SOIL SCOUT

Soil Scout User Manual

www.soilscout.com

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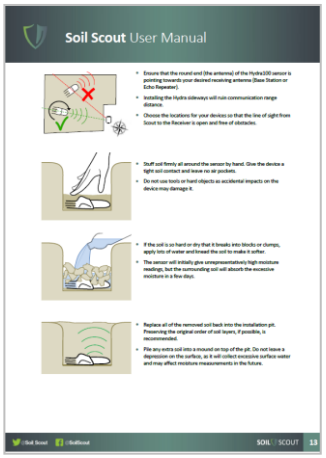


Manual version September 21, 2023

Introduction

Thank you for becoming a Soil Scout user! You now have the most advanced wireless soil monitoring equipment at your disposal. Please read through this manual to get full benefit from the unprecedented opportunities the system can provide.

The system is intended to achieve near real-time wireless monitoring of underground measurement data, such as soil moisture and temperature. Before using the system for any other purposes, contact the manufacturer.

The system is designed for either the ITU Region 1 (comprising of Europe, Africa, the Middle East west of the Persian Gulf including Iraq, the former Soviet Union and Mongolia) or ITU Region 2 (comprising of the Americas, Greenland and selected parts of Asia and Pacific.

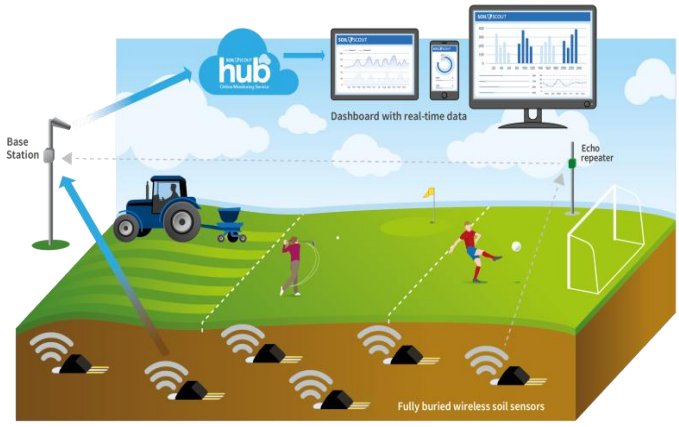
NOTE! All devices of your Soil Scout solution - the Soil Scout Hydra sensors, Echo repeaters and the Base Station with its internal cellular modem and antenna - are approved for normal operation in your region with no further licenses required. Using the system in regions other than originally intended for may violate local radio frequency regulations. For more detailed information on allowed regions and countries please contact your local Soil Scout distributor.

The Solution in a Nutshell

Soil Scout sensors are fully buried underground and transmit soil measurement data packets periodically. The sensors do not interconnect, they create no mesh nor receive any signals.

Receivers - both the grey Base and the green Echo - are intended for installation on a mast, pole, on a wall, or occasionally using temporary means such as up a tree. Receivers capture radio packets sent by the Soil Scout Hydra sensors and/or Echo Repeaters with an external Receiving Antenna, connected to the Receiver with the provided coaxial cable.

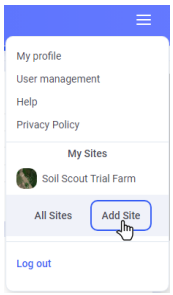
An Echo Repeater retransmits the packets, while a Base Station uploads them to the Soil Scout Hub via cellular (LTE/UMTS/GSM) networks. Every unit has a unique ID on their type label, which must be input to the Soil Scout Hub, so that measurements are identified and recorded accordingly.



GETTING STARTED 1-2-3

- **Setup and Check Devices at Office** *(Chapters 1-5)*
- **Plan the Field Work** *(Chapter 6)*
- **Install the Equipment** *(Chapters 7-13)*

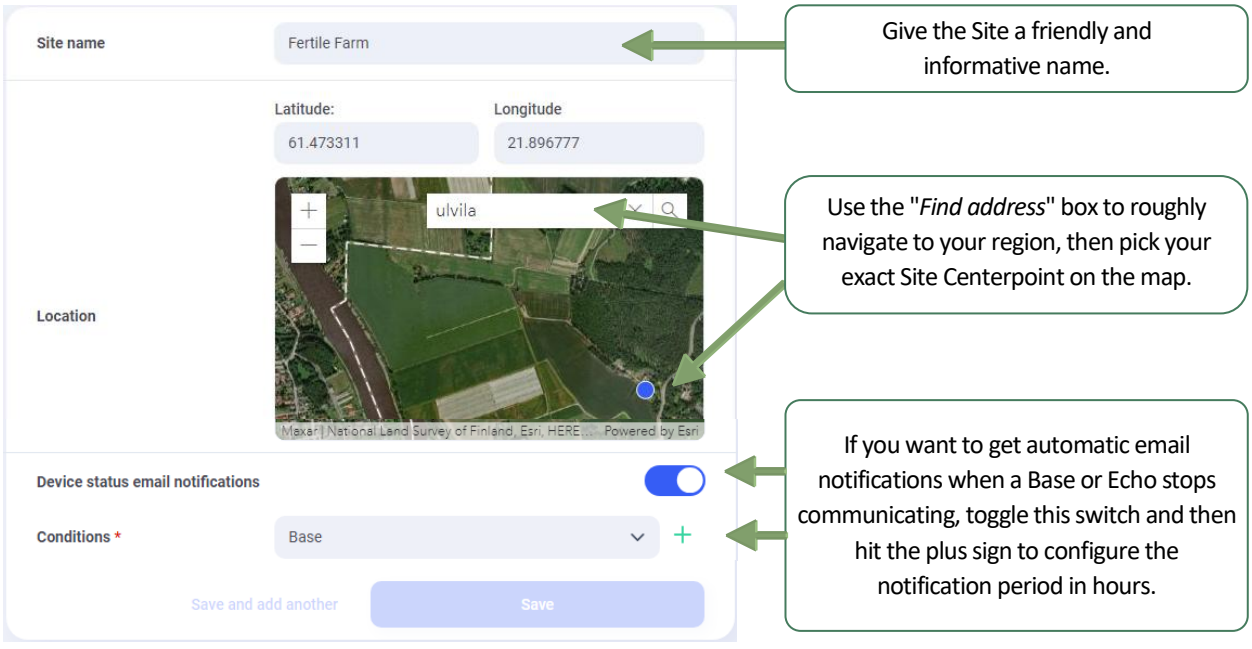
1. Create a New Site



Usually for a new customer, the first Site is already created and according devices added onto the site. If you are a returning customer or want to split your hardware into multiple sites, you can do so by yourself.

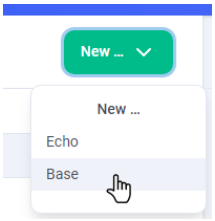
- Unbox all devices
- Recharge the Base Station with the supplied PSU for a few hours
- Start the simple setup process at your computer

Log into the Soil Scout Hub at https://soilscouts.fi with the user name and password provided to you by your Soil Scout representative. Select "*Add Site*" from the upper hand thee lines menu. This will pop up the New Site dialogue.

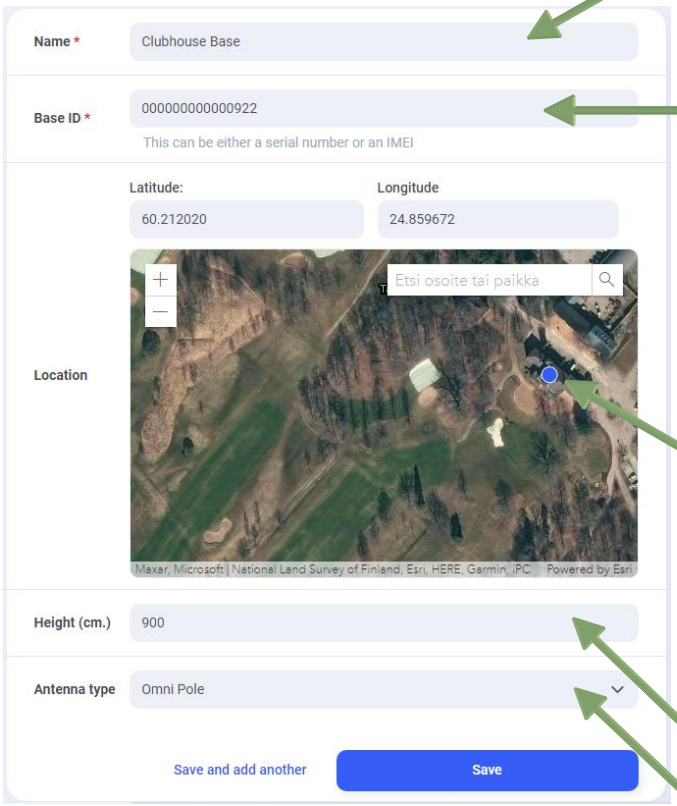


Example settings for getting email notifications to farmer@fertilefarm.ff when a Base has been offline for 6 hours, or an Echo has not connected for 24 hours.

2. How to Add Base Station and Echo (or Edit)



On the *Receivers* Page RECEIVERS you can enter a New Base and Echos to your Site. Every Site needs at least one Base Station and may have multiple of them. The process of creating a new device is identical to editing the properties later.



