Wireless Sensor Network for Measuring Soil Moisture

Sensor Installation Guide

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Subject to technical modifications.

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1 Introduction

The SoilNet wireless sensor network

SoilNet is a wireless network application which is based on the IEEE802.15.4 standard (Bogena et al., 2010). The radio module used for SoilNet is a ultra-low-power, low-cost wireless microcontroller JN5148 from Jennic Ltd. ,featuring a 32-bit RISC processor with up to 32 MIPs performance, and a fully compliant 2.4GHz IEEE802.15.4 transceiver.

To develop SoilNet applications the JenNet network protocol stack is used. JenNet supports star, tree and linear network topologies, and provides self-healing functionality for robust communication. The JN5148 radio module consists of several layers. The software interfaces link the hardware components (physical layer and peripherals) with the user application. The application support layer (APS) and the application programming interface (API) allow the user to control the sensor network and to handle the communication between the devices. In addition, the APS layer specifies what kind of device the hardware is (e.g. coordinator, router, or end device). The media access control layer (MAC) based on the IEEE 802.15.4 standard operates on top of the physical layer (PHY) and is responsible for the routing within the network. The PHY layer comprises not only the transceiver, but also the sensors and energy source.

Typically, SoilNet is composed of three different components (coordinator, router, sensor unit). The coordinator unit is the top of the network tree. It stores information about the network and provides a link to other networks. SoilNet uses the tree Each SoilNet network has a single coordinator. An important task of the coordinator is to initiate the wireless links within the network. The second type of device is the router, which acts as a relay station that passes data from other devices. The third type of device is the sensor unit, which communicates with its parent node (either the coordinator or a router). The sensor unit is in a non-active sleep modus for a significant amount of the time to save energy. Therefore a 3.6 V lithium battery can support a sensor unit for at least 60000 measurements. SoilNet supports automatic routing formation and restoration, adding and moving nodes and handshaking mechanisms to ensure unbroken data package transfers.

The 2.4GHz radio transmission frequency used for SoilNet determines to a large extend the transmission range between transmitter and receiver. The maximum distance between a sensor unit and at least one router is 1000 m (free sight conditions), whereas the maximum distance between two routers or between a router and a coordinator is 2000 m. In case of hybrid underground configuration with the sensor unit being buried

5 cm below the surface, the transmission range between a sensor unit and router decreases to max. 100 m (depending on soil water content; see also Bogena et al., 2009).

Specifications of the SoilNet components:

Sensor unit:

- A SoilNet sensor network can consist of up to 300 sensor units.
- Each sensor unit can host up to 9 SDI-12 sensors (e.g. to measure soil moisture, matrix potential, pressure etc.), 4 sensors with analog output signal, and one reed switch sensor (e.g. rain gauge).
- A real-time clock enables high precision measurement timing and synchronization.
- Measurement frequency of each sensor unit is individually configurable (from 3 minutes to 60 minutes). The frequency can be changes remotely at any time.
- Up to 3.8 Mio measurements can be stored on the onboard SD-Card
- The offline modus enables measurements without the need of a radio network

Router:

- A full automatic weather station (Viasala WXT520) and 2 digital temperature sensors can be connected.
- Solar panels are used for self-sustaining electrical power supply.
- A 12V battery buffer ensures electrical power supply for up to 3 months.

Coordinator:

- OpenVPN data link is used for transnational communication with a net control station.
- Solar panels are used for self-sustaining electrical power supply.
- 12V battery buffer ensures electrical power supply for up to 3 months

SoilNet software functions:

- Configuration of network parameter
- Visualization and processing of sensor data
- Data output routine for data analysis and data archiving
- Control of network connection quality
- Automatic messaging in case of critical value exceeding

Literature

Bogena, H.R., Herbst, M., Huisman, J.A., Rosenbaum, U., Weuthen, A., Vereecken, H. (2010): Potential of wireless sensor networks for measuring soil water content variability. Vadose Zone Journal, 9 (4): 1002-1013.

Bogena, H.R., Huisman, J.A., Meier, H., Rosenbaum, U., Weuthen, A. (2009): Hybrid wireless underground sensor networks: Quantification of signal attenuation in soil. Vadose Zone Journal, 8 (3): 755-761.

