Intelligent Irrigation System for Low-cost Autonomous Water Control in Small-scale Agriculture

Deliverable D1.4a

First report on test and validation in controlled agriculture environments

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Executive Summary

Deliverable D1.4a describes why sensor accuracy and calibration is important for the project. Moreover, it describes the testing environment as well as the infrastructure available at the Agricultural University of Athens (AUA) that can be used to study the calibration and accuracy of INTEL-IRIS sensing platform. In addition, a preliminary accuracy testing is also included.

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1. Introduction

Optimal greenhouse microclimate condition allows the grower to achieve better crop growth, better quality, and the lengthening of the production season (Vox et al., 2014). In addition, crop growth is basically determined by the climate variables in the environment and by the amounts of water and fertilizers that can be supplied by irrigation. Therefore, crop growth can be managed by controlling these variables (Cañadas et al., 2017).

The goal of the INTEL-IRRIS project is to propose low cost but highly efficient water systems for irrigation optimization. To achieve this, hydrological monitoring is essential. Hydrological monitoring is recognized as one of the most important factors in hydrology and flood risk management (Segovia-Cardozo et al., 2021). Traditional monitoring strategies to gather hydrological data are difficult to use due to their high costs. However, in recent years a new generation of low-cost sensors for hydrological monitoring, logging and transition has shown promising potential (Hund et al., 2016, Hubbart et al., 2005, Zhang et al., 2017). According to Paul and Buytaert (2018), such sensors can be used for extended smart monitoring networks and improved data coverage. In INTEL-IRRIS project tensiometers as well as capacitive sensors are used to provide these data.

Tensiometers can be used to determine soil moisture tension for a soil between approximate field capacity and some minimum available moisture. However, unless a supplemental method of estimating soil moisture is also used, you must make daily observations. The simplest method available at this time operates in a manner like your bank account in that moisture withdrawals are subtracted, and moisture deposits added. The current balance is the item of concern, and when it drops below a specified minimum, you know it is time to make a deposit (i.e., irrigate). The checkbook procedure can be used to determine how much water to apply while the tensiometers are used to tell you when to irrigate. This method also allows an additional calculation for predicting the date when future deposits are required to maintain a minimum deposit. This accounting procedure must be updated daily to ensure that the soil moisture content will not drop below the desired minimum balance.

The capacitive sensor introduced from DFRobot is a new type of waterproof soil moisture sensor. Compared with the previous version of the soil moisture sensor, it has increased waterproof performance, optimized corrosion resistance, increased plate length and optimized circuit performance. Compared with the resistive sensor, the capacitive soil moisture sensor solves the problem that the resistive sensor is easily corroded and can be inserted into the soil for a long time without being corroded. The sensor has increased waterproof performance, and the sensor can still be used normally after being immersed in water; the length of the capacitive electrode plate is increased, and the soil moisture information can be measured more accurately. The sensor has a wide input voltage and can work in a wide voltage range of 3.3V-5.5V. Compatible with Arduino, ESP32, micro: bit, control board, Raspberry Pi, and other common control boards. The standard designed DFRobot-Gravity interface can be directly connected to the Gravity IO expansion board. A micro-PC such as a Raspberry Pi requires an external ADC (analog signal to digital signal) module to work. Since this sensor will detect soil moisture based on the principle of capacitive sensing, it will show different humidity when placed in different soil moisture, different tightness, and different insertion depth. Even in the same place and at the same depth, when the second insertion is made, since the first extraction has caused loosening of the soil, the humidity may be lower than the first reading.

