Evaluation presentation and development of a web based irrigation management tool

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Abstract

In Greece about 70% of the consumed water supply is used for irrigation, and thus optimal irrigation management is an increasingly important crop production objective. At the plain of Arta at Epirus (Greece), the irrigation systems (both central and private) suffer from fundamental problems regarding their design, installation and management. With the given infrastructure, rational water management could promptly and directly increase irrigation efficiency. Based on this hypothesis, a pilot web service was developed and has operated for 6 years. In the present paper, the meteorological network, the web service and the calculation procedures used in the system, along with the front end capabilities, are presented. The main features of the service are the publication of information regarding daily reference and crop specific evapotranspiration. The calculations are based on actual meteorological data and an estimator, based on water balance calculations, for the time and duration to the next irrigation event. The pilot version of the system has already disseminated recommendations to more than 8,000 agro-meteorologists, agronomists, irrigation engineers and farmers. Feedback from the end-users is positive, and relevant water consumption and crop yield data are presented. These results were used to enhance and expand the system at Arta and to upgrade a related web service that is operating in Puglia (Italy).

Keywords: irrigation practice, water needs, web based irrigation scheduling

INTRODUCTION

The EU Water Framework Directive (WFD) 2000/60/EC (EU, 2000) dictates that action has to be taken to protect water mainly in qualitative but also in quantitative terms. In this direction, various measures are proposed to be adopted by member states, among which are the promotion of water-efficient technologies and water-saving irrigation techniques. The UN Environment Program (UNEP, 2005) concluded that a challenge of water-related issues for Mediterranean countries is to apply integrated water demand management models in agriculture and in this context to develop added value tools for optimization of irrigation efficiency. AQUASTAT (2014) states that, in Greece, about 70% of the available water resources are used for irrigation purposes and 82% in Epirus (SWW, 2013). In this framework, irrigation stakeholders are facing a rising challenge to lower water and energy consumption. With the given infrastructure, irrigation system efficiency at end user level would promptly increase if more efficient irrigation techniques (e.g., micro-irrigation) were expanded along with auditing procedures, frequent maintenance and rational water management practices. In the framework of management, the control of irrigation systems involves the determination of frequency, timing and duration of irrigation events.

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Every approach for setting up an irrigation schedule is based on the estimation of the crop or landscape water needs; commonly done by means of an energy and/or mass balance method (Allen et al., 1998; Donatelli et al., 2006). The use of installed or web based software applications for estimation of plant's water needs and setting up irrigation schedules is nowadays a common practice for irrigation managers, farmers and in some cases for garden owners. Some good examples are Ref-ET (Walter et al., 2001), CropWat (FAO, 2014) and CIMIS (CDWR, 2014). In Greece, relevant products concerned in most cases installed software (Chartzoulakis et al., 2007). Evaluation of these tools showed impressive results with reported reduction of water consumption for irrigation by 20% for olives (Chartzoulakis et al., 2007) and of 45% for landscape irrigation (Davis et al., 2009; Nouri et al., 2013). In every case, these tools should be adjusted for local conditions and this presupposes knowledge of the special characteristics of the crops for each region and of the local irrigation practice.

The web tool that is presented in this paper is operational at pilot level since 2008. About 8,000 irrigation recommendations have been generated during this period and selected farms, which take advantage of the tool, are continuously monitored and provide data that are used for the system's evaluation. The characteristics of the tool and the results of its evaluation are presented along with the design outlines for its successor, which is under development.