2 Installation

2.1 Borehole

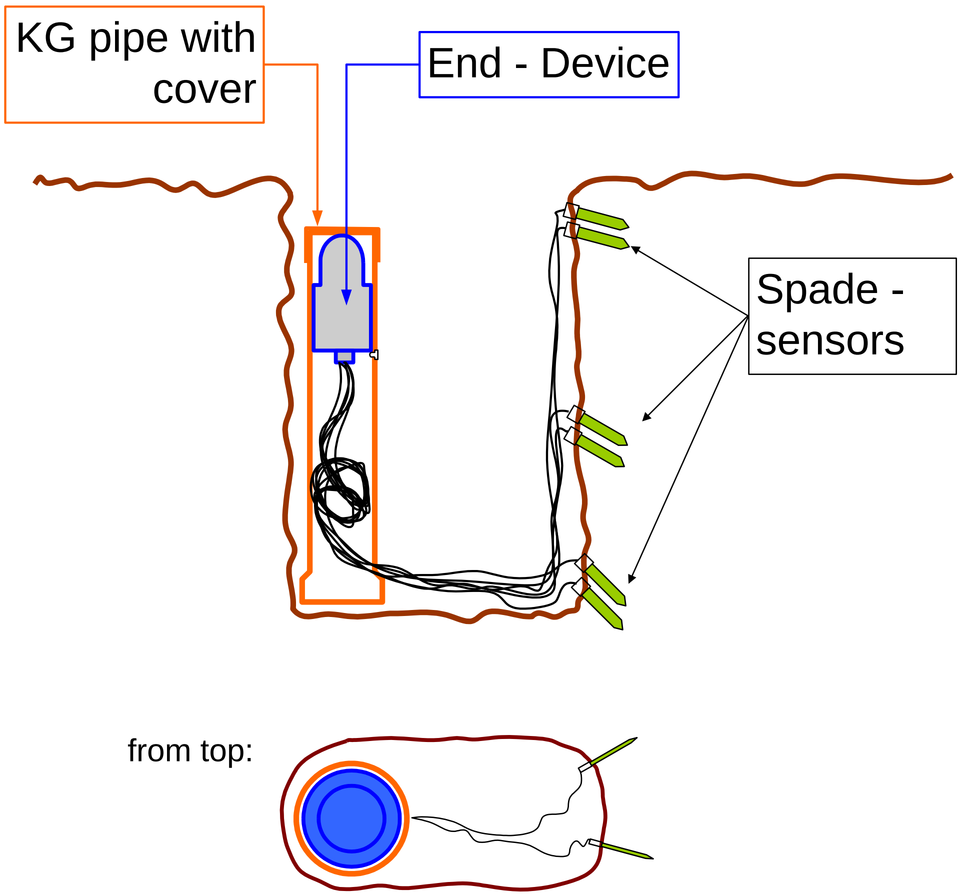

Figure 1: Schematic diagram of installation

To install the End-Devices and sensors in the soil, we suggest to drill an elongated hole which will contain the KG-pipe on one side and the sensors on the other side.

At the FZJ we are using a drilling machine, in order to drill two holes at a distance of 30cm, each with a radius of 30cm. After that, the soil between the holes has to be dug by hand (see figure 2).

The depth of the hole for the KG-pipe should be 62 - 65cm, the depth for the sensors will follow the installation depth you choose.

Figure 2: Drilling machine, digging the soil between the holes

The advantage of using such a drilling machine is to get two soil cores in plastic liner, one used for further investigations; the other is used to backfill the borehole in the end.

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Figure 3: Elongated hole from the top

In figure 3 one can see the right hole drilled a little bit deeper because the installation depth of the sensor is less deep than the length of the KG-pipe.