Give the Base/Echo a friendly and informative name, which also makes sense in the alphabetical Device list.

Receiver serial number is printed on the device sticker, such as "BST_789" or "ECHO_56789". Enter the numbers only. The system may append a required amount of zeros to the nuber. If you can't find the ID, refer to Chapter *Receiver Overview*.

Choose a location from the map. If you have recorded in-field coordinates, type them into the box.

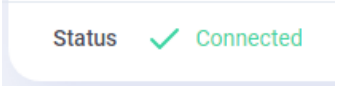
The preferred coordinate format is degree decimals, such as: 61.474344, 21.889887. If you enter coordinates in some other format (such as 61°28'27.6"N 21°53'23.6"E), make sure that the coordinates are converted accurately.

On a mobile device in the field, you can also choose "*Use current location*" once you have tapped the *Find address* box.

Enter the height of the receiving *antenna* in your regional units and antenna type.

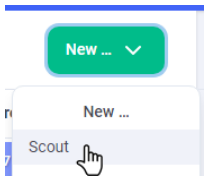
Choice of units can be done in "*My Profile*" that is located in the upper right corner three line menu.

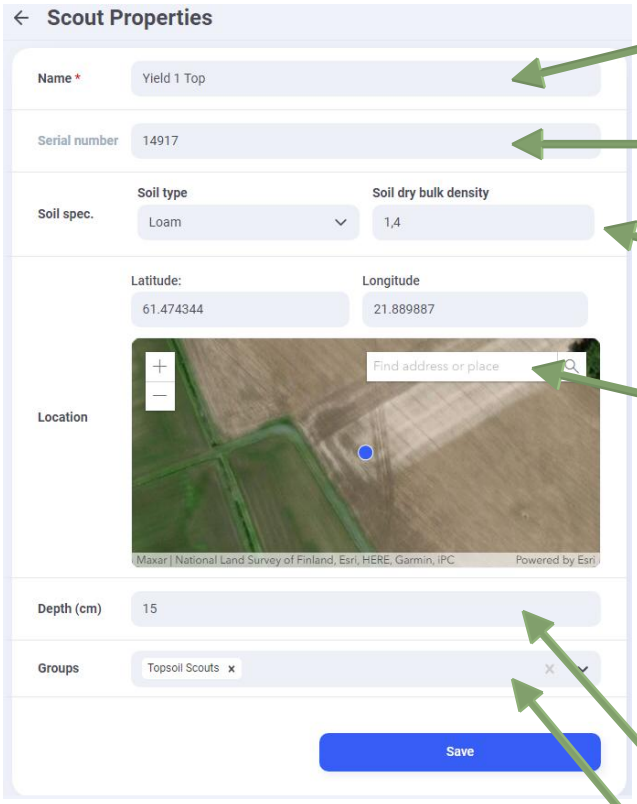
Once you have added the Base Station onto your Receivers list, switch the Base on. There should be a Yellow or Green blinking LED. In a few minutes, try refreshing the Receivers web page. The Receiver Overview should now state "Status: Connected".



3. How to Add Scouts (or Edit)

On the *Scouts* page SCOUTS, add your sensors to your Site by creating *New > Scout*. Later on, clicking on the pen book symbol on the device list will open a window where you can edit the device specific properties.





Give the Scout a friendly and informative name, which also makes sense in the alphabetical Device list.

Scout serial number is the 5-digit ID number on the device, such as "15678".

Select which soil type your sensor will be installed in. The system will suggest a dry bulk density, which is required for the Salinity extrapolation.
Enter a more exact value, in case you have one.

Choose a location from the map. If you have recorded in-field coordinates, type them into the *Find address* box.

The preferred coordinate format is degree decimals, like: 61.474344, 21.889887. If you enter coordinates in some other format (such as 61°28'27.6"N 21°53'23.6"E), make sure that the coordinates are converted accurately.

On a mobile device, you can also choose "*Use current location*" once you have tapped the *Find address* box.

Depth/Height is important for later reference.

You can include the new Scout into Groups when creating the device or edit it later.

Once you have added your Scouts to the Device List, leave the sensors in the near vicinity of your Base station and make yourself a cup of coffee.

The sensors have their own predestined rythm of performing measurements and transmitting them, and the Base will pick up the signals and upload them to the Hub Server. In a little while a green tick symbol will appear next to each Scout symbol as a sign of the sensor connecting the server via the Base.

4. Receiver Overview and Operation

The Receiver units are fully plug and play, the power switch being the only user input. Base Stations come with a built-in SIM and are pre-configured for your regional settings.


Base Station 200


Echo Repeater 200

The Receivers have a few common main parts; a **solar panel** for independent operation during the growing season, a **power switch**, a **status LED**, a DC input **power connector** (to be used when solar power is not available in sufficient quantity) and a **coaxial connector** for the receiving antenna. There is also a rechargeable lithium **battery** and a retransmission (Echo) or cellular (Base Station) **antenna** inside the enclosure, but these are not intended for user access or service. The **D9 connector** is reserved for connecting a rain gauge or other auxiliary connection, and should not be connected without separate, detailed instructions.

Base Stations also have a two-row text display. This display provides detailed information on the cellular network, received packets, upload progress etc. For power saving reasons, the display backlight is only operational for the first 60 minutes after a power-up. Later on, the display will continue displaying data but depending on ambient light brightness it may be difficult to read. If another hour of display operation is required, the unit can be briefly powered down and back up using the power switch.

The signal LED is always operational when the unit is switched on and there is sufficient battery voltage. Below is a short list of how each LED blink pattern correlates to operation status.

Base Station LED Pattern	Status
Green blink every 1 s	Normal operation
Single long blue blink	A new packet was just received
Yellow blink every 1 s	No new packets received within last 1 h
Yellow blink every 5 s	Unit is on power saving break, will autonomously resume operation later
Red blink every 5 s	Battery too low for operation, please recharge
Red solid or long blink	The unit is about to perform an automatic reboot

Echo Repeater LED Pattern	Status
Green blink every 1 s	Normal operation
Single long green blink	A new packet was received and retransmitted
Yellow blink every 1 s	No new packets reveived within last 20 min
Red blink every 5 s	Battery too low for operation, please recharge

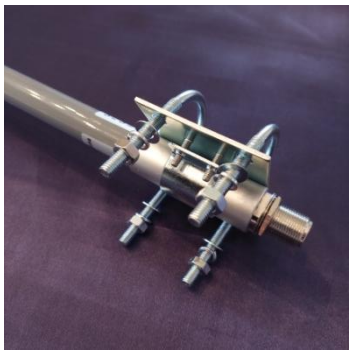
5. Pre-assembly of Receiving Equipment

The units are fully plug and play, the power switch being the only user input. Base Stations come with a built-in SIM and are pre-configured for your regional settings.

Receiver On a Pole

If you're installing the Receiver on a pole where you can slip the unit in place over the top, use a crosshead screwdriver (size PZ2) to fix all four screws onto the backplate just a couple turns each.

If you're installing the Receiver halfway a pole, leave the two bottom screws unattached until final installation.



Omnidirectional Antenna

When installing an omnidirectional pole antenna, preassemble it by attaching the metal strap onto the backplate with the 4 crosshead screws (size PH1). Slip in the antenna and make sure that the backplate is vertically aligned with the antenna metal capsule. Do not over tighten.

On actual install location assemble the u-bolts onto the backplate. Place the smooth washers first, then the spring washers and finally the 10 mm nuts.

Directive Antenna Installation

When installing a directive antenna, preassemble the angle iron onto the antenna with the two screws provided (size PH3). Make sure to have the mounting plate to your right hand side when the red arrow is pointing "UP" and antenna is viewed from behind.

On actual install location put the u-bolt first through the toothed bracket piece, then the mounting plate from the right hand side. Place the smooth washers first, then the spring washers and finally the 10 mm nuts.

NOTE: Information regarding screws and bolt types are provided with best available accuracy, but may change without notice.

All Soil Scout devices are ready for use when delivered. The Receivers have been tested during manufacture and there is no way to adjust the operation – you just need to switch them on.

However, since the battery is in a shelf condition upon delivery, it is good practice to let the unit charge a while before switching on. This can be done using either a DC power supply

or placing the unit outside, directly facing the sun, for a few hours. It will charge even when it's not switched on.

Add the Base Station to your Site in the Hub as outlined in the Hub chapter of this Manual, if that hasn't already been done for you. Then switch the Base Station on and let it sit - you should see the unit go green in the Hub and diagnostics data update. When switching it on for the first time in a new location, this should not take more than 5 minutes, depending on the local cellular network. On the unit display you can see a scrolling text of network details once the unit has connected to a local cellular network.

Leave the Base Station on and add the Echo Repeater device to the Site accordingly. Switch it on and confirm that it appears online in the Hub Receivers page. If the Base Station is running indoors with no power supply, this can take up to 20 minutes.

6. Plan Before Installing any Equipment

All Soil Scout devices are ready for use when delivered. The Hydra transmitters have been tested and put into operation in manufacturing and there is no way to adjust their operation.

