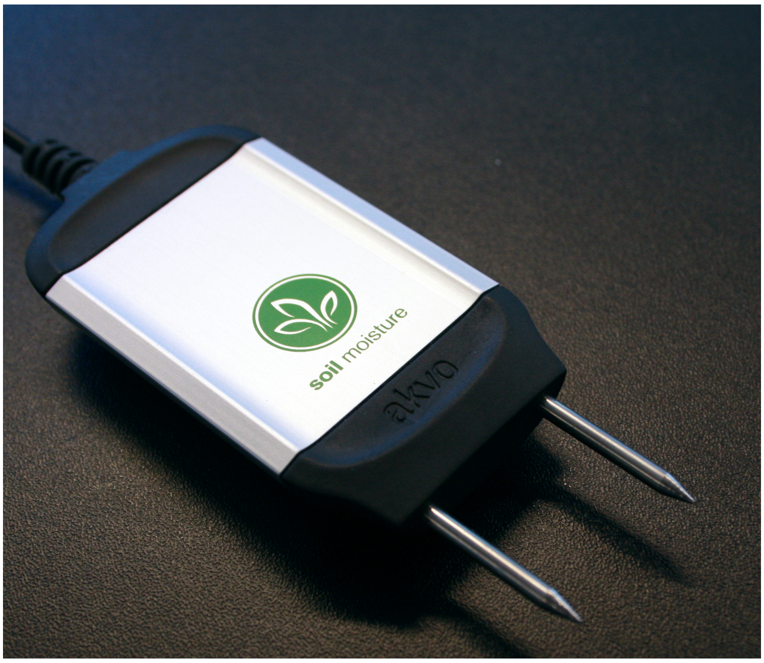
SODAQ

BUILDING A SUSTAINABLE INTERNET OF THINGS

SOM

USER MANUAL



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Chapter 1

Introduction

The purpose of the Soil Moisture (SOM) sensor is to provide an indication of whether there is sufficient water in the soil to grow specific crops. It measures the volumetric water content (VMC), in percentages, with a theoretic range of 0 -100%. In practice, most soils will not have a volumetric water content higher than 50%.

The sensor unit has two probes. One probe emits a radio wave with a frequency of 75Mhz, and the other probe measures the signal (in volts). Because the dielectric constant of soil is about 4 and the dielectric constant of water is 80, the dielectric permittivity and thus the capacitance between the probes highly depends on the soil water content. This is why the voltage on the second probe will vary with different water contents. The analog voltage is digitalized and converted into VMC by the SOM's software. To read the values, the sensor unit needs to be connected with a cable to a smartphone.

A mobile phone app (Akvo Caddisfly) is used to display the percentage of soil moisture.

Chapter 2

Specifications

Measurement time	Continuous
Accuracy	±10% max. VWC error
Power supply	micro-USB
Power consumption	40mA at 5V USB power
Low power mode	Available, 30mA at 5V USB power, possible in software
Output	Digital, USB
Operating temperature	-10°C to 60°C
Measurement range	0-100 % VWC (Volumetric Water Content)
Time to first measurement	5-15 seconds (depending on soil VWC)
Interface	PC, smartphone
Supported smartphones	Any smartphone with USB On-The-Go (OTG) Host support
Casing	Aluminum, polyurethane, 316 stainless steel probes, waterproof

Chapter 3

Using the device

For the soil moisture sensor, the user can plug in the sensor to the USB port of the smartphone and start the Caddisfly App. You can obtain the application by downloading it from the Google Play Store (listed as Akvo Caddisfly).

3.1 Setting up

3.1.1 Soil

As the SOM measures VWC, the measurement accuracy depends largely on how uniformly the water droplets are distributed throughout the soil. This means that unevenness in soil compression, air bubbles, roots and rocks all have a direct effect on the readout of the sensor. Therefore, the user should insert the sensor in uniform soil, with the soil compression as uniform as possible. Any air gaps should be avoided, or at least they should be uniform throughout the sensor's measurement volume. This measurement volume is estimated to be about 220 ml, shaped as a cylinder around the transmitting probe, the height of the cylinder slightly longer than the probes. When the soil is wet, it takes up to 15 seconds for the sensor to reach a steady state VWC value. In dry soils, this is about 5 seconds.

