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

Deliverable D1.4b

Final report on test and validation in controlled agriculture environments

Responsible Editor:	AUA
Contributors:	
Document Reference:	INTEL-IRRIS D1.4b
Distribution:	Public
Version:	1.1
Date:	July 2023

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Document revision history

Version	Date	Changes
V1.1	July 10th, 2023	Public release
V1.0	July 5th, 2023	First draft version for internal approval
V0.1	July 3rd, 2023	First release for review

Executive Summary

Deliverable D1.4b describes the experimental setup and the data analysis that was performed to test and verify - in a controlled environment - the sensors developed by the INTEL-IRRIS project.

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1. Introduction

Following the first reports conclusions – where in a 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 – a second, more detailed study was performed using more capacitive sensors as well as watermark tensiometers. In addition, the watermark tensiometer was tested next to the capacitive sensor. They were tested in different soil types and at different depths so to understand better their performance.

2. Experimental setup

2.1. Soil types

To understand and verify the abilities of the INTEL-IRRIS' sensors we tested them at 3 different soil types. As shown in pictures 1 and 2, we prepared 3 pots, one with 100% sand, one 100% soil from the area of the Agricultural university of Athens (AUA) and one with 50%-50% mixture of sand and AUA soil. The configuration of the experimental settings was realized with the help of Guillaume Gaillard from UPPA who visited AUA in April 2023.

Pictures 1 & 2: Soil preparation

INTEL-IRRIS sensors data as per pot

- Soil Area 1 (SA1) □ pot 1
- Soil Area 2 (SA2) □ pot 2
- Soil Area 3 (SA3) □ pot 3

2.2. Sensors placing

To mimic the open field soil environment, we used deep pots so we could place the sensors on two different depths. For these measurements we used the watermark tensiometers. The first sensor was put at a depth of 30cm and the second one at a depth of 15cm.

- Watermark tensiometer 1 (WT1) is at a depth of 30cm
- Watermark tensiometer 2 (WT2) is at a depth of 15cm

Moreover, capacitive sensors were also used to measure soil moisture and were placed at the surface of Soil Area 2 (SA2) and Soil Area 3 (SA3).

- Capacitive sensor (C-AA)
- Capacitive sensor (C-AB)

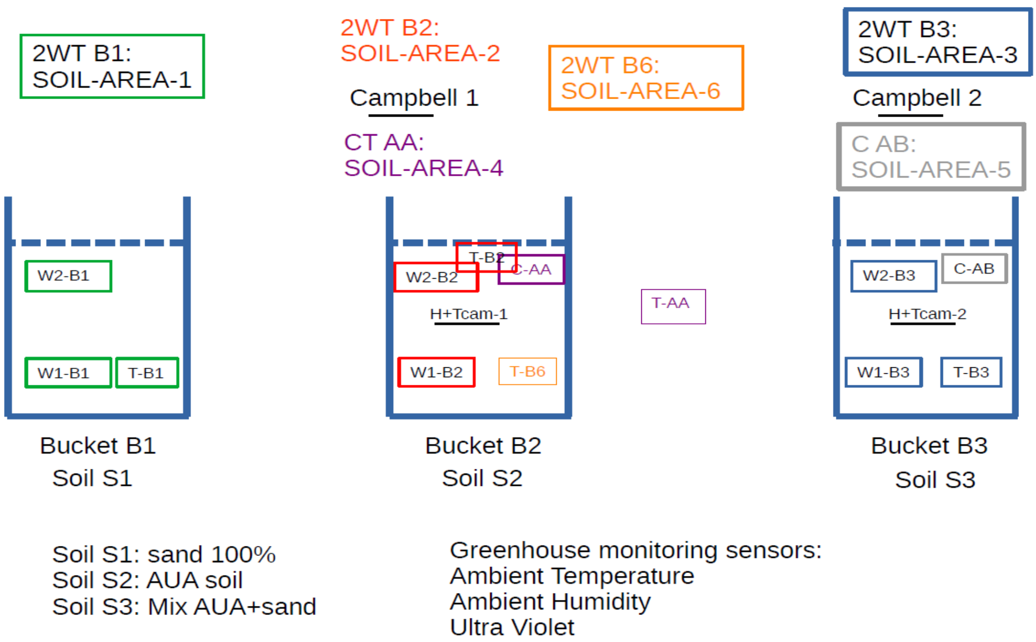
In each SA there was also placed a sensor to measure the temperature of the soil.

