Citation: Todorovic, M., E. E. Riezzo, V. Buono, M. Zippitelli, A. Galiano, and V. Cantore, 2016. Hydro-Tech: an automated smart-tech Decision Support Tool for eco-efficient irrigation management. International Agricultural Engineering Journal, 25(2): 44-56.

Hydro-Tech: an automated smart-tech decision support tool for eco-efficient irrigation management

Mladen Todorovic[1,*], Erminio E. Riezzo[2], Vito Buono[1], Mario Zippitelli[2], Angelo Galiano[3], Vito Cantore[4]

(1. *CIHEAM – Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano (BA), Italy*;

2. *Sysman Progetti & Servizi srl, Via A. Montagna 2 - zona PIP, 72023 Mesagne (BR), Italy*;

3. Dyrecta Lab, Via Vescovo Simplicio 45, 70014 Conversano (BA), Italy;

4. CNR – Institute of Science of Food Production, Via Amendola 122/O, 70126 Bari, Italy)

Abstract: Hydro-Tech is a new automatized decision support system which integrates the results of scientific achievements and technological innovations in the fields of crop water requirements and irrigation scheduling, on-field data acquisition, transmission and management, and application of web and app tools for real-time irrigation management. The system combines agronomic, engineering, environmental and economic aspects of water management, aims to improve the eco-efficiency of agricultural water use and may be applied at both farm and irrigation district scale using the advanced technological solutions for the continuous sensor-based monitoring of the soil-plant-atmosphere continuum and the remote control of irrigation supply networks. Hydro-Tech is based on the standard FAO-56 approach for the estimation of reference evapotranspiration using the Penman-Monteith equation and determination of crop water requirements and irrigation inputs under different water management strategies. The system has a modular and flexible structure which permits the creation of the user specific scenarios based on the real on-farm conditions and constraints. As such, the system allows the estimation of reference and crop evapotranspiration under limited data availability and employs the latest scientific achievements to recover the missing data and to develop the crop coefficient curves according to the specific crop species, biometric and phenological characteristics. The crop development is modeled by means of both calendar-day and heat-unit concepts. The real-time soil water balance is based on a simply cascading approach, runs on a daily basis and includes the high-resolution weather forecasting data which permits the pro-active irrigation management considering three to seven forthcoming days. A dynamic multi-crop/multi-plot/farm optimizer supports the user-defined setting of constraints and irrigation priorities at the farm scale by taking into account the water availability at its quality, the soil water moisture level and eventual crop water stress, and the economic parameters. Hydro-Tech provides standard interfaces connecting the on-field devices with the client software application through a Data Cloud Network (Hydrotech Data Cloud, HDC) which permits wireless, via new generation of smart devices (tablets, smartphones), and continuous monitoring of the on-field conditions and the remote control and management of irrigation. Hydro-Tech was developed within the framework of the EC-ERDF program and it is actually operated in the Apulia Region (Italy) at different farms for the irrigation management of

Received date: 2014-10-21 Accepted date: 2016-01-04

[*] **Corresponding author: Mladen Todorovic,** CIHEAM – Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano (BA), Italy. E-mail: mladen@iamb.it.

peach and olive orchards, wine and table grapes, and vegetables. Several examples of application showing the enhancement of eco- efficiency of local agricultural systems are briefly described.

Keywords: irrigation management, decision support system, resources use efficiency, wireless communication, automated control

1 Introduction

Sustainable agricultural water management requires reliable and easy-to-use methods to support real-time irrigation scheduling especially in arid and semi-arid regions where water is scarce resource. This means a comprehensive knowledge of weather, soil, crop and irrigation system characteristics needed to determine 'when' to irrigate and 'how much' water to supply in respect to the specific environmental conditions and management strategies. On-farm irrigation scheduling can be supported by means of several technical and scientific methods based on the evaluation of soil/plant water status and/or on the simulation of crop-soil water balance, although for all basic approaches both advantages and disadvantages are normally found (Jones, 2004). Therefore, it is often convenient to combine more than one of these approaches to arrive at the desired procedure.

Nowadays, the application of new technologies for control and automation of irrigation is receiving growing attention. This is due to: i) maturity of the technologies for acquisition of real-time digital weather, soil and crop data, ii) improved methodologies for estimation crop water requirements and irrigation scheduling; iii) improved reliability and effectiveness of sensors used for measurements of the soil-plant-atmosphere system; iv) easier access to data describing soil-plant-atmosphere continuum from remote sites through wireless connections; v) increased communication options offered by telemetry/remote control systems, being installed both in collective pressurized systems and in individual farms; vi) the cost-effectiveness of these technologies in developed countries when compared to labor costs (McCarthy et al., 2011; Romero et al., 2012; Zapata et al., 2012).

In the last few years (2011-2014), a consortium of private ICT companies and Research institutions has been developed a new automatized decision support system which integrates the results of scientific achievements and technological innovations in the fields of crop water requirements and irrigation scheduling, on-field data acquisition, transmission and management, and application of web and app tools for real-time irrigation management. The system, called Hydro-Tech Decision Support System (HT-DSS) aimed: a) to design a 'simple and practical', user-friendly computer/mobile-based DSS, by considering also the end-user feedbacks and specific requirements; b) to test and validate at farm level the effectiveness and reliability of simulations for different vegetables, fruit trees and grapevine crops, under different agronomic, management and pedo-climatic conditions; c) to test the effective integration of different technologies and d) to evaluate the most cost-effective solutions. The main algorithms of the model are briefly introduced in this paper, together with a description of the on-going experimental activity at farm level in Apulia region (Southern Italy).

