Main Features and Application of a Web-based Irrigation Management Tool for the Plain of Arta

Nikolaos Malamos[1], Ioannis L. Tsirogiannis[2], Antonis Christofides[3], Stavros Anastasiadis[4], Silvia Vanino[5]

[1]Technological Educational Institute of Western Greece, Dept. of Agricultural Technology, 27200 Amaliada, Greece, e-mail: nmalamos@teimes.gr
[2]Technological Educational Institute of Epirus, Dept. of Agricultural Technology, 47100 Kostakii, Arta, Greece, e-mail: itsirog@teiep.gr
[3]National Technical University of Athens, Dept. of Water Resources and Environmental Engineering, Iroon Politechniou 5, 15780 Zografou, Athens, Greece, e-mail: anthony@itia.ntua.gr
[4]Chios, Greece, e-mail: anastasiadis.st00@gmail.com
[5]Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria, 41 Nomentana St., 00161, Rome, Italy, e-mail: vanino@inea.it

Abstract. Agriculture plays a key role in the management of water use. Especially in Greece, irrigation is an essential element of agricultural production and agricultural water use has a substantial share in total water use. The presented study illustrates the key features of the IRMA_SYSTEM, a regional, user-friendly computer/mobile-based, open and free modular software for estimating site specific crop water requirements and irrigation scheduling at multiple scales, from farm to water basin level. The estimation of irrigation water requirements and irrigation scheduling is based on a modification of the FAO 56 approach. The system takes into account historical and forecast agrometeorological data, along with crop and soil-water data to accomplish its tasks. Also, it is fully customizable, allowing the users to add site and crop specific information taking advantage of additional data. Feedback and evaluation procedures are already applied and expected to contribute to the improvement of the system.

Keywords: irrigation scheduling, open source software, agrometeorological information

1 Introduction

According to the EU Water Framework Directive WFD, 2000/60/EC (EU, 2000 (Greek law (GL) 3199; Govern. Gazette (GG) A'280 9-12-2003) and Presidential Decree (PD) 51;GG A΄54 8-3-2007)), action is needed to protect waters primary in qualitative but also in quantitative terms. In the framework of the UN Environment Program (UNEP, 2005) it was concluded that a challenge of water-related issues for Mediterranean countries is to integrate water demand management in agriculture and

Proceedings of the 7th International Conference on Information and Communication Technologies in Agriculture, Food and Environment (HAICTA 2015), Kavala, Greece, 17-20 September, 2015.

to develop added value tools to optimize efficiency in irrigation. In 2012, the EU-report on identifying water saving potentials in the EU countries mentioned that improving water application efficiency would save 15 to 60% of water use (BIO Intelligent Service, 2012). Also CMMC (2013) predicts a reduction up to 60% in water availability for irrigation in extended Mediterranean areas of EU countries. These facts make optimum irrigation water management a top priority goal. Beyond these, the European Landscape Convention (which was adopted by the Greek state in 2010, GL 3827;GG A'30 25-2-2010) promotes protection, management and planning of natural, rural, urban and peri-urban areas including land, inland water and marine areas and must be also taken into account as an integral part of the environmental and agricultural legislative framework. Among the various measures which member states are proposed to adopt and develop are added value tools to optimize efficiency in irrigation.

The purpose of the present study is to illustrate the key features of such a tool, the IRMA_SYSTEM (http://arta.irrigation-management.eu/), which is a regional, user-friendly computer/mobile-based, open and free modular software for estimating site specific crop water requirements and irrigation scheduling at multiple scales, from farm to water basin level, with high spatial resolution. The system takes into account historical (from the system's stations) and forecast agrometeorological data, along with crop and soil-water data to accomplish the above mentioned tasks. Also, it is fully customizable, allowing the users to add site specific information in order to customize the output of the system, taking advantage of additional information.

Similar systems are: the California Irrigation Management Information System (CIMIS, http://wwwcimis.water.ca.gov/), the Hydrotech-DSS (Todorovic et al. 2013) and the ServiziAgronomici e Fitosanitari, Consiglio Irriquo (http://www.agrometeopuglia.it) (AssocodiPuglia, 2008).

2 Materials and Methods

2.1 Study Area

The Region of Epirus (hydrological area GR05; Fig. 1) is located at the North-West part of Greece, it has a total area of 9.203km^2 (agricultural land corresponds to the 14% of it) and a population of 353.820 p. The plain of Arta (45.329 ha, the biggest of the region), is located at the south edge of Epirus, it is part of the Aracthos and Louros hydrological basins (GR14 and GR46; WFD, 2013) and intersects with Amvrakikos Wetlands National Park.