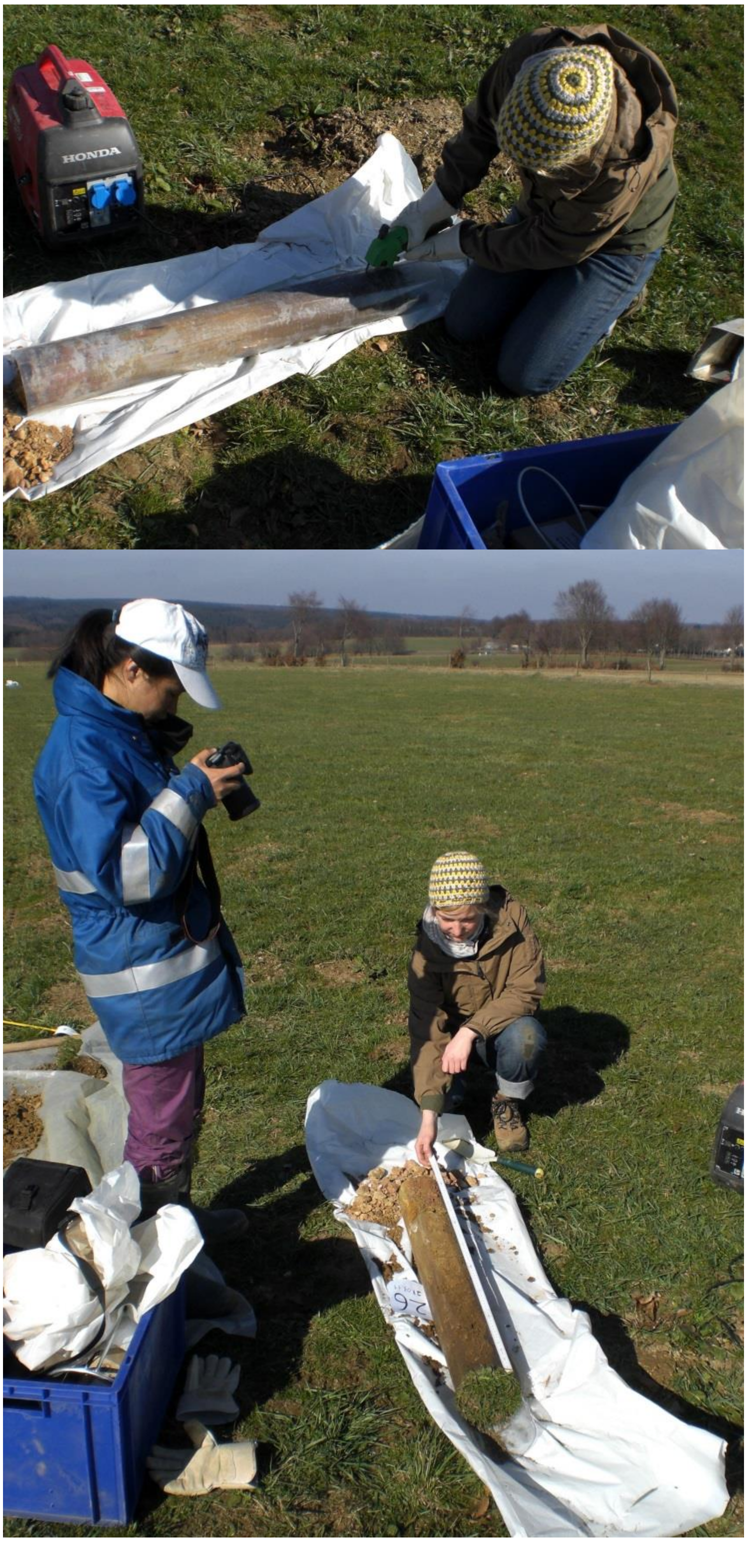


Figure 4: Measuring and taking pictures of the soil core

To document and subsequent evaluation the second liner will cut with an electric hand saw, measured and photographed.

3 Installing the sensors

3.1 Preparation

To install the sensors you need the following:

- End-Device with sensors
- KG-pipe with top cover
- Service-Unit
- Laptop (BoxCon Software)
- Installation tool
- rubber mallet

We highly recommend that the Coordinator, the Routers as well as the "Control Panel Application” (installed on a laptop) are to be in operation, before starting the installation of the End devices.

Otherwise you will get no validation that the connection of the End Devices with the network is correct.

