AI-powered DSS for resource efficient nutrient, irrigation and microclimate management in greenhouses

HortiMED Towards circular horticulture
Closing the loop on Mediterranean greenhouses

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INTRODUCTION & OBJECTIVE

- A primary challenge for the horticultural industry is to ensure high yield and product quality while using resources in an efficient and sustainable way. Decision Support Systems (DSS) are important tools to manage greenhouses and significantly affect resource efficiency and environmental impacts, but are not extensively used due to their complexity and lack of easy-to-use interfaces. Besides, greenhouses are complex dynamic non-linear systems with different simultaneous physical, chemical and biological processes and with different timescales, difficult to control with conventional control techniques. The overarching aim of the **HortiMED H2020 PRIMA** funded project is to **improve resource efficiency in greenhouses** through an innovative and easy-to-use DSS supported by Artificial Intelligence (AI). HortiMED DSS integrates sensors, smart algorithms and efficient greenhouse control procedures, and applies AI techniques to deliver (i) Expert advisory services to help farmers in intensive knowledge tasks where climatic, crop & nutrient variables decisively influence crop growth & productivity (e.g. precise water & fertilisers' needs), and (ii) Cost-effective partial or full automation of greenhouses (e.g. fertigation, ventilation, heating).
- The target of the present study is to **introduce the general architecture of HortiMED's DSS** in order to integrate all relevant variables in the decision making process moving from an input-intensive to a knowledge-intensive farming. HortiMED is implemented in three demonstrative greenhouses located in Spain, Algeria and Egypt representing High, Medium and Low Technology greenhouses, respectively; specific features and **different data sources feeding the DSS of the High Technology Greenhouse (HTG)** in Meñaka, Bizkaia (Spain) are also presented. Finally, **AI Hybrid Models** are introduced.

MATERIALS & METHODS

- The HTG in Meñaka is used for the cultivation of tomato (*Solanum lycopersicum*). The tomato is grown in a soil-less system consisting of expanded perlite substrate grow bags with drip irrigation. The cultivation area comprises two sectors of ≈ 1.540 and 1.600 m^2 each; in each sector fertigation is controlled independently. Climate control system is operated by Sysclima (INTA Crop) which collects and stores in a SQL database data of several variables including, among others: (i) temperature (T) and (ii) relative humidity (RH) (inside greenhouse) and (iii) T, (iv) RH, (v) radiation, (vi) wind speed and (vii) rain through a meteorological station located outside the greenhouse. Actuators for climate control inside the greenhouse include ventilation and shading systems. The heating system, composed of four pellet boilers located at different parts of the greenhouse, is automatically activated and/or deactivated based on the value of air temperature inside the greenhouse (the T set point is usually 12ºC). Nutrient management is done through an autonomous fertigation system (Agronic 5000, Sistèmes Electrònics Progrés).
- Complementary sensors to those of Sysclima were deployed including: (i) a solar radiation sensor (Model 06350102, Progrés), (ii) a T & RH probe (Model HMD88, Vaisala) and (iii) a CO_2 probe (Model GMD20, Vaisala). The T & RH probe was enclosed in an aluminum pipe of 120 mm diameter equipped with a fan (Model 8314U, Ebmpapst) in order to increase the accurateness of the measures taken. The pipe was placed in a central position in the greenhouse, hanging from the roof at a distance of ≈ 1m from the floor (Figure 1). Likewise, 3 monitoring points for drainage water were selected (Drain tray 1, Drain tray 2 and Drain tray 3). Each drain was equipped with a rain gauge (Model 100.053, Darrera) and a pH and an EC probe (Models HI1001 and HI3001, respectively, both from Hanna). In order to quantify the drainage water a prototype (not off-the-shelf) system was developed consisting of a PVC drain tray placed under the substrate bag to collect the excess irrigation water that flows through a drainage hole created in the lower part of the substrate bag (Figure 2). Complementarily, a reference measurement point was selected, where the drippers were removed from the substrate bag and placed inside a plastic tray so that the irrigation inflow could be measured with a rain gauge and the pH and EC could be monitored too to compare such values with those obtained in the drain trays 1-3. All sensors were connected to a data logger (TM221 Logic Controller from Schneider Electric) and data registered with a 10 minutes periodicity.

Figure 1: Photograph of the ventilated system used to operate the T and RH sensors.

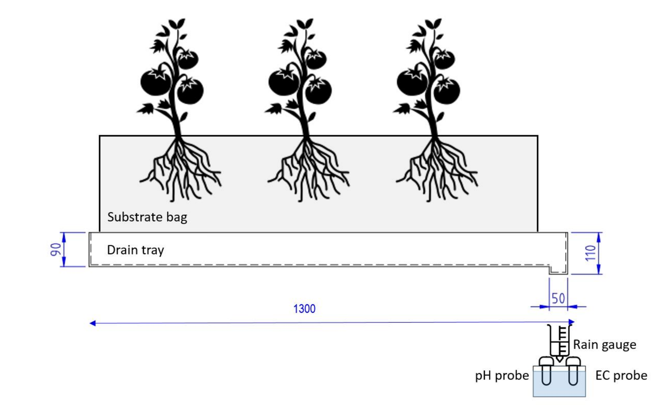

Figure 2: Prototype developed for the quantification and monitoring excess irrigation water .