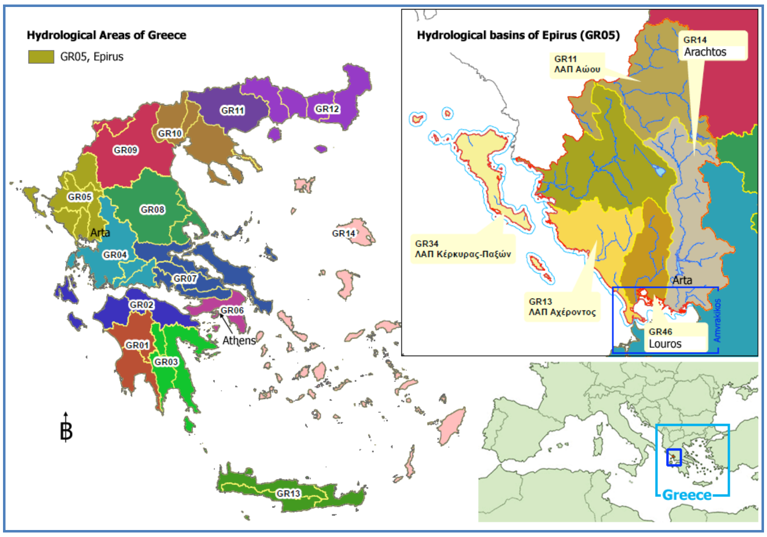

Fig. 1. Hydrological basins of Greece, along with the hydrological basins of Epirus. (WFD, 2013)

2.2 Estimation of daily and hourly potential evapotranspiration, with the Penman - Monteith equation

The Penman - Monteith (PM) equation for the estimation of reference evapotranspiration was developed to describe potential evapotranspiration (PET) of a reference grass crop, which is defined as the rate of evapotranspiration from a hypothetical crop with an assumed fixed height (12 cm), surface resistance (70 sm^{-1}) and albedo (0.23), closely resembling the evapotranspiration from an extensive surface of a disease free green grass cover of uniform height, actively growing, completely shading the ground, and with adequate water and nutrient supply (Allen et al., 1998, Eq. 1). To ensure the integrity of computations, the weather measurements should be made at 2 m (or converted to that height) above an extensive surface of green grass, shading the ground and not short of water. Standard methods are proposed by Allen et al. (1998) to compute the parameters of Eq. 1 from the observed climatic variables.

$$PET = \frac{0{,}408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0{,}34 u_2)} \qquad (1)$$

where PET is the grass reference evapotranspiration (mm day^{-1}), R_n is the net radiation at the crop surface (MJ m^{-2} day^{-1}), G is soil heat flux density (MJ m^{-2} day^{-1}), T is mean daily air temperature at 2m height (^{o}C), u_2 is wind speed at 2 m height (m s^{-1}), e_s is saturation vapor pressure (kPa), e_a is actual vapor pressure (kPa), e_s–e_a is saturation vapor pressure deficit (kPa), Δ is slope of the vapor pressure curve (kPa C^{-1}), and γ is psychometric constant (kPa C^{-1}). This equation uses standard meteorological records of solar radiation (net, short wave, or sunshine duration) or sunshine duration, minimum and maximum air temperature, air humidity (preferably minimum and maximum relative humidity) or wet and dry bulb temperature, and wind speed.

In areas where substantial changes in wind speed, dew point or cloudiness occur during the day, calculation of the PET equation using hourly time steps is generally better than using 24-hour calculation time steps. Such weather changes can cause 24-hour means to misrepresent evaporative power of the environment during parts of the day and may introduce error into the calculations. With the use of the IRMA_SYSTEM, automated weather stations, weather data are available for hourly periods. Therefore, the PM equation was applied on an hourly basis (Allen et al., 1998).

2.3 Estimation of irrigation needs

The irrigation needs are estimated based on an approach that is called root zone soil water depletion, which is a simplified soil water balance based on an initial soil moisture condition and runs for a specified time period (*start date*, *end date*).