MATERIALS AND METHODS

Area, crops and irrigation practice

The Region of Epirus (ROE) is located in northwest Greece, where agricultural land corresponds to 14% of the total area. The plain of Arta (45,329 ha, the biggest of ROE), is located at the south of Epirus and it is part of the Aracthos and Louros hydrological basins (SSW, 2013). The elevation of the plain is between 0 and 100 m and the terrain is almost flat as 72% of the area has a slope up to 8%. A recent analysis of about 200 soil samples (0-30 cm) distributed over the plain showed that the pre-dominant soil texture is medium to heavy (TEIEP, 2010). The water table rises up to less than 1 m below the surface during winter in many parts of the plain, but it remains deeper than 1.5 m during summer. The climate of the area is of Mediterranean, which is characterised by hot summers and rainy, moderate winters. Data from the HNMS (2014) shows a 30 years average annual precipitation of 1084 mm, while the monthly average temperature ranges from 4.7°C in January to 32°C in August. The main crops of the plain of Arta and their irrigated and non-irrigated acreages are presented in Figure 1 (DAERSA, 2012). A survey regarding end-users' irrigation systems at the plain of Arta (Tsirogiannis and Triantos, 2009) revealed fundamental problems regarding design, installation and management. That study was focused on three of the main crops of Arta, i.e., orange and olive orchards and kiwi. The survey was conducted using both onsite interviews and comparisons between actually applied water with estimated water needs. The results revealed that surface irrigation was used in 40% of the cases. Sprinkler irrigation was also used in 40% of cases and drip irrigation comprised 20% of the cases. The vast majority of the systems were not designed and installed by professionals and their management was based on empirical irrigation schedules. Water meters, pressure gauges, tensiometers and other control devices were rarely installed. The comparison between applied water and estimated water needs, according to FAO paper 56 methodology (Allen et al., 1998), revealed great differences between them. For citrus and kiwi, excess water was generally applied while too little was applied to olives.

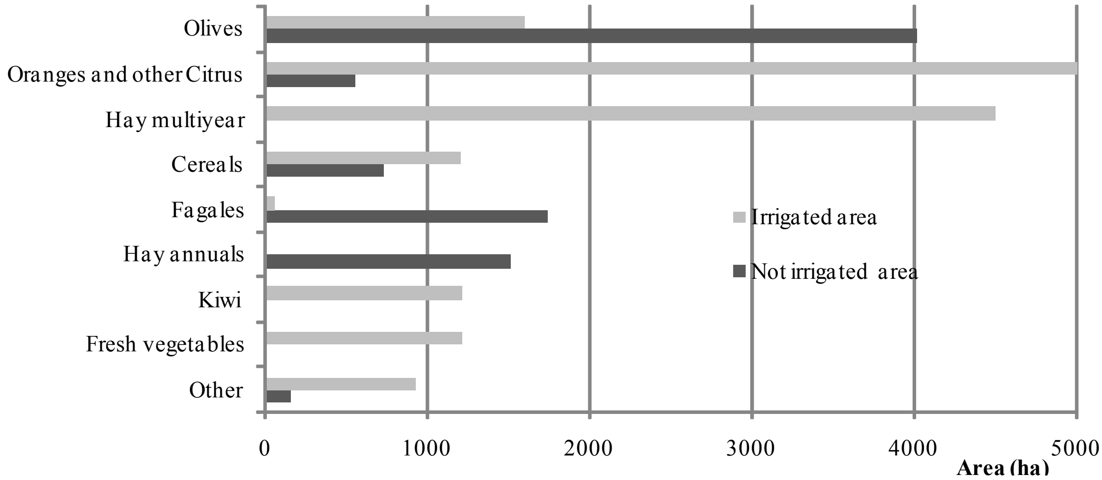

Figure 1. Crops of the plain of Arta (DAERSA, 2012).

System characteristics

The above presented context was the motivation to develop a user friendly web-based information system that would assist local agronomists and act as advisors to farmers and landscape managers to promote good irrigation management practices and document relevant decisions. The website is hosted at: http://probiosis.teiep.gr. It is available in Greek language and provides: a) daily evapotranspiration data (ET_o and ET_c of selected crops), b) an archive of evapotranspiration data, c) a tool for estimation the time and the duration of the next irrigation event and d) documentation regarding use of the tool and the information that the users provide to adjust it to their specific cases.