However, it is good practice to perform certain procedures before mounting receiving equipment or burying Hydra transmitters. This way device setup can be verified with the least effort before going out in the field.

Set up your site in the Soil Scout Hub as outlined in the Hub Manual. Power up your Base Station and check that it reports to the online Hub properly – detailed instructions for this are found in the Receivers chapter of this manual.

Keep the Hydra sensors in near vicinity to the Base Station for an hour and check all scouts report data to the Cloud. Once they do, you can be sure everything will work out in the field as well.

Make a plan of your sensor deployment before going out. It is easier and more reliable to execute a good plan and write down eventual changes to it, than simultaneously carry out the field work and document it. A good plan covers following:

- Map of intended locations where each Hydra goes
- Hydra ID numbers on the map
- Intended depths of each Hydra
- Means to write down soil observations during installation
- Positioning device or other means to exactly record the realized locations

Keep a copy of your plan in office and make a backup of a modified plan after the field work. Remember, that after deployment there are no means to resolve an individual Scout Hydra's location. The transmissions are very short, occur seldom and often have powers below noise floor, so feasible technical methods to triangulate devices do not exist to date.

7. Field Installation of a Receiver

Receivers should always be installed upright, so that all connectors point directly downwards. The solar panel should be directed in the direction of best sunlight, typically this is directly south in the northern hemisphere and directly north in the southern hemisphere. Close to the equator the direction can be chosen freely (and based more on local obstacles) since sunlight is more abundant. If the Receiver is situated where not enough sunlight can be harvested, the unit should be used with the provided mains power supply.

NOTE: If you're using a PSU, it must be protected from weather.

If you're using a short antenna cable, slip the Receiver onto the pole and tighten the backplate screws just a little. Add the Antenna to the pole. An omnidirectional antenna must sit on the highest end of it, having the highest U-bolt just 1 cm (½ inch) below the top - otherwise the pole itself will interfere with the antenna and cause poor performance.

In some cases the pole is very high and a longer antenna cable has been provided, so the Receiver can stay lower down the pole. When using a longer antenna cable, twist it around the pole, leave a little slack and use a cable tie to fix it to the pole as sturdy as you can. The cable connectors are not intended to carry the full weight of the cable, especially during windy conditions.

Directive Antennas can be mounted at any point of a pole, but preferably as high as possible. Make sure that the antenna cable travels from Receiver to Antenna going around the pole. This makes sure that the cable will not accidentally find its way into the front of the solar panel.

The directive antenna has a 90 degree arc of reception, i.e. 45 degrees to either side of the pointed direction. Vertically the arc is 60 degrees, which in typical installations means you can just set the antenna slightly down from horizontal and it will receive properly from near and far. The omnidirectional antenna will receive signal from all directions, but must be mounted on the very top of a mounting pole or mast, so that the pole itself is not interfering with the antenna.

The Receiver's internal antenna (for cellular connection in a Base, and for retransmissions in an Echo) is omnidirectional and does not require orientating.

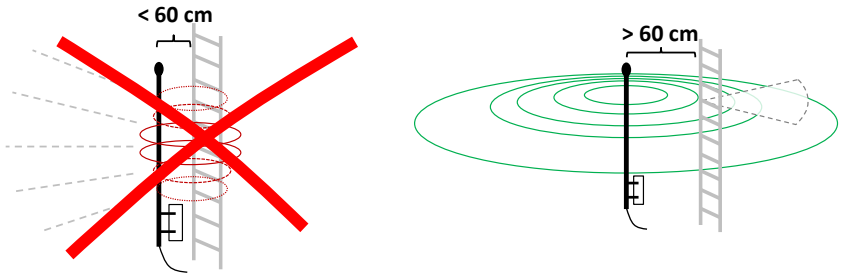
The external antennas and the units themselves must always be well away from metal objects and surfaces, such as tin roofs, ladders etc so that the radio waves are not short circuited, resulting in lowered performance.

8. Receiving Antenna Placement

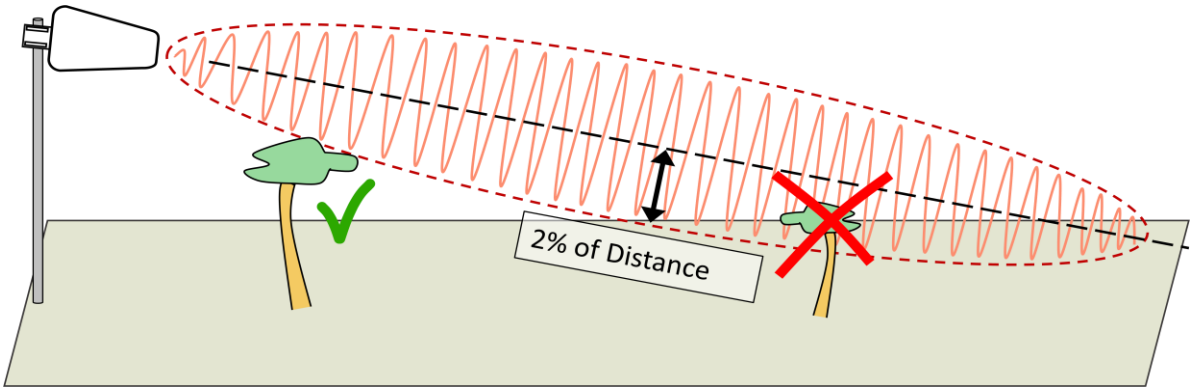
Radio signals do not "magically appear" at the antenna as some might think. Instead, they travel much like a beam of light from the transmitter to the receiving antenna in a straight line. When choosing locations for Receivers and mounting their Antennas, it's good to understand a few aspects regarding radio wave propagation:

- The deeper a Soil Scout Hydra100 sensor is buried, the closer the Receiver must be
- The higher the Receiving Antenna is elevated, the longer a range can be expected
- The receiving antenna near field (60 cm / 2' radius) must remain clear of any objects
- The "line-of-sight" is not like a laser, but a tube few meters wide (2% of the distance)
- All obstacles within the line-of-sight tube diminish and ultimately block the signal
- Obstacles between Echo and Base also impact their ability to connect

NOTE: Soil Scout has lots of experience and understanding in the wireless operating conditions our customers have, and are happy to evaluate your installation plans and troubleshoot operation in more detail.



Omni Directional antennas need at least 60 cm (2') clearance around the antenna. The same applies at all sides and the front of a Directive Antenna, but not behind it.



The Line-of-Sight for a radio wave needs some clearance around the straight line.

9. Echo Repeater Operation

The purpose of an Echo Repeater is to expand a Soil Scout site to wider areas than just the reception range of a single Base Station. An Echo boosts the signal level of any packets it receives by a retransmission, but it does not alter the information in any way. Consequently, it is impossible to distinguish an original Scout measurement data packet from one that was repeated once or even multiple times.

If there is uncertainty whether a Scout is being picked up directly or via an Echo, the only way to make sure is to switch off the nearest Echo and check whether the received packet count from that Scout remains the same over a longer period of time (eg. 24 hours). Note that if this results in the Scout not being picked up, the corresponding data for that period will be lost.

10. Base Station Power Management

The Base Station is the gateway that uploads soil measurements to the Soil Scout Hub server over a cellular mobile network. A Base has several internal operating modes that the unit employs depending on the battery charge level. No user interference is required, the Base Station switches between states fully autonomously.

- **Full Operation - Unit is supplied with external power (input voltage exceeds 9VDC)**

  In this mode, all packets received by the Base are uploaded to the Hub with a latency of no more than 60 seconds.

- **Normal Battery Operation – Unit is not supplied with external power, battery is full**

  In this mode power is conserved by buffering incoming packets and uploading so that the largest delay introduced to any one packet is less than 20 minutes. The fastest single Scout inside the Site will define the latency pattern, i.e. a 5-minute sensor on the Site will enforce a cycle where no packets will lag more than 5 minutes.

- **Low Battery Operation, First Stage**

  In this mode Base Station operation is active for one hour followed by a hibernation period of one hour. The active period is just as is normal battery operation. The hibernation allows for extended usage in low-light conditions while keeping up with day-long trends in the readings.

- **Low Battery Operation, Second Stage**

  Battery has kept discharging even more, so the hibernation is increased to 3 hours, meaning that each one hour of operation is followed by a three-hour period of no operation.

- **Low Battery Operation, Third Stage**

  Hibernation is prolonged even further to 5 hours, so there are now four active one-hour periods within a full day. This is the last extreme measure to stretch operation for approximately one more day.

- **Battery Empty**

  The battery is so close to being fully depleted that no further operation is possible. The unit will shut down internally and blink a red LED, until either battery is charged or it depletes so low that even the LED stops blinking. Solar recharging remains operational.

Hibernation means that the unit will not receive any new packets nor will it upload any diagnostic packets to the Hub, but stays completely offline. If the Hub is set to send an automatic email warning when a Base Station goes offline, this might cause frequent redundant emails. If your Base is running on solar power without a PSU, you may prevent such behaviour simply by increasing the alarm time threshold to more than 6 hours.