RESULTS

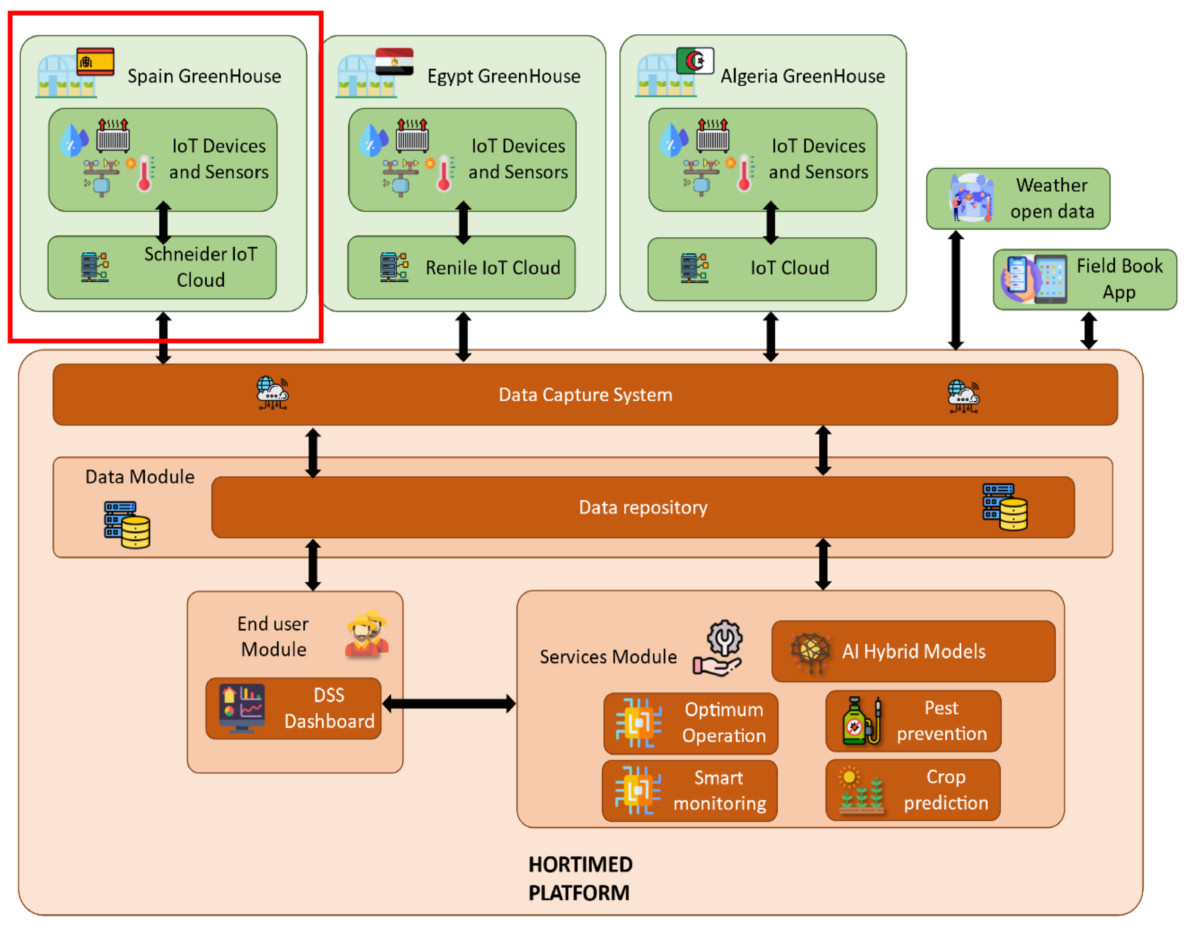

Figure 3: DSS – Logical Architecture of HortiMED's DSS.

Layer-based design: Block 1: Greenhouses (Spain's Greenhouse has been framed in red); Block 2: Data Capture System and Block 3: HortiMED platform services. These three layers are implemented in a distributed manner such that they function autonomously. In addition, this type of architecture promotes scalability by being able to deploy more distributed nodes, thus increasing the availability and response capacity of the system.

