defecating inside the gauge funnel, thereby blocking the funnel hole.

1.4 Connect each gauge to a data logger and power supply. The power supply can be a 12 V battery with an external solar panel.

1.5 Telemetry of the data is recommended via radio or cell modem. When this recommendation is not feasible, adequate data storage should be available.

1.6 Install a tipping bucket gauge, such as Hydrological Services Tipping Bucket Rain Gauge Model TB-3, at measurement sites for comparison purposes only. This additional rain gauge helps identify instances of gauge failure (NCEI, 2022).

1.7 For sites with snowfall, follow the *USDA LTAR Common Experiment measurement: Snowfall* protocol (Biederman et al., 2024)

2 Measurement

2.1 For a weighing rain gauge, the amount of water is measured over a specific time step of collection, typically ranging from one-minute to five-minute time steps. These data points can then be aggregated into hourly and annual measurements.

2.2 For a tipping bucket, as the buckets fill, a switch will be triggered, and the gauge will count how often the switch is triggered.

2.3 As the gauge is calibrated to a specific volume by the manufacturer, use the number of times the switch is triggered to calculate the amount of rainfall.

2.4 The frequency of recording rainfall data should be every 1 min to run process-based runoff and erosion models.

3 Site maintenance

3.1 Clean the funnel and tipping bucket mechanism periodically to ensure accurate readings. After this cleaning, tip the bucket five times (minimum) and note the exact time of the tips for data integrity purposes.

Then, replace the funnel on top of the rain gauge with the top screen installed. Double-check the funnel level.

3.2 To aid in calibration, a rain gauge calibrator, such as the NovaLynx® 260-2595 Tipping Bucket Rain Gauge Calibrator, could be used for static or dynamic calibration.

- Static calibration consists of adjusting each bucket to tip for a measured volume of water and is recommendable for initial calibration adjustments.
- Dynamic calibration consists of adjusting both buckets to achieve the correct output count for a measured volume of water at a constant flow rate, and it is recommendable for minor adjustments and verification.

3.3 For weighing rain gauges, above and below the bucket inlay should be cleaned and checked for insects, which can affect rainfall readings.

Note

Check the accuracy of the weighing mechanism at least annually by adding a known amount of water or calibrated weights.

Long-term maintenance should include routine replacement of aging sensors.

3.4 To prepare for winter, clean weighing rain gauges and monitor relative humidity and bucket content to spot condensation. Add appropriate antifreeze and propylene glycol to the catch basin to prevent freezing and evaporation, respectively.

Note

Re-zero the device after adding the antifreeze and propylene glycol.

Continually monitor the level of the liquid in the gauge and/or empty and recharge the gauge routinely to maintain adequate storage space. Alternatively, a rim heater, if equipped, could be turned on along with an appropriate power source.

3.5 Review data and battery voltages daily to verify adequate site power. Conduct site visits periodically.

2. Data processing and quality control

4 Data should be stored by a data logger and transmitted via telemetry if possible.

5 Rainfall amounts can be aggregated over different time intervals to obtain accumulated rainfall.

6 Take care in processing data from weighing gauges to address abnormal variations, such as evaporation (declining trace), fluctuations due to wind, and unexplained additions, perhaps due to insects/birds in the gauge.

7 Regarding data processing and quality control, follow the general recommendations for water quantity variables.

8 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 (Saha et al., 2024).

3. Data file formats and metadata

9 Text or .csv files or user-created spreadsheets/databases.

10 Metadata should include latitude, longitude, and gauge type and size.

11 In addition, keep a record of maintenance on gauges within the network.

12 Regarding data storage and metadata, follow the general recommendations for water quantity variables. Please refer to the "Data storage and accessibility" section, as well as the "Metadata" section, in the *USDA LTAR Common Experiment measurement: Best practices for collection, handling, and analyses of water quantity measurements* protocol (Baffaut et al., 2024).

Recommendations for data collection

13 Table 1. Summary of recommendations for measuring rainfall.

A	B	C
Attribute	**Preferred**	**Minimum**
Spatial scale	Plot	Field
Frequency	1 min	5 min
Covariate metrics	Air temperature, wind speed, soil moisture and temperature, solar radiation, relative humidity, wetness	Air temperature, wind speed

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