11. Hydra100 Sensor Overview and Operation

The Soil Scout Hydra100 device, depicted below, is intended for underground installation, while the Gateway for receiving the data transmitted from underground is intended for installation above-ground and in air. Each sensor unit has a unique ID on a sticker on the front face, which is used to distinguish the data source in the Soil Scout Hub.

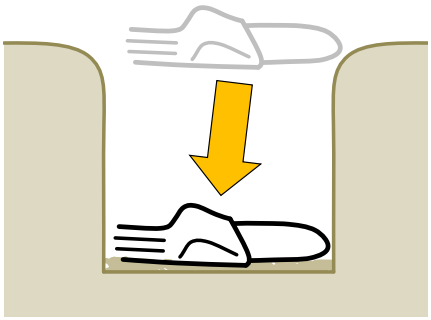
The Hydra has an embedded antenna, battery, electronics and sensors. The antenna is in the semi-circular end, while the soil sensor head is the set of three prongs in the other end. The battery and electronics are molded inside the plastic center and cannot be replaced or accessed in any way.

Hydra sensors have a preset interval to perform measurements and transmit the results, typically every 20 minutes. There are other variants available, and the preset interval cannot be adjusted after production.

The device is permanently sealed in manufacturing and is fully waterproof to allow installation in completely water-filled environments, where no hazardous chemicals such as solvents are present.

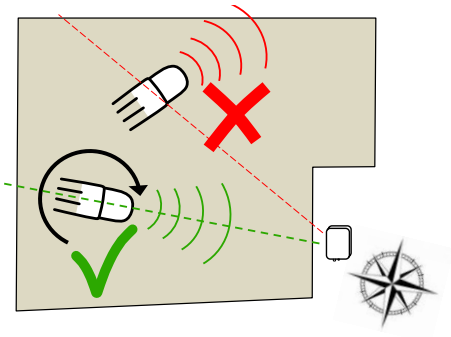
The radio transmitter produces the maximum allowed radio power of 27 dBm (500 mW) according to European radio regulations (Directive 1999/5/EC). Any attempts to enhance the transmission power by self-made means will cause prohibited emissions and are therefore strictly forbidden.

12. Field Installation of Hydra100 Sensors

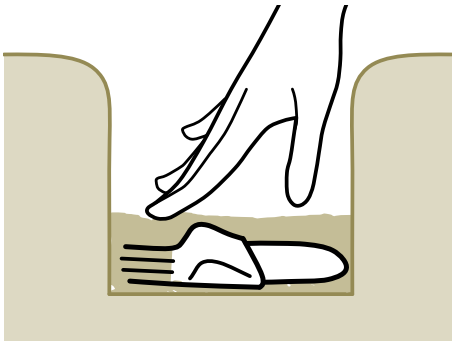


- Dig an installation hole to the desired installation depth only. Digging too deep will disturb the bottom soil.
- Leave approx. 1 cm (0.4") of loose soil on the bottom of the pit to allow for firm soil contact with the device.
- Place the device on the pit bottom. Place only one Scout in one pit.

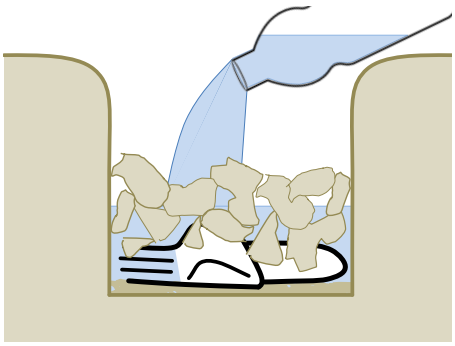
NOTE: Before installation, write down the 5-digit Hydra ID code for each unit you are burying. During installation, record exact depth and precise coordinates for the location.



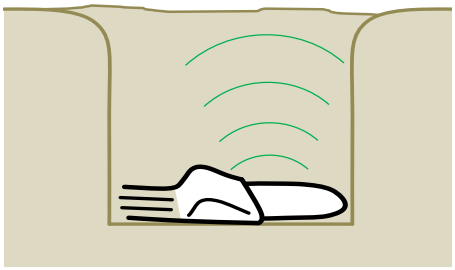
- Ensure that the round end (the antenna) of the Hydra100 sensor is pointing towards your desired receiving antenna (Base Station or Echo Repeater).
- Installing the Hydra sideways will ruin communication range distance.
- Choose the locations for your devices so that the line of sight from Scout to the Receiver is open and free of obstacles.



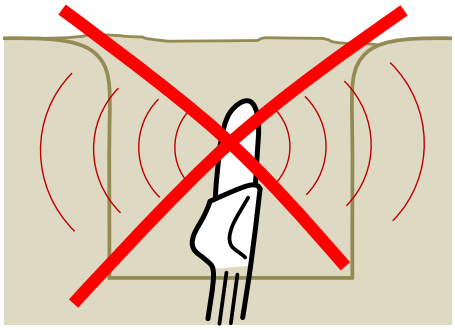
- Stuff soil firmly all around the sensor by hand. Give the device a tight soil contact and leave no air pockets.
- Do not use tools or hard objects as accidental impacts on the device may damage it.



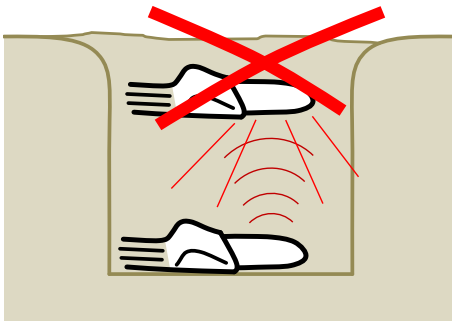
- If the soil is so hard or dry that it breaks into blocks or clumps, apply lots of water and knead the soil to make it softer.
- The sensor will initially give unrepresentatively high moisture readings, but the surrounding soil will absorb the excessive moisture in a few days.



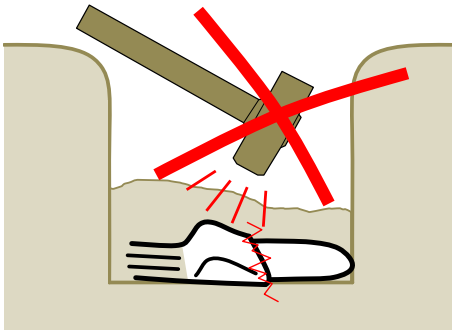
- Replace all of the removed soil back into the installation pit. Preserving the original order of soil layers, if possible, is recommended.
- Pile any extra soil into a mound on top of the pit. Do not leave a depression on the surface, as it will collect excessive surface water and may affect moisture measurements in the future.



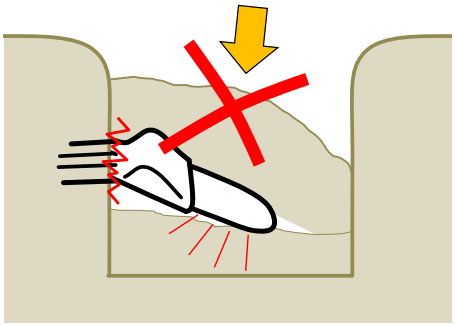
- Do not place the Scout in an upright position. The radio signal would be unable to get up in the air and the the sensor will not communicate.



- Do not place multiple Scouts in one pit. The top one will block radio transmissions from deeper ones. Give each Scout its own pit and keep the pits at least 0.6 m (2 feet) apart.



- Do not use tools to compact the soil. Once the sensor is well covered, it's OK to step on the soil to compact it to the original compaction level.



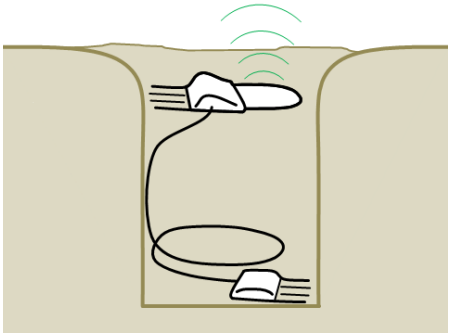
- If you choose to push the sensing head pins into the undisturbed soil wall, be absolutely sure to have the sensor flat and firm on the bottom of the pit. Any loose soil beneath the sensor will compact back over time, causing a high risk of breaking the sensing head pins.
- If the soil is too hard to penetrate gently pushing by fingers, use a pocket knife or similar tool to make the opening before pushing. Bear in mind, that the warranty will not cover for mechanically broken sensors.

A few good practices on how to set up a larger monitoring site instrumentation step by step:

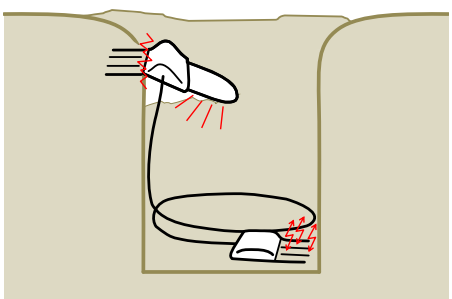
- Begin by installing sensors close to a Receiver and make sure they communicate before working your way further out.
- Install Scouts in sessions, if possible, and observe the performance before you continue.
- When you have reached the limit of reception range, put up an Echo Repeater and continue the process.