DIGITAL FIELDBOOK APP

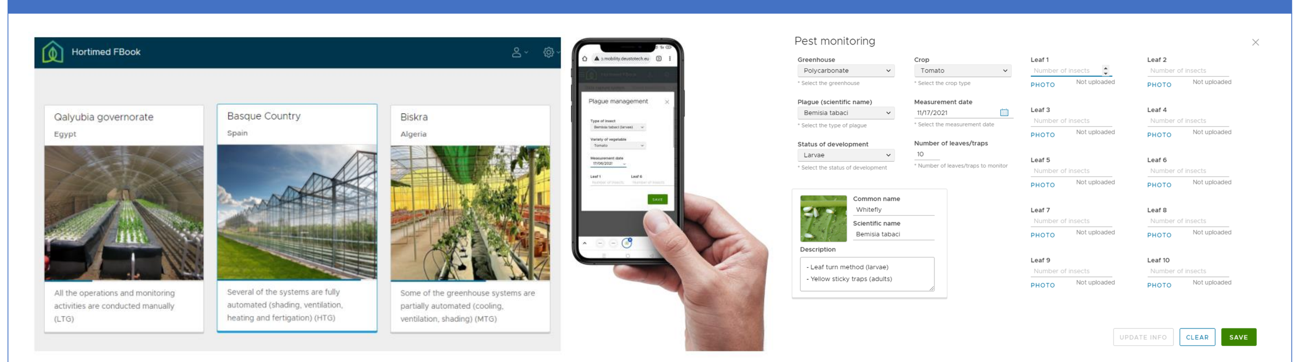

Figure 4: Newly developed digital tool for field data collection (1-FieldBook screen using web browsers; 2- FieldBook screen using portable devices; and 3-detail of one of the pest monitoring data forms).

IOT DEVICES & SENSORS

A common API for the registration, monitoring, curing and provisioning of the data received from sensors and/or external open data sources has been implemented. This API allows the automated and periodic collection of information from the different greenhouses. For the HTG, this architecture has been adapted to retrieve data from an IoT application of Schneider (using the TM221C Logic Controller).

Figure 5: Example illustrating the humidity and pH & CE values measured by the probes located in the HTG (Spain) and automatically transferred to HortiMED's DSS ("Smart Monitoring" section).

OPEN DATA SOURCES

OpenWeather · AEMET · euskalmet

AI HYBRID MODELS

An AI based simulator has been developed with a flexible architecture that includes specific modules for intensive horticulture systems. Implemented in MATLAB-Simulink, a library of hybrid (AI and mechanistic) models describes: (i) indoor greenhouse climate dynamics (combining AI models with temperature, radiation and gas exchange models); (ii) the growth of crops (considering photosynthesis, respiration, organogenesis and ripening as main driving mechanisms); (iii) control mechanisms for the greenhouse systems (e.g. heaters, windows, shading, etc.) and (iv) cultural practices (e.g. pruning). Figure 6 shows the digital twin developed for HortiMED HTG (Spain).

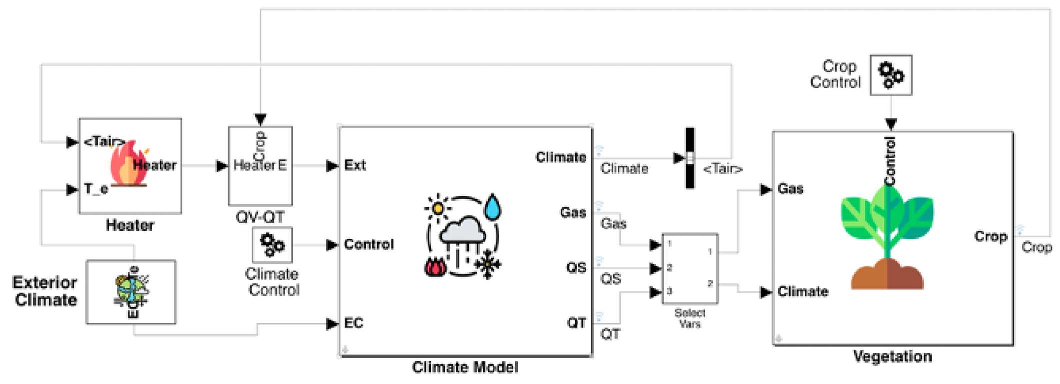

Figure 6: Example of the digital twin built on MATLAB-Simulink for HortiMED HTG (Spain).

CONCLUSIONS

- The general architecture of HortiMED's DSS has been introduced (Figure 3).
- The different data sources for the Meñaka HTG have been described. In detail those include open data sources for meteorological data, manually collected data (and recorded in a digital FieldBook) and variety of IoT sensors comprising those of Sysclima and complementary sensors deployed in novel (prototype) systems specifically designed within HortiMED.
- Data collected are used to feed innovative AI hybrid models. AI hybrid models are capable to well describe the HTG system behaviour. Additional work aiming at the validation of HortiMED's DSS is currently in progress, including the testing of different advanced control strategies to improve resource efficiency and circularity in HortiMED demonstrative greenhouses.

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Acknowledgments

The HortiMED project (Grant Number 1915) is part of the PRIMA Programme supported by the European Union.

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