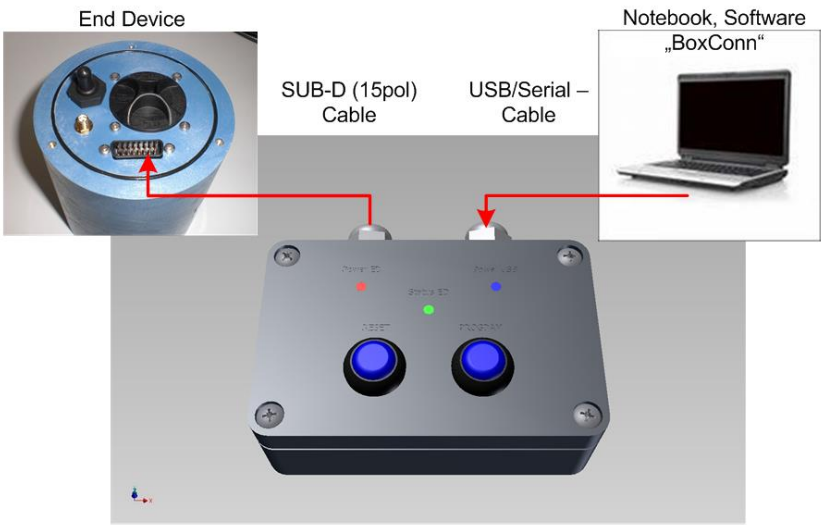
First, all sensors are put through the KG-pipe.

This is important to do first, because a holding nut (a cap nut) attached to the pipe will prevent the End-Device sliding down the pipe. Therefore the pipe cannot be pulled over the End-Device after installation.

Loosen the three screws and open the top cover of the End-Device. The screws can remain in the cylinder.

Please be careful with the removed cover: the cable of the antenna is very thin and sensitive.

Please connect the End-Device (**OFF**) and your Laptop using the Service-Unit.



(Run “BoxCon 1.0” Software). For details see SoilNet BoxCon 1 0_EN.pdf (Chapter 4)

Attention!

Between the cover and the cylinder there is a sealing ring which is lubricated with special grease. It's absolutely important that there is no dirt between cover and cylinder to ensure the full tightness of the housing.

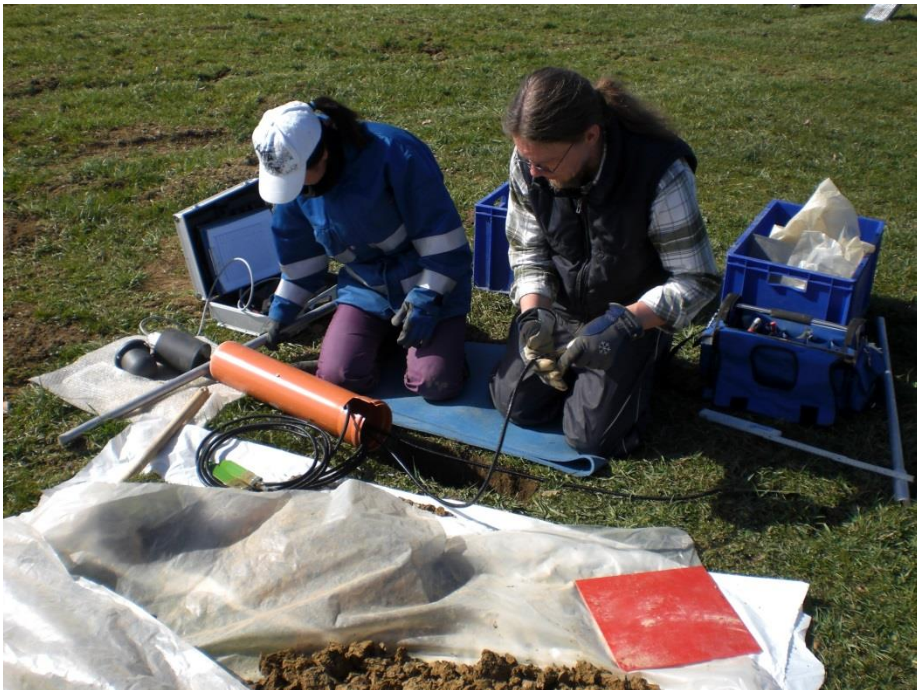


Figure 5: Preparation of installation

Switch on the End-Device to measure (or if it’s already on, push reset button on the service unit).