3.1.2 Placing and removing the sensor

Figure 3.1: Advised positioning of the SOM

The sensor should be put with care into the soil, as the stainless steel probes are connected directly to the PCB inside. The advised sensor position is shown in figure 3.1: the probes are fully inserted in the soil. It is best to install the sensor vertically. During the lab test, the sensor had less than 0.5 % deviation when the angle at which the probes enter the soil was varied.

Make sure that the aluminium casing is not inserted in or touching the soil. Also, do not touch the sensor while taking measurements. This will influence the values of the measurement.

When removing the sensor from the soil, **do not remove the sensor from the soil by pulling the cable.** Remove the sensor by grabbing the aluminum casing.

3.2 Using

- To measure the moisture content of the soil, the probes of the sensor have to be pushed in the soil
- Click 'read' in the app. The display on the smartphone provides the value of the moisture in % immediately, nevertheless the operator should wait until the output reading stabilizes
- The soil moisture value is read, stored to the memory and sent to the database
- After the measurement the unit is removed from the soil
- The unit has to be cleaned, preferably with water and dried with a clean cloth

3.3 Further calibration

As there can be a significant variation in the mineral and organic composition of the soil, the sensor can be calibrated to a specific soil type. See Appendix B.

Appendix A

Settings and Debugging

A.1 Installing the Arduino IDE and drivers

Info on www.support.sodaq.com

1. Download the Arduino IDE https://www.arduino.cc/en/Main/Software
2. Install the Arduino IDE and start it
3. Click on File → Preferences and at the bottom you should see 'Additional Boards Manager URLs'. This is where you need to paste the following URL: http://downloads.sodaq.net/test/package_sodaq_index.json
4. When you have pasted the URL, click 'OK' and you are ready for the next step.
5. Click on Tools → Board → Boards Manager
6. Scroll all the way to the bottom, you should see SODAQ SAMD Boards. Click on it, and install the latest version.

Now it is possible to use the built in serial monitor of the Arduino IDE (Tools > Serial Monitor) or use a different serial monitior i.e. PuTTY.

A.2 Programming the sensor

The micro-USB connector that sends the data to the smartphone or the computer, is also used to program new software on the microcontroller of the sensor.
After downloading the SODAQ board files (info on `www.support.sodaq.com`), the sensor can be updated to the latest software. For connecting the micro-USB to a computer, a micro-USB female to male USB converter is needed. The sensors are programmed by the manufacturer with the latest software, but is otherwise fully open source to the buyers.

Figure A.1: Programming the SOM with the adapter

A.3 Menu

The sensors come pre-programmed and pre-calibrated. The following commands can be used with a computer to get different values from the device or whenever necessary recalibrate or change certain values.

COMMAND	**RESPONSE/KEY**
STATUS	”OK”
DEVICE	Identifier ID (e.g. ”Soil Moisture 44”)
READING	VWC %
R (same like reading, for compatibility with older versions)	VWC %,
RAW	Voltage
GET <KEY>	The value of KEY or NOT_SUPPORTED SOM KEY options: ”POINTS” ”DRYPOINT” ”WETPOINT” ”ID”
SET <KEY> ”VALUE”	SOM set KEY options: ”DRYPOINT” ”WETPOINT” ”ID”
PROCESS	SOM Calibration process Instructions in the terminal

Appendix B

Calibration

B.1 Introduction

The SOM's are factory-calibrated. In this condition, they have an accuracy of 90%. When the user wants a better accuracy, the sensor can be calibrated to a specific soil type. Using professional equipment, the team of SODAQ verified that the voltage output of the SOM can be approximated with a linear equation. However, this equation is different for different soil types, so the calibration procedure will be about determining this equation. In soils with high organic matter, this equation may be quadratic, but this is again soil-specific.

B.2 Preparing the soil

For calibration of the sensor, some care should be taken to get uniform soil. Take a representative soil sample and heat it at 110 °C for at least 24 hours. This procedure will dry out any soil to 0% VWC. When it comes out of the oven, it might be best to sieve the soil to remove larger soil particles or small rocks. This avoids possible measurement errors, caused by air bubbles.