2. AUA INFRASTRUCTURE AND SENSOR CALIBRATION & ACCURACY

2.1 Importance of calibration

Sensors are electronic devices, sensitive to environmental changes. Extreme and sudden changes to these environmental conditions can give output values which differentiate them from the measured output. The comparison and correction of these values is called sensor calibration. It is an important procedure as it increases the performance and reliability of the sensor. The calibration process increases the performance and functionality of the system as it helps to reduce its errors. A well calibrated sensor provides more accurate results. Sensors, among other measuring systems, are calibrated to check their accuracy and repeatability. In order to have precise, consistent, and repeatable measurement outputs it is necessary to have calibrated sensors. Each sensor type has a specific measurement range and accuracy and different strengths and weaknesses. Even the most sensitive and precise measurement system or equipment can lose accuracy due to environmental exposure, aging, and usage. Therefore, sensor calibration is crucial.

2.2 Importance of accuracy

Accuracy describes how close an indicated value represents the actual measured value being monitored, while considering all possible sources of error that are relevant. Accuracy is specified in terms of inaccuracy or error. In addition, according to Soulis et al. (2015), accuracy is an important factor affecting the efficiency of soil moisture sensor-based irrigation scheduling systems. Moreover, accurate determination of soil moisture can be helpful on surface evapotranspiration and crop yield estimation (Li et al., 2022).

Approaches for measuring soil moisture content mainly refer to ground observation methods. These methods are more accurate, but they are not cost-effective and are difficult to use on large crops (Seneviratne et al., 2010). According to Li et al. (2022), ground observation is important because of its high accuracy as the respective results are used to validate and calibrate remote-sensing and data-assimilation-based soil moisture content measurements. At the same study Li et al., (2022) describe three ground observation approaches:

(1) gravimetric measurements, which destroy the original soil structure and thus preclude continuous monitoring of soil moisture content at the same location,
(2) measurements using hand-held devices, which facilitates verification on the soil surface but makes it difficult to measure soil moisture content at multiple depths, and
(3) automatic observation stations, which are suitable for continuous monitoring at multiple depths.

2.3 AUA infrastructure

Agricultural University of Athens (AUA) is one the most historical universities in Greece. It was founded in 1920 and since then has offered high quality studies in the agricultural field. The campus is located in the city of Athens and includes an area of 250 acres. There are 28 building complexes with 42 well equipped laboratories for research and educational purposes.

The Laboratory of Farm Structures is under the Department of Natural Resources Development and Agricultural Engineering which belongs to the School of Environment and Agricultural Engineering. The Laboratory covers the area of research and provision of knowledge concerning the:

1. Engineering background
    - Technical drawing
    - Statics – Strength of Materials
    - Transport Phenomena
    - Agricultural buildings – building physics
    - Computational and applied mechanics
    - Soil mechanics
    - Surveying

2. Design, planning, operation, optimization, and environmental impact of various agricultural enterprises (poultry houses, greenhouses, aquacultural plants etc.) and generally technical projects concerning rural infrastructure

3. Development of artificial environment for plant growth and production (greenhouses, hydroponics etc.) implementing advanced technologies

Moreover, the laboratory has a full-scale hydroponic greenhouse with controlled climate, a fully irrigated experimental agricultural area as well as a well-equipped chemical laboratory for soil parameters analysis. In addition, the laboratory is equipped with all kinds of technological equipment necessary to perform soil measurements, data collection, and measurements such as sensors and data loggers. A few of them are listed below:

- Sensors:
    - CS616-LC, Water Content Reflectometer
    - THERMOCOUPLES Chromium-Vanadium for temperature measurements
    - Temp/Hum rotronic digital/analog sensors
    - UV/TOTAL SOLAR RADIATION Measurement CUV3
    - PAR sensor
    - HotWire Anemometer / windspeed, direction, gust ATMOS44 Series
- Data loggers:
    - Zentra data logger (cloud based)
    - Campbell CR800 series
    - Campbell CR10X

3. First small scale test

3.1 Understanding the INTEL-IRIS sensor

Next to the sensor (SEN0308) developed for the INTEL-IRRIS project (picture 1) a water content reflectometer (CS616) sensor (picture 2) from Campell Scientific was used.