2 Description of the system (HT-DSS)

An overall structure of HT-DSS is given in Figure 1 and it is based on the integration of the following series of software and hardware components: a) a specific module for the collection and elaboration of weather data collected by meteo stations close to the area of interest b) a water balance model for the simulation of daily soil water balance; c) a short-time (three-seven days) weather forecasting module for the soil water balance computation for incoming days; d) a specific 'multi-plot and multi-crop management module' for the optimal water allocation considering all farm's irrigated plots, water availability and economic parameters of cultivation; e) capacitance sensors, for the real-time monitoring of soil water content; f) modern information and communication technologies for data-cloud computing; g) specific software applications for both 'desk' computers and ‘mobile’ devices (tablet, smartphone); h) field data-loggers, connected with weather and/or soil moisture sensors; i) remote monitoring in the water supply network (volumes, discharges, pressures, etc.) and control of actuators (at the level of pumping station, hydrants, electro-valves, etc.) to support farm operational management; j) module for the estimation of economic product added value and eco-efficiency.

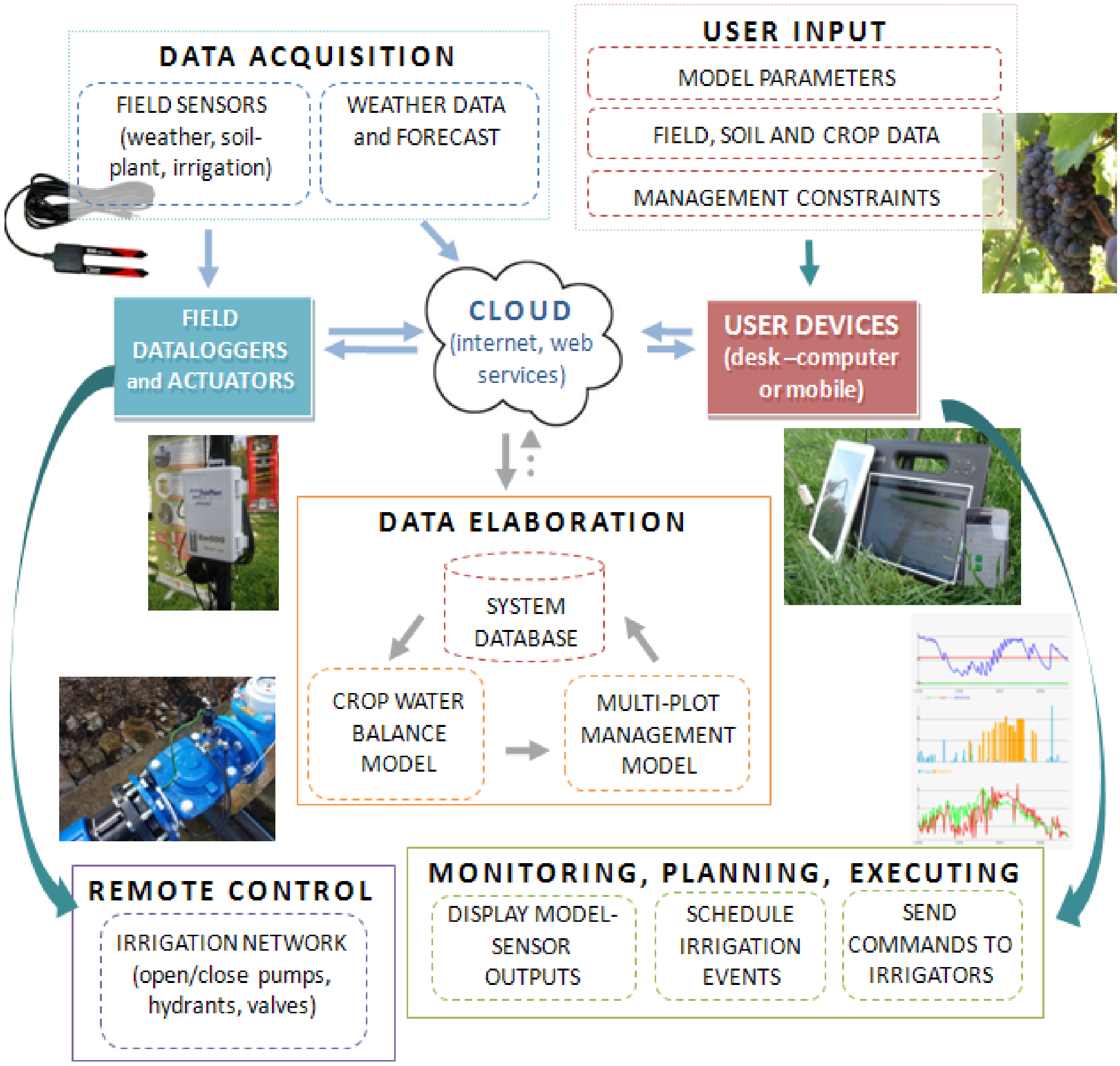

Figure 1 Overall structure of the Hydro-Tech DSS

The HT-DSS is designed to run simulations at the scale of a single ‘irrigated plot’, defined as the field-unit cultivated with the same crop (also in terms of cultivar type, planting date, density, etc.), with relatively homogeneous soil characteristics (average depth, texture, soil water holding capacity, etc.), weather (precipitation input), agronomic management practices (e.g. fertilizer input, mulching, etc.) and irrigated with a uniform irrigation method/system. Crop-soil water balance and irrigation scheduling are computed by means of a specific model, originally written in the MS Excel® programming language and previously tested and applied for similar applications (Todorovic, 2006). The model estimates crop evapotranspiration, irrigation water requirements and relative yield through the standard procedure proposed by the FAO 56 Paper (Allen et al., 1998), and it is composed of three main calculation ‘modules’ (Figure 2): the ‘ET_o module’, the ‘water balance module’ and the ‘management module’. Furthermore, specific databases are created to store and manage historical climate, soil and crop data. Reference evapotranspiration (ET_o) can be estimated by several methods depending on the availability of input data and including: a) the standard FAO Penman-Monteith approach (Allen et al., 1998); b) the Hargreaves-Samani equation (Hargreaves and Samani, 1985) and c) the Penman-Monteith-Temperature approach (PMT) (Allen et al., 1998; Todorovic et al., 2013), last two using only the measurements of minimum and maximum air temperature.

