

A Holistic Irrigation Advisory Policy Scheme by the Hellenic Agricultural Organization: An Example of a Successful Implementation in Crete, Greece

Nektarios N. Kourgialas 

Water Resources-Irrigation & Environmental Geoinformatics Laboratory, Institute of Olive Tree, Subtropical Crops and Viticulture, Hellenic Agricultural Organization (ELGO DIMITRA), 73134 Chania, Greece; kourgialas@elgo.gr; Tel.: +30-282-108-3442

Abstract: The aim of this communication article is to present a successful irrigation advisory scheme on the island of Crete (Greece) provided by the Hellenic Agricultural Organization (ELGO DIMITRA), which is well adapted to the different needs of farmers and water management agencies. The motivation to create this advisory scheme stems from the need to save water resources while ensuring optimal production in a region like Crete where droughts seem to occur more and more frequently in recent years. This scheme/approach has three different levels of implementation (components) depending on the spatial level and end-users' needs. The first level concerns the weekly irrigation bulletins in the main agricultural areas of the island with the aim of informing farmers and local water managers about crop irrigation needs. The second level concerns an innovative digital web-based platform for the precise determination of the irrigation needs of Crete's crops at a parcel level as well as optimal adaptation strategies in the context of climate change. In this platform, important features such as real-time meteorological information, spatial data on the cultivation type of parcels, validated algorithms for calculating crop irrigation needs, an accurate soil texture map derived from satellite images, and appropriate agronomic practices to conserve water based on cultivation and the geomorphology of a farm are considered. The third level of the proposed management approach includes an open-source Internet of Things (IoT) intelligent irrigation system for optimal individual parcel irrigation scheduling. This IoT system includes soil moisture and atmospheric sensors installed on the field, as well as the corresponding laboratory soil hydraulic characterization service. This third-level advisory approach provides farmers with specialized information on the automated irrigation system and optimization of irrigation water use. All the above irrigation advisory approaches have been implemented and evaluated by end-users with a very high degree of satisfaction in terms of effectiveness and usability.

Keywords: sustainable agricultural water management; smart irrigation systems; decision-making platforms; climate–water adaptation in agriculture



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1. Introduction

In arid and semi-arid environments, water scarcity in combination with water-related climate change effects is setting extra pressure on water supplies [1,2]. A characteristic example of this rising concern is the islands of the Mediterranean Sea, where agriculture and tourism are the main economic sectors. Especially for irrigation, which is the largest consumer of water in the Mediterranean zone with up to 70% of total water withdrawals, increasing water demand from tourism will reduce the availability of freshwater for agriculture, affecting both the quantity/quality of water supply as well as food production [3,4].

Based on the above, effective use of irrigation water is a crucial factor in undertaking water scarcity problems and enhancing crop yields. Dealing with this crucial issue of

water sufficiency in areas such as the islands of the Mediterranean, documented and continuous information to the governments, water management agencies, and farmers is required [5]. Below the five main guidelines that could provide a sustainable solution to this problem in such areas are summarized [6–9]: (a) Creation of small and targeted hydraulic projects aimed at the proper distribution of water resources (irrigation water). (b) Reuse of liquid waste (tertiary treatment) for the irrigation of tree crops/installation of units for the reuse of liquid waste in large hotel units with the aim of covering their irrigation needs. At the same time, creation of well-adapted, small, and energy-independent water desalination units. (c) Use of crops resistant to extreme climatic conditions (varieties and rootstocks). (d) Good agricultural practices in the field to store water and reduce water losses. (e) proper irrigation advisory policy approaches, including intelligent irrigation/new technologies for the most efficient use of water from the source to the parcels.

The first two guidelines require the immediate assistance of the state through the acceleration of the implementation processes of old and new construction projects (without failures) to immediately integrate new hydraulic constrictions into the networks. On the other hand, the last three guidelines require evidence-based information and guidance to farmers and water management agencies by institutions specialized in the field of agricultural research. This communication paper especially deals with the last of the above five guidelines, as currently great attempts are made by farmers and local water managers to save water and minimize its cost, guaranteeing irrigation crop efficiency at the same time [10]. Thus, the increasing interest from end-users for new irrigation techniques to accurate irrigation scheduling, avoiding under-irrigation and over-irrigation, and maintaining environmental sustainability is a requirement that the experts should give high priority to.

To increase water-use efficiency and optimize the timing and amount of water applied requires appropriate smart irrigation systems, remote sensing/computational modeling technologies, as well as precise approaches to calculate soil properties and crop water requirements [11–13]. Several irrigation models have been proposed to calculate water crop requirements. Most of these models need a broad range of inputs, such as plant, climatic, and soil–water data obtained by monitoring equipment in the field and laboratory analysis. The above inputs/services, in most cases, especially at large region studies, are not accessible or profitable to the end-user [14]. Currently, there are many online irrigation platforms on the market incorporating several web-based tools for instrument/sensor data visualization. These platforms, in most cases, need the establishment of costly monitoring equipment and software system licenses. Thus, these platforms are uneconomical, especially for small parcel owners who are the majority in Mediterranean regions or for cultivation products with relatively low marketing costs. In addition, these platforms require skilled end-users who know how to explain the meaning of the data, evaluate the results, and provide the right advice [15–17]. Moreover, aspects of advising precision farming that have not been given significant focus until now are suggestions about proper agricultural practices related to water and soil as a means of crop adaptation to extreme climate–water conditions. This advice, for instance, the deficit irrigation, could be crucial for drought-affected agro-ecosystems such as the Mediterranean one [18]. Additionally, a notable conception for a precision irrigation management plan that has not been given substantial emphasis includes the precise determination of soil mechanical composition (soil sand, silt, and clay percentage), which is a time-consuming and high-cost approach and difficult to apply to large-scale studies [14].