Figure 1: SEN0308 on tomato plants (*Solanum lycopersicum*)

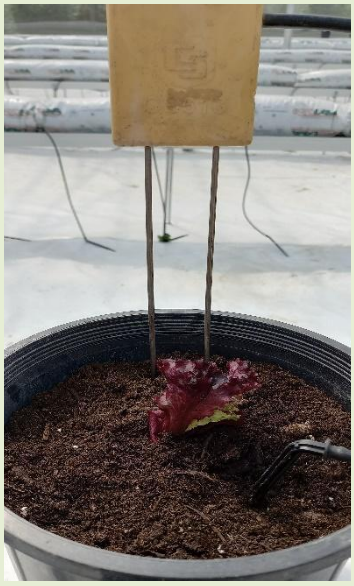

Figure 2: CS616 on red lola (*Lactuva sativa*)

To better understand the function of the sensors, air measurements as well as water measurements were taken (charts 1 & 2).

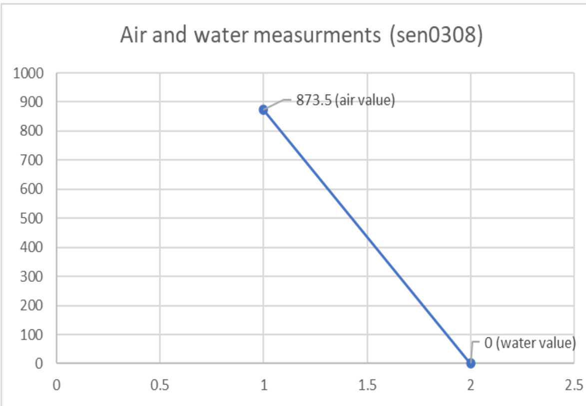

Chart 1: Air and water measurements from sen0308

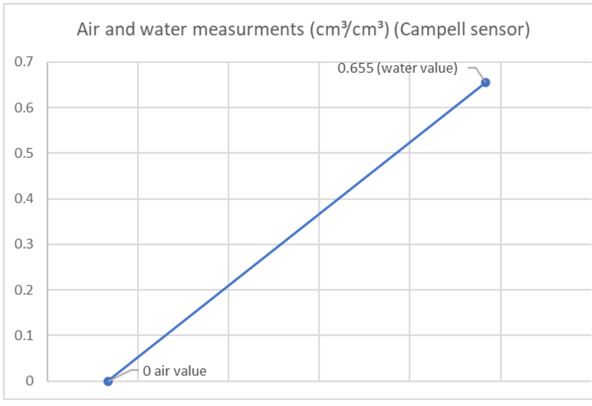

Chart 2: Air and water measurements from CS616

3.2 Experimental materials

The experiment was set inside a greenhouse, however due to the intense heat, the temperature was not fully regulated. Commercial soil was used to fill the pots consisting of 40% blond peat, 10% black peat, 20% clay and 30% vegetable humus. Two different types of plants were planted, *Solanum lycopersicum* (tomato) and *Lactuva sativa* (red lola). The irrigation was scheduled with a water timer and the soil moisture was measured with the aforementioned sensors.

3.3 Experimental data

The irrigation was scheduled in the beginning at 15 minutes for every 4 hours.