- Soil Temperature Sensor (TB1)
- Soil Temperature Sensor (TB2)
- Soil Temperature Sensor (TB3)
- Soil Temperature Sensor (TB6)

All the described information can be found in Table 1 which enlists the sensors per SA and Scheme 1 where a more detailed version of the experimental setup is available.

Soil Area 1 (SA1)	**Soil Area 2 (SA2)**	**Soil Area 3 (SA3)**
Watermark tensiometer 1 (W1-B1) Watermark tensiometer 2 (W2-B1)	Watermark tensiometer 1 (W1-B2) Watermark tensiometer 2 (W2-B2)	Watermark tensiometer 1 (W1-B3) Watermark tensiometer 2 (W2-B3)
Soil Temperature Sensor (TB1)	Soil Temperature Sensor (TB2)	Soil Temperature Sensor (TB3)
	Capacitive sensor (C-AA)	Capacitive sensor (C-AB)
	Soil Temperature Sensor (TB6)	

Table 1: INTEL-IRRIS sensors per soil area



Scheme 1 : Schematical representation of the experimental setup

In SA2 and SA3 there were also placed soil moisture sensors from the Cambell system. Water content reflectometers CS616 were used as in the first experiment.

Picture 3 & 4 : INTEL-IRRIS sensors' placement

3. Data analysis

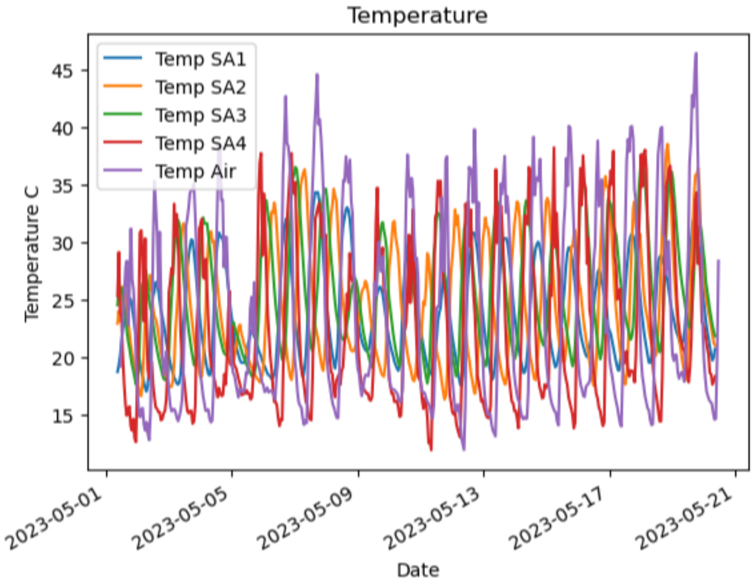


Figure 1 : Soil temperature comparison, including air temperature

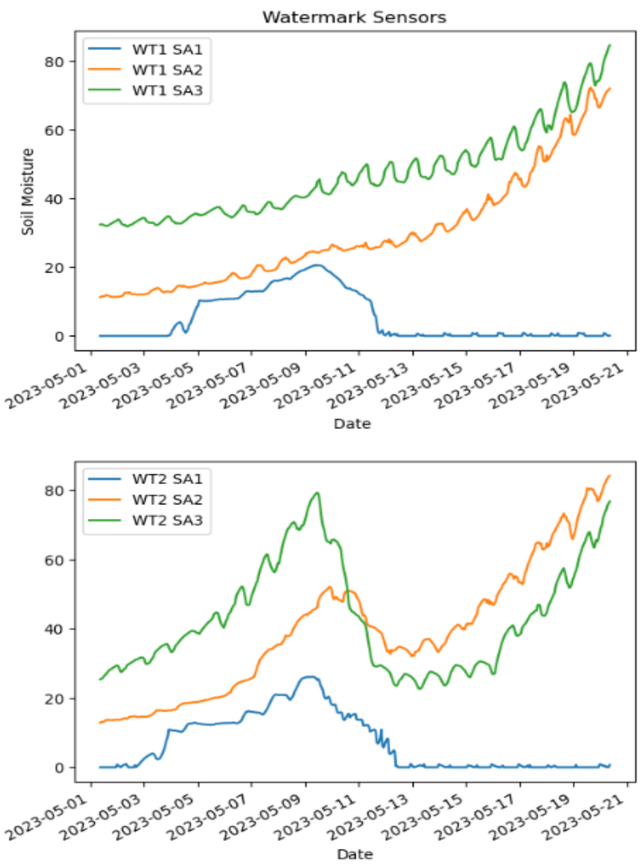


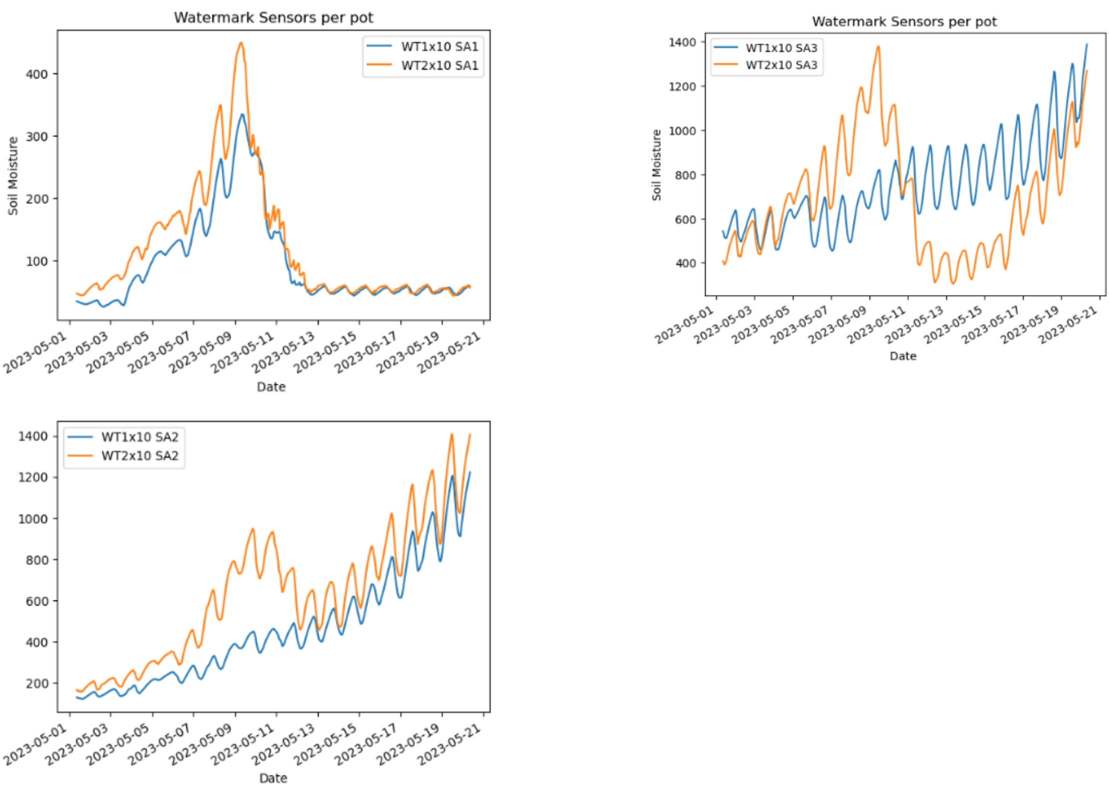
Figure 2 & 3 : Soil moisture from watermark tensiometers in two different depths

The experiment took place in the greenhouse of AUA where the environmental parameters can be controlled and measured and lasted for 21 days.

