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IR2MA
Large Scale Irrigation Management Tools for Sustainable Water Management in Rural Areas and Protection of Receiving Aquatic Ecosystems

Subsidy Contract No: I1/2.3/27

WP 3

Deliverable 3.3.4

Upgrade of DSS and IRMA prototype for sensor-based irrigation management

Project co-funded by
European Union, European Regional Development Funds (E.R.D.F.) and by National Funds of Greece and Italy

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Partners

PB1/LB UNIVERSITY OF IOANNINA - Research Committee (UoI) http://www.rc.uoi.gr/

PB2 REGION of EPIRUS (ROE) http://www.php.gov.gr/

PB3 ISTITUTO SCIENZE DELLE PRODUZIONI ALIMENTARI (ISPA/CNR) http://www.ispacnr.it/

PB4 CIHEAM - ISTITUTO AGRONOMICO MEDITERRANEO – BARI (IAMB) http://www.iamb.it/

PB5 CONSORZIO PER LA BONIFICA DELLA CAPITANATA (CBC) http://consorzio.fg.it/

Associated partners

REGION OF PUGLIA (ROP) http://www.regione.puglia.it/

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Deliverable 3.3.4

Upgrade of DSS and IRMA prototype for sensor-based irrigation management

Report on performed activities and main results

Involved partners:

PB3 ISTITUTO SCIENZE DELLE PRODUZIONI ALIMENTARI (ISPA/CNR, Bari, Italy) http://www.ispacnr.it/

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Introduction

As part of the IR2MA Project, a specific research and demonstration activity has been implemented for the upgrade of a prototype system (the GICK “Greenhouse Irrigation Control Kit”) for automatic smart management of greenhouse crops irrigation, based on sensors for monitoring the substrate parameters. This prototype was previously developed by CNR - ISPA with the technical support of the company Sysman Progetti e Servizi srl as a part of the concluded IRMA project (ETCP Greece - Italy 2007 - 2013). The scientific results of this activity were published in Agricultural Water Management journal, as a part of the outcomes of the above mentioned IRMA project:

Montesano F.F., van Iersel M.W., Boari F., Cantore,V., D'Amato, G., Parente, A., (2018). Sensor-based irrigation management of soilless basil using a new smart irrigation system: effects of set-point on plant physiological responses and crop performance. Agricultural Water Management, 203, 20-29.

Briefly, the prototype in question, conceived by exploiting the most advanced technologies (and, where possible, open-source) at the time the activity was carried out, is composed by distinct operational sections, aimed at acquiring data from sensor networks, useful to feed a decision algorithm and the consequent automation of irrigation for greenhouse crops:

• **Sensor networking** section: connection of the system to the cloud for monitoring and setting the irrigation strategy;

• **Measurement** section: reading of the SDI-12 soil probes from a wireless sensor network;

• **Automation** section: management of monostable solenoid valves/pumps for the delivery of the irrigation intervention.

For further technical details on the GICK prototype, please refer to the aforementioned publication and to the technical documentation provided by Sysman Progetti e Servizi srl, available to the PB3.

The upgrade activity, leading to the realization of a GICK2 version of the smart irrigation system, was aimed to:

- updating the wireless transmission technologies used,

- the integration of further types of sensors for the acquisition of a wider range of data useful for the management of precision irrigation,

- the development of specific functions software for increasing the versatility of use of the system, guaranteeing the possibility of integrating different irrigation management strategies (sensor-based, model-based).

The company Sysman Progetti e Servizi srl, currently actively involved in the design and implementation of support systems for the rational management of irrigation, with prospects for diffusion in Mediterranean agro-ecosystems, has proposed to make available for the upgrade of the aforementioned prototype a technological infrastructure developed as part of the IoF2020 project, of which it is a partner, based on modern technologies for the creation of sensor networks in the IoT field for the monitoring of soil/substrate and climatic parameters and for the automatic management of irrigation and remote control.

In consideration of their mutual skills and area of interests, CNR - ISPA and Sysman Progetti e Servizi srl boast an active collaboration on issues relating to the rational management of production processes in agriculture through the use of innovative tools, which have led to numerous research products and common projects (projects already concluded or in progress: Sedema, Hydrotech, Irritech, IRMA, EcoLoop; E-Crops; SOILLESS-GO).

Prototype implementation and testing

Based on the above mentioned premises, the prototype update activity included a preliminar phase of study for the design of the overall architecture of the new GICK2 system, a subsequent phase of technical implementation of the system, and a final stage of testing. The latter was performed through demonstrative applications in both a commercial farm associated to Consorzio per la Bonifica della Capitanata (CBC, PB5 of the IR2MA project), and at the experimental farm “La Noria” of the CNR-ISPA (PB3). Refer to deliverable 5.3.4 “Applied research and demonstration activities on the improvement of irrigation scheduling for under cover crops” for a detailed report of the agronomic aspects of the demonstrative activities.

The overall activity was divided into 2 main tasks:

Task 1: Creation of an advanced prototype for greenhouse irrigation management.