Based on the above, there are several gaps in the effective implementation of an integrated irrigation advisory policy approach that can be covered and therefore provide the requested information. These gaps are filled by the proposed irrigation advisory approach on the island of Crete (Greece), which is well adapted to the different needs of farmers and water management agencies, offering them the ability of selection

among three different levels of services. This depends on the spatial level of implementation (for instance, municipal, agricultural catchment, and farm/parcel applications) and end-user needs, including either free services (weekly irrigation bulletins at a regional level and web-based platform information on parcel-level irrigation needs) or low-cost services (automated irrigation system and optimization of use of irrigation water at parcel level).

In Crete, the irrigation period was extended from mid-to-late September in the 1960s, 1970s, and 1980s to early and mid-October in the early 1990s and 2000s, while after 2005 until today we see a gradual extension of the irrigation period until the middle-to-end of November. The above, in conjunction with the parallel extension of the tourist season, sound the alarm and point to the necessity of implementing preventive measures and more efficient use of water, mainly in the agricultural sector, which is also the main consumer of water, reaching rates of over 80% of total consumption of water on the island. Thus, the goal and motivation of the proposed irrigation policy advisory approach provided by the Hellenic Agricultural Organization (ELGO DIMITRA) to farmers and local water managers is the efficient use of irrigation water, ensuring agricultural production even under extreme climatic conditions. In summary, this paper demonstrates an innovative, holistic, and multi-level policy advisory scheme for efficient irrigation tailored to different spatial scales and different end-users' needs in terms of accuracy and cost of implementation. This scheme was designed and successfully implemented throughout the Mediterranean island of Crete.

2. Study Area

The proposed irrigation advisory approach is successfully applied on the island of Crete, the largest island in Greece and one of the largest islands in the Mediterranean Sea, covering an area of about 8265 km² [4]. Crete includes four prefectures: Chania, Rethymnon, Heraklion, and Lassithi. The elevations on the island ranged from zero to 2456 m MSL. The island of Crete is one of the most important rural and touristic regions in the Mediterranean, where intensive agriculture and tourist activities enhance water scarcity. Increased water demand, as well as agricultural and tourist activities, appear in late spring, summer, and early autumn, when water is less abundant. The overall agricultural area of Crete is about 3205 km², with the major agricultural areas being cultivated with tree crops. The primary water need (81% of the total consumption) in Crete is irrigation, followed by domestic/touristic and industrial demand (19% of total consumption). In addition, of the irrigation water applied, only 65% is used in the crops, as 35% is lost either during its transfer from the source to the field or from its improper use in the field (inefficient irrigation) (Figure 1). Moreover, large parts of the coastal area in Crete are affected by seawater intrusion. This phenomenon can be more severe in coastal areas with high groundwater pumping rates needed to cover the needs of demanding agricultural and tourist activities [19,20]. Considering the above as well as that the Mediterranean islands are extremely prone to climate change, the introduction of a holistic and well-adapted irrigation management approach is a challenge for implementing operational and efficient water policies. Thus, the establishment in Crete of the proposed irrigation management approach well-adapted to the needs could be used in turn as a representative and demonstrative example of a successful policy framework to properly manage water needs for balancing the main water consumers (agriculture and tourism).

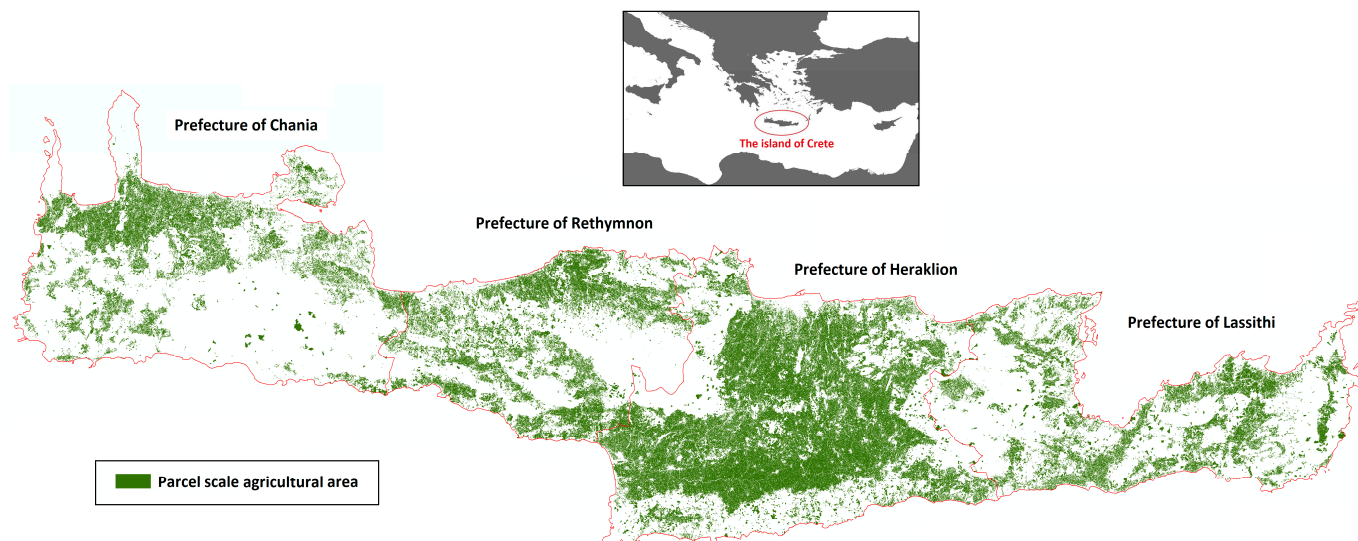


Figure 1. The four prefectures of Crete as well as the agricultural areas at parcel scale (1:250,000 scale).

