TreeTalker®Soil

User Manual

Nature 4.0

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TreeTalker®Soil

Overview

With TreeTalker®Soil, you can monitor soil temperature and moisture along with air temperature and relative humidity, capturing essential environmental and microclimatic data.
It provides key insights to understand the physiological status of the soil and make data-driven decisions.

When integrated with TreeTalker®Cyber or TreeTalker®Water, it delivers a complete overview of forest and crop health and growth. TreeTalker®Soil is the starting point to monitor:

Water Use Efficiency (WUE)
The ratio between agricultural production and the amount of water used. It shows how efficiently plants or irrigation systems use available water, maximizing yield while minimizing losses.

Tree Water Budget
The balance between water input (rainfall, irrigation) and water loss (evapotranspiration, drainage). It helps determine precise irrigation needs, optimizing plant health and saving water.

Parameter:

1. **Soil Volumetric Water Content (VWC)**
   The Volumetric Water Content (θ v) represents the volume of liquid water relative to the total volume of the soil sample.

2. **Soil Temperature**
   This parameter measures the thermal state of the soil using a high-precision resistance-based probe (TT-C_20).

3. **Soil humidity**
   This parameter represents the raw electrical output from the capacitive sensor before any mathematical conversion into water volume.

Soil Volumetric Water Content (VWC)

1. Definition and Measurement Unit

The Volumetric Water Content **(θ v)** represents the volume of liquid water relative to the total volume of the soil sample.

Measurement Unit: cm3 H_2O / cm3 soil

Sensor Output and Display: The sensor generates a raw signal in Volts (V dc). This signal is processed and displayed as a decimal fraction (for example, 0.54).

- **Data Interpretation:** A value displayed as 0.54 means that 54% of the total soil volume is occupied by water.
- **Conversion:** To obtain the percentage, simply multiply the displayed decimal value by 100.

2. Interpretation of Values (Reference Ranges)

Based on experimental tests conducted, the following reference points should be used to interpret the displayed data:

- **Saturation Point (Maximum):** The reading stabilizes around **0.55 (55%)**. At this stage, the soil has reached its maximum Water Holding Capacity.
- **Dry Soil (Minimum observed)**: During testing, values reached a minimum of approximately **0.18 (18%)**.
- **Signal Relationship:** There is an inverse relationship between the voltage and the displayed value; a **lower voltage** corresponds to a **higher water content.**
  - ~**0.95 V** ≈ Highly saturated soil (displayed as **0.55**).
  - ~**1.21 V** ≈ Dry soil (displayed as **0.18**).

3. Technical Factors Influencing Accuracy

To ensure correct data analysis, consider the following environmental factors:

- **Soil Salinity**: High salinity (NaCl) or Electrical Conductivity (EC) can cause a decrease in the voltage reading. This may result in the displayed VWC value appearing slightly higher than the actual moisture level.
- **Thermal Stability**: The sensor is highly stable across different temperatures. Variations between 25°C and 50°C cause a negligible change of only 0.0008 V per 1°C, which does not significantly affect the displayed moisture value.
- **Probe Variability:** Small natural variations exist between individual sensors (average standard deviation between 0.006 and 0.020 V). For professional monitoring, it is recommended to focus on the **moisture trend** (increase or decrease) shown on the display.

4. Calibration Methodology

The conversion from the raw Voltage signal to the displayed decimal value is performed using a **Four-Parameter Logistic Curve**. This mathematical model ensures high scientific precision ($R^2 > 0.92$) across the operational range of the sensor. We now proceed with the analysis of the second fundamental parameter provided by your probe: Soil Temperature.

Soil Temperature

1. Definition and Measurement Unit

This parameter measures the thermal state of the soil using a high-precision resistance-based probe (TT-C_20).

Measurement Unit: Degrees Celsius (°C).

Sensor Output and Display: The probe generates a raw signal in **Ohm** (Ω). This signal is automatically converted by the system and displayed as a numerical value in **°C.**

Data Relationship: The relationship between electrical resistance (Ohm) and temperature is inverse; as the t**emperature increases**, the **Ohm reading decreases** following an exponential decay curve.

2. Interpretation of Values (Reference Ranges)

Based on scientific calibration tests, the probe is designed to operate reliably across a wide range of environmental conditions:

- **Operational Range:** The probe has been validated for temperatures ranging from **4.6°C** up to **50°C.**
- **Reference Point:** At a standard temperature of 25°C in pure water, the probe typically reads approximately 10.43 Ω.
- **Sensitivity:** The conversion formula is highly accurate, with a statistical confidence level (R^2) of 0.9985, ensuring that the displayed temperature closely reflects the actual environmental state.