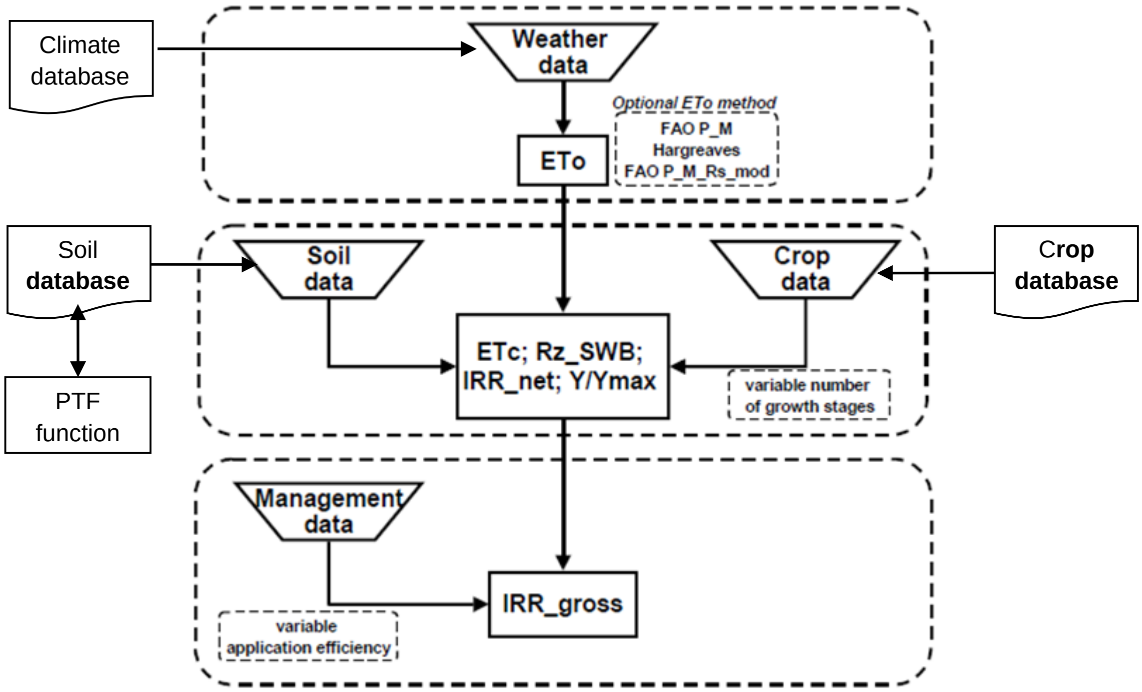

Figure 2 Main calculation modules and databases of the irrigation scheduling model (adapted from Todorovic, 2006)

The daily crop evapotranspiration (ET_c) is calculated from ET_o following the single-K_c approach, where the effects of both crop transpiration and soil evaporation are integrated in a single crop coefficient (K_c). The effect of soil water stress is considered by multiplying ET_c by the water stress coefficient (K_s), resulting in the 'actual' or 'adjusted' ET_c value (ET_{c_act}) as:

$$ET_{c\_act} = K_s\, K_c\, ET_o \quad (1)$$

The soil water balance is computed on a daily basis where water deficit in the soil (D) is calculated according to the following equation:

$$D_i = D_{i-1} - P_i - IRR_i - CR_i + ET_{c\_act,i} + RO_i + DP_i \quad (2)$$

In Equation 2, IRR is the net irrigation requirement (calculated by the model or inserted as an input), P is effective rainfall, DP is deep percolation, CR is the capillary rise and RO is surface runoff (all variables expressed on a daily basis, in mm, and *i* and *i-1* denotes on-going and previous day, respectively). Both RO and CR were assumed to be negligible, respectively because the field was flat and irrigated with low intensity, and because of the karstic soil features and the very deep water table. DP is calculated as the excess of water in the root zone as caused by excessive precipitation and/or irrigation.

The model runs on a daily basis and the length of growing stages can be determined either on a fixed calendar day basis or using the heat unit concept and growing degree days, i.e., generated from the air temperature data.

Relative yield reduction (YR) due to soil moisture stress is expressed as a percentage of the maximum production achievable under optimal conditions. The coefficient K_y can be set either for the whole season or for each specific growth stage. Accordingly, YR can be computed either by means of a unique K_y for the whole season (Stewart et al., 1977) or by a multiplicative approach considering different K_y for each growing stage (Rao et al., 1988).

In HT-DSS, a specific multi-plot and multi-crop management module has been created for the contemporary simulation of the crop water balance for all the irrigated plots, as dependent to the same water source (e.g. hydrant), and by considering available short-time weather forecasts. Then, a specific dynamic optimizer, based on non-linear optimization model, is applied to support the optimal setting of the irrigation priorities at the multi-plot scale.

Further characteristics of the system include: a) correction of the K_c values in relation to local climate and crop characteristics, b) variable and dynamic deficit irrigation scenarios, managed by setting a variable management allowable depletion (MAD) threshold in relation to the water stress sensitivity of different phenological stages, c) use of pedo-transfer function for soil parameters estimation, d) estimate of irrigation costs and benefits including the economic added value and eco-efficiency of specific irrigation scenario.

Furthermore, the system allows the display of real-time soil water content data measured by the sensors in order to check/compare/update the simulation results. A standard interface connecting the on-field devices with the client software application through a Data Cloud Network (Hydrotech Data Cloud, HDC) was developed. It supports wireless, via new generation of smart devices (tablets, smartphones, laptops), and continuous monitoring of the on-field conditions and the remote control and management of irrigation.

3 HT-DSS on-field implementation and technology transfer

The expected interaction between the end-user and the information system is related to three main actions, to be undertaken under an ergonomic graphical interface: 'data entry', 'consultation of results' and 'start of remote procedures'. According to these requirements, the system is designed according to a 'three-tier' architecture characterized by a user-friendly/multi-channel interface layer, an application layer with web-services and a data-storage layer. The approach is compatible with the development of software components separated into independent elements, which communicate with each other according to a client-server architecture making use of well-defined interfaces, giving the whole system a high degree of scalability and maintainability.