The web site is based on a straightforward concept. Meteorological stations monitor climatic information, which is retrieved at the end of each day. For the estimation of crop water needs in the plain of Arta, two meteorological stations where used (model Vantage Pro2 Wireless, Fan-aspirated, DAVIS), one at Vlaherna (39°10'21.74"N; 21°05'01.87"E) and one at Kompoti (39°10'21.74"N; 20°59'57.92"E). Both stations are equipped with air temperature and relative humidity sensors, a pyranometer, a rain gauge and an anemometer. Reference evapotranspiration and potential crop evapotranspiration (ET_c) for the selected crops in the area are calculated at the end of each day using the Penman-Monteith approach (Allen et al., 1998) and crop coefficient (K_c). The use of proper K_c values that reflect the characteristics of local cultivars, growing period and local agricultural practice is of great significance for accuracy in estimating ET_c (Allen et al., 1998; Holzapfel et al., 2000; Palomo et al., 2002; Orgaz et al., 2006). The ET information (reference as well as potential for citrus, kiwi, olives and turfgrass) is posted at the front page of the website and stored in the relevant database. The irrigation consultant or the end user can retrieve this information to determine irrigation schedules. The web site also includes an estimation tool to estimate the time and the duration of the next irrigation application. The user provides basic information regarding the site of the field, the soil type, the crop, the available flow and the irrigation system type as well as information regarding the time and duration of the last irrigation. Then a script that is based on water balance equations – as described in FAO p56 (Allen et al., 1998; Jhorar et al., 2009) uses the stored historical ET information along with measured ET and rainfall to forecast for the next three days – is calculated using the Bolam model (Lagouvardos et al., 2003) – to provide recommendations regarding the time and duration of the next irrigation event. Both the daily water balance table and the recommendation are available on the screen and can be printed as a report. A guide regarding the use of the tools and the estimation of the various factors that are used for the next irrigation recommendation is available along with other documents and links to general concepts and special techniques of irrigation scheduling. The dynamic web tool was designed following the object oriented approach and developed using PHP scripting language (Zend

Technologies, 2009).

A series of classes were developed for collecting meteorological data and field measurements from external sources. During operation, classes collecting external data are invoked periodically using two Cron Jobs, and the web server data are collected using CURL operations. Collected data are stored in the database. Another set of classes was developed to perform the required calculations, display historical data and provide advice regarding the time and duration of next irrigation. Configuration parameters are stored in special files. Temporary and permanent data are stored in a MySQL database (Sun Microsystems, 2008).

Characteristics of the users that participated in the evaluation

For evaluation purposes, ten users were monitored for a period of three years (2011-2013). They agreed to use the recommendations generated by the system to irrigate selected fields and keep records regarding water consumption. Simple survey forms and common 2-inch mechanical water meters were used for that. The peculiarity of local farms that commonly consist of a number of individual fields was an advantage for this case because it is common for a farmer to own 2-3 fields of the same crop in the same area of the plain. All of the selected fields had similar characteristics: they were flat and horizontal, their soil was of medium texture, the water table was lower than 1.5 m during irrigation period, the crops were in early maturity age and irrigation water was delivered using micro-sprinklers.

RESULTS AND DISCUSSION

The above presented system has provided more than 8,000 irrigation recommendations. The area (ha) of the sample that was irrigated using the recommendations generated by the system and that which was irrigated conventionally (based on the experience of the farmer) for olives, oranges and kiwis are presented in Figure 2. Figure 3 presents the average water consumption from irrigation and the corresponding average yield for the two management approaches. Using the recommendations that were generated by the system resulted in a +10% increase in water usage for olive production, but the change in management gave a +15% shift in yield quantity. For citrus and kiwi, there was a decrease of -3 and -7%, in water consumption when recommendations from the system were used. Yield was increased by +2 and +11%, respectively, for the two crops.