3. The Irrigation Advisory Policy Approach Provided by Hellenic Agricultural Organization (ELGO DIMITRA)

The proposed holistic irrigation advisory policy approach includes the following components: (1) weekly informative irrigation bulletins for the main agricultural areas of Crete; (2) an innovative web-based digital decision support system for the accurate determination of the irrigation needs of Crete's crops at a farm level as well as optimal water–climate adaptation strategies; and (3) specialized low-cost services at parcel level, including the installation of sensors, laboratory analysis of soil hydraulic properties, and an open-source IoT smart system for optimal and automated parcel-level irrigation scheduling (Figure 2). The above irrigation advisory policy approach is established and applied on the island of Crete by ELGO DIMITRA and specifically by the Institute of Olive tree, Subtropical crops, and Viticulture (IOSV) in Crete (Laboratory of Water Resources, Irrigation, and Environmental Geoinformatics). The action mentioned is in line with the legislative mission of ELGO DIMITRA, including among others [21]: (a) providing advisory support to the Ministry of Rural Development and Food for the formulation, monitoring, and updating of the national agricultural policy; (b) conducting agricultural research through planning, undertaking, and implementing research programs and the interconnection of agricultural research with agencies of the agricultural sector; (c) the continuous monitoring of phenomena, such as climate change and food crises, and their potential consequences; and (d) the planning, organization, and implementation of education, training, and information activities.

Below is a more detailed presentation of these individual components, comparisons between them, as well as their evaluation by end-users (farmers, agronomists, and water policymakers).

3.1. Weekly Informative Irrigation Bulletins

From 2018 until today, the Institute of Olive tree, Subtropical crops, and Viticulture of ELGO-DIMITRA in Crete, in collaboration with the Region of Crete, offers free of charge advice to farmers individually or through collectives on how to use irrigation water properly, meeting the real needs of their crops. The specific bulletins refer to the main agricultural Region of Crete and the main cultivation of it, including olive, citrus, and avocado crops, as well as viticulture. The bulletins provide information on a weekly basis about how much water (correct irrigation dose in m^3 per 0.1 ha) should be irrigated per crop, according to meteorological data, the age and the phenological stage of the crop, as well as the type of soil. Also, in the case of reduced water reserves in specific agricultural areas, information and advice on strategic adaptation such as deficit irrigation (application of a reduced irrigation dose in those stages of crop development in which water is not

a critical factor) is also provided (Figure 3). The irrigation bulletins concerning the main agricultural areas of the four Regional Units of Crete (in total 20 different agricultural regions of the whole Crete) are sent by ELGO DIMITRA to the Region of Crete in electronic form every week of the irrigation season between April and November each year. In turn, this information is posted on the website of the Region of Crete (<https://www.crete.gov.gr/deltia-ardeysis-2024/>) (accessed on 2 September 2024) and also sent via about 2000 emails to relevant water policymakers and farmers in Crete in order to inform them about the real water needs of the crops with a view to saving water resources and optimal performance of the crops.

The three different levels (components) of the proposed irrigation advisory policy scheme

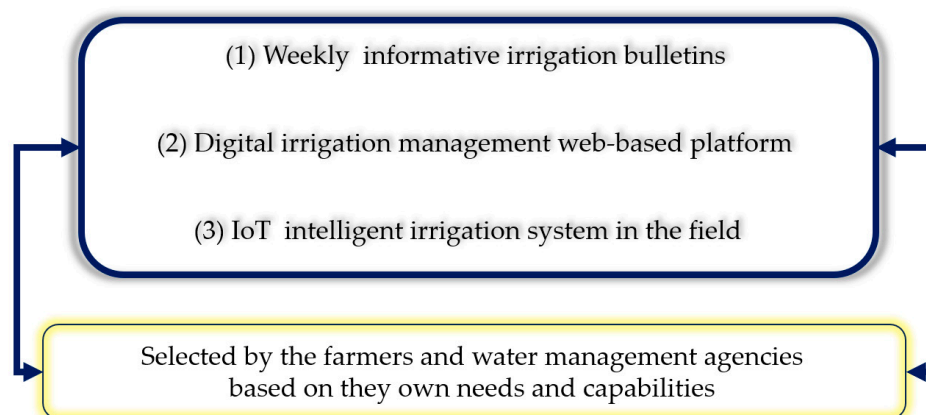


Figure 2. The flow chart of the proposed irrigation advisory policy approach.



HELLENIC AGRICULTURAL ORGANIZATION (ELGO DIMITRA) - DG AGRICULTURAL RESEARCH
Institute of Olive Tree, Subtropical Crops & Viticulture (IOSV)
Water Resources, Irrigation & Env. Geoinformatics Lab.
E-mail: kourgialas@elgo.gr



Region of Crete
Directorate of Rural Development
E-mail: kfotakis@crete.gov.gr

WEEKLY BULLETIN OF CROP IRRIGATION NEEDS (Prefecture of Chania) (Cubic Meters per 0.1 ha), For the period: 18/7/2024 – 24/7/2024