After the authentication procedure, a list of macro-areas and a list of irrigation zones are proposed to the end-user, to proceed to the detailed information on the current status of the each zone, on future weather conditions, on projections and on the irrigation advice processed by the expert system. The most significant trends are also conveniently represented graphically, such as for datasets collected from weather and ground stations. The rendering of the graphical interface is suitably decoupled from the remote content processing through asynchronous HTTP requests to the REST web-service, allowing user interactions while waiting for responses.

The 'web-service' exposes the remote methods required for each interaction with the application-layer and the data-storage layer. The web-application and the mobile-application takes advantage of the web-service as an interface to information and commands inside the information system, for which it constitutes an universal level of abstraction, open to the implementation of new user interfaces (such as a mobile-application for IOs and future data mining tools).

The 'application-layer' is the expert system responsible of the whole data processing required to find an optimal solution to the water balance equation, and is implemented in Java and PHP. The execution of the solver is launched invoking a remote method exposed by the web-service. The insertion of new inputs performed by the end-user (such as the insertion of a new irrigation) or performed at system level (such as an update in weather data) results in the loss of validity for the latest solution found: every time this condition occurs during the consultation phase, the calculation of a new solution is automatically launched without user interaction. Finally, the ‘data-storage layers’ is the database-server on which is recorded the whole dataset of collected and processed information, and is implemented as a relational database. An example of mobile ANDROID application, suitable for most of smartphones, is illustrated in Figure 3, in which the following screen display are shown: a) suggestion of the next irrigation (day, amount), with the level of current and projected 3-days changes in the percentage of soil water content (the ‘red’ color means ‘under stress’); b) the seasonal trend of soil water depletion, with respect to the RAW threshold, together with the graph of rainfall and irrigations; c) meteorological variables: temperatures, daily rainfall and relative humidity; d) daily trend of soil water content at different depths as recorded by soil moisture sensors.

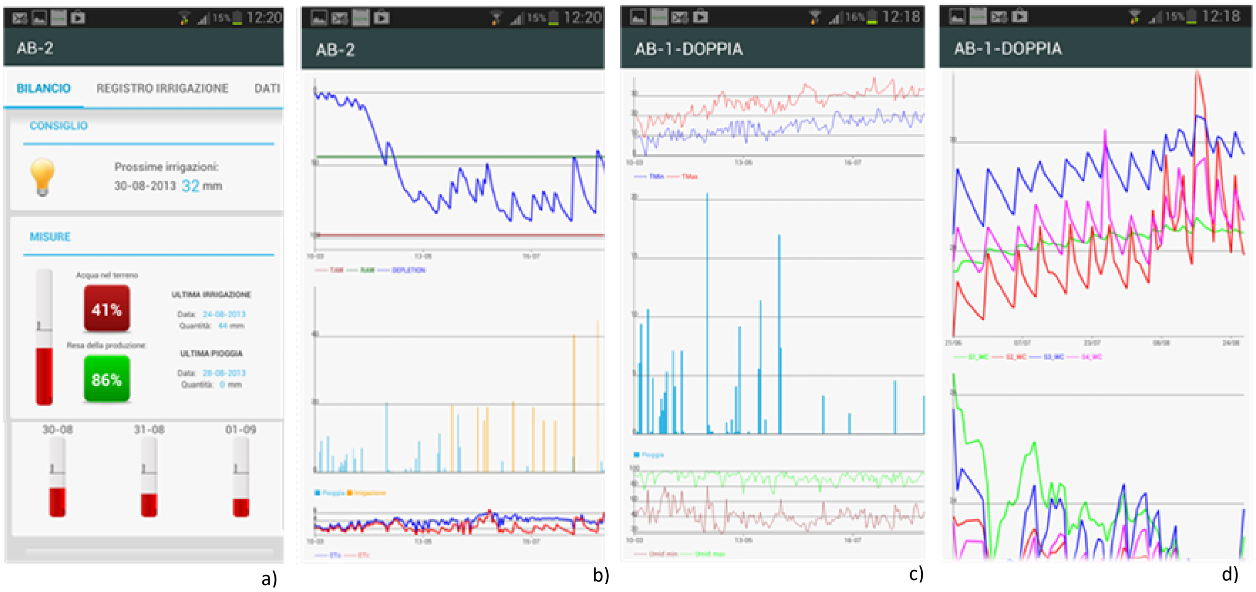

Figure 3 Example of MOBILE Android application.

4 Description of on-farm experimental/testing sites

Nine farms were selected in the Apulia Region (Southern Italy) to host the project experimental activities (for a total of 12 different crops and 20 irrigated plots). These farms (Figure 4) represented different pedo-climatic conditions, crops, total surface, level of organization and technical assistance. In each farm, a weather station has been installed for the site-specific acquisition of climate variables as required by the model to estimate reference evapotranspiration. Additional climate data are also automatically acquired by the HT-DSS from the public agro-meteorological service, based on a wide-spread regional network of field stations, by which the HT-DSS automatically ‘compensate’ some possible failures in data records by the on-farm station (Figure 4: the symbols in the map refer to the network of stations of the regional agro-meteorological service, www.agrometeopuglia.it).

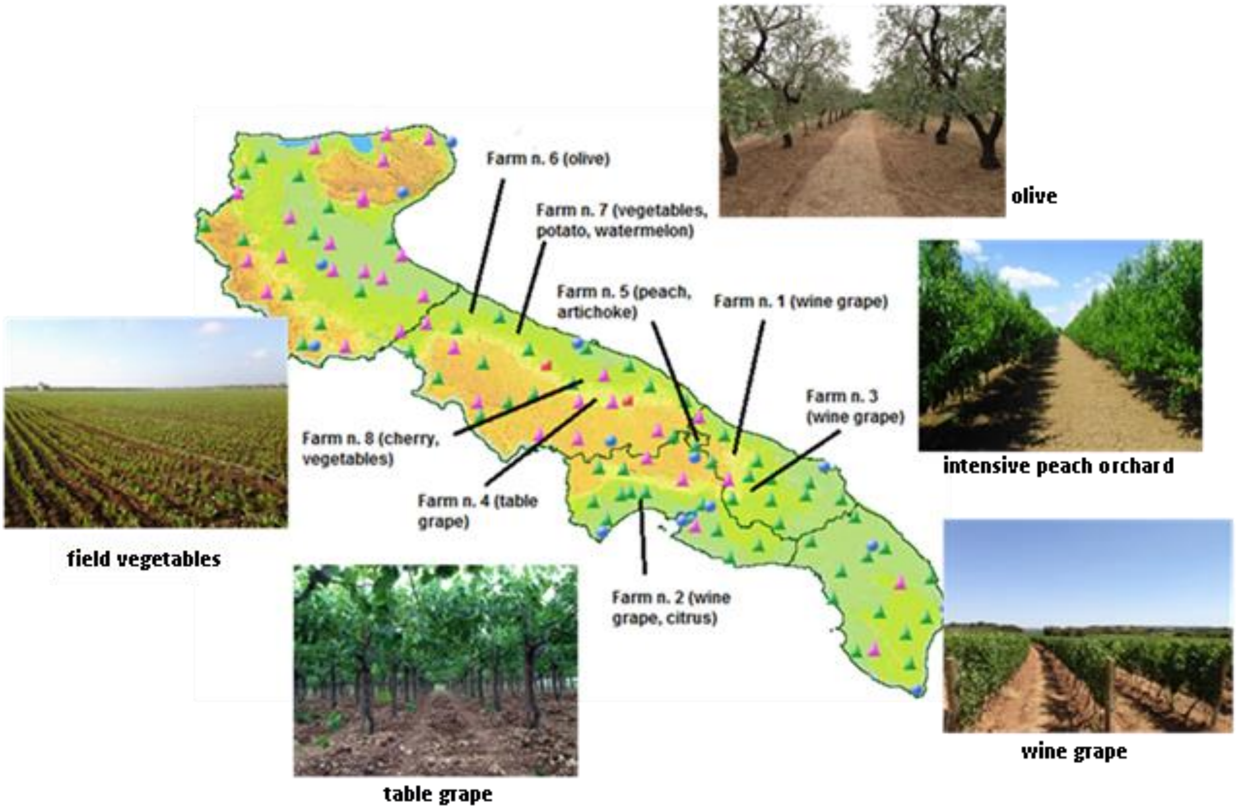

Figure 4 Location of selected experimental farms together with some representative photos of different cropping system.

The basic data about the experimental/testing sites were acquired to describe the irrigation system design (hydrant discharge, number of irrigated plots and areas, sprinkler/drippers spacing and discharge, etc.) and physical limitations (maximum and minimum volumes for each irrigation, fixed/flexible intervals) and management constraints (according to farmers' objectives).

Soil samples have been taken in order to evaluate the basic physical soil characteristics as required by the model for the soil water balance simulation. The soil texture has been determined by the 'pipette method' and the corresponding texture class has been referred to the USDA classification. Following crops were taken into consideration: table and wine grapes, olive, peach, cherry, citrus, potato, vegetables, artichoke, and watermelon. For each crop, the most suitable planting dates, the values of depletion fraction (p), initial and maximum rooting depth, crop coefficient (K_c), length of development stages (L), maximum height (h) and yield response factor (K_y), were determined considering the reference values (Allen et al., 1998; FAO Water, online). The basic crop parameters for the model were initially set according to Allen et al. (1998) and Allen and Pereira (2009).

The preliminary results of testing in 2013 are presented for Farm n. 5 (Figure 4) and the peach orchard cultivation. This farm is located in Mesagne (BR), with latitude 40.56, longitude 17.84 and altitude of 52 m above sea level. The selected plot is of about 3 ha, cultivated with an intensive seven years old peach orchard, medium-late maturing cultivar, with planting spacing of about 4.5 x 4 m, and an average plant height of 3 m. The soil is a loamy textured type, without gravels, with a maximum depth of 0.70 m (from soil survey). In the top layer (0-0.3 m), volumetric water content at saturation, field capacity and wilting point are respectively of 0.43, 0.24 and 0.10 cm^3/cm^3, with a corresponding estimated holding capacity of 170 mm/m. The plot is irrigated as a whole, connected to an hydrant with a discharge of 50 m^3/h, by means of two drip lines for each row, with a correspondent calculated irrigation intensity of about 1.67 mm/h.

5 Results of field applications

In farm n. 5, HT-DSS was set up to follow a case of specific regulated deficit irrigation (RDI) scenario applied to peach orchards. The selection of model parameters was done in relation to each growing stage and the specific sensitivity to water stress (Figure 5, top) and the irrigation strategy was defined following the suggestions of Girona and Fereres (2012). In the case of stone fruits (like peach), the periods of floral development and fruit set are very sensitive to water deficits, and thus damaging water stress should be avoided during 'flowering' and stages I and III of fruit development (respectively early fruit development and late fruit enlargement), while some moderate stress could be allowed during stage II (intensive vegetative growth, stage of pit hardening for fruit), that could be also useful to control an excessive vegetative growth and to improve fruit quality without a yield penalty. Some additional water savings could be also obtained during the postharvest period (stage IV), provided that severe water stress is avoided.

From the beginning of the cropping season, the farmer has irrigated constantly according to the timing and amount suggested by the HT-DSS. A deficit irrigation strategy has been scheduled by means of a variable MAD threshold depending on the different water stress sensitivity of peach stages, resulting in the following model simulations (Figure 5): i) unstressed conditions during the flowering and early fruit development (Stage I) due to the sufficient water stored in the soil profile during the winter season, so no irrigations have been required; ii) a moderate water stress (depletion lower than the readily available water, RAW threshold) during the Stage II of crop development, with the start of the irrigation season scheduled at the end of May; iii) a fast recovery of the unstressed conditions during the Stage III, with an irrigation interval of four-five days and with amounts of about 20-25 mm per each application; iv) no further irrigations suggested during the post-harvest period

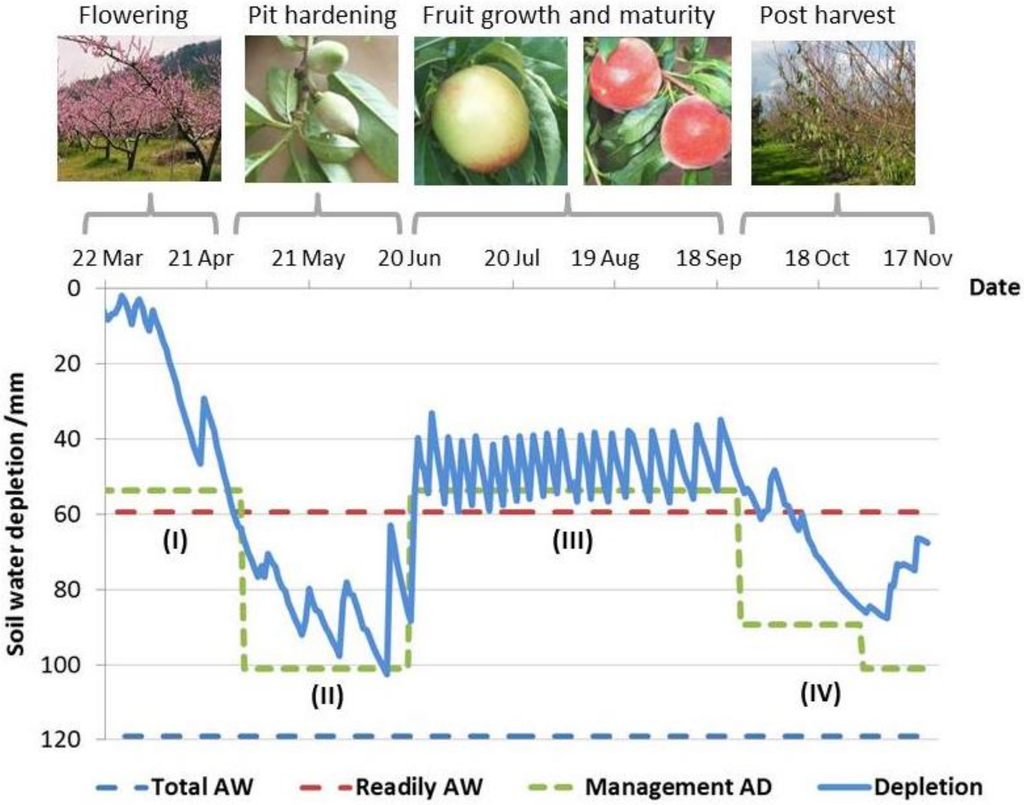

Figure 5 Graphical representation of the soil water depletion in the root zone as simulated by the HT-DSS with respect to main peach phenological stages (AW = available water; AD = allowable depletion).

The trend simulated by the model has been substantially confirmed by the correspondent variation of the soil water content (SWC) measured by capacitance sensors placed at different depths in the root zone. More specifically, Figure 6 shows the trend in the SWC in two layers during the Stage III of peach development (summer months): a) in the top layer (about 0.30 m), where most of the root water extraction occurs, the graph shows the ‘peaks’ (up to saturation) corresponding to the arrival (and quick passage) of the water flow, together with the trend of the average SWC which is progressively recovered and constantly set between a critical threshold value and the field capacity (0.20-0.24 cm^3 cm^{-3}) ; b) in the bottom layer (about 0.60 m), where the water content has been reduced during Stage II because of the deep root extraction, the SWC has progressively increased, but without overcoming the field capacity threshold and thus not resulting in deep percolation below the root zone.

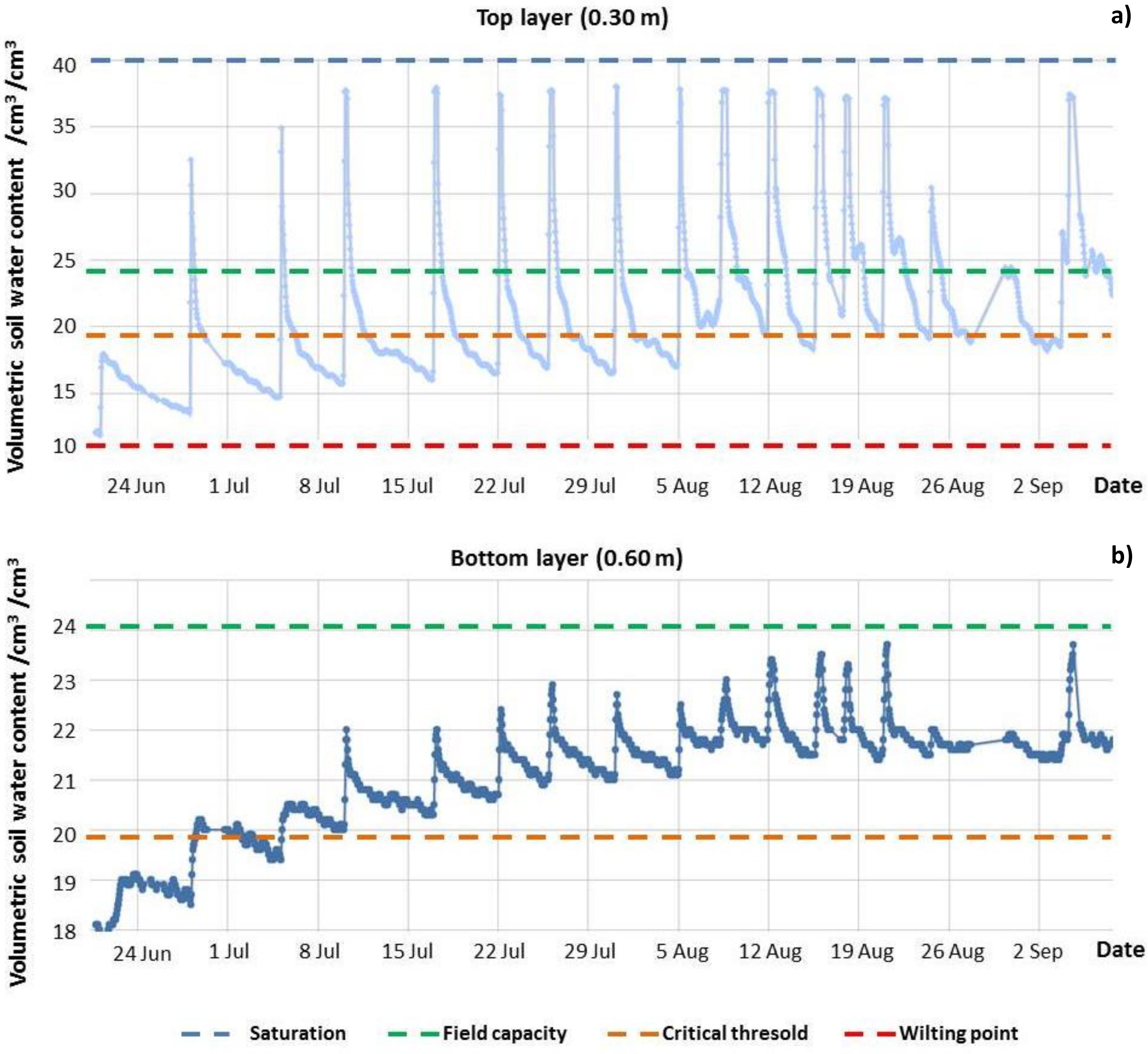

Figure 6 Graphical representation of the level of volumetric soil water content (SWC) as continuously measured during summer months by dielectric soil sensors in the top (a) and the bottom (b) layers of the peach orchard.

The analysis revealed that the irrigation strategy suggested by the HT-DSS has permitted a reduction of the seasonal water supply of about 15% with respect to the volumes applied to similar surrounding peach orchards managed with the current farm irrigation strategy (Figure 7), while keeping the yield almost unchanged (about 30 t/ha). The resulting water saving (corresponding to about 900 m^3/ha) was mostly related to the reduction of the deep percolation losses as determined by the inefficient farm irrigation scheduling approach, normally providing too high volumes of water (30-35 mm) at very close intervals (one-two days) during the summer months (see the slope of the cumulative irrigation curves in Figure 7). Accordingly, the irrigation water productivity was increased from 5 to 5.9 kg/m^3, i.e. by almost 18%. Additional benefits are related with the increase of farm economic added value and eco-efficiency in terms of water and energy use and corresponding CO_2 emission in the atmosphere.

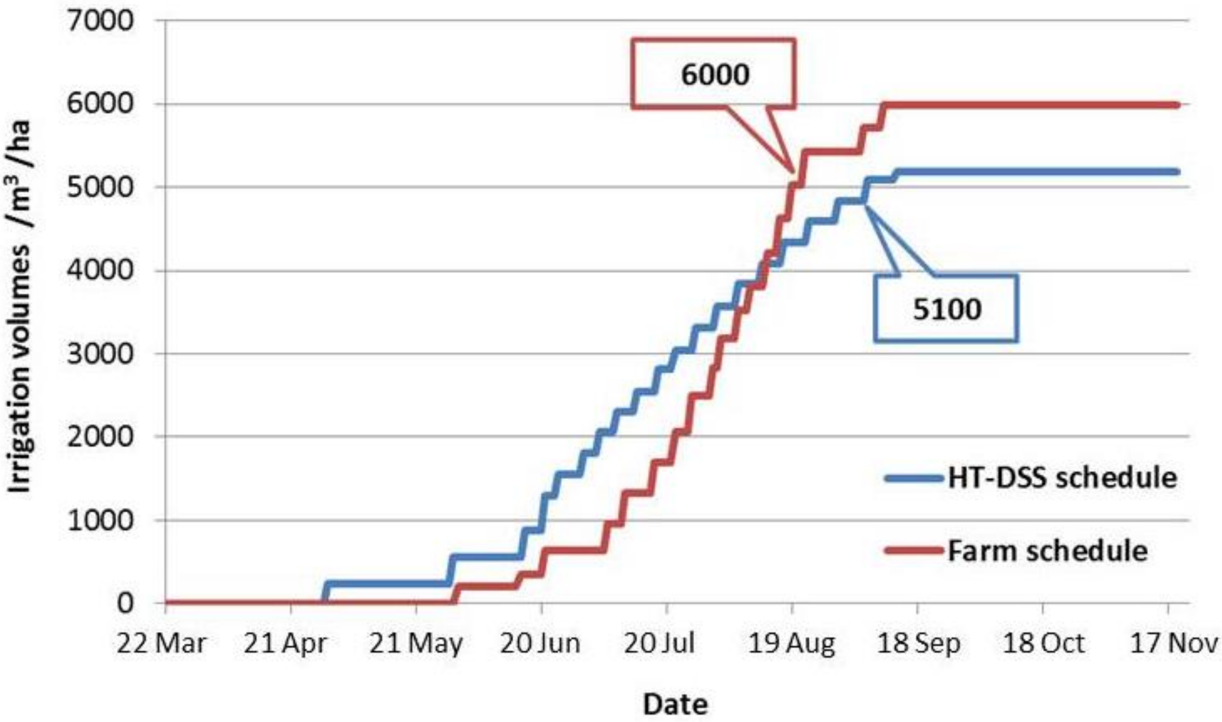

Figure 7 Cumulated curves of irrigation volumes applied to peach orchards according to the HT-DSS (blue line) and to the traditional farm scheduling approach (red dot line).

A synthesis of the results including the testing of the system also on other crops is reported in Table 1. In general terms, a variety of different irrigation scheduling approaches have been observed in practice, and commonly the ‘HT-DSS assisted’ irrigation scheduling resulted in slight (5%-10%) to relevant (15%-20%) reduction in seasonal water application. These water savings have been mainly due to: i) the reduction in the average irrigation volume applied at each irrigation event, by considering the effective percentage of wetted soil and the correspondent water holding capacity (resulting also in a reduction in the deep percolation below the root zone); ii) a more ‘regular’ irrigation timing, as effectively linked to the evaporative demand of the atmosphere and the overall soil water balance; iii) the possibility to manage ‘deficit irrigation’ strategies (in the case of fruit crops and grape), with a controlled level of stress during the less sensitive growth stages.

Table 1 Examples of the irrigation scheduling results for a selected number of crops, comparing the current farm approach with the HT-DSS assisted one.

		Farm scheduling	HT-DSS scheduling	Total volume variations

Crop	Scheduling method	Number of irrigations	Total volume m^3/ha	Number of irrigations	Total volume m^3/ha	m^3/ha	%
Eggplant	None	20	5011	22	4011	-1000	-20
Peach	Tensiometers	30	6000	24	5100	-900	-15
Watermelon	None	56	3300	55	2917	-383	-12
Potato	None	15	3500	14	3110	-390	-11
Tomato (for processing)	Tensiometers	20	4580	29	4200	-380	-8
Wine grape	Pressure chamber	26	1890	24	1850	-40	-2
Olive	None	7	2025	10	2445	420	21
Table grape	Tensiometers	19	2390	22	3157	767	32

Moreover, in some relevant cases (e.g. olive and table grape), the HT-DSS has suggested an increase in the irrigation frequency and total volume applied, in order to avoid possible water stress resulting from an under-estimation of the actual crop water requirements by the farmer. Finally, it is interesting to notice that, where the HT-DSS has been initially calibrated against a well-established farm scheduling method (e.g. pressure chamber for wine grape), the results obtained by the system in terms of irrigation scheduling were quite similar to those obtained by the pressure chamber device.

6 Conclusions

Sustainable agricultural water management requires reliable and easy-to-use methods to support real-time irrigation scheduling especially in arid and semi-arid regions where water is a scarce resource. Nowadays, the effective technology-transfer for control and automation of irrigation is receiving growing attention from both the research institutions and the private companies. A key-aspect for the concrete application of these technologies in agriculture is related to the development of decision support systems (DSS) that allow the real-time processing of large amount of field data into reliable and practical (‘user-friendly’) information to be used in the decision making process.

In the framework of the HydroTech project, the wide experimental/testing activity has been lasting for two years and provided large data and field evidence of the strengths and the weaknesses of HT-DSS in relation to both software and hardware components, as well as of the risks and opportunities related with their application at farm level. The HT-DSS developments has been based on the effective ‘integration’ of several software and hardware components, namely on-ground field data-loggers and sensors (for continuous data acquisition in the soil-plant atmosphere system), farm system modeling (for both the simulation of crop water balance and the estimation of economic product added value and eco-efficiency), software applications for both ‘desk’ computers and ‘mobile’ devices (to allow system configuration, input management and display of results), and remote monitoring and control in the water supply network (at the level of pumping station, hydrants, electro-valves, etc.).

The most important benefits of the on-farm application of HT-DSS were related to the water saving for several horticultural crops (field vegetables and fruit trees), resulting in slight (5%-10%) to moderate (15%-20%) reduction of seasonal water application. These water savings were the results of more accurate estimation of crop irrigation requirements and irrigation volumes which permitted the reduction of deep percolation and evaporation losses.

In other cases (such as cherries or wine grapes), the issue of product quality in relation to water regime seems to be of higher relevance, and the scientific knowledge should be effectively integrated with the local experience in crop water management, to design the best suited DSS strategy according to the farmer's perspectives. In these cases, the main results obtained with HT-DSS were related to the possibility to set and manage crop-specific 'deficit irrigation' strategies, allowing a controlled level of water stress during the less sensitive growth stages.

The experience gained from the farm application of HT-DSS indicated the following further scientific research and technological improvements: i) field data acquisition has been evaluated as a 'critical' point for the application of the DSS (e.g. for the reliability of model calculations) and further improvements are needed in terms of the quality control of input data as well as to ensure the continuity of transmission by on-field monitoring devices; ii) soil sensors provided useful information for both models' calibration and real-time field monitoring, but problems related with their installation, maintenance and calibration should be considered in the perspective of more cost-effective solutions; iii) on the other side, plant sensors are foreseen as powerful tools for the continuous monitoring of the level of plant water stress, but further research is needed for the definition of the crop-specific critical thresholds to be used in practical on-farm management; iv) finally, a careful and detailed description of crop characteristics and soil properties is needed to support the selection/calibration of model parameters at farm scale.

The overall results of testing for different crops indicated the satisfaction of the clients emphasizing the relevant saving of water, energy and time (dedicated to water management), the increase of water productivity, economic benefits and eco-efficiency of farms. These experiences, gained at regional level with different type of farms, have confirmed that support tools and DSS for agricultural water management are effectively required by farmers, technicians and decision makers who are looking for a more efficient farm management permitting greater added value and eco-efficiency. Furthermore, this helps to fulfill the mandatory regulations concerning environmental issues (e.g. limitations in groundwater extraction or protection of aquifers from nitrate pollution). Actually, the HT-DSS is entering in the commercialization phase offering locally tailored solutions for different farm setup, crops, pedo-climatic and management conditions. The product is promoted through www.blueleaf.it.

Acknowledgements

This work has been realized within the 'HydroTech' project, supported by the Apulia Region in the framework of the Operative Programmes O. P. Puglia 2007-2013 - European Regional Development Found (ERDF) (Axes I – Line 1.2 Action 1.2.4 – "Grants to support regional partnerships for innovation").

[References]

[1] Allen, R. G., L. S. Pereira, D. Raes, and M. Smith. 1998. Crop evapotranspiration. Guidelines for computing crop water requirements. FAO, Rome. *FAO Irrigation and Drainage Paper*, 56.

[2] Allen, R. G., and L. S. Pereira. 2009. Estimating crop coefficients from fraction ground cover and height. *Irrigation Science*, 28(1): 17-34.

[3] FAO. 2015 Water [on-line]. http://www.fao.org/nr/water/topics_productivity.html. (accessed 15-12-2015)

[4] Girona, J., and E. Fereres. 2012. Peach. In: Crop yield response to water (Eds. Steduto P., Hsiao T.C., Fereres E., Raes D.). *Food and Agricultural Organization of the United Nations, FAO Irrigation and Drainage Paper*, 66: 392-405.

[5] Hargreaves, G. H., and Z. A. Samani. 1982. Estimating potential