After 7 seconds you should see the following:

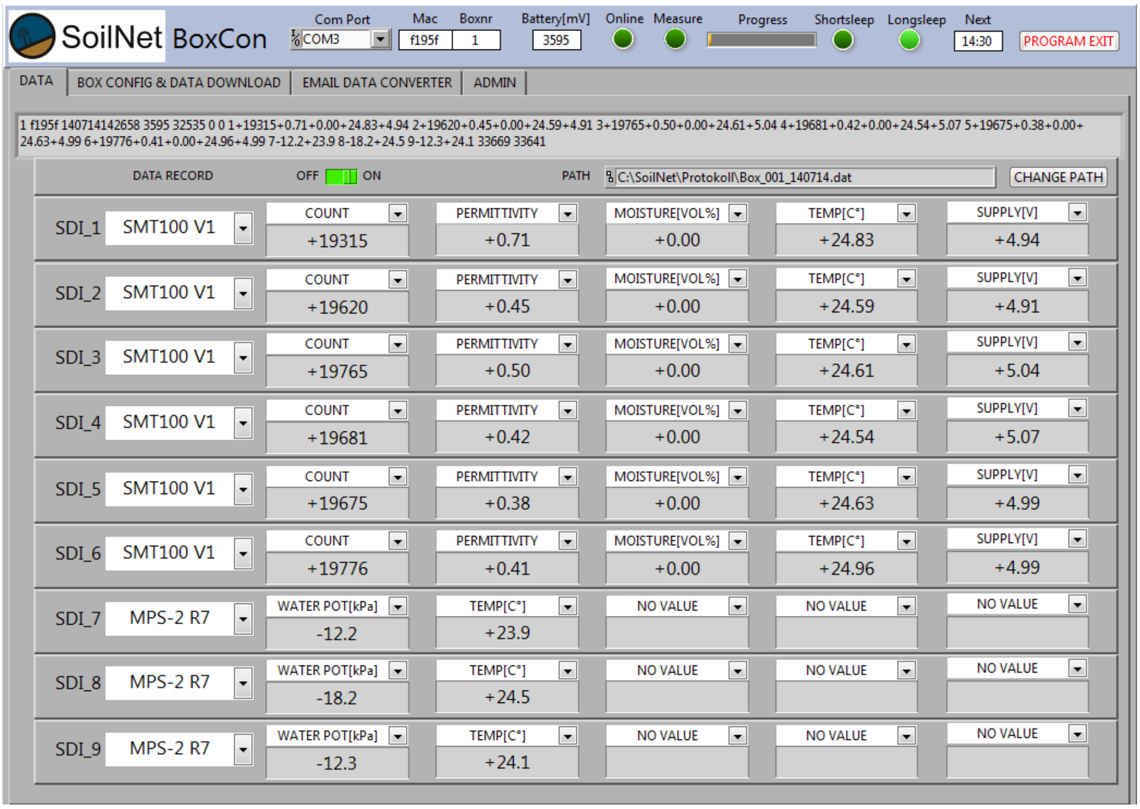


Figure 6: BoxCon, sensors not installed yet

Each row shows the measured values of one sensor: (Sdi-12 address 1-9)

- column 1 -> COUNT (Raw count value SMT100)
- column 2 -> PERMITTIVITY (dielectric permittivity Ɛa SMT100)
- column 3 -> MOISTURE(Vol%, TOPP,SMT100)
- column 4 -> TEMP(Temperature in Celsius,SMT100)
- column 5 -> SUPPLY(Sensor Power in Volt,SMT100)

Complete explanation for all shown values please read “SoilNet BoxCon Manual”, Chapter 3.

As long as the sensors aren't installed in the soil yet, all the values in percent should be 0,0.

3.2 Inserting the sensors

3.2.1 Inserting the sensors

The sensors are numbered consecutively (according to the numbers in the display). Using the installation tool the sensors will be driven into the soil. For this purpose, please place the sensor on the head of the tool.

Figure 7: Plugging on the sensor

Please note:
In the pictures you see older equipment to some extent. The colour of housings may have changed and the head of the installation tool has improved (see fig.8).

Figure 8: Actual sensor and installation tool

Because of the tight fit of the sensor in the head of the tool, it is very important to keep it clean.