Region *	IRRIGATION	CROPS								
		OLIVE TREES (Mature trees)			CITRUS TREES (Mature trees)			AVOCADO TREES (Mature trees)		
		Soil Type			Soil Type			Soil Type		
		Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fine
ALIKIANOS AGIA	Water Needs (m ³ /0.1ha)	9	9	9	22	22	22	24	24	24
	Number of Irrigations	1	1	1	2	2	2	2	2	2
	Irrigation Dose (m ³ /0.1ha)	9	9	9	11	11	11	12	12	12
VOUKOLIES TAYRONITIS	Water Needs (m ³ /0.1ha)	8	8	8	20	20	20	22	22	22
	Number of Irrigations	1	1	1	2	2	2	2	2	2
	Irrigation Dose (m ³ /0.1ha)	8	8	8	10	10	10	11	11	11
KOLYMPARI	Water Needs (m ³ /0.1ha)	8	8	8	20	20	20	22	22	22
	Number of Irrigations	1	1	1	2	2	2	2	2	2
	Irrigation Dose (m ³ /0.1ha)	8	8	8	10	10	10	11	11	11
BRYSES APOKORONOU	Water Needs (m ³ /0.1ha)	9	9	9	22	22	22	22	22	22
	Number of Irrigations	1	1	1	2	2	2	2	2	2
	Irrigation Dose (m ³ /0.1ha)	9	9	9	11	11	11	11	11	11
KISSAMOU BAY - KASTELI	Water Needs (m ³ /0.1ha)	8	8	8	20	20	20	20	20	20
	Number of Irrigations	1	1	1	2	2	2	2	2	2
	Irrigation Dose (m ³ /0.1ha)	8	8	8	10	10	10	10	10	10
FALASARNA	Water Needs (m ³ /0.1ha)	10	10	10						
	Number of Irrigations	1	1	1						
	Irrigation Dose (m ³ /0.1ha)	10	10	10						

* The above irrigation doses, per crop, also apply to neighboring areas with the same microclimate

COMMENTS: a) In the case of 2 or 3 doses (number of irrigations), it is recommended that they be applied 3 or 2 days apart, respectively.

b) Indicative number of trees/plants per 0.1 ha: Olive 20, Citrus 40, Avocado 30.

The recommended irrigation doses are calculated according to the meteorological data, the growth stage and the age of each crop, as well as the soil type.

[The water reserves of each region are also considered]

ATTENTION: For olive cultivation and for the specific time period in case of reduced water availability, it is recommended that the amounts of water mentioned in the table be reduced from 50% to 100% depending on water availability.

Figure 3. A demonstration example of a weekly informative irrigation bulletin (first component of the proposed framework).

3.2. A Digital Irrigation Management Web-Based Platform

The second component of the proposed irrigation advisory policy approach, for users more familiar with new technologies, concerns a free-access online irrigation platform, which gives the possibility to irrigate with a “click” on the digital map. To be more specific, ELGO-DIMITRA, as coordinator, in collaboration with other local institutes and universities, created an innovative system of personalized information for the irrigation needs of each plot of agricultural land. This platform was installed for the island of Crete in the context of NSRF 2014–2020 project MIS: 5028242 “DEcision system For Irrigation in Crete based on Innovative Technologies—DE.F.I.C.I.T.”, which is co-financed by the Crete Operational Program and the European Regional Development Fund (ERDF).

This free-access web platform at farm scale (<https://www.irrigation-crete.gr/> (accessed on 2 September 2024)) was installed in 2022, providing irrigation management recommendations for tree crops and vineyards (the foremost cultivations in Crete) without requiring any measurement in the field by the user [19]. Thus, for the first time this platform allows the user to: (a) know, with coordinates or not, on a weekly basis the irrigation needs for olive, citrus, avocado, and vine plots/parcels all over Crete. Irrigation scheduling is performed considering the age as well as the phenological stage of each crop; (b) have access to proper agronomic practices based on the characteristics of each plot, such as the geomorphology and the water availability, with the goal of maximum possible yield and water saving. Moreover, it offers access to adjustment water management strategies, such as deficit irrigation in regions with low water availability, and (c) identify the soil texture (distribution of the percentage of sand, silt, and clay) and the slope of the land relief in every plot of land in Crete (Figure 4). The advantages of this digital irrigation platform compared to earlier developed irrigation platforms are that the current platform integrates a simultaneous crop evapotranspiration module, soil texture data, proper irrigation practices, and geolocation services to offer suggestions for applying a proper irrigation dose and rate. The crop evapotranspiration module was designed to use real-time meteorological data for 70 meteorological stations well distributed in the whole area of Crete; the digital soil texture data were produced from remotely sensed Sentinel-2 imagery in combination with field surveys (for calibration and validation processes), while the proposed best agronomical practice information was gathered from existing specialized literature. This web-based platform was developed using open-source data and free tools to eradicate end-user software package costs. In addition, this internet access platform was constructed for end-users with relatively limited knowledge of the internet and geoscience technologies and allowed operators to retrieve parcel-level outcomes on a smart mobile device.

Thorough descriptions of the above-mentioned free-access web-based platform at farm scale can be found by Kourgialas et al., 2022 [19].

3.3. An IoT Intelligent Irrigation System in the Field

Currently, the “intelligent” systems come in to make use of all the available information and lead to sound decision-making in the field. Internet of Things (IoT) technology as a part of intelligent systems can significantly contribute to water-use efficiency and crop productivity by providing real-time accurate information on soil moisture and meteorological data [22]. As part of our third component of the proposed irrigation advisory approach, a monitoring system using IoT terminal nodes with a TEROS 12 smart soil sensor by METER Group, Inc., Pullman, WA, USA, has been developed by ELGO DIMITRA to accurately measure soil moisture [units: volumetric water content (VWC)], soil temperature [units: Celsius (°C)], and soil electrical conductivity [units: $\mu\text{S}/\text{cm}$ (ECa)]. In the above nodes, information from climate–crop-related sensors, such as air temperature and leaf temperature [units: Celsius (°C)-obtained using an infrared sensor], is also integrated [22].

Each node uses appropriate software to receive readings from the moisture sensor and transmit data via message exchange protocol (MQTT) to the cloud and from there to an open-source Things Board IoT platform for data visualization (Figure 5). Based on the above and in case the soil moisture is below certain limits and needs watering, a warning

message is sent to the farmer informing him/her of the irrigation needs and the specific dose that should be applied per tree [22,23]. Considering that the main irrigated crops in Crete, such as olive, citrus, avocado, and viticulture, have in general shallow root systems (the active root zone is typically up to 30 cm soil depth), it is important to apply irrigation water at the active root zone, decreasing deep percolation. Thus, the TEROs 12 smart sensor is installed at that depth. In this depth, there is a lowest threshold of critical matrix potential, called the lower limit of the readily available water, which needs to be retained. There is a great range of these thresholds depending on the crop type, the phenological stage, as well as the soil type [22,23].