The GICK2 prototype has been designed with the scientific coordination of the CNR-ISPA. A technological infrastructure developed by Sysman as part of the IoF2020 project, based on modern technologies for the creation of the network of sensors in the IoT field for monitoring soil parameters/substrate and climatic conditions, and for automatic irrigation management and remote control, was used for the prototype development. Specifically, the prototype consists of a central unit (based on a single-board-computer) powered by the electricity network, to which monostable solenoid valves or pumps for actuation and wireless battery-powered and connected nodes are connected with the central unit via LoRa commercial modules: nodes can be equipped with soil sensors (temperature and humidity), climatic sensors (T / RH, radiation) and, in general, with SDI12 sensors.

A schematic and graphic representation of the GICK2 prototype is provided in Fig. 1.

The entire infrastructure of the system has been build up on most popular commercial prototyping boards, minimizing the development of custom hardware in order to contain as much as possible the costs of the final prototype. For this reason, moreover, the system used, where possible, open source technologies and frameworks.

The entire implementation of the irrigation management system included also the development of a cross-platform and responsive web platform through which it is possible:

• monitor the status of the solenoid valves in real time;

• analyze the data measured by the sensors;

• set new conditions for automatic irrigation (based on set-points values to be compared with the measured data).

All monitored parameters (soil and air temperature and humidity, solar radiation, opening-closing times of the solenoid valves) will also be made available on the

BluLeaf® platform ('greenhouse' module, beta version) within a user account which will was made available by Sysman to CNR ISPA for the aim of this collaboration.

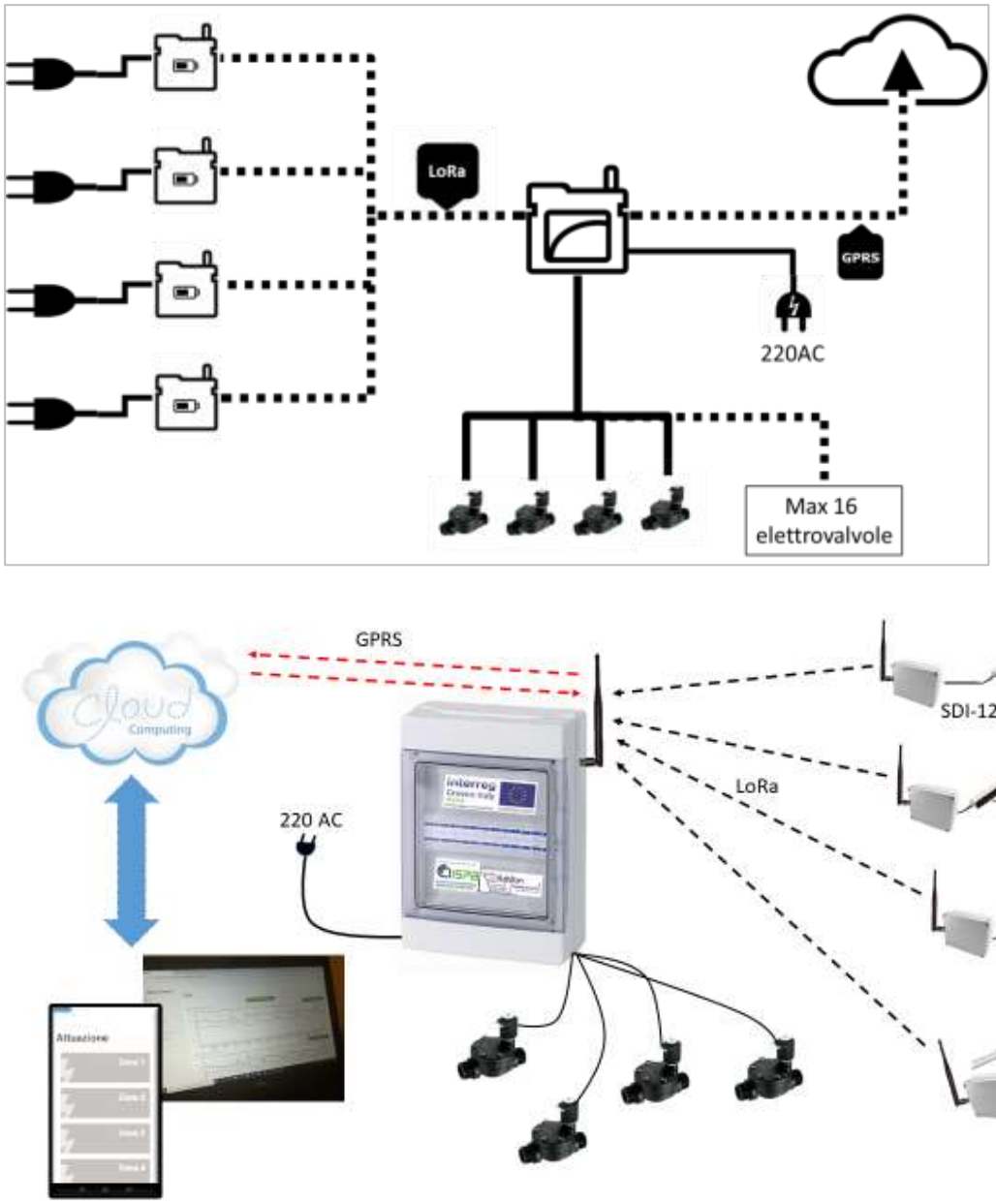

Figure 1: Representation of the GICK2 system for sensor-based irrigation management of greenhouse crops

Task 2: Installation of the prototype and testing in cultivation trials.