13. Field Installation of Dual Depth Sensors (HydraDDS)

When two depths are measured in one location, HydraDDS is the choice. The Master unit carries out regular measurements of its own, but performs radio transmissions on the behalf of both sensor heads. The sensing is identical in both the Master and Slave part and they both have their own unique ID numbers.



- When installing a Dual Depth Sensor (HydraDDS) make sure to roll the excess cable near the bottom of the pit, so that the cable will not interfere with the transmission antenna.
- The master unit with the round antenna performs all radio transmissions. Therefore, to obtain good transmission range, the master unit must always be the shallow one, and the slave sensor head the deeper one.



- Do not push the Mater unit's prongs into the installation pit wall. When soil recompacts over time, it may break the prongs.
- When rolling excess cable into the pit, make sure the cable does not travel closer than 5 cm (2") to the Slave sensing head. The cable has metal inside and will disturb measurement results by interfering with the sensor prong's near field.

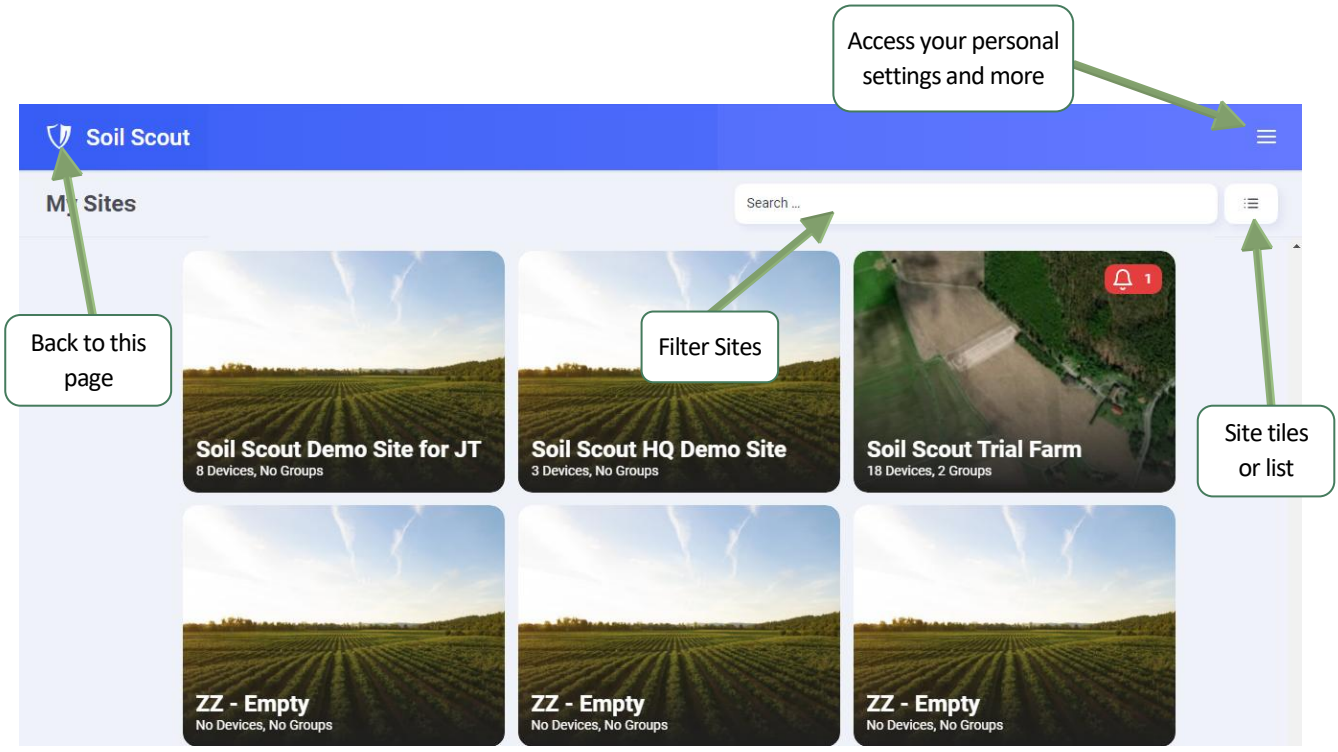
14. Soil Scout Hub

The Hub is the web-based online dashboard to view, analyze, manage and share your soil measurements. The Hub requires a login name and password, which you will obtain from your Soil Scout representative.

The Welcome screen shows a list of all Sites that you have permission to view or edit, each represented as a tile. This top-level view provides a summary of devices on the Site, as well as whether there are any Alerts requiring attention. The number of triggered Alerts are presented in red.

Click on the Site that you wish to access.

NOTE: If you only have one Site, Login will land you directly onto that Site's Device list instead.



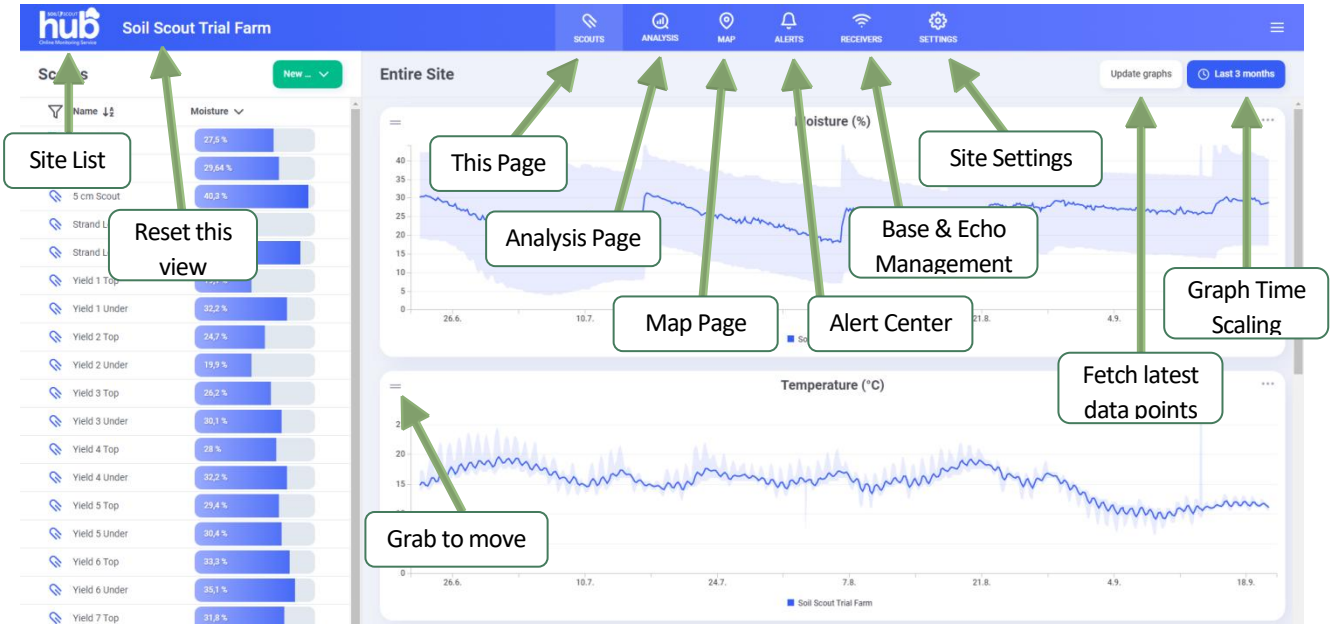
15. Site View (Main Page)

This page presents all the main information regarding your soil measurements. The top bar contains quick access to all core functionalities.

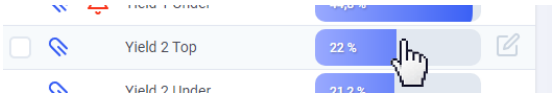
The Device List on the left presents both sensor groups and individual sensors with general information.

The sensor list can be filtered and sorted by name or measurement values. The measurement bars can be configured to show moisture, temperature or salinity.

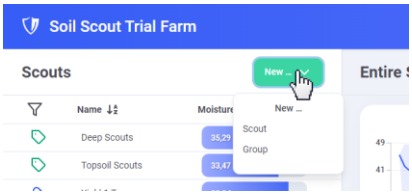
A red bell stands for ongoing Alerts. The sensor has reached a thresholds that you have defined for a Scout Group. The bell is a link to the according Alert rule page.



When hovering the mouse hand cursor on a list item, the pen book symbol will appear to the right. The pen book button will take you to the **Properties** of this Scout / Group / Device.



The **New** button is for adding new **Devices** to your site or creating new **Groups**, which are the basis for comparing different areas as well as for creating automated Alerts.

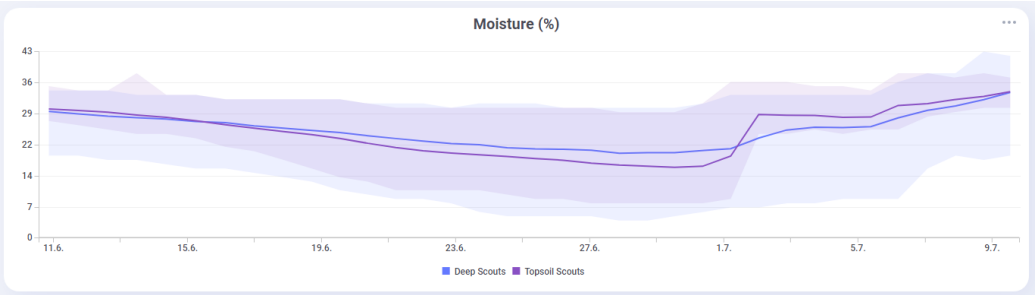


16. Viewing Graphs

The **Entire Site** graph is a plot of *all devices* on the device list. The solid line is the moving average, while the shaded tube represents the min and max values.