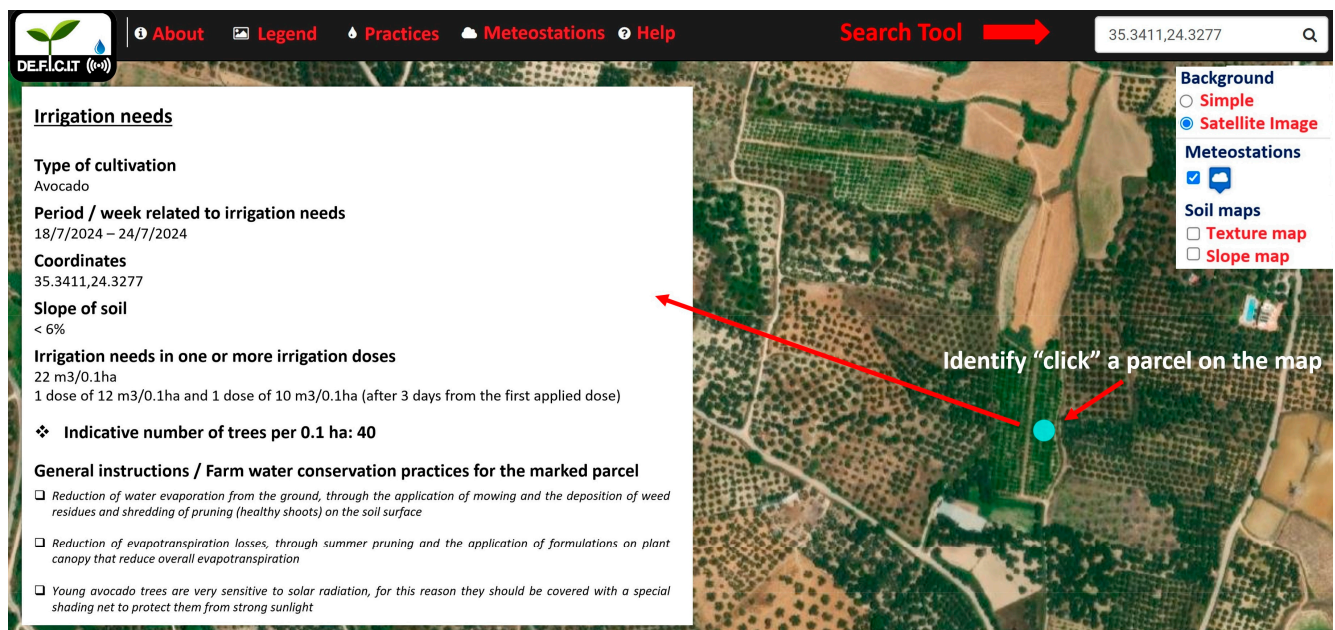


Figure 4. A schematic representation of the free access digital irrigation management web platform at parcel scale: <https://www.irrigation-crete.gr/> (accessed on 2 September 2024) (second component of the proposed framework).

Another advantage of this farm-scale IoT smart irrigation system is that it can provide separate suggestions for saline water irrigation [high levels of electrical conductivity (EC_w)]. Thus, the above IoT smart irrigation system, using the appropriate mathematical approach, can relate the yield reduction for each crop with the levels of soil saturation extract (EC_e) as well as correlate, with various soil properties, the EC_e and the soil electrical conductivity (EC_a) that the TEROs 12 smart sensor measures. In general, there is the following relationship among the different types of electrical conductivities: EC_w < EC_e < EC_a. Thus, when the EC_a, at a soil depth of 30 cm, is greater than a specific threshold (depending on the crop and the level of yield reduction that we would like to avoid), the proposed IoT system suggests using, for example, irrigation water only at critical stages of growing or a higher dosage of water in larger time intervals for leaching salts from the soil and removing salt water to the borders of the wetted soil, and accordingly, the main volume of water in the soil remains close to the EC_w values [22,24,25]. Detailed descriptions of the reliability of the specific IoT intelligent irrigation system of the proposed irrigation advisory policy approach can be found by Tzerakis et al., 2023 [22]. Figure 6A depicts the installation of the above-mentioned IoT intelligent irrigation system in the field.

The installation of the above system is accompanied by the provision of a service to determine the critical hydraulic properties of the soils that define the optimal limits of variation of the soil moisture in the field as well as the percentage (%) of soil moisture or the threshold of critical matric potential, which should be kept constant over time depending on the phenological stage of the crop. The determination of these soil properties is carried out

quickly and accurately through the use of specialized equipment available from IOSV and the Water Resources, Irrigation, and Environmental Geoinformatics Laboratory. Based on this laboratory analysis and the phenological stage of the crop, critical hydraulic properties of the soils such as the total available soil water (the difference between the volumetric soil water content of field capacity and permanent wilting point multiplied by the effective root depth) as well as the readily available soil water (a fraction of the total available soil water that a crop can extract from the root zone without suffering water stress) can be determined. Analytically, the above hydraulic properties and others can be estimated using KSAT, HYPROP 2, and WP4c laboratory analysis systems. Figure 6B(1–4) illustrates the above-mentioned laboratory devices. For this purpose, undisturbed soil samples have to be extracted from the soil depth of 30 cm close to the TEROS 12 smart sensor. Afterwards, soil cores are transferred to the laboratory and saturated according to the protocol. Once saturation, the KSAT system (METER Group, Pullman, WA, USA) is engaged to measure the saturated hydraulic conductivity of the soil sample. In turn, the HYPROP 2 system (METER Group, Pullman, WA, USA) is employed to measure soil moisture distribution and hydraulic conductivity at different tensions for the creation of the moisture retention curve. Finally, a dew point hygrometer, the WP4c (METER Group, Pullman, WA, USA), is used to measure soil water potential in drier ranges (up to -300 MPa). The combination of the results of KSAT, HYPROP 2, and WP4C into HYPROP-FIT software provides a high-accuracy soil water retention curve [26–28].