Figure 1 shows that the soil temperature measurements follow the increase and decrease of the air temperature with a few exceptions. However, these exceptions can be explained by the irrigation schedule.

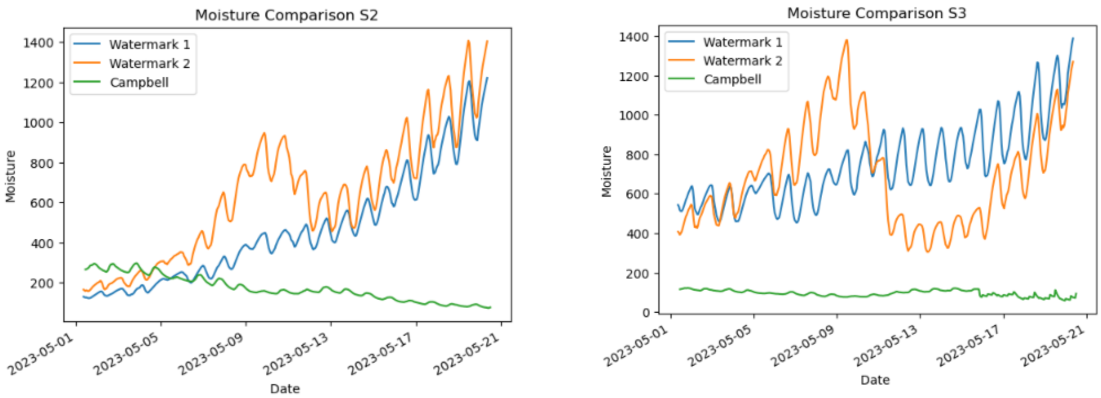
Moreover, figures 2 & 3 show the differences between the soil types in both depths of the pot. It can be noticed that in SA1 (100% sand) there is little to none water retention whereas in the other two soil types (SA2 & SA3) water is being retained in the soil.

In figures 4,5 & 6 the soil moisture from two different depths is compared. The comparison shows the same results in figure 4, as sand cannot retain water. However, in figures 5 & 6 the differences in each figure can be explained from the fact the watermark tensiometers are placed in different depths and that water retention influences the measurements.



Figures 4, 5 & 6: Soil moisture measurements from watermark tensiometer in each pot

Next, we compared the measurements obtained from the watermark tensiometer with those of the Campbell sensors from each pot. The data from Campbell were multiplied by 1000 to get the same order of magnitude. So, a qualitative analysis was performed. Figures 7 & 8 show this analysis. It can be seen that the peaks and lows in each case follow a similar pattern.



Figures 7 & 8 : Comparison of the watermark tensiometer and Campbell sensors soil moisture

Figures 9 & 10 show the comparison between the INTEL-IRRIS temperature sensors and the Campbell temperature sensors per SA. Both sensors have similar measurements with small differences. However, these differences are related to time expression from each software and not affected from the hardware that obtained the measurements.