The prototype created as part of task 1 has been installed and operated for testing in two different environments:

- **in a greenhouse of the company "Nicola Carrillo", in Acoli Satriano (FG), associated to CBC, selected by the CNR – ISPA in collaboration with CBC, for experimentation and technology transfer in a real environment (september-december 2019)**. The Sysman provided technical support for the installation of the GICK2 prototype and constant verification of its operation during the production cycle. CNR-ISPA acted in the definition and implementation of an experimental protocol providing the use of the GICK2 as a system for smart irrigation approaches (sensor-based irrigation management, and DSS model-based approach through the BluLeaf® DSS, based on evapotranspiration and crop water balance) in comparison with the irrigation management based on the empiric experience of the farmer. The system was applied to a greenhouse zucchini cultivation. A detailed description of this activity, including the result of the experiment is reported in Deliverable 5.3.4 (Applied research and demonstration activities on the improvement of irrigation scheduling for under cover crops). In summary, the use of the prototype was successful under a technical point of view, leading to a complete and full automation of the irrigation management. The data obtained at the end of the cycle showed an average water saving of 38% compared to the total water supplied to the zucchini crop at the farm level, in the face of yield and qualitative results not different from the crop performance obtained with irrigation managed by the farmer's experience. A selection of images from the testing activity in the farm "Nicola carrillo" is provided below. Moreover, in Annex 1 is reported a scientific publication arising from this activity:

Canaj, K.; Parente, A.; D'Imperio, M.; Boari, F.; Buono, V.; Toriello, M.; Mehmeti, A.; Montesano, F.F. Can Precise Irrigation Support the Sustainability of Protected Cultivation? A Life-Cycle Assessment and Life-Cycle Cost Analysis. *Water* **2022**, *14*, 6. https://doi.org/10.3390/w14010006

The scientific publication is available in open access mode at the following link:

https://www.mdpi.com/2073-4441/14/1/6/htm

Geographical location and satellite mage of the Azienda Carrillo farm, where the demonstration and testing activity of the GICK2 system was implemented.

The demonstrative zucchini cultivation trial where automated irrigation through the GICK2 system was implemented.

- In the period **August-December 2020**, sensor-based irrigation was applied through the GICK2 system on a cherry tomato cultivation trial at the Experimental farm La Noria, grown on perlite substrate (see picture below). Refer to Deliverable 5.3.4

(Applied research and demonstration activities on the improvement of irrigation scheduling for under cover crops) for a detailed description of the experiment.

In summary, the treatments under comparison consisted in timer-based irrigation (the adjustment of the irrigation scheduling was applied on the periodic measurement of the drainage fraction, with a 50% as a target according to the common practice when saline water is used) compared with smart sensor-based irrigation operated by the GICK2 system. In this case, the irrigation strategy consisted in the automatic application of irrigation only when the volumetric water content in the substrate dropped below a predetermined set-point, resulting in *on-demand* irrigation. At each irrigation, the system checked the substrate EC measured real-time by sensors and decided between a low-leaching irrigation (<10% target) when substrate EC was <5 dS/m, and a high-leaching irrigation (≈30% target) with rain water (with the aim to leach out salts in excess) when substrate EC was >5dS/m.

Sensor-based irrigation allowed for a **water saving of approximately 58% and a WUE increase of approximately 73%** compared with timer-based irrigation. Moreover, optimal irrigation management allowed to apply a controlled saline stress resulting in **improved fruit quality** (9.0 compared to 7.5% dry matter content and 7.8 compared to 6.8 °Bris total soluble solids content, on average, in sensor-based and timer-based treatment, respectively).

Cultivation trial of cherry tomato at the Experimental Farm La Noria (August-December 2020), where the GICK2 system was tested for smart automatic irrigation management of soilless crops.

GS3 sensors (Decagon Devices) connected to a wireless node

The GICK2 system connected to devices (solenoid valves and pipes) for automatic irrigation

Conclusions

The activities carried out allowed to design and implement a smart system for automatic precision irrigation. The system showed to be sufficiently versatile and reliable. In fact, it has been conceived to be adaptable to different smart irrigation management strategies, taking advantage of advanced technologies for wireless sensor networking and cloud computing.

The system was tested in real cultivation environment, where proved to be able to fully automate irrigation management. Significant ameliorations of water use where achieved as an effect of the GICK2 use compared to empiric irrigation management.

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