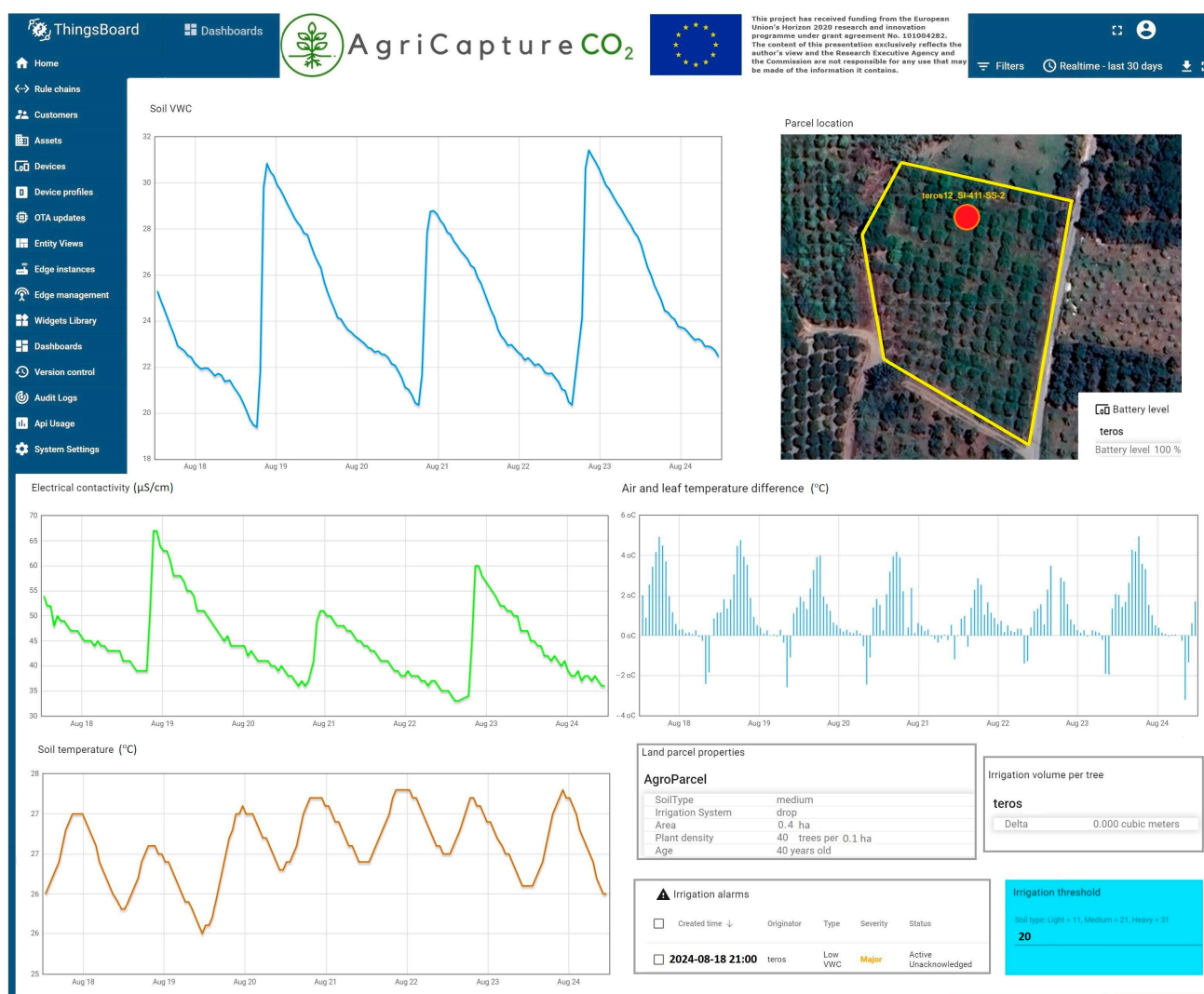


Figure 5. The open-source Things Board IoT platform for data visualization.