More importantly, when you select one or more **Groups** for comparison by clicking their select boxes on the left, you will see a similar compilation of tubes, which enables a convenient method to compare selected areas or depths with each other.

The three dots in the upper right hand corner contains graph specific options, such as reveling Alert rule lines, exporting data, hiding this graph and more. Alert rules will appear as dashed lines. Downloading the *Comma Separated Values* (csv file) will export all visible data (without down filtering) to your preferred spread sheet software. The firts line contains information on the contents of each culomn.



This example comparing two Scout Groups (Deep Scouts & Topsoil Scouts) shows that 1.7. rain has quickly wetted the topsoil and diminished variability, while deep soil reacted several days later and less dramatically.

Selecting different time spans from the time scale menu will bring up different data sets. Dragging on the graph will allow for zooming in, while clicking on *Reset zoom* will bring you back out.

NOTE: The database contains a large amount of data, but to give you a smooth browsing experience, only a filtered set of data is being downloaded depending on the time span and zoom level.

Howering the mouse hand tool on the graph line legend will enable to highlight individual lines in the graph, clicking on them will toggle them on and off.

All formatting, such as the tool tip date and time units, automatically uses regional settings of your browser.

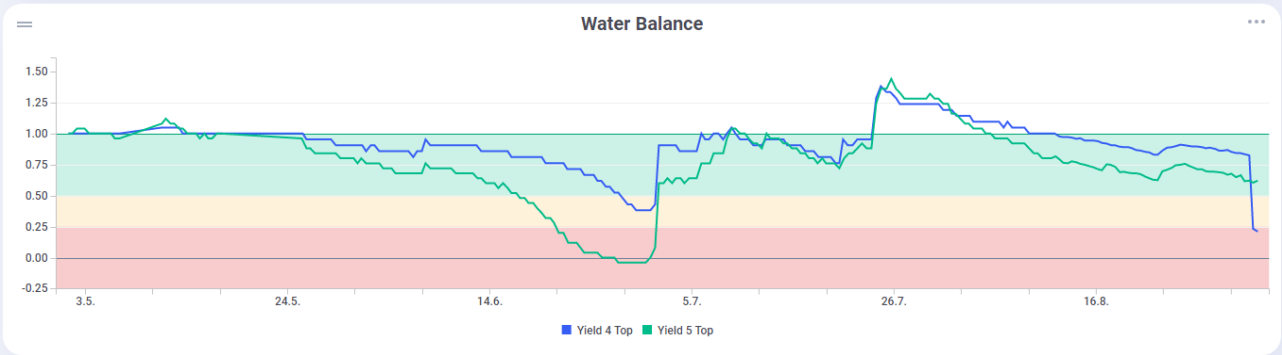
The Salinity graph extrapolates *what the Electrical Conductivity (EC)* ***would be*** *if the soil was saturated wet*. Would you rather see the momentary raw EC without extrapolation, you can choose "*Bulk conductivity*" in the Salinty graph options ••• menu. More detailed information on the Salinity and EC with interpretation guidelines can be acquired from Soil Scout.

17. Water Balance Graph

While the **Moisture (%)** graph presents the volumetric water content, the **Water Balance** graph indicates plant water availability, based on Scout specific *Field Capacity* (FC) and *Wilting Point* (WP) settings. The simple principle is, that *Water Balance* equals to 1, when soil moisture is at FC and plenty of water is readily available for plants. On the other hand, *Water Balance* is 0 when soil moisture has reached WP, and plants are at risk of wilting permanently.

The Irrigation Threshold is usually considered halfway, at Water Balance 0.50. Above this limit (the green zone) plant growth is not severely limited by water availability. Below the Irrigation Threshold (the yellow zone) growth starts to decline. Agronomically, this means that the crop may not be able to fully benefit from additional inputs such as fertilizer, unless water availability improves by rain or irrigation.

In other words, the purpose of the Water Balance graph is to enable comparison of moisture data from locations with varying water holding capacities on a uniform agronomical scale.

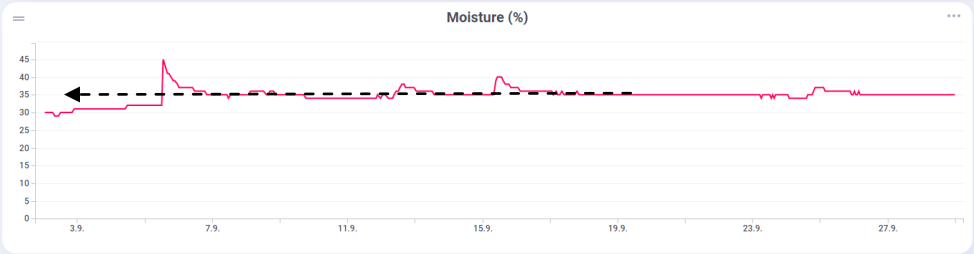


In this example the mid summer completely dried up the location "Yield 5" topsoil down to Wilting Point 0.00, while "Yield 4" had a better water holding capacity and plant water availability was almost not endangered at all. The location "Yield 5" would have needed more water on June 17th.

When creating a New Scout Device, the dialogue will suggest soil type specific default values for FC and WP. You can adjust these values any time later in the *Edit Device Properties* page. You may have accurate FC values from a soil laboratory report, but you can in fact also identify your Scout specific FC value by observing the moisture data by following this procedure:

With your local knowledge, zoom the Scout Moisture Graph to a moment, where you know the soil has been properly wetted, over irrigated or received heavy rain. You will observe, that every time after such a wetting event, the moisture will settle down to a certain moisture level. This water holding level is the Scout specific Field Capacity, as the moisture declination is caused by drainage and/or percolation.

In some cases, for example in the absence of natural rains, you might consider causing the over watering situation artificially, for example pouring lots of water on the installed sensor or performing one excessive irrigation event. Another option is to pick soil samples next to the sensors and have them analysed for water holding properties.



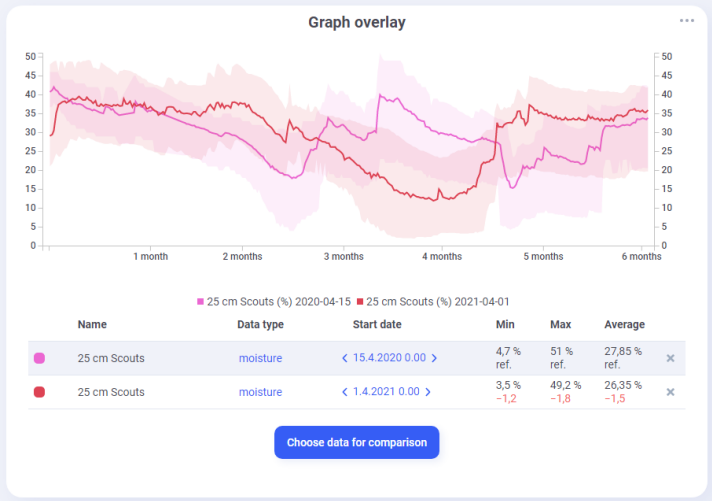
The graph above shows moisture from a Scout during Autumn rains, and the soil gets saturated repeatedly. One day after each rain event the moisture declination stops at 35 %, which represents the location specific water holding capacity, the Field Capacity.

NOTE: You can also adjust the Scout specific Irrigation Threshold, but then a Water Balance Graph with Scouts at different Irrigation Threshold levels *will not be able* to show the colour zones.

18. Analysis Page

The graphs on the Site View (main page) can show data from selected devices, but they are all in the same time axis. The **Analysis** page is a tool for comparing any data graphs from different times. As an example, you can plot soil moisture from several growing seasons on top of each other to analyze the seasonal differences. You can also plot any parameters, suchs as temperature and salinity into the same graph. In addition, you can save the created Analysis and it will be visible for other users of the same Site.

A typical Analysis would be to compare two (or more) growing seasons with each other. Below is an example, where two seasons of data from the Group "25 cm Scouts" is plotted. Note, that the 2020 season has been set to start on April 15th, while 2021 season is beginning April 1st. This way the two graphs are syncronized based on growth stage rather than calendar. during 2021 it was easy to observe, that the early season had favourable moisture, but from the third month drought hit hard compared to the late season rains in the previous season.



This Analysis example is showing two moisture graphs from the Group "25 cm Scouts" from two seasons beginning at different dates.

The Analysis can have as many graphs you wish, but too many will make the graph unclear. You can hide and show graph lines by clicking their legends.

The graph lines are live, which means that an unfinished line will extend as data accumulates, and every time you open a particular Analysis the "ongoing season" graph will have grown longer.