B.3 Equations to derive the VWC

According to lab tests, the voltage on the probes $V(x)$ can be approximated by a linear equation

$$V(x) = ax + b \tag{B.1}$$

with x the added water content. This equation holds for different VWC's on the linear line from 0 to 50% VWC, at that point most soils will be fully saturated. The equation will be used in this form for calibrating, for determining x again (added water - VWC) the equation is rewritten as:

$$x = \frac{V(x) - b}{a} \tag{B.2}$$

a and b are the factors that will be found by the calibration. Please note that x is the added water and is linked to VWC by

$$VWC = \frac{V_{water}}{V_{soil+water}} \times 100\% \tag{B.3}$$

So from equation B.1, the present water volume in the soil can be found, while the VWC can be found from equation B.3. If enough volume of soil is around the sensor in the lab calibration test, this will be representative for the final soil. This volume is estimated to be about 300 mL.

For every sensor, this equation, the calibration equation, can be obtained. If this equation is inserted in the sensor's software, a calibrated VWC will be outputted by the sensor.

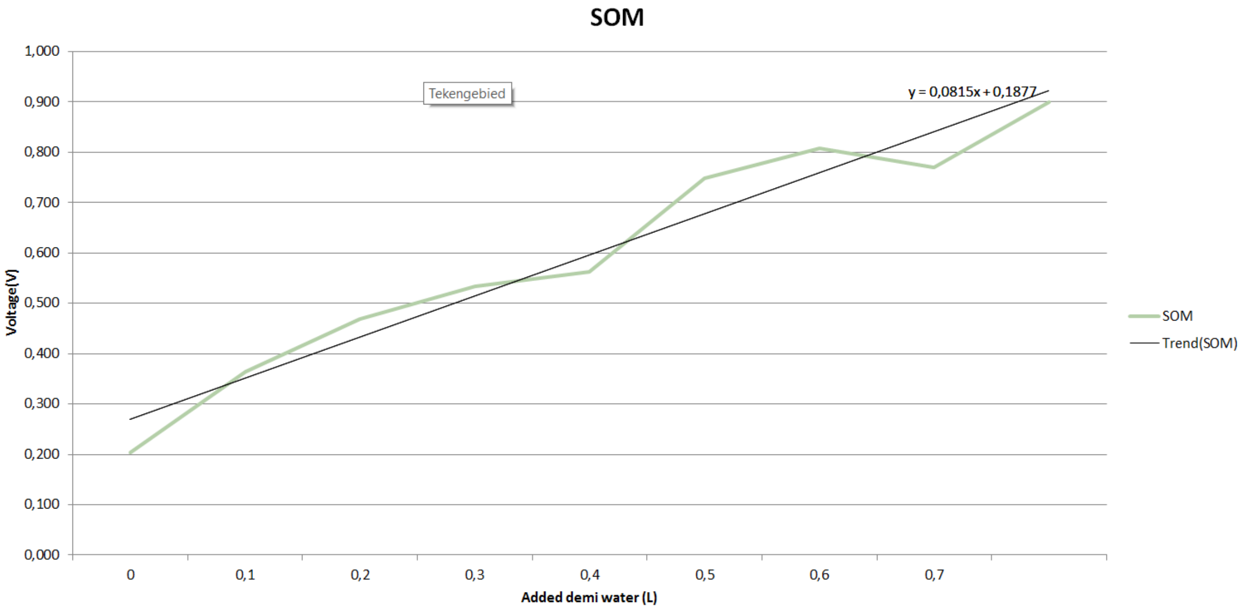

Figure B.1: Plot of a lab test with the trendline drawn in the same graph.

B.4 Simple calibration procedure

During a lab sample, in which 5 SOMs were tested, the slope of the three lines (a in equation B.1) appeared to be 0.0014, while the overall voltage-to-added water response was very linear. Because the added water-to-VWC relation is not linear (see equation B.3, the voltage-to-VWC function is also not linear. SOM1 has a very linear measurement curve, so when that one is taken to visualize the voltage-to-VWC relation, figure B.2 is obtained. The polynomial regression curve is also plotted, and it can be seen that the curve has at least the order 2. As can be seen from the 5 SOM1 curves, the dry-soil voltage is varying more than 30 %, while the slope a of the measurements is varying roughly by 16 %. If the dry soil voltage is measured, the first inaccuracy is already out of the way. To remove the slope error, a second calibration point at a known VWC should be obtained.

