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INNOVATING IRRIGATION: AFFORDABLE SMART SOLUTIONS FOR WATER SUSTAINABILITY

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ABSTRACT

Agriculture accounts for 70–80% of global freshwater use, a level increasingly unsustainable under climate change. This study reports the development and field validation of a low-cost smart irrigation system for tomato and melon in Tuscany (2021–2023). The system integrates evapotranspiration-based models, wireless sensor networks, and adaptive control algorithms. In 2023 it achieved up to 50% water savings compared to traditional practices, without yield reduction, at a total cost below €6000. Findings demonstrate the potential of smart irrigation to enhance water-use efficiency and sustainability in Mediterranean agriculture

Keywords: Smart Irrigation, Evapotranspiration Models, Water Use Efficiency, Sustainable Agriculture

INTRODUCTION

Optimizing irrigation practices is crucial to ensure food security while reducing water inputs. Smart irrigation systems, integrating sensors, wireless communication, IoT devices, and adaptive models, have emerged as effective solutions to enhance irrigation scheduling and water-use efficiency. Recent studies have demonstrated their potential across different crops and climates, highlighting improvements in yield and water productivity (Singh et al., 2023). Evapotranspiration (ET) based models offer a robust framework for irrigation management by linking plant water use with environmental conditions (Di Gennaro et al., 2024).

MATERIALS AND METHODS

The experiment was conducted at the demo farm Tenuta di Alberese (42°41.614´N; 11°8.536´E) in Grosseto, Italy, over three growing seasons (2021–2023) with tomato (Heinz 5108) and melon (Sweet Melon). Crops were cultivated from mid-May (transplanting) to mid-August (harvest) under three irrigation treatments: 100% of local traditional practice (T1), and reductions of 75% (T2) and 50% (T3). Six replicates per treatment were applied, with plot sizes of 3.0 × 5.0 m for tomato and 2.5 × 5.0 m for melon. Replicates were arranged in line due to irrigation system constraints. A fully automated smart irrigation system was implemented, capable of independent operation, real-time flow control, and remote data communication. The system regulated irrigation volumes through litre counters rather than time, supported by pressure regulators, filters, and an automatic pipe-washing function. Irrigation scheduling was based on an evapotranspiration (ET) model: crop evapotranspiration (ETE) was estimated as

ETE = Kc × ETo. Crop coefficients (Kc) were derived from growing degree days and validated with local phenological models for tomato and melon. Reference evapotranspiration (ETo) was obtained via the Agrosat platform using SEVIRI/MSG satellite data combined with land-cover information. Once ETE was calculated, it was converted into litres per surface area, with irrigation applied twice weekly from 30 days after transplanting until late July.

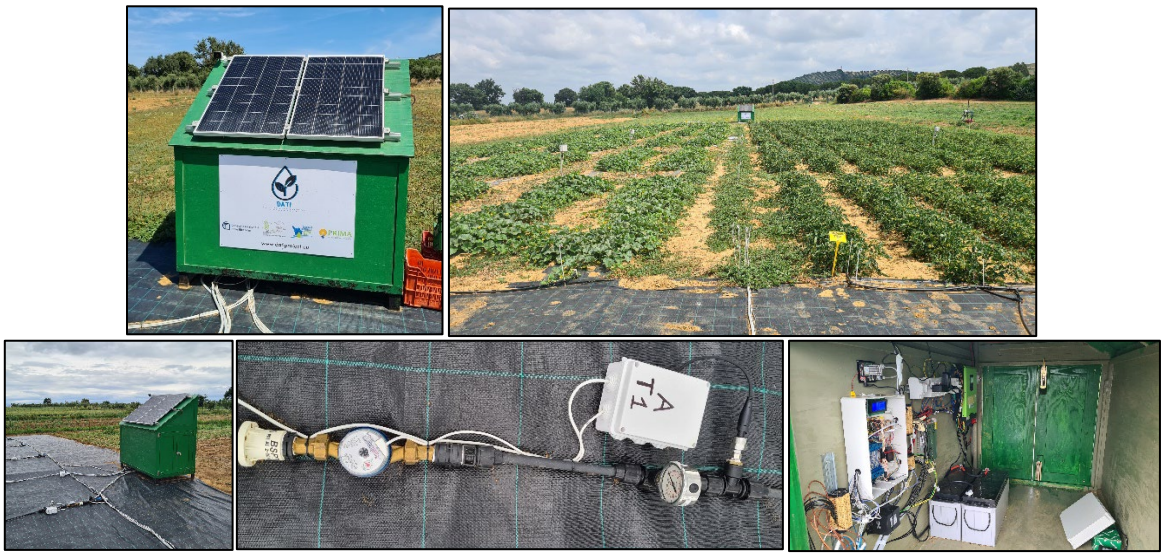

Fig. 1 Smart irrigation system installed in the field.

RESULTS & DISCUSSION

ETE increased during the season, peaking at 5.1 mm in mid-July, when crop water demand and stress were highest. In 2021, irrigation volumes under T1 reached 511 mm for tomato and 454 mm for melon, with progressively lower values in T2 and T3. In 2022, irrigation decreased sharply (e.g., 159 mm in T1 tomato) due to a closed system with pressure control. In 2023, the ET-based smart irrigation system applied 188 mm (tomato) and 168 mm (melon) in T1, reducing water use by ~50% (1800 m^3/ha), compared to local conventional practices (≈3000 m^3/ha). These results confirm the potential of ET-driven smart irrigation to enhance efficiency and sustainability in Mediterranean cropping systems

CONCLUSIONS

The DATI smart irrigation system, based on evapotranspiration models, significantly reduced water use in tomato cultivation without yield losses. Its integration of sensors and wireless networks enables precise, real-time water management while minimizing waste and energy costs. Despite challenges in long-term sensor deployment, the system demonstrates strong potential for sustainable irrigation in Mediterranean agriculture.

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