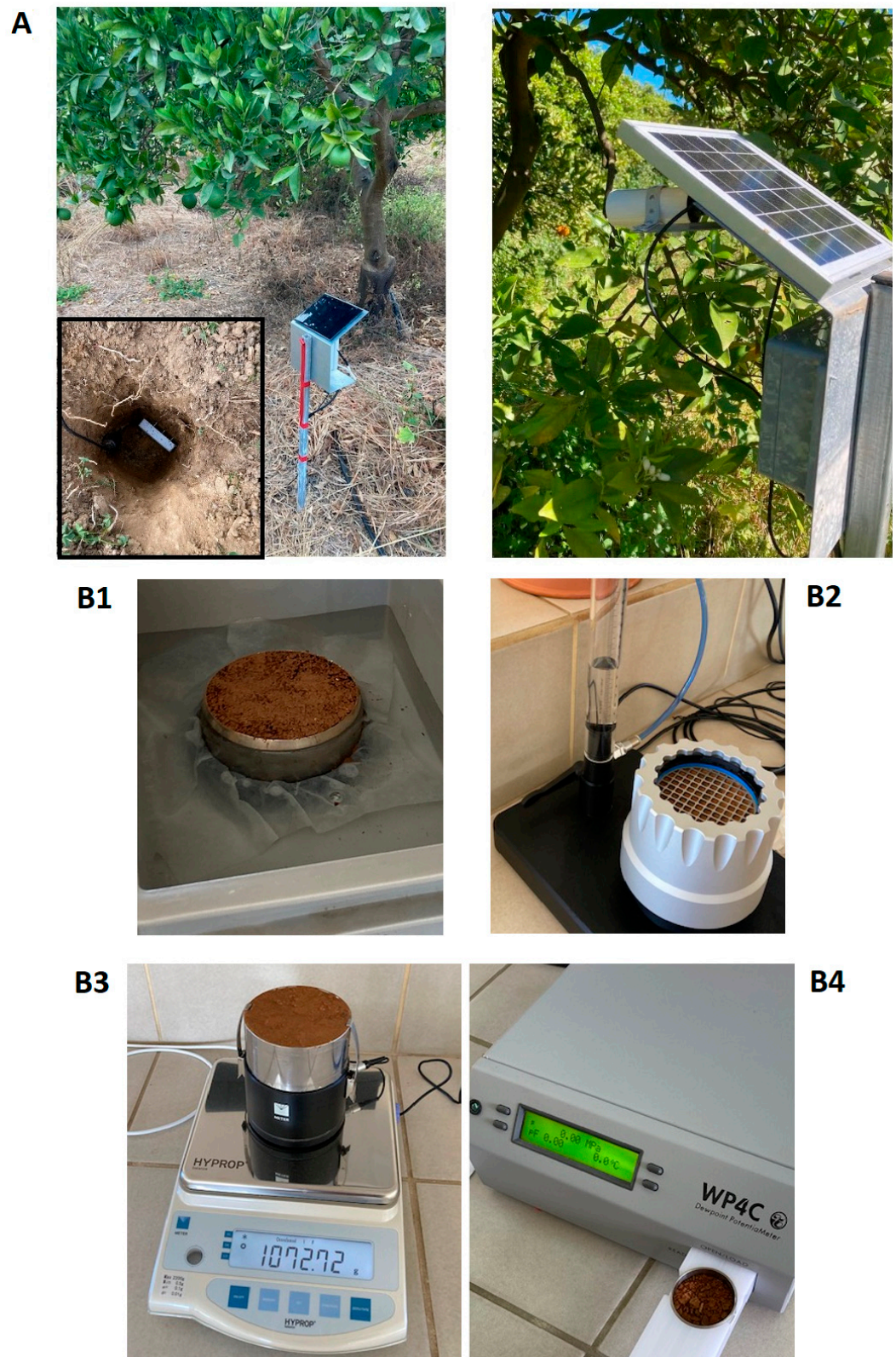


Figure 6. (A): The installation of the IoT intelligent irrigation system in the field. B(1–4): The accompanied devices for laboratory analysis service to determine the critical hydraulic properties of the soils [(B1): undisturbed-saturated soil sample; (B2): KSAT device; (B3): HYPROP 2 device; and (B4): WP4c device] (third component of the proposed framework).

The above laboratory analysis devices provide accurate results regarding the determination of soil hydraulic parameters, information that in sensor-based irrigation is mainly obtained from empirical or literature approaches. In addition, the combination of IoT technology with the analysis of laboratory devices that we mentioned above is a procedure applied for the first time in Greece, a fact that defines the innovative character of this third component of the proposed irrigation advisory framework [22] [Figure 6A,B(1–4)].

Based on the above, farmers have complete monitoring of the climatic and soil–water conditions prevailing in their field and can access all of this through their smart phones, fully controlling the needs of their plots. Another ability of our IoT smart irrigation system concerns the capability of this system to automatically control the electric valve based on soil moisture levels, a fact that can improve the efficiency of irrigation and save the farmer time and effort. This system is energy-independent and low-cost as it is based on open-source software, and the hardware on edge devices contains widespread economical modules. It is also completely reliable in terms of the accuracy of soil moisture recording. The above IoT smart irrigation system and service were established and verified in the context of the European project AgriCaptureCO₂-Horizon 2020. This system, which has been in full operational use since 2021, offers an efficient irrigation support service to farmers, giving them the opportunity to be trained before using it.

4. Advantages of the Proposed Holistic Irrigation Advisory Policy Scheme—Level of Satisfaction and Further Improvements

The proposed irrigation advisory policy scheme can offer local farmers and water management authorities, for the first time in Greece, the ability to support proper irrigation conservation approaches, depending on spatial scale of interest (for instance, either for agricultural area or for parcel scale) and the precision of irrigation practices that they would like to be applied [29]. Thus, the user can select among three different components: (a) the weekly informative irrigation bulletins; (b) a digital irrigation management web-based platform; and (c) an IoT intelligent irrigation system for parcel-scale implementations. Table 1 describes and compares the main characteristics and capabilities of each of the above three components. The planned application and usage of this scheme could be addressed as a successful implementation approach by local bodies such as municipalities, local irrigation network organizations, group or individual farmers, cooperatives, as well as regional water directorates, the Ministry of Rural Development and Food, and decision-makers for water management at the national and European level.

Up until now, user testing has been conducted by farmers, agronomists, and water managers from different locations and organizations in Crete, randomly selected concerning their “hands-on” experience with the components of the proposed irrigation advisory policy framework. Specifically, during four different dissemination actions, one-day events, held in each of the four prefectures of the island of Crete, surveys were conducted regarding the acceptance of the three components of the proposed irrigation advisory policy approach. Specifically, the Delphi method was used to quantify and collect the opinions of a total of 120 farmers, agronomists, and water management experts. The Delphi method can be characterized “as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem” [30]. The questionnaire for each survey included two questions. The first was about the level of awareness and familiarity of the user with the proposed irrigation advisory policy approach (three classes of awareness were noted: not at all aware/familiar; relatively aware/familiar; and fully aware/familiar), and the second question was about the percentage of satisfaction in terms of effectiveness and usability, where five classes of satisfaction (in terms of percentages) were applied: 0–20%, 20–40%, 40–60%, 60–80%, and 80–100%. User feedback was very satisfactory with regard to both the awareness and the effectiveness of the whole proposed approach. Specifically, 74% of the respondents answered that they were fully aware/familiar, and 82% of the respondents answered that they were by 80–100% satisfied by the proposed irrigation advisory policy approach.