The basis for the calculation is the following ormula (Allen et al., 1998):

$$D_{r,i} = D_{r,i-1} - (P_i - RO_i) - IR_{n,i} - CR_i + ET_{c,i} + DP_i \quad (2)$$

where: i is the current time period (i.e. the current day, or hour), $D_{r,i}$ is the root zone depletion at the end of the previous time period, P_i is the precipitation, RO_i is the runoff, $IR_{n,i}$ is the net irrigation depth, CR_i is the capillary rise, $ET_{c,i}$ is the crop evapotranspiration, DP_i is the water loss through deep percolation.

The following limits were imposed on $D_{r,i}$:

$$\Theta_s <= D_{r,i} <= ASM \quad (3)$$

where Θ_s is the soil moisture at saturation and ASM is the total available soil water, which is the difference between Field Capacity (FC) and Permanent Wilting Point (PWP) as they are presented in Fig. 2. This approach is slightly different that the one proposed by Allen et al., 1998, since they propose that $D_{r,i}$ is always positive.

RO_i equals the amount of water that exceeds soil moisture at saturation after heavy rain, i.e.:

$$RO_i = P_i + \Theta_{i-1} - \Theta_s \text{ when } (P_i + \Theta_{i-1} - \Theta_s) > 0 \quad (4)$$

where Θ_{i-1} is the soil moisture at the previous time step. CR_i and DP_i are considered zero, since in the case of the Arta plain there is a shallow water table and equilibrium between them is considered.

The equation therefore becomes:

$$D_{r,i} = D_{r,i-1} - P_i - IR_{n,i} + ET_{c,i} + RO_i \quad (5)$$

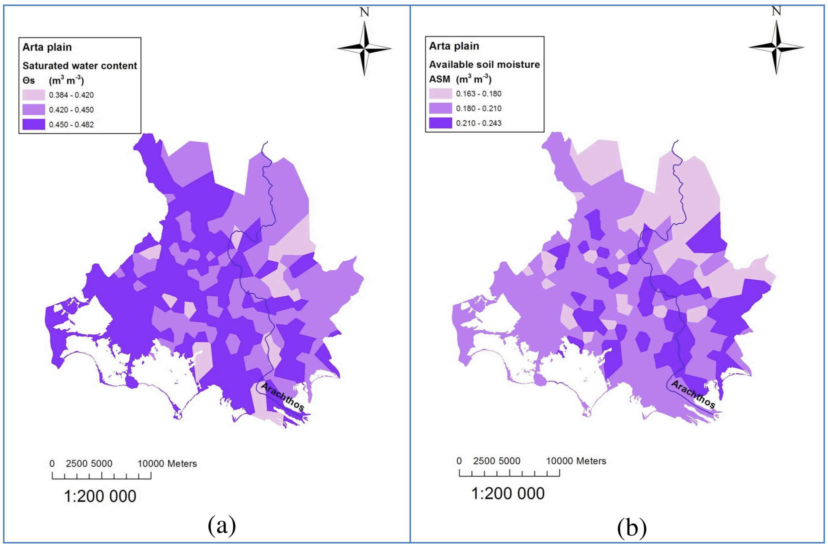

Fig. 2. Saturated water content (Θs) map (a) and Available soil moisture (ASM) map (b) of IRMA_SYSTEM area at Arta plain.

$ET_{c,i}$ is calculated using crop coefficient approach by multiplying evapotranspiration by crop coefficient Kc (Allen et al., 1998).

Each time the user irrigates, the initial depletion derives from the provided irrigation water volume. An essential simplifying assumption of this method is that each time we irrigate without providing the irrigation water volume, we assume that enough water was applied in order for the soil moisture to reach FC (i.e. zero depletion). Therefore, in this case we have i=1 and $D_{r,1}=0$.

The point i=1 is specified by *start_date*, which is a datetime object. The *initial_soil_moisture* will usually equal FC (this, according to the essential simplifying assumption, means that the crop was irrigated on *start_date*). However, if the crop has not been irrigated recently, *initial_soil_moisture* will be set to another value (such as a soil moisture measurement made at *start_date*).

Soil moisture (Θ_i) and depletion are related with this formula:

$$\Theta_i = FC - D_{r,i} / \text{Root depth} \quad (6)$$

So, since the *initial_soil_moisture* is given, $D_{r,1}$ is also known.

The method returns the root zone depletion for *end_date* in millimeters (mm). Precipitation and ET_c must have non-null records for all days from the day following *start_date* to *end_date*.