This second point should be relatively far away from the dry-soil point to reduce the leftover error. During the lab test, it was noticed that, when the soil approached saturation, the soil became so wet that the sensor could move free around in the soil, affecting the reading a lot. In order to have a stable measurement point, it is advised to choose the second point at a point where the soil is still sturdy enough to keep the sensor in a fixed position.
With this information in mind, the following simple calibration method can be used:

1. Oven-dry 2 litres of soil for 24 hours at 105 °C.
2. Put 1 litre of soil in 2 equal boxes. The box should be such that there is 10 cm of soil next to and under the probes.
3. Add 300 mL of demineralized water to the second box and mix as good as possible with the soil.
4. type 'process' and follow the instructions on the serial monitor.
5. The sensor is ready to use.

This simple calibration method is implemented in the standard software that is delivered by the manufacturer(SODAQ). It is activated by sending `process` to the serial monitor. The user should follow the instructions to sucessfully complete the calibration. If i.e. a different second calibration point is needed, the values can be changed in software.

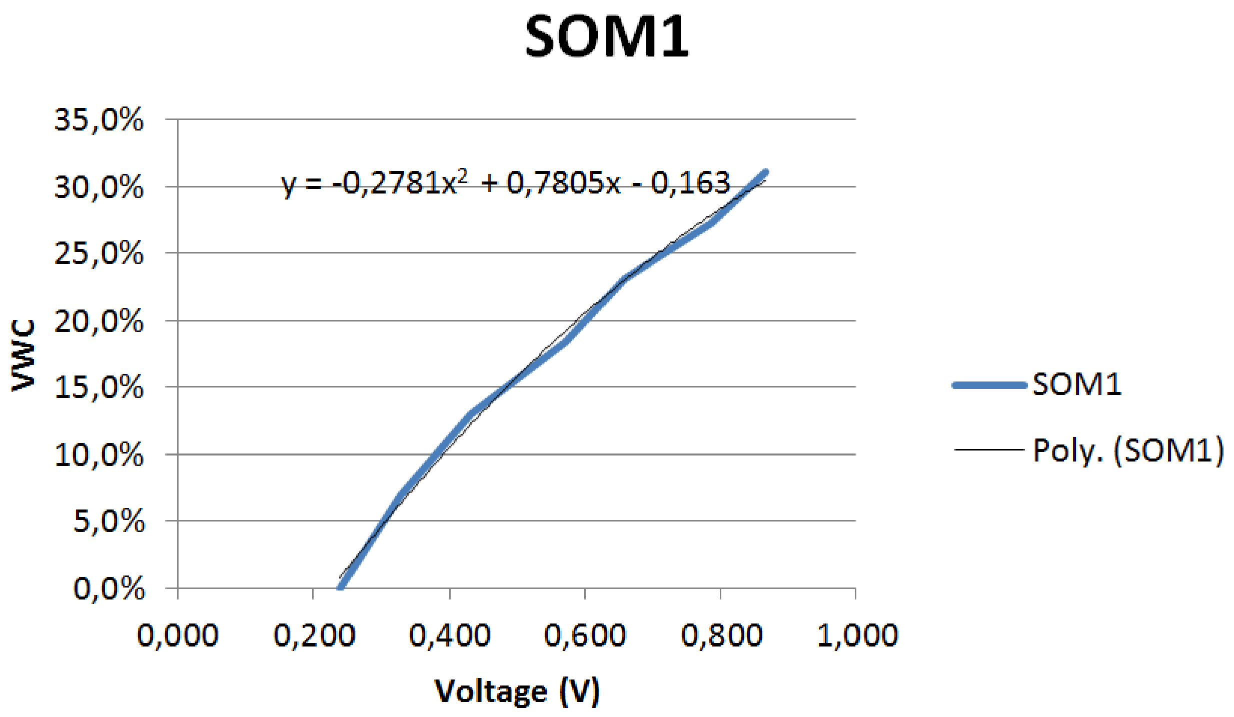

Figure B.2: Plot of SOM1 in 1 litre soil, relating voltage to VWC

B.5 Advanced calibration procedure

Sometimes, it is difficult to mix the soil and water very good, for example when certain equipment is missing. In that case, the second point from section B.4 could have a significant offset, causing a slope error. Because all values are derived from this slope, the slope error will grow very large at large voltages. To compensate for bad mixing or bad equipement or when a high precision is needed, more measurement points can be taken and a trend line can be drawn in Excel. This is exactly what has been done for this report. The effect can be seen in figure C.2 and C.4, where clearly some measurement values have an error, but still a reasonable slope is obtained. To get the curve, it is advised to get 5 or more measurement points untill the soil is fully saturated. The tested soil in the lab was fully saturated at approximately 40 % VWC, which comes down to 400 mL added to 1 litre of soil. The description will use a 7 datapoints measurement. To calibrate using the advanced procedure, proceed with the following steps:

1. Oven-dry 7 litres of soil for 24 hours at 105 °C.
2. Put 1 litre of soil in every box
3. Add 75 mL demineralized water to the second box, 150 mL to the third box and add for every new box 75 mL more. Make sure it is mixed well and avoid air bubbles.
4. Type 'raw' in the serial monitor to read the probe voltage
5. Read the probe voltage for every box and list it next to 'added mL' in Excel or another sheet program
6. Create a scatter chart from the obtained values. The trend line gives the slope of the curve.
7. Write the new obtained values to the software and reprogram the sensor.

B.6 Conclusion

Both calibration procedure -when the soil is well-mixed- allow the user to calibrate the sensor for every any soil type. However, this means that after calibration, the sensor does work only for that soil type. Further research is needed to quantify the differences between all different existing soil types to calibrate the sensor for any soil type in one simple soil type that can be bought anywhere.

Appendix C

Calibration graphs

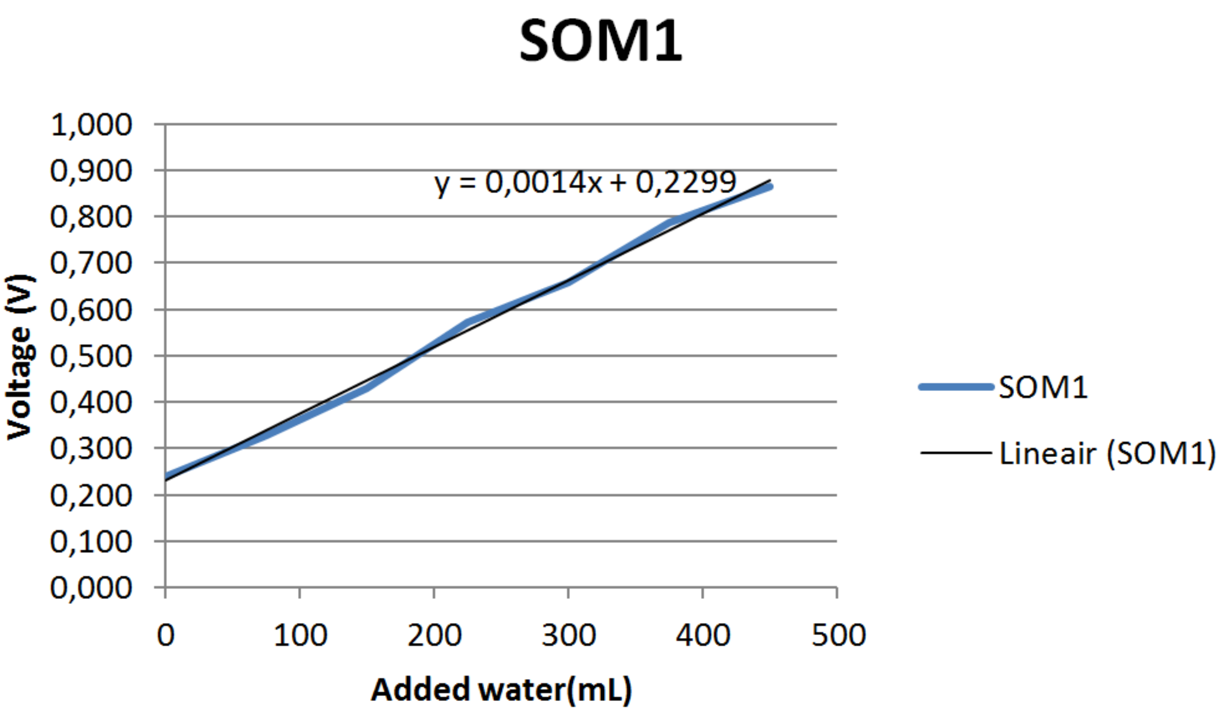

Figure C.1: Plot of SOM1 in 1 litre soil

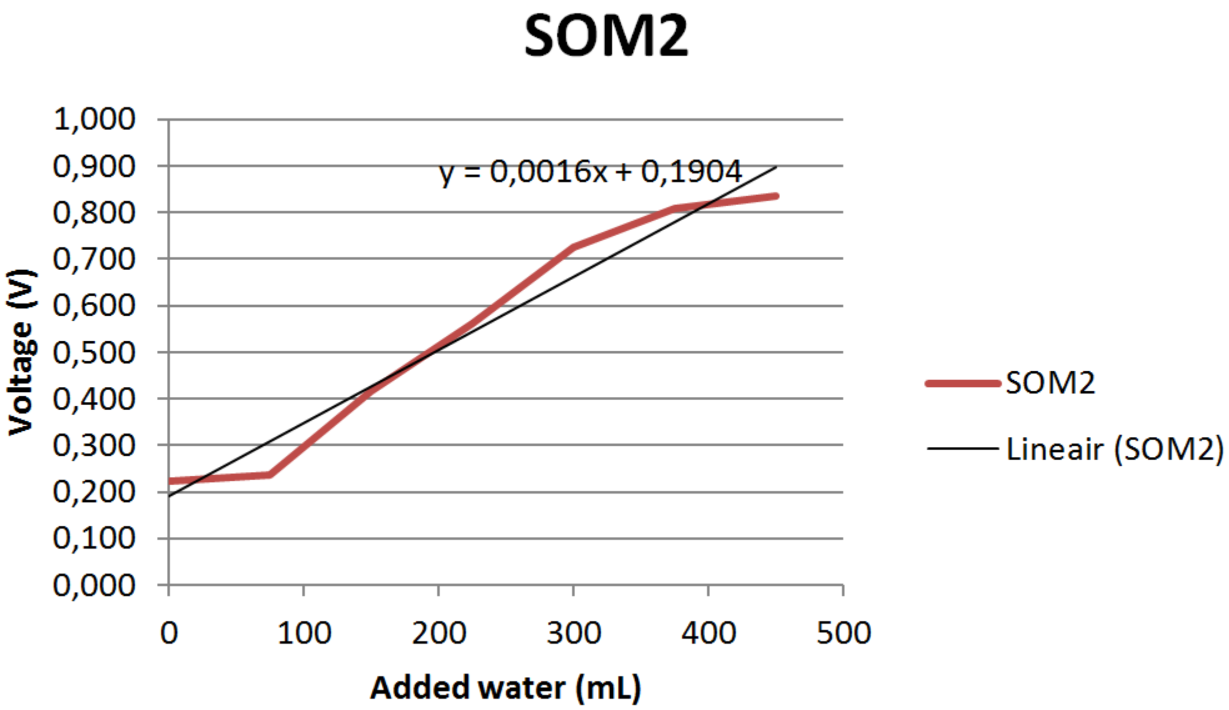

Figure C.2: Plot of SOM2 in 1 litre soil

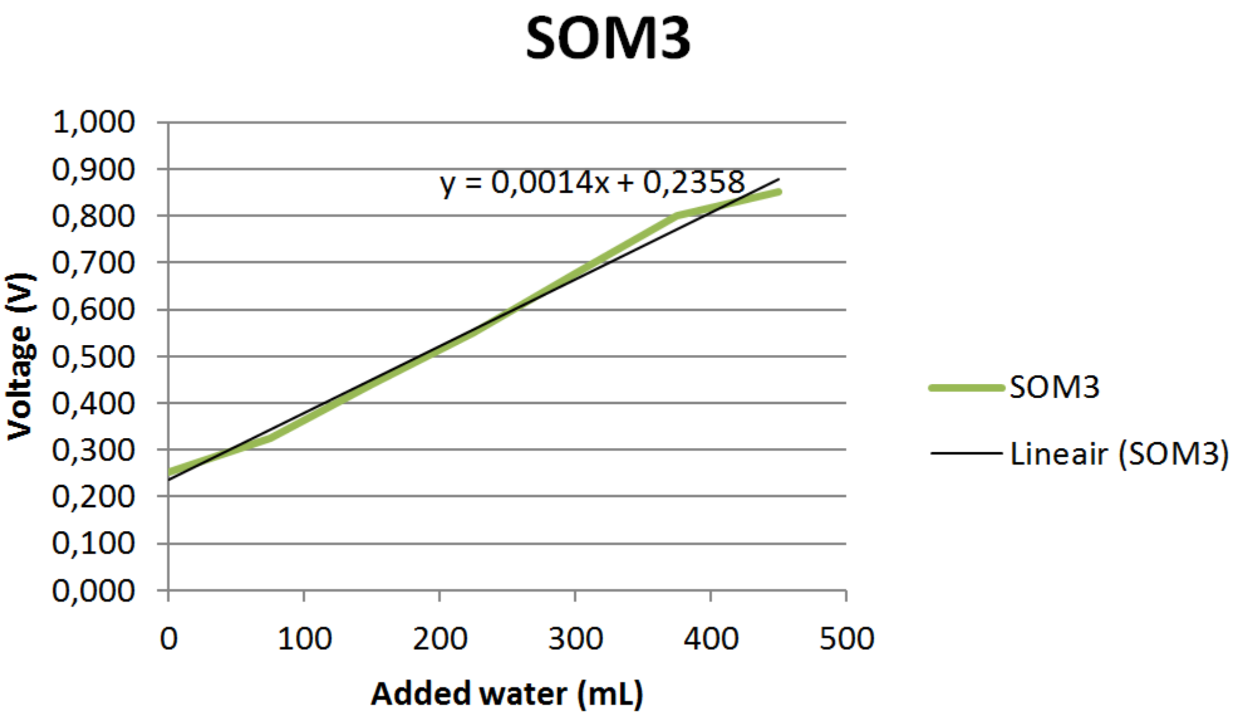

Figure C.3: Plot of SOM3 in 1 litre soil