To create an Analysis, click New analysis and give the analysis a familiar name which will also be understood by your collegues. Add data to the graph by clicking Choose data for comparison and choosing the Scouts and/or Groups you wish to add. You can choose the same data multiple times, if you wish to have several graphs from the same source but different times.

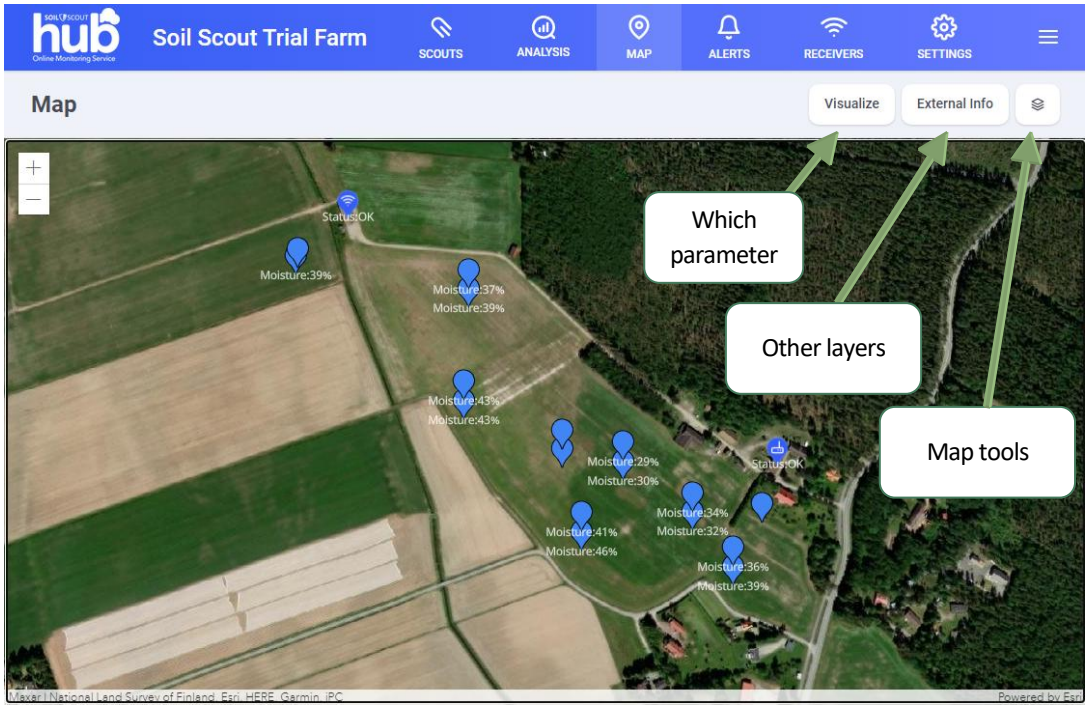
When the graphs appear in the plot, you can change the Data Type (moisture, temperature…) and the Start Date of each line. Also the time span, 12 months by default, can be changed and will be saved with the Analysis.

If you wish to make copies of the Anaylsis with modified settings, just click Save As... and type in a new name for the new Analysis.

19. Map Page

The Map interface is built on the ArcGIS API for JavaScript library. Here are a few notes on how to interpret and operate the Map:

- The symbols for Scout, Base and Echo Repeater are similar to their corresponding symbols in the Device List.
- Clicking on the symbols will pop up an measurement information text box.
- If a device has not connected for 2 hours, the symbol becomes yellow (Waiting).
- If a device has not connected for 12 hours, the symbol becomes red (Not connected).
- The *Visualize* menu lets you select which soil parameter you wish to evaluate on the map. Moisture colours are defined based on water balance, temperature on a scale from blue (cold) to red (hot).
- External info contains a selection of other data sources, such as a satellite NDVI biomass map. Choose a date range of interest and the system will pick the best quality image from the selected period.
- The Map Widgets menu will allow you to enable Find and Measurement tools, as well as to customize the map imagery.

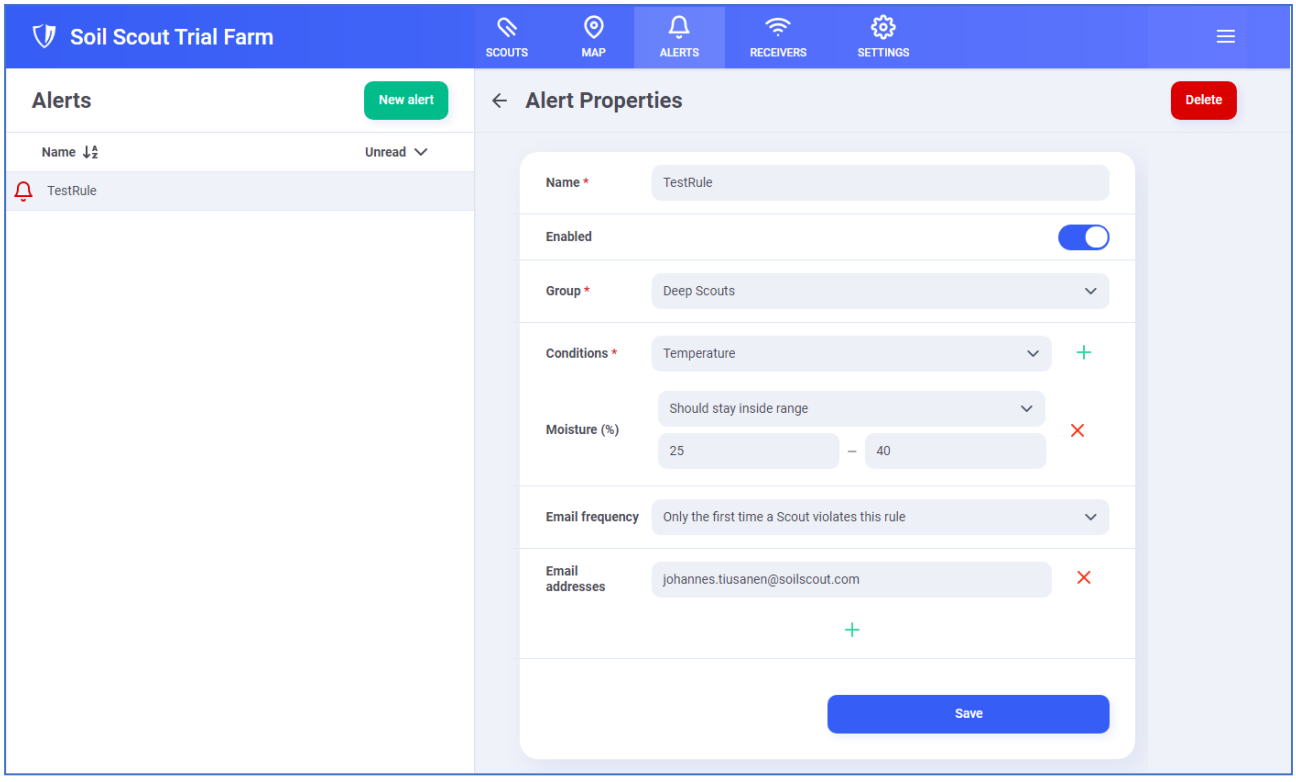


20. Alerts

The automatic Alert system enables you to set predefined measurement value conditions, which will trigger the Alert and send an according notification email, if desired. The Alert can only target a Group, but you can create a group of one Scout.

Once configured and saved, the Alert will start monitoring for measurements that will trigger the Alarm. When the defined Alarm is no longer relevant for you, you can turn the *Enabled* switch off for later use.

When an Alert has triggered, it will keep the red bell on the Tool Bar until it has been acknowledged by a user. The red bell remains on the Device List as long as the triggering condition remains true. All triggering events are logged into the *Notification History*.



In this example the rule "TestRule" will start monitoring that Scouts in the "Deep Scouts" group stay inside the desired moisture range 25-40 %. If a measurement value outside the range is received, the email recipent will get notified. When a second group member triggers the condition, a new email will not be sent.

21. Maintenance

All Soil Scout devices are maintenance free.

22. Troubleshooting Receivers

No light on the LED

If power is switched on but the LED is not blinking, the battery has gone fully empty. Recharging the unit in bright sunlight or using an external power supply for a couple of hours will resume operation. If after prolonged charging and turning the power switch off and on again the unit still won't show any lights, please contact your local distributor.

No diagnostics in the Hub

Receivers transmit diagnostic data once every 20 minutes except in Hibernation. If the unit is switched on and no diagnostics can be observed after an hour, switch the power off and on again, check the display for the cellular network status (Base only) and double check the correct Device ID number on the Hub Device settings. If the problem persists, contact your local distributor.

23. Troubleshooting Hydra100 and HydraDDS Sensors

No data coming in from a Hydra sensor, right after installation

The standard Hydra100 sensor reports once per twenty minutes. A single packet can be lost by chance, but if several packets regularly go missing, the Scout is either too deep or too far or both. Bring the unit closer or install an Echo Repeater to cover that location.

No data coming in from a Hydra sensor, after initially working

If the Scout has been at the very edge of reception, changing conditions can render the received signal strength too low to be picked up. Such changes are increased moisture levels, increased salinity in the soil, growing plants and other objects in the radio path. Bring the unit closer or install an Echo Repeater to cover that location.