2.4 System Implementation

The system is a product of cooperation between experts in the fields of meteorological data acquisition, agricultural cultivation and landscapes water needs, irrigation management, irrigation controllers manufacturing and software developers. The general organisation of the system is presented in Fig. 3, while the flowchart of the system modules is presented in Fig. 4.

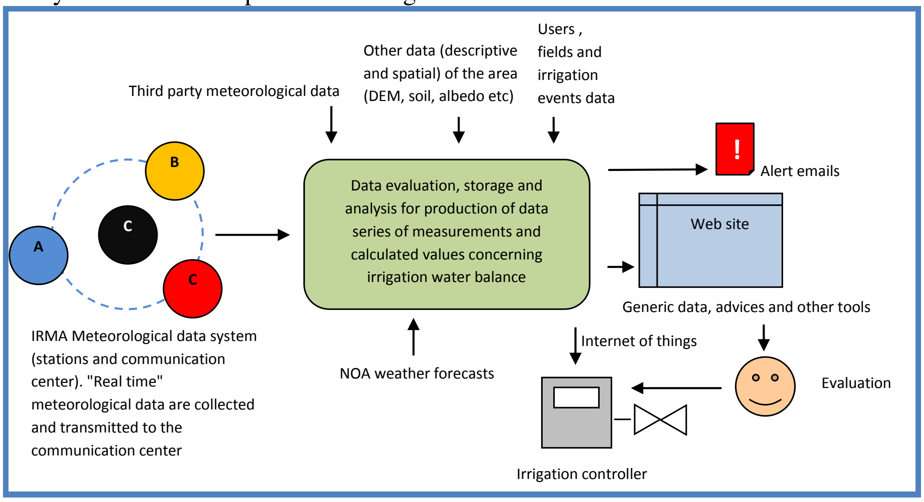

Fig. 3. IRMA_SYSTEM organisation plan

The IRMA_SYSTEM is a user-friendly computer/mobile-based, open and free modular software, with its source available at: https://github.com/openmeteo/aira, under the terms of the GNU General Public License as published by the Free Software Foundation, written in Python and Django, along with NumPy (http://www.numpy.org/) and GDAL - Geospatial Data Abstraction Library (http://www.gdal.org/) modules.

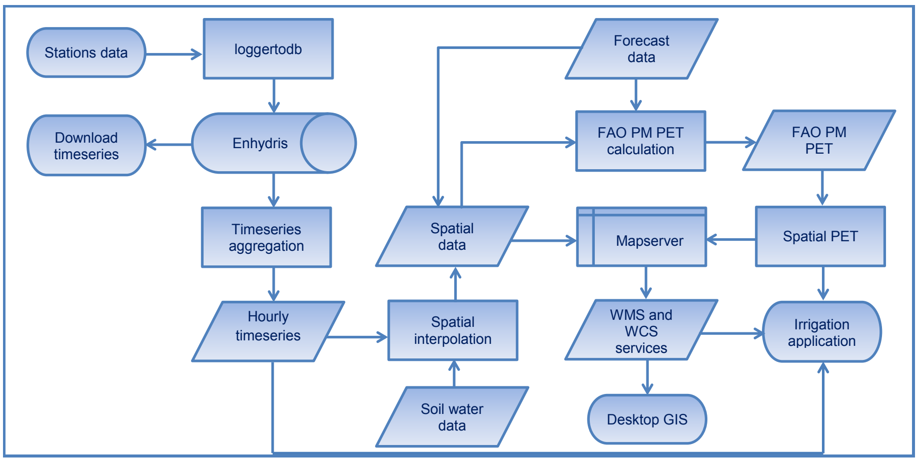

Fig. 4 Flowchart of IRMA system modules

The Enhydris database (http://system.irrigation-management.eu, https://enhydris.readthedocs.org) web interface, with the available meteorological stations is presented in Fig. 5. It includes a map that provides information about the location of each station, together with the identification numbers, water basin, water division, owner and type of the meteorological stations.

Agrometeorological data timeseries and crop water requirements estimations are provided to users and visitors, while irrigation advices and a series of other utilities will be available only to registered users. Users that want more precise results will have to install meteorological and/or soil moisture sensors and dataloggers at their fields.