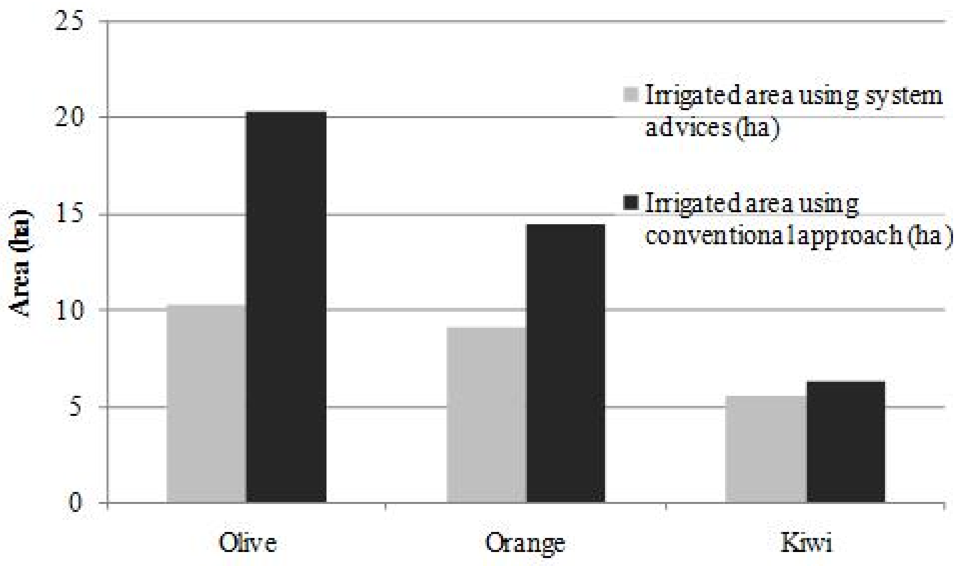

Figure 2. Area of sample crops for system evaluation.