3. Technical Factors Influencing Accuracy

To provide the most transparent data analysis, it is important to note how the probe interacts with the surrounding soil:

- **Soil Moisture Influence:** High soil moisture (Volumetric Water Content) can cause a very slight increase in the Ohm reading. In practical terms, this may lead the sensor to measure a temperature approximately **1.3°C lowe**r than the actual value when the soil is extremely wet (e.g., measuring 23.7°C when the actual temperature is 25°C).
- **Salinity Immunity:** Unlike moisture sensors, the temperature probe is **not sensitive to soil salinity**. Fluctuations in salt concentration (NaCl) or Electrical Conductivity (EC) do not affect the accuracy of the temperature readings.
- **System Stability:** The probe demonstrates high consistency, with minimal variability between different units, ensuring that trends recorded across a field are comparable.

4. Calibration Methodology

The displayed temperature is calculated using an **Exponential Decay Equation** ($y = y_0 + a \cdot e^{-bx}$). This model was specifically chosen to handle the non-linear nature of thermistor based readings, providing stable and repeatable data for agricultural and environmental monitoring.

Soil Humidity (Raw Signal)

1. Definition and Measurement Unit

This parameter represents the raw electrical output from the capacitive sensor before any mathematical conversion into water volume.

- **Measurement Unit**: Millivolts (**mV**).
- **Data Representation:** It is displayed as a direct electrical value (e.g., **1150 mV**).
- **Sensor Behavior:** This is an analog signal. It is important to know that **the signal decreases as the moisture increases.**

2. Reference Values (Laboratory Standards)

To interpret the raw mV data, there are these laboratory benchmarks:

- **In Air (Dry):** Approximately **2226 mV**.
- **In Distilled Water (Saturated):** Approximately **1320 mV.**
- **In Soil (Operational Range):**
  - **1210 mV** Dry soil condition.
  - **950 mV** Fully saturated soil (at water holding capacity).

3. Why monitor the Raw Signal (mV)?

Providing the raw voltage/millivolt data is useful for several reasons:

- **Hardware Health:** It allows the user to check if the sensor is working correctly (e.g., if the signal is 0 mV or above 2500 mV, there is likely a wiring fault).
- **Direct Comparison:** It removes any potential errors introduced by the conversion formula, showing exactly what the probe is "feeling" in the ground.
- **Salinity Detection:** As noted in the technical report, a sudden drop in mV that doesn't match an irrigation event might indicate an increase in soil salinity or fertilizer concentration.

4. Technical Stability

The laboratory tests confirm that this mV signal is extremely stable against temperature changes, with a drift of less than **1 mV per degree Celsius** (0.0008 V/°C). This ensures that fluctuations in the millivolt reading are almost exclusively due to changes in soil properties (water or salts) rather than air temperature.

5. Data Interpretation & Field Monitoring

To effectively use the Raw Signal for environmental monitoring, the focus should be on observing **trends** over time rather than isolated single values:

- **Drying Trends:** A consistent increase in the value (e.g., moving from **1000 mV toward 1200 mV**) indicates a progressive decrease in soil moisture. This trend allows for the identification of the soil's "drying curve" under specific environmental conditions.
- **Saturation Threshold:** When moisture is added to the soil (via rainfall or other events), the millivolt value will drop rapidly. A stabilization around **950 - 1000 mV** indicates that the soil has reached its maximum water-holding capacity. Values remaining at this level for extended periods may suggest poor drainage or water logging.

- **Soil Texture Adaptation:** While **1210 mV** serves as a benchmark for "dry" conditions in sandy loam soil, different soil textures (e.g., clay or silty soils) may exhibit slightly different baselines. It is recommended to correlate the mV readings with the first visible signs of plant water stress to accurately identify the specific "critical point" for each unique environment.
- **Event Tracking**: Sudden fluctuations in the raw signal are excellent indicators of rapid changes in the soil matrix, such as water infiltration depth or changes in salt concentration following fertilization.

Data string

11-11-2025 15:42:50,9325A102,3,76122,65,41,5518,36,15356,65,4036,1986,5053,1359,1368,0,0,0,0

String Value	Struct Variable	Interpretation
11-11-2025 15:42:50	*(Prefix)*	System timestamp for the log entry.
9325A102	serial_number	Unique device identifier.
3	string_type	Packet protocol version or type.
76122	Time	Measurement cycle timestamp (internal sync).
65	acceleration_component_X	X-axis gravity/tilt component.
41	acceleration_std_X	X-axis vibration/stability measure.
5518	acceleration_component_Y	Y-axis gravity/tilt component.
36	acceleration_std_Y	Y-axis vibration/stability measure.
15356	acceleration_component_Z	Z-axis gravity/tilt component.
65	acceleration_std_Z	Z-axis vibration/stability measure.
4036	V_bat	**Battery Voltage** (4036 mV = 4.036 V).
1986	air_temperature	**Air Temperature** (e.g., 19.86 °C).
5053	air_RH	**Air Relative Humidity** (50.53%).
1359	Soil_H1	**Soil Humidity 1 (Raw mV)**.
1368	Soil_T1	**Soil Temperature 1 (Raw Ohm)**.
0, 0, 0, 0	Soil_H2...T3	Inactive channels or sensors not connected.