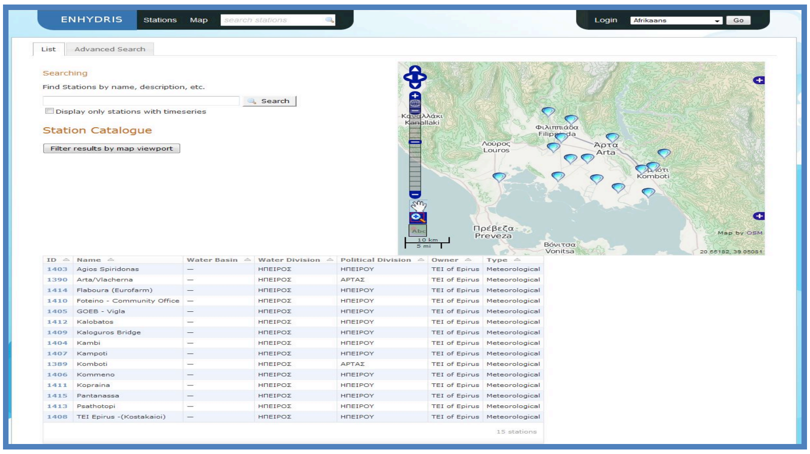

Fig. 5. The Enhydris database web interface

Agriculturalists, green infrastructure managers, farmers and gardeners will be able to use the system for setting up irrigation schedules, plan and record irrigation events as well as self-training regarding irrigation management.

Figure 6 presents the home page of the system. The main feature is the map presentation of the different variables, in daily time scale, that are involved in the irrigation requirements methodology presented above, such as: Rainfall, Potential Evapotranspiration, Humidity, Temperature, Wind speed and Solar Radiation, with high spatial resolution of 70×70 m grid. The maps are produced by implementing the Inverse Distance Weighting (Burrough and McDonnell, 1998) method for spatial interpolation, found in the GDAL library.

The system provides this information of the study area, through the WMS service provided by the Mapserver that was set for the purposes of the present project (http://mapserver.org/). The historical data are kept from 1/1/2015 onwards, while several maps produced by satellite images are also available.

Registered users can add their fields into the system (Fig. 7) using a map, in order to pinpoint the geographic location of each field, with the help of the Hellenic Cadaster orthophoto imagery basemap (http://gis.ktimanet.gr/wms/ktbasemap) that allows zoom in scales up to 1 m. The user should provide information regarding the field's area, crop, irrigation type and strategy. Also, a list of the user's already register fields is available at the bottom of the page.

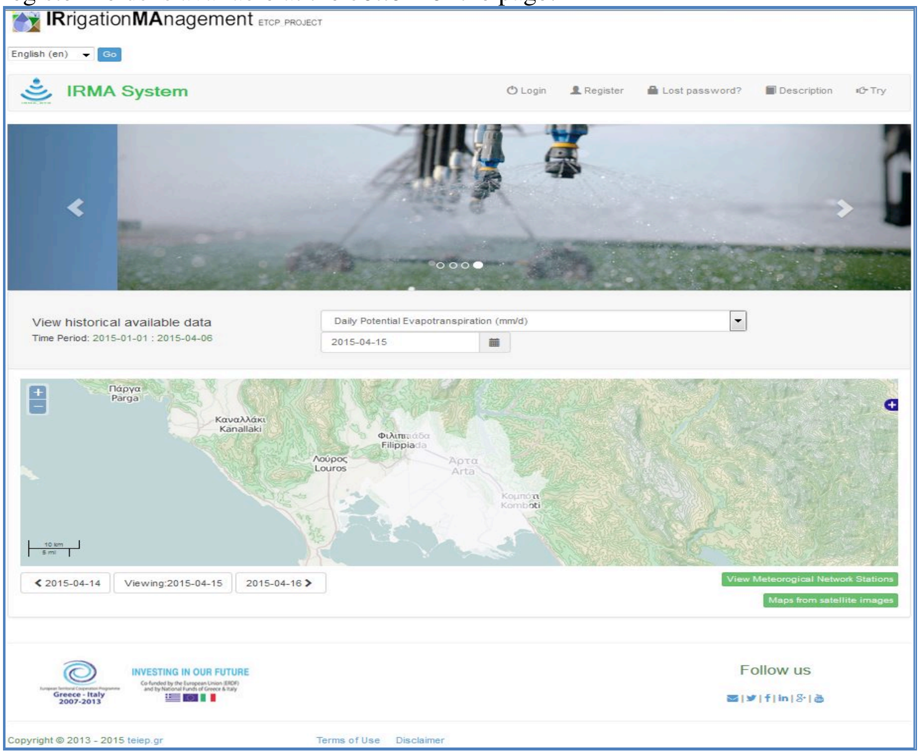

Fig. 6. IRMA_SYSTEM front page

If appropriate information is available to the registered users, they are able to modify the properties of each field, based on this information, as shown in Fig. 7. This information consists of parameters grouped in three major categories:

- Irrigation Management
- Crop Parameters
- Soil Parameters

Irrigation Management includes information regarding irrigation efficiency and strategy. Crop includes information regarding the crop coefficient (Kc), the maximum allowed depletion factor (MAD), the estimated maximum and minimum root depth. Soil includes information regarding the FC, PWP and Θ_s. Appropriate ranges and the system's default values, according to literature, are available to the user in order to provide guidance.

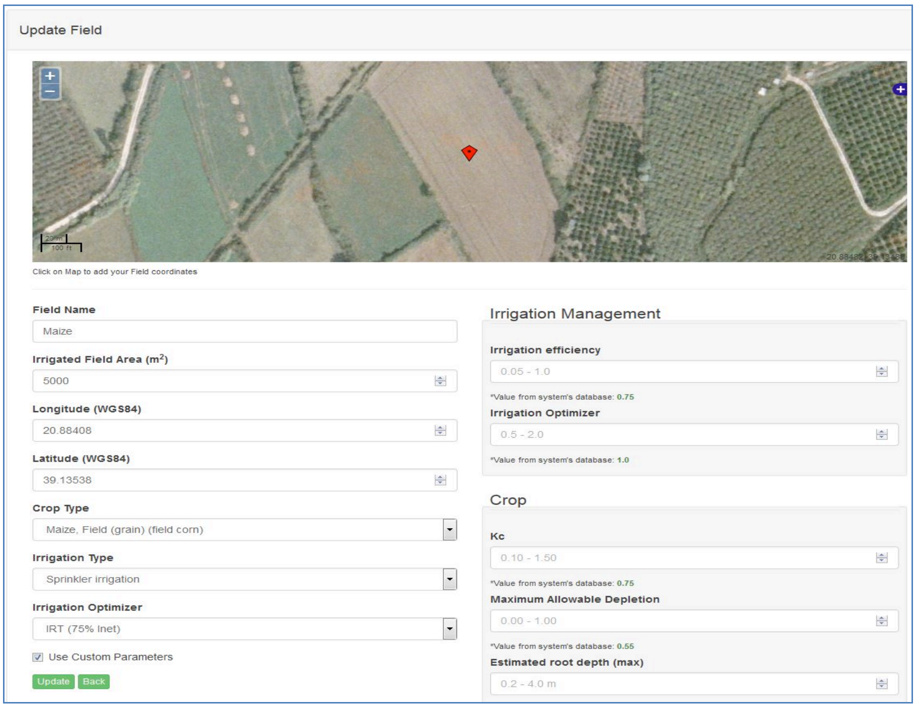

Fig. 7. The Update Field module of the IRMA_SYSTEM

Since the initial soil moisture is included in the initial conditions of the soil water balance module of the IRMA_SYSTEM, register users should add the irrigations that they have applied for each field, in order to get the appropriate irrigation advices. If the user does not provide information about the applied irrigation water volume, the system assumes that the applied water was enough in order for the soil to reach field capacity. Figure 8 depicts the irrigation events list module of the IRMA_SYSTEM.

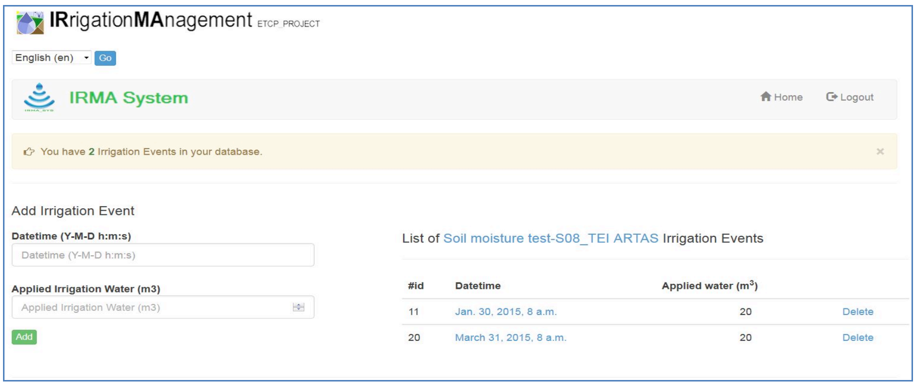

Fig. 8. The Irrigation Events list module of the IRMA_SYSTEM

Since the registered users provide the above information, the system produces detailed irrigation advice estimates, in hourly basis, based on both historical and forecast data as presented in Figures 9, 10.