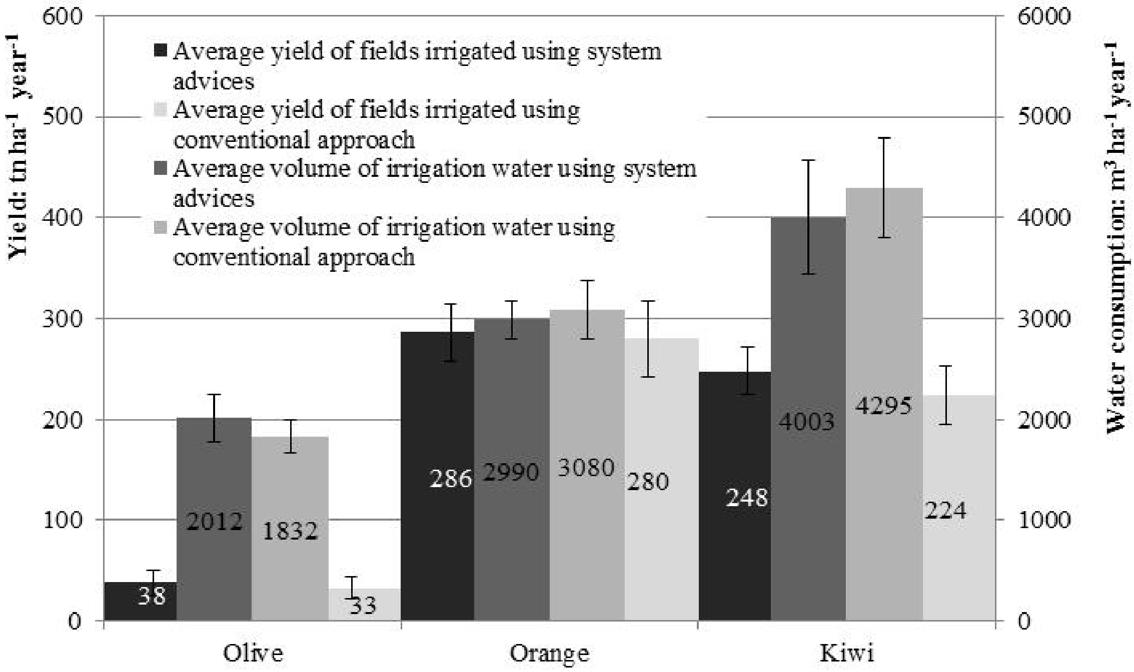

Figure 3. Comparison of irrigation water consumption and relevant yield for the 3-year evaluation period. Error bars represent ± 1.0 standard deviation.

Feedback regarding the use of such systems was optimistic. Better irrigation water management, in most cases, decreased the water and energy consumption while increasing the yield. The lower water consumption was environmentally beneficial because there were fewer effluents, which in many cases contain residuals of fertilisers, chemicals and other contaminants. It also contributes to management of water tables.

From 2013, a new system will enhance and expand the existing pilot system at Arta and a similar system that operates in the Region of Apulia in Italy (http://www.agrometeopuglia.it/opencms/opencms/Agrometeo/Irrigazione/consiglioIrriguo). This system, which is funded by ETCP GR-IT 2007-2013, will be available from the middle of 2015 at: http://arta.irrigation-management.eu/.

A meteorological station network will continuously monitor data to estimate plant water requirements and to set up irrigation schedules. The system will be compatible with various types of meteorological stations to allow other organizations or individuals to be linked and provide data. The use of a dense network of stations will provide better accuracy regarding the microclimatic effects. Data from meteorological stations surrounding the study area (plain of Arta) will be used as boundary values. Also, quality checking procedures will be implemented and unexpected values or gaps will be flagged and filled using suitable spatial interpolation methodologies. Data collection will be performed by the open source software package ENHYDRIS (Kozanis et al., 2012), which allows the storage and retrieval of raw data, processed time series, model parameters, curves and meta-information such as measurement stations overseers, instruments, events, etc.

The system calculates current water needs on an hourly basis. The daily water budget is found by aggregating the hourly time series at the end of each day. For special cases like soilless production or substrate based landscaping systems, the system is capable to provide values of selected parameters (e.g., solar radiation and rainfall) in a finer timescale (e.g., 10 min). Forecasts regarding weather parameters will be available. Spatial interpolation of the collected data (measurements and forecasts) in an appropriate grid size will provide evapotranspiration (Allen et al., 1998) and other water budget parameters throughout the study area. In this way, irrigation scheduling at field level will be feasible by incorporating site specific data and meteorological stations that monitor only some parameters (i.e., solar radiation, cloudiness or temperature) can contribute to the system. Data manipulation and visualization will be performed by an open source software package which will include the GRASS, GEOSERVER and OPENLAYERS open source software modules, in order to be able to provide – via web GIS – the information in map and table format.

The system will be implemented in an interoperable and flexible way so that data are easily accessed by users or by stand-alone smart irrigation controllers connected to the internet and other similar applications. In every case, the final information will help to develop site specific irrigation schedules that are evaluated by irrigation specialists before they are applied.

CONCLUSIONS

The evaluation of irrigation practice for three of the main crops of Arta revealed significant problems which lead to low water use efficiency. In order to succeed in prompt improvement of irrigation management in the area, a web service was developed where crop water requirements are calculated and formation of irrigation schedules can be carried out using inputs regarding climate, crop, soil and irrigation system. After 6 years of operation and dissemination of advice to more than 8,000 users, the overall opinion about the system is positive. Evaluation of the system showed that it can really contribute to irrigation management improvement and crop yield shift. A number of comments that were collected all these years envisaged the design of its successor. The new system will incorporate a more dense meteorological stations' network, spatial integration operations which will involve topography and hydrological data and GIS capabilities and improvement of the user interface and self-training documentation.

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