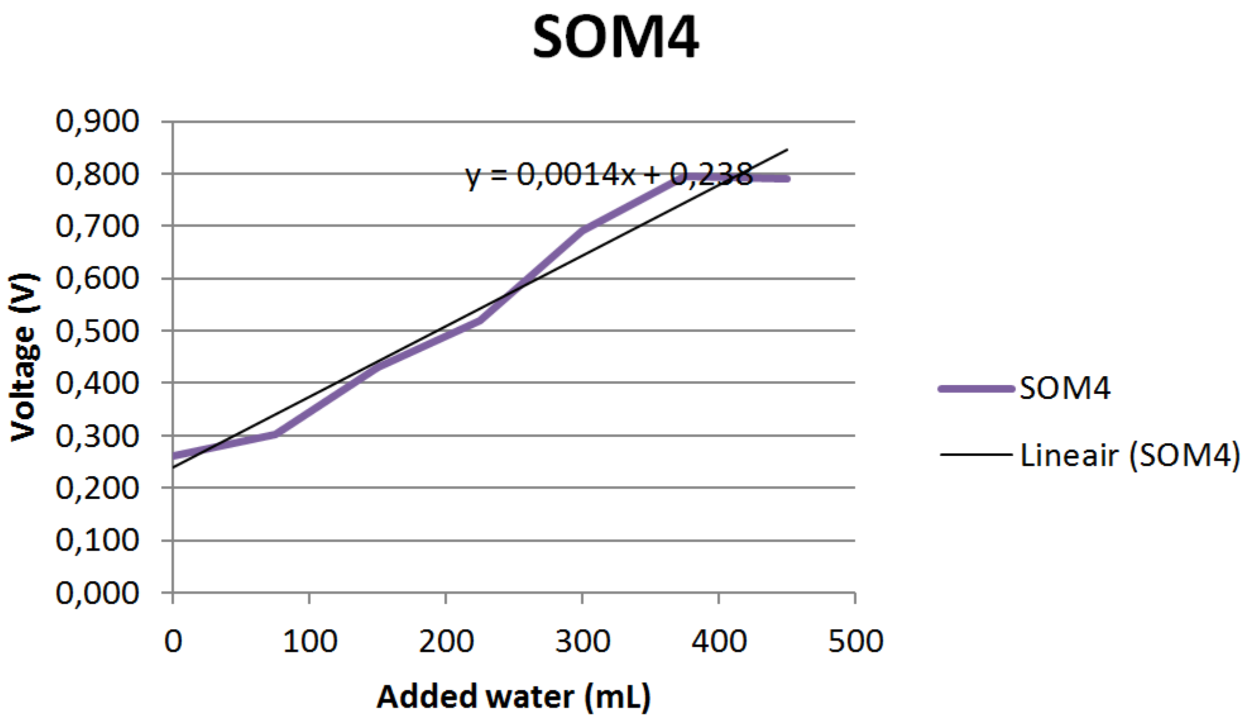

Figure C.4: Plot of SOM4 in 1 litre soil

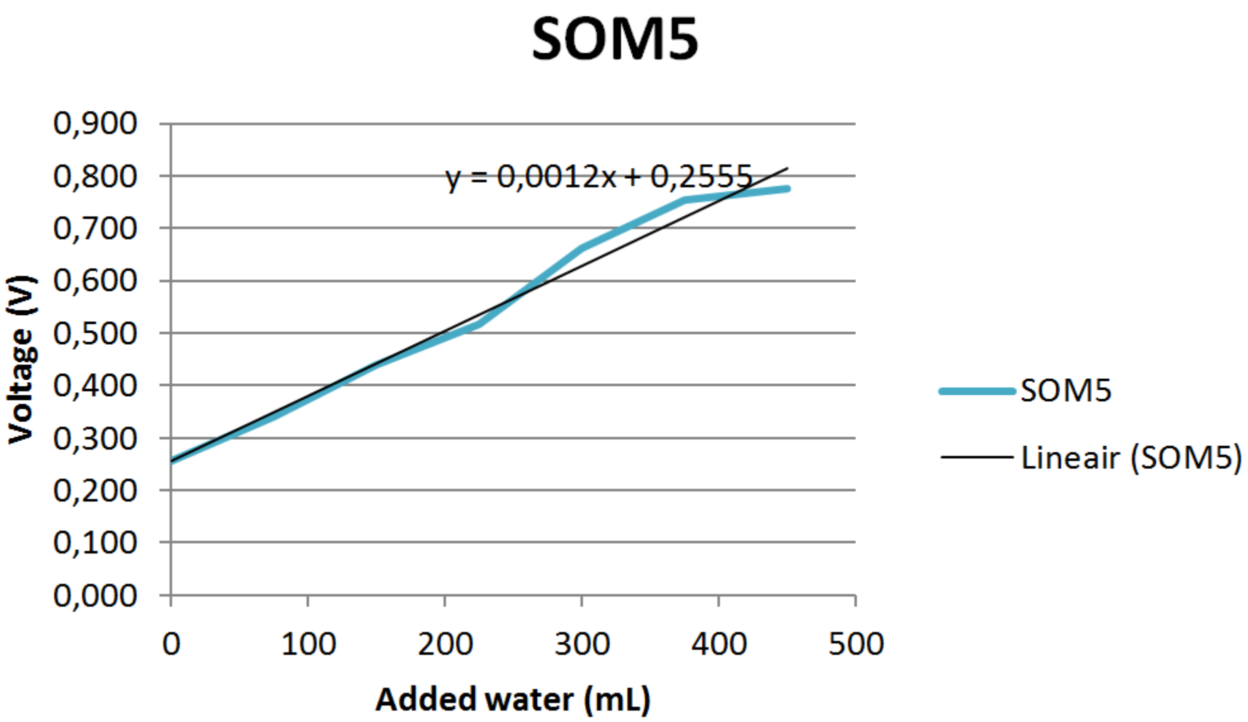

Figure C.5: Plot of SOM5 in 1 litre soil

Appendix D

Validation

To validate the design and calibration of Soil moisture meters, GS3 by Decagon, a commercially available and widely used combined EC/soil moisture sensor was used.

The sensors were tested in a water-soil mixture. This water-soil mixture was created by adding 300mL of tap-water to 1L of dried soil. This mixture is then mixed for approximately 15 minutes to ensure the soil is completely mixed with the tap-water. After this the soil is pressed to be as compact as possible. This way the minimum of air is left inside the mixture.

Sensor	Soil (%)
Decagon GS3	34
SOM1	38
SOM2	34
SOM3	31

Figure D.1: Comparison Decagon GS3 and SOM sensors

The table above shows the results of the measurement with multiple Soil Moisture sensors compared to the Decagon GS3. With each sensor 5 readings were taken to have the average Soil Moisture percentage. This shows that the Soil Moisture sensors are within the accuracy range of the sensor.

The readings of the SODAQ sensors are consistent and within 12% of the reference value. As soil is impossible to get absolutely homogeneous, a deviation in the moisture reading is expected.