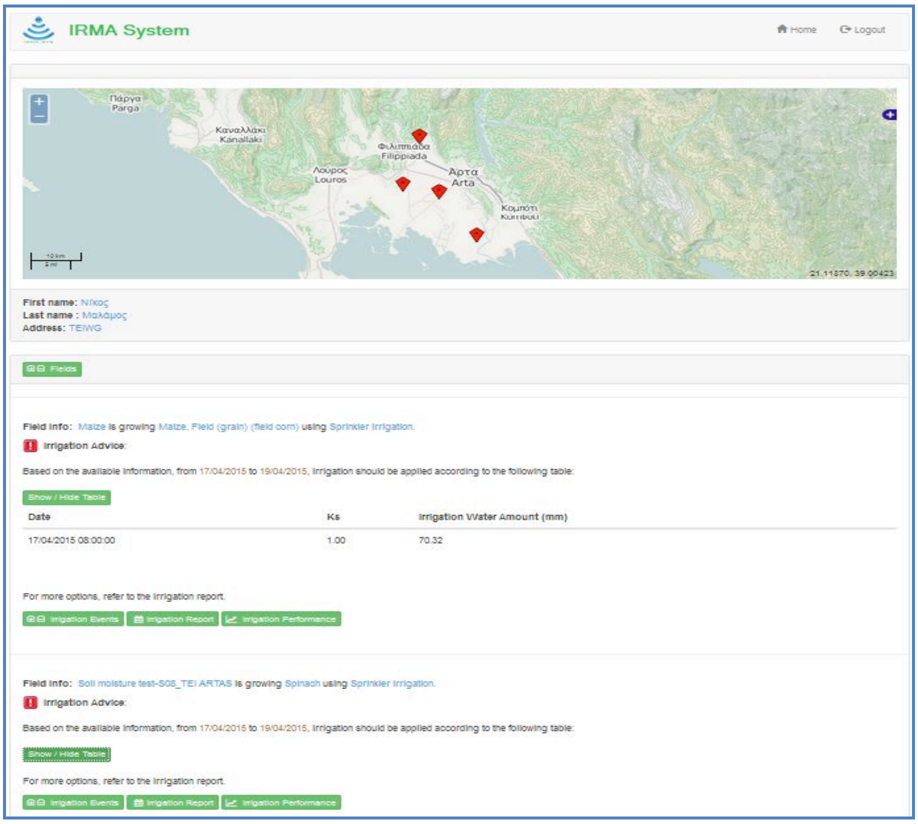

Fig. 9. Irrigation advice module of the IRMA_SYSTEM

2.5 Evaluation and Feedback

A feedback procedure will be available for users that want to contribute to the improvement and evolution of the system by evaluating it. A series of training seminars for agriculturalists, which are expected to be the main type of users (in order to analyze the provided information before make relevant suggestions to farmers and green spaces managers) will follow the development. Also special seminars for end users, in order to have a basic understanding of the system operation will be made. Relevant training and help material will be available at the tool's web site.

Field evaluation will be held for both agriculture and landscaping case studies, against soil moisture readings from installed sensors at the agrometeorological stations and irrigation water amount recordings.