Elaborated output

1. SoilData.csv

1. **date** Measurement timestamp in ISO 8601 format, with UTC timezone offset.
2. **ID** Unique identifier of the TreeTalker sensor (e.g., 9325A103). Allows individual devices to be distinguished within distributed monitoring networks.
3. **x, y, z / std-x, std-y, std-z** Raw accelerometer readings along the three spatial axes. These values monitor any movement or displacement of the sensor over time. Low standard deviations confirm the device remained stationary; sudden changes would indicate physical disturbance of the installation.
4. **yaw, pitch, roll** Orientation angles (degrees) derived from the accelerometer. Used to detect tilting or displacement of the sensor over time.
5. **vbat** Battery voltage in millivolts (mV). Enables remote monitoring of the device's energy status. Values around 3900–4100 mV indicate a healthy battery.
6. **airt / RH** Air temperature (°C) and relative humidity (%).
7. **es / ea / VPD** Saturated vapour pressure (es) and actual vapour pressure (ea), both in Pascals. The VPD (Vapour Pressure Deficit) is the difference between the two and expresses the evaporative demand of the atmosphere.
8. s**oil_H1_V** Raw electrical signal from the capacitive soil moisture sensor, expressed in Volts (V). The signal is inversely proportional to water content: lower values indicate wetter soil. Manual reference values are ~1.21 V for dry soil and ~0.95 V for fully saturated soil.
9. **soil_VWC1** Soil Volumetric Water Content (θv), expressed as a decimal fraction (m^3 H_2O / m^3 soil). This is the converted value derived from the raw signal via a four-parameter logistic curve ($R^2 > 0.92$). A value of 0.52 indicates that 52% of the total soil volume is occupied by water, close to saturation (maximum ~0.55).
10. **soil_T1** Soil temperature in °C.

2. Spectra.csv

1. **date** Measurement timestamp in ISO 8601 format, with UTC timezone offset.
2. **ID_x / ID_y** Unique identifier of the TreeTalker sensor. The suffix _x refers to the first spectrometer channel (string type 6), and _y to the second (string type 7). Both channels belong to the same physical device.
3. **string_x / string_y** Protocol packet type identifier. Value 6 corresponds to the first spectrometer data string; value 7 to the second. These distinguish the two spectral acquisition modules of the sensor.
4. **ts_x / ts_y** Internal synchronization timestamp of the measurement cycle (arbitrary units). Used for data alignment and consistency checks between the two spectrometer strings.
5. **gain_x / gain_y** Analog gain setting of each spectrometer channel at the time of acquisition. A lower gain value (e.g., 3) is applied to the first channel, and a higher one (e.g., 10) to the second, reflecting different sensitivity levels optimized for different spectral regions.
6. **B410–B860 (spectral bands, string_x)** Reflectance values from the first spectrometer, expressed as dimensionless decimal fractions. Each variable name indicates the central wavelength of the band in nanometers, covering the visible and near-infrared spectrum: B410 (violet), B460 (blue), B510–B560 (green), B610–B680 (red), B705–B730 (red-edge), B760–B900 (near-infrared).
7. **B415–B680-b (spectral bands, string_y)** Reflectance values from the second spectrometer channel, covering a partially overlapping spectral range with slightly different band positions (B415, B445, B480, B515, B555, B590, B630, B680).

8. **CLEAR** Broadband visible light intensity measured by a non-filtered photodiode (arbitrary units). Represents the total integrated light signal across the visible spectrum and is useful as a quality control variable: zero or near-zero values indicate nighttime or sensor obstruction.
9. **NIR** Broadband near-infrared light intensity measured by a dedicated NIR photodiode (arbitrary units). Together with CLEAR, it provides a direct estimate of the NIR/visible radiation ratio, relevant for canopy light interception studies.
10. **NDVI** Normalized Difference Vegetation Index, calculated from the red and near-infrared bands. It ranges from -1 to +1, where values above ~0.2 generally indicate active green vegetation.
11. **A1_corr** A corrected spectral index, likely derived from specific band combinations to account for sensor response or atmospheric effects. Values in this dataset range approximately from -1 to +0.24, with a median around -0.19. The negative values may reflect particular canopy or illumination conditions.

Training Manual

TreeTalker®Soil installation

Guidelines & regulation

TreeTalker®Soil installation

The TreeTalker® Soil device can be installed at the base of a tree, on a fence, or on a pole, approximately 40 cm above the ground.
When installed near a tree, the supplied cable (2.5 m long) allows you to maintain an adequate distance from the roots.

1. Insert the pole into the ground and secure the device to it. A mounting strap is included, but screws or cable ties can also be used.

2. Dig a trench in the soil leading to the point where the hole for the probe will be made.

3. Dig a hole approximately 50 cm deep using an auger or a shovel.

4. Insert the soil probe horizontally at the deepest point, pushing it into the soil along one of the vertical walls of the hole.
   It is recommended to work in moist soil or to soften the ground beforehand to facilitate insertion and avoid damaging the probe. Avoid creating air pockets and do not install the probe in overly dry or rocky soil.

5. Lay the cable inside the trench and secure it to the pole with a cable tie.

6. Cover the hole with soil.

7. Here is the TreeTalker® Soil correctly installed.