Sensor and Installation tool then require to be conducted by a person, while a second person softly hit on the end of the tool with a rubber mallet. Do not use an iron hammer!

Figure 9: Inserting the sensor

Attention!

Although the sensors are very robust, they might be damaged for two mean reasons:

- **Bending the head of the sensor**
  There's great protection of the sensor by the installation tool. However, there is a risk bending the sensor head by inserting the sensor. Therefore one has to conduct the sensor with a firm grip.

- **Stones in the soil**
  If the sensor impinges upon a stone, it can be damaged. There could be some scratches on the side of the sensor, when touching slightly a stone, which doesn't affect the sensors function normally. But it may shatter the sensor also if hit a stone head-on.

So, both persons have to work carefully and with increased sensitivity. As soon as one person feels enhanced resistance, e.g. due to a stone, the sensor should be placed anew.

3.2.2 Verification of the data

After the sensor has been placed, the measured data will be verified with the BoxCon Software.

Please press the "reset" button (Service Unit) once to restart the measurement again.

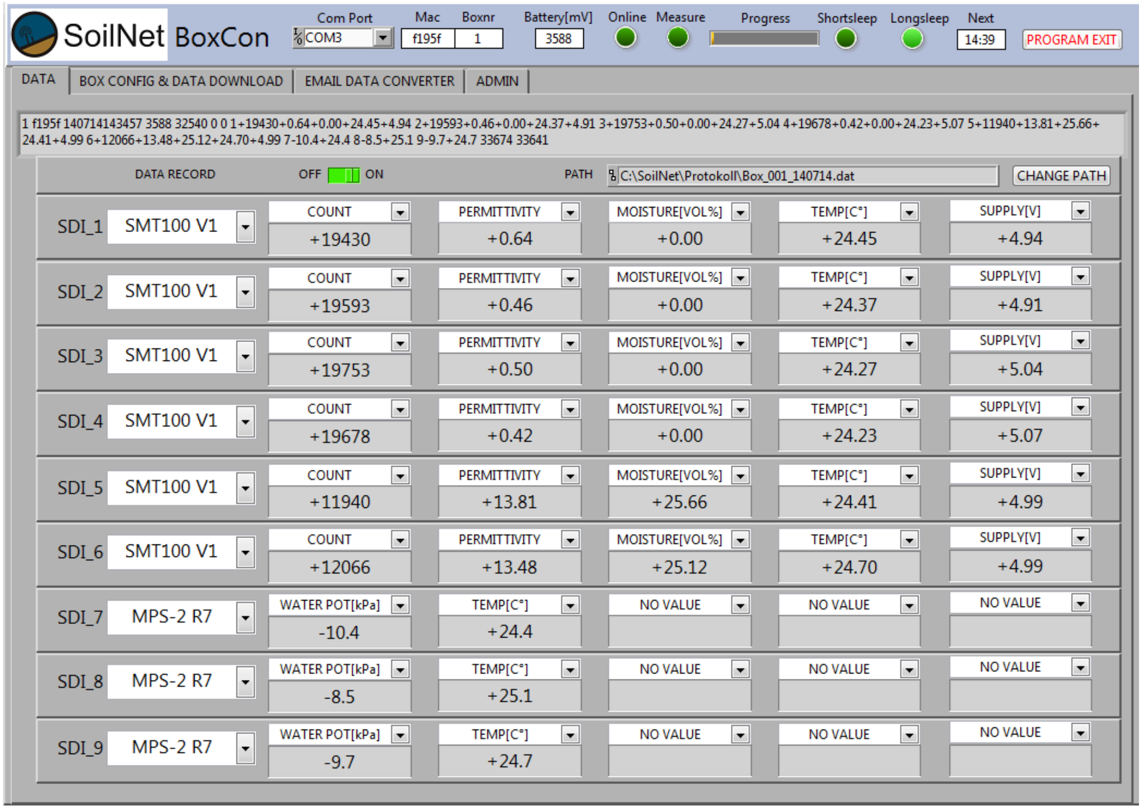


Figure 10: Verification of the data

In figure 10 you can see, that sensors 5 and 6 are placed, it shows values of 25,66% and 25,12%, while sensors 1-4 are showing 0%.