Moisture reading is very low after installation

The sensor needs to be properly in contact with the soil. This can best be achieved by working a part of the soil around the Scout with water into a moist paste and stuffing the paste tightly around the sensor.

Moisture reading doesn't change during heavy watering event (rain or irrigation cycle)

Percolation speed through the soil is largely dependent on soil type, installation depth and the crop growing. If the readings don't change, chances are that it's because the conditions at sensor level don't change - meaning that the sensor is actually working correctly.

The moisture reading is strange, and you think the sensor is broken

If you want to make sure the sensor reacts to water, place it fully submerged in the center of a large bucket of water and check the reading. It should typically rise above 60%. Moisture will never rise even close to 100%, not even when fully immersed since the sensor value is calculated for soil with water, not water without soil.

A Receiver ran out of battery in the winter and is not recovering in the spring

If the internal battery of a Base or Echo gets completely depleted and then stays uncharged for additional months, it may require several days of bright sunlight to even start recharging. Bring the Receiver indoors and plug it on the PSU for a few days and it should recover normal operation.

24. Miscellaneous Notes

Soil moisture is always stated as the volumetric moisture fraction, i.e. a value 25% means that there is 2,5 decilitres (or 250 grams) of water in one litre of wet soil.

Time stamps are presented in the time zone of your browsing device. However, the CSV export uses Greenwich Mean Time (GMT) zone Coordinated Universal Time (UTC) time format, such as "2020-08-03T14:20:22.970198Z"

Salinity is a Hillhorst equation extrapolation of what the Electrical Conductivity (EC) would be if the soil was saturated wet. When soil is dry, the extrapolation is inaccurate. The accuracy is approximately as follows: Good = moisture > 40 %; Intermediate = moisture 25-40 %; Inaccurate = moisture < 25 %.

Backups of the server and databases are saved periodically, but any changes you make in the online configuration (coordinates, soil types, etc.) will take effect immediately and are irreversible.

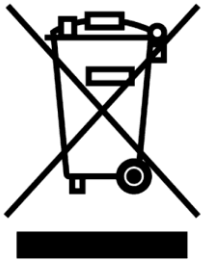
Soil type is saved for each measurement data point according to the present Device Properties. If you change soil type later, you will be prompted if you wish to recalculate old measurements, and can define the time period of recalculation.

Read only user level will keep some of the mentioned features hidden for such users.

On mobile devices with narrow screens, Device list and Graphs are not presented simultaneously. Also some comparison features cannot be used due to excessive complexity.

25. Compliance Statements and Disclaimer

Soil Scout ltd. / Soil Scout Oy hereby declares that Soil Scout Echo Repeater and Base Station are in compliance with the following requirements and other relevant provisions of:



- **RoHS Directive** (2011/65/EU)
- **WEEE Directive** (2012/19/EU)
- **Battery Directive** (2006/66/EC)
- **RED Directive** (2014/53/EU)
- **EMC Directive** (2014/30/EU)
- **Low Voltage Directive** (2014/35/EU)
- **ErP Directive** (2009/125/EC)

Please dispose this product by taking it to your local collection point or recycling center.

This will help to protect the environment in which we all live.

The relevant Declaration of Conformity is available online at http://soilscout.com/legal

FCC compliance: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Changes or modifications not expressly approved by Soil Scout ltd. could void the user's authority to operate the equipment.

Disclaimer: Soil Scout ltd. / Soil Scout Oy disclaims any and all liabilities related to or arising from third parties' products or services, which use the data generated by a Soil Scout product. Soil Scout ltd. / Soil Scout Oy disclaims any and all liabilities related to or arising from the functioning / malfunctioning of third party product or service, its interoperability with a Soil Scout product, safety of a third party product or service as well as any other liabilities related to or arising from a third party product or service. Soil Scout ltd. / Soil Scout Oy shall not be liable for any data transfer fees or any other fees which might be due to or related to the use of Soil Scout products.

The information in this document has been provided in good faith and is accurate to the best of our knowledge at the time of writing. Any errors or omissions are unintended. New features and aesthetic styling of the service is an ongoing process, and this guide may occasionally be outdated.

The products are protected by patents.

26. Technical Specifications

Specifications subject to change without notice. For additional information, please contact the Soil Scout team at info@soilscout.com

Hydra100 Scout (Periodically Transmitting Undergound Sensor Unit)

Radio power	27.0 dBm (500 mW) ERP, Bandwidth <250 kHz, duty cycle <0,001%.			
Frequency Variants	869.525 MHz (ITU-1) 921.700 MHz (ITU-2) 920-925 MHz (FHSS)	Europe & selected other markets Americas, Australia, NZ & selected other markets Hong Kong, China		
Battery capacity	3000 mAh, encapsulated primary lithium			
Life expectancy	Up to 20 years @ 1 cycle per 20 minutes			
Encapsulation	Black polyurethane molding			
Dimensions (L × W × H)	129 × 59 × 25 mm (5.1" × 2.3" × 1.0")			
Sensors	Temperature 3-prong integrated Capacitive (moisture content) & Resistive (EC / salinity) DDS (Dual Depth Sensor) has same specification for both sensing heads			
Moisture Accuracy	± 2 % mean error (1 % with correct soil type, 1 % installation repeatability) Salinity-compensated capacitance sensor, 95MHz			
	Resolution 0.3 %-points (in default soil type)			
EC Accuracy	± 0.2 dS/m mean error, Typical resolution 0.1 dS/m, Range 0 to 20 dS/m Four-electrode Wenner probe, 1kHz			
Dielectric Accuracy	± 2 % mean error, Resolution 0.5 to 1.5 □, Range 1 to 135 □			
Temperature Accuracy	Range -40 to +80 °C / -40 to 176 °F Accuracy: +/- 0.1 °C / 0.18 °F			
Resolution	-40 to -11 °C -10 to +10 °C +10.5 to +80 °C	1.00 °C 0.25 °C 0.50 °C	-40 to 12 °F -12 to +50 °F +51 to +176 °F	1.80 °F 0.45 °F 0.90 °F

Base Station 200 (Receive-only 4G Gateway)

Receiver RF sensitivity	-100 dBm, BNC connector	
Frequency Variants	869.525 MHz (ITU-1) 921.700 MHz (ITU-2) 920-925 MHz (FHSS)	Europe & selected other markets Americas, Australia, NZ & selected other markets Hong Kong, China
Operating Voltage	10-24 VDC, 500 mA In-built 2Wp solar panel and 20Wh Li-ion battery (3 days)	
Power Supply	100-240 VAC with 5 m (16'4") lead (included)	
Dimensions (L × W × H)	175 x 140 x 100 mm (6.9" x 5.5" x 3.9")	
Mounting	50 mm (2") pole mount / wall mount	
Data interface	4G modem with 3G/2G fallback, internal SIM-card for most regions	

A selection of Omni-directional / Directional antennas are compatible

Echo Repeater 200 (Packet Repeating Transmitter)

Receiver RF sensitivity	-100 dBm, BNC connector
Frequency Variants	869.525 MHz (ITU-1) Europe & selected other markets 921.700 MHz (ITU-2) Americas, Australia, NZ & selected other markets 920-925 MHz (FHSS) Hong Kong, China
Operating Voltage	10-24 VDC, 500 mA In-built 2Wp solar panel and 20Wh Li-ion battery (10 days)
Power Supply	Mains power supply available as accessory (same as for Base Station)
Dimensions (W × H × D)	175 × 140 × 100 mm (6.9" x 5.5" x 3.9")
Mounting	50 mm (2") pole mount / wall mount
Radio transmit power	27 dBm (500 mW) ERP, Bandwidth <250 kHz, duty cycle <0,1%
Transmit Range	10 km / 6-mile line-of-sight from Echo to Base / another Echo

Hills and buildings between radios will decrease range. Base Stations & Repeaters dynamically daisy chain.

Polar Night (Additional Battery Unit)

Operating Voltage	10-24 VDC, 500 mA
	Built-in 2Wp solar panel and 100Wh Li-ion battery
Output Voltage	7.4 VDC (nominal), 2A
Power Supply	Mains power supply available as accessory (same as for Base Station)
Dimensions (W × H × D)	175 × 140 × 100 mm (6.9" × 5.5" × 3.9")
Mounting	50 mm (2") pole mount / wall mount
Operating time extension	With Echo: 6-8 weeks, With Base: 2-3 weeks

Freezing and hot ambient temperatures will decrease operating time.

Soil Scout Hub (Online Monitoring and Analysis Service)

Connectivity	Web based HTTPS browser interface at https://soilscouts.fi
Preferred browsers	Chrome, Firefox, Safari
API	Query-type RESTful JSON API with JWT-based authentication
User Functionalities	User/Site/Preference management Hardware device management Real-time data view, History Graph view, Map view System alarms, Device grouping, Email alerts Historical data comparison tool Data download in CSV format
Server components	Google Cloud hosted Linux server in Finland Timescale database Nginx web server React frontend
Security	HTTPS protocol, user-specifically isolated data access
Backup	Obtained measurement data is never deleted Hosted server complete backup daily, stored for 30 days


SOIL SCOUT