Table 1. The main characteristics and capabilities of the three components of the proposed irrigation advisory policy scheme.

Components of the Proposed Irrigation Advisory Policy Scheme	Scale of Implementation	Simplicity of Obtaining the Information Needed	Cost of Use	Method to Determine Irrigation Scheduling–Accuracy in Prediction of Irrigation Needs	Special Services Offered
Weekly informative irrigation bulletins	Region level	Yes [No needed action from the user]	No [Free available Information]	➤ Incorporating crop type, age, and phenological stage of the crop and crop evapotranspiration ➤ Irrigation needs ($\text{m}^3/0.1 \text{ ha}$) and applied doses per week ➤ Sufficient accuracy in irrigation needs prediction	➤ Informing about the appropriate period for applied deficit irrigation for each crop
Digital irrigation management web-based platform	Parcel and Region level	Yes [Users were able to acquire irrigation information with just a click on the digital map] Basic internet knowledge is needed	No [Free available information via web]	➤ Incorporating crop type, age, and phenological stage of the crop, crop evapotranspiration, and soil texture information ➤ Irrigation needs ($\text{m}^3/0.1 \text{ ha}$) and applied doses per week and for individual parcels ➤ High accuracy in irrigation needs prediction	➤ Deficit irrigation approaches ➤ Proper agronomical recommendations for adaptation to climate change ➤ Irrigation management at river basin scale
IoT intelligent irrigation system in the field	Parcel level	Yes [Users were able to obtain irrigation information via Things Board IoT platform] Required the establishment of special equipment (sensors) in the field and soil laboratory analysis	Low Cost [sensor installation and lab. analysis cost EUR 100 (one-time cost) plus monthly full operational service cost of EUR 20]	➤ Incorporating crop type, age, and phenological stage of the crop, soil moisture levels, and soil hydraulic properties ➤ Irrigation needs (liter/plant/time) for individual parcels ➤ Very high accuracy in irrigation needs prediction	➤ Deficit irrigation approaches ➤ Proper agronomical recommendations for adaptation to climate change ➤ Hydraulic soil properties ➤ Saline water irrigation management ➤ Automatic control of irrigation

Nevertheless, systematic user testing needs to be applied so as to further improve user interaction with the irrigation advisory policy scheme and especially with the IoT intelligent irrigation system. In addition, as most farmers in Crete irrigate empirically and many times refuse to implement practices of correct use of irrigation water, a particular challenge we had to face was to convince the farmers about the benefits they could have when implementing the proposed system as far as it is about securing their production

and income, saving water resources, and optimally adapting their parcels to extreme climatic conditions. However, despite the difficulties, the overwhelming majority of the users in our case study seem to be convinced about the abilities of the proposed advisory system, which offers three different and well-adapted components that can be used and selected by the user based on their own needs and capabilities. Furthermore, a weakness of the proposed system is that so far, its implementation has only been carried out on the island of Crete. Therefore, there is a need to extend its application to other regions of Greece by capturing different environments and crop growth conditions. Thus, as a future prospective, the proposed irrigation advisory policy approach has the capability of escalating its applications/implementations. For instance, additional services can be added, such as:

- Extending the implementation at national scale or even areas from other Mediterranean countries.
- Considering more crop types or even crops from other Mediterranean countries.
- Conducting systematic user testing so as to further improve the irrigation advisory policy usability.

5. Conclusions

One of the key challenges of the coming decades is to increase global crop production to meet increased food needs. For the majority of Mediterranean areas, such as the island of Crete, irrigation is a key element of agriculture. In such areas, irrigation water needs will continue to increase in the coming years also due to climate change, evidence that indicates the necessity of applying rational irrigation. According to the Ministry of Rural Development and Food of Greece, the effective use of irrigation water in Greece does not exceed 65%, and the main reason for this is that farmers and irrigation water management bodies, instead of choosing the mandatory use of an irrigation advisory system and its remote control, choose to apply irrigation empirically, quantitatively, or with time limitations. This tactic does not consist of rational use since it does not cover the needs of the crops nor does it ensure the economy of water, as farmers tend to over-irrigate when the price is low to feel “safe”. In addition, irrational irrigation in many cases leads to over-pumping and/or waterlogging and salinization of soils. Given that there is also competition for water with other uses in Mediterranean areas, such as tourism, the proposed irrigation advisory scheme can offer savings and reasonable use of irrigation water. Based on so far evidence, the implementation of the proposed system as a whole scheme (three different levels of implementation) with the appropriate dissemination actions to be implemented by the farmers and water distribution agencies could contribute to saving irrigation water of the order of 30%. Additionally, the implementation of the proposed IoT intelligent irrigation system (third component of the proposed framework) is expected to result in a reduction in water and energy consumption and therefore a reduction in CO₂ emissions. The reduction in emissions will also come from the automatic control of irrigation, minimizing the cost of moving to the parcels. Taking into consideration that the proposed advisory irrigation scheme has been implemented in Crete during recent years with very successful results, we must overcome any doubts and hesitations on the part of the farmers about the use of new technologies in irrigation water and use this advisory tool as a demonstrator of custom-made solutions, raise awareness, and inspire water managers as well as farmers for a wider adoption of irrigation practices to alleviate water-related climate change effects in agriculture.

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