In our example two sensors have been installed in the same depth, so one can compare their values easily. If there should be a stone beside one sensor, or one sensor only has bad soil contact, one can see the effect of the sensor reading in the data display. Thus the sensor might have to be placed to a different position in order to receive correct soil moisture measurements.

The sensors should be inserted until the hand grip is reached. If you insert the hand grip as well, the soil around the sensor will be loosen and the contact with the soil might be disturbed.

In soft soils it might be possible to insert the sensors by hand..

Figure 11: Inserted sensors and backfilling

After the sensors have been inserted in the deepest layers and verified, they should be backfilled partially. Meanwhile you should measure again by pressing "Reset" because the values may change a little while backfilling.
Backfilling at the right time will prevent loosen the upper sensors by wobbling or pulling their cables.

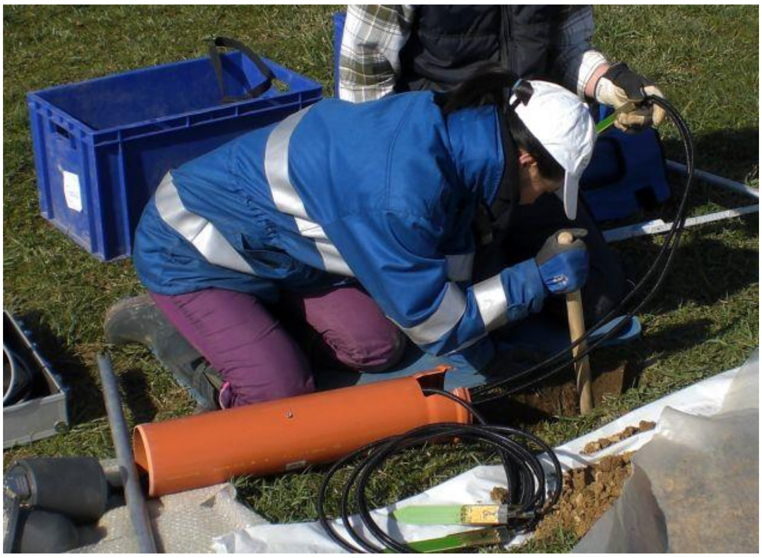


Figure 12: Backfilling of the sensors and compacting of the soil

With a wooden rod you can compact the soil. Please watch out not to touch the stuck out hand grips of the sensors.

Only when the KG pipe is installed, the borehole can be backfilled permanently.

3.2.3 Inserting the KG pipe

After all the sensors have been installed and verified, the KG pipe will be set into the hole. Therefore one has to pull out the cables carefully. Please be careful not to pull the sensors.

Figure 13: Inserting the KG pipe

The cables should not be too tight.

Figure 14: Cable guiding

3.2.4 Backfilling the borehole

During filling the borehole the Laptop should remain connected, so you can make further measurements to verify the sensor readings.

In close proximity to the sensors the soil around the sensors should be compact by hand, otherwise you can use the wooden rod carefully.

With a couple of little stones one can prevent the KG pipe to be pressed against the wall of the borehole, since otherwise you can not put on the cover in the end.

The KG pipe should end up to 3-4 cm below the soil surface.

Figure 15: Stones as spacer

3.2.5 Closing the End-Device

Is the backfilling almost finished, the cable of the service unit is removed from the End-Device and the antenna cover is screwed onto the Cylinder.

Please watch out the End-Device to be not switched off by the antenna cable when mounting the antenna cover.

Attention!

The O-ring of the antenna cover is lubricated with special grease to ensure the permanent full-tightness of the housing. Even after installation, especially when the case was open to the outdoors, make sure that the O-ring is well greased.

Figure 16: Lubricating the O-ring

When the housing is closed, the cables have to be "screwed" into the KG pipe, that is, the cable is pushed into the pipe spirally. It must be ensured that no cable obscures the retaining screw in the KG pipe, since the End-Device rests on it and is otherwise too high out.

Figure 17: "Screwing" the End-Device into the KG-pipe

The end-device must finish with the top of the KG pipe. After that, the pipe can be closed with the lid and the borehole can be closed completely.

Figure 18: Closing the borehole

The cover can easily be covered with soil. It is, however, by losses in wireless signal strength expected if too much soil or vegetation remains on the lid.