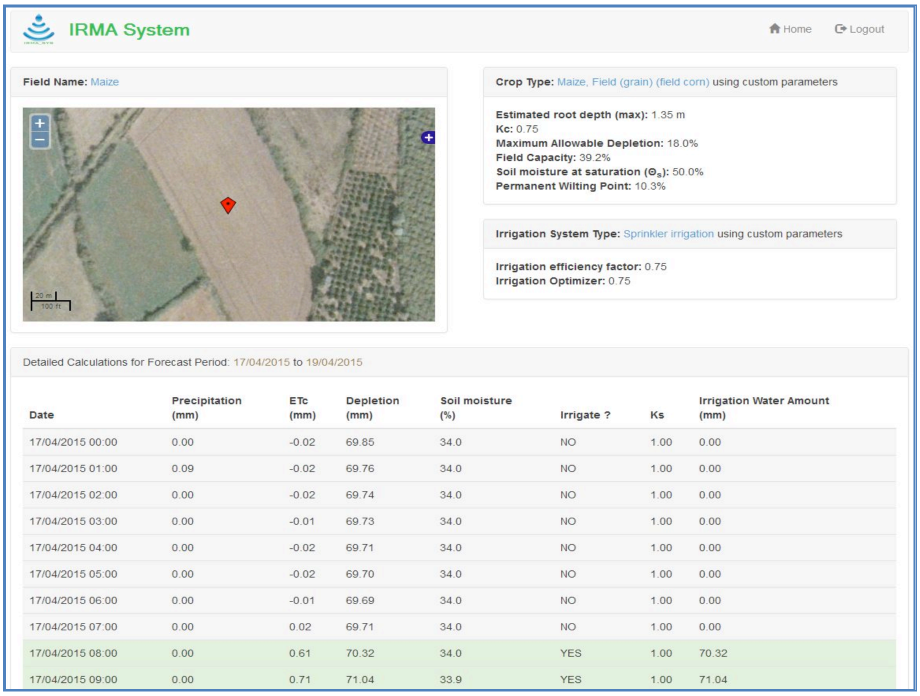

Fig. 10. Detailed irrigation report module of the IRMA_SYSTEM.

3 Conclusions

The IRMA_SYSTEM is an added value regional management and planning tool designed to contribute along with the other tools of IRMA project (http://www.irrigation-management.eu/) to the improvement of efficiency in irrigation techniques and irrigation scheduling from farm to water basin level, with high spatial resolution.

It is a user-friendly computer/mobile-based, open and free modular software that provides crop water requirements estimations and irrigation advices to users and visitors, based on agrometeorological data timeseries and a modified FAO 56 approach.

The system is fully customizable, allowing the users to add site and crop specific information in order to customize the output of the system, taking advantage of additional information.

It is easily expandable, since the individual modules are independent of the number of stations and accepts all kinds of forecast data.

The feedback and experimental evaluation procedures will contribute to the further improvement and versatility of the system, aiming at increased experience gain at regional level with different type of farms, crops and soil water information.

Acknowledgments. This work has been co-financed by EU / ERDF (75%) and national funds of Greece and Italy (25%) in the framework of the European Territorial Cooperation Programme (ETCP) GREECE-ITALY 2007-2013 (www.greece-italy.eu): IRMA project (www.irrigation-management.eu), subsidy contract no: I3.11.06.

References

1. Allen, R.G., Pereira, L.S., Raes, D., Smith, M. 1998. Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56. FAO, Rome.
2. AssocodiPuglia, 2008. Agronomical and Crop Protection services, Irrigation advice. Available at: http://www.agrometeopuglia.it/opencms/opencms/Agrometeo/Irrigazione/consiglioIrriguo. Accessed: 1/2/2014 (in Italian)
3. BIO Intelligent Service, 2012. Water savings potential in agriculture in Europe: finding from the existing studies and application to case studies.
4. Burrough, P.A. and McDonnell, R.A., 1998. *Principles of Geographical Information Systems*. New York: Oxford University Press.
5. CMMC (Euro-Mediterranean Centre on Climate Change), 2013. Regional Assessment of Climate Change in the Mediterranean. Available at: http://www.eea.europa.eu/data-and-maps/indicators/water-requirement-1/assessment, accessed: 1/9/2014.
6. EU - European Union 2000. The EU Water Framework Directive - integrated river basin management for Europe. Available at: http://ec.europa.eu/environment/water/water-framework/index_en.html.
7. Todorovic, M., Cantore, V., Riezzo, E.E., Zippitelli, M., Gagliano, A., and Buono, V., 2013. HYDRO-TECH: An integrated decision support system for sustainable irrigation management (i): Main algorithms and field testing. *In*: N. Lamaddalena, M. Todorovic, and L.S. Pereira, eds. *1st CIGR Inter - Regional Conference on Land and Water Challenges*. Bari: CIHEAM-IAMB, 87.
8. UNEP - United Nations Environment Program 2005. Mediterranean Strategy for Sustainable Development - A Framework for Environmental Sustainability and Shared Prosperity. UNEP(DEC)/MED WG.277/4. Available at: http://www.un.org/esa/sustdev/natlinfo/indicators/egmIndicators/MSSD_latest_eng.pdf.
9. WFD, Special Secretariat for Water (Greek State), 2013. Management plan for the hydrological basins of Epirus (GR05). Athens (in Greek).