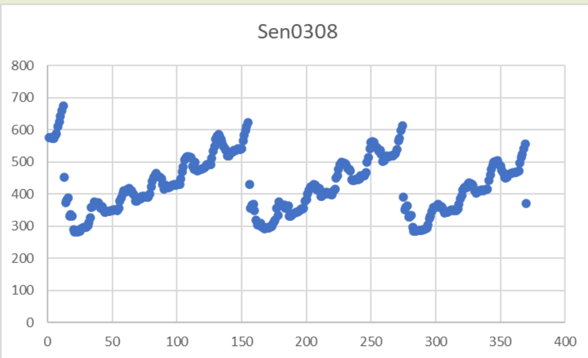

Chart 3: Soil moisture measured by sen0308

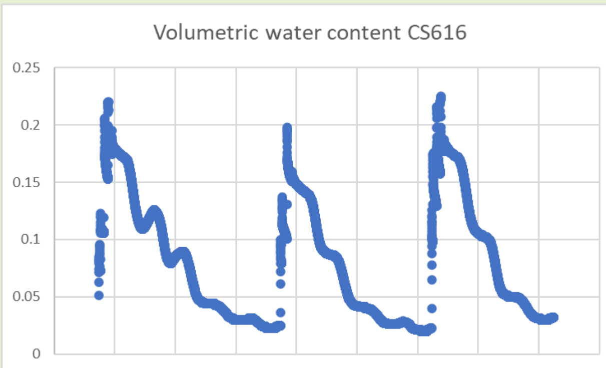

Chart 4: Volumetric water content measured by CS616

It was obvious from the measurements that the irrigation schedule was not optimal for the plants. The drops and picks that are observed in charts 3 & 4 are due to human intervention to the schedule as. Every morning after reading the data the irrigation was left open for 3 hours and then was put back to the previous schedule.

Following the knowledge gained from the first cycle the irrigation schedule was changed to 20 minutes for every 4 hours. As seen from charts 5 & 6 that was a more efficient schedule for these crops. The plants were not as stressed as with the previous schedule.

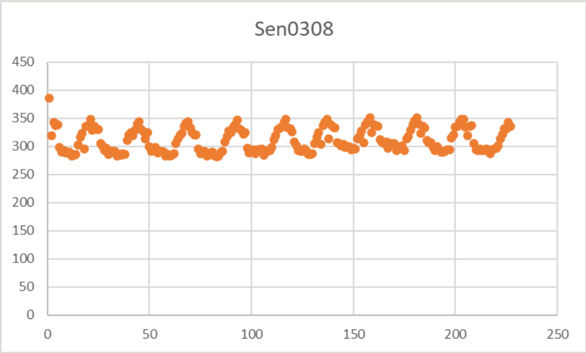

Chart 5: Soil moisture measured by sen0308

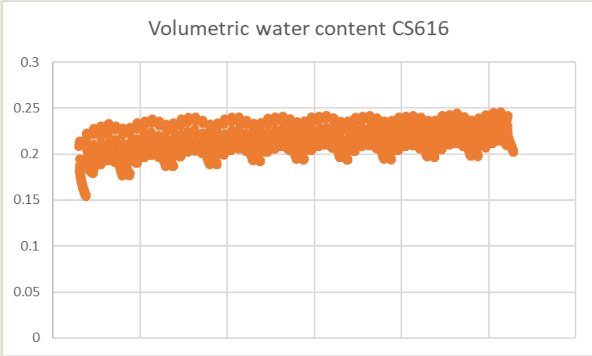

Chart 6: Volumetric water content measured by CS616

With this irrigation schedule it was managed to have healthy in the eye plants and a sufficient yield as shown in the pictures below.

4. Conclusion & next steps

The objective of this report was to demonstrate why sensor accuracy and calibration is important for the INTEL-IRRIS project and how AUA can contribute to this. With the infrastructure of AUA, it is possible to obtain measured soil moisture content values of soil moisture sensors under different soil moisture content conditions through calibration experiments and calibrating them using linear calibration.

In the short experimental study, it was possible to use the data from the sensor developed by the INTEL-IRRIS project (SEN0308) to create an irrigation schedule that provided sufficient water for the crop to grow and fruit.

However, a more detailed study needs to be performed. In the next steps more capacitive sensors as well as the use of watermark tensiometers will be needed. Following that, the data from these sensors will be compared with high-end and well-known sensors from the market using ground observation approaches. At the same time a database will be formed with the environmental data that have an immediate effect on the microclimate of the greenhouse and consequently on irrigation.

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