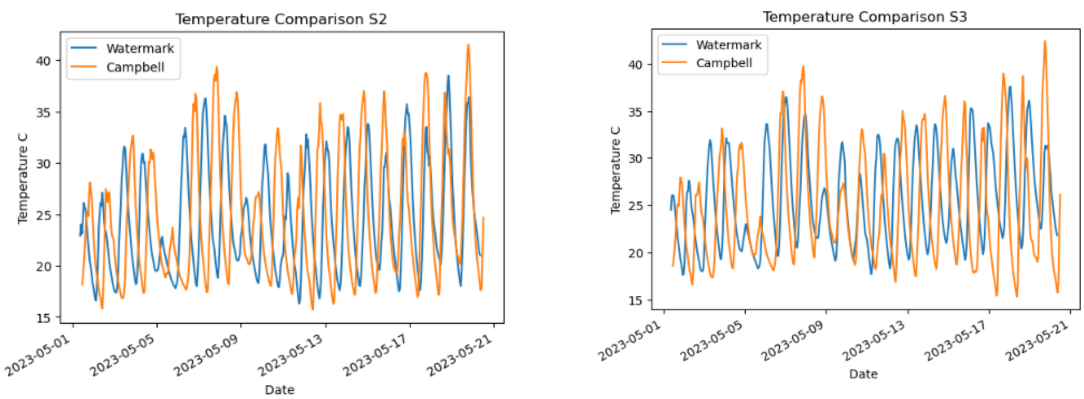
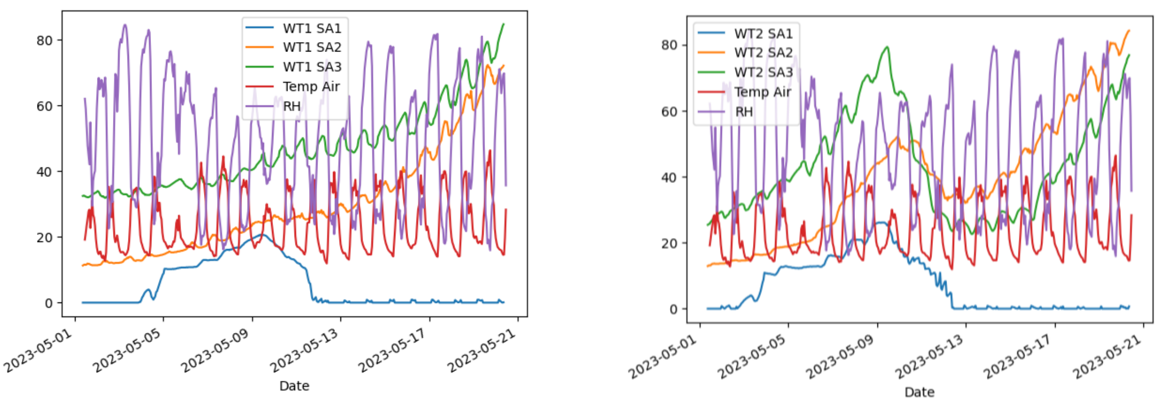


Figure 9 & 10 : Temperature compsarison between INTEL-IRRIS and Campell sensors

Figures 11 & 12 present the data from the watermark tensiometer and how these were possibly affected by the greenhouse climate as measured from the inhouse HOBO data logger.



Figures 11 & 12 : Watermark tensiometer and greenhouse climate data from HOBO

4. Discussion

The objective of this experimental study was to collect the data from the sensors (capacitive and watermark tensiometers) developed by the INTEL-IRRIS project and compare those with high-end and well-known sensors from the market in order to validate their accuracy. The experiment took place at the greenhouse of the AUA where it was possible to control the environmental conditions in a certain degree. The greenhouse is equipped with sensors in order to monitor and control these conditions and these data were used as well for the study's purpose.

Pictures 5 & 6 : Succesfull installation of equipment at the greenhouse

The equipment was installed and remained in place for the total period of the experiment. There were daily visits to the greenhouse to check the condition of the hardware and to collect data as well.

Temperature data were collected from three different sources (INTEL-IRRIS, Campbell, HOBO) and did not show large differences.

Soil temperature data collected from INTEL-IRRIS sensors (TB1, TB2, TB3 and TB6) and the Campbell sensor had similar measurements throughout the experimental duration.

Unfortunately, the soil moisture data collected from the three sources could only be analyzed qualitatively. However, they follow the same trend and patterns.

Acronyms List

Acronym	Explanation

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Acknowledgement

This document has been produced in the context of the PRIMA INTEL-IRRIS project. The INTEL-IRRIS project consortium would like to acknowledge that the research leading to these results has received funding from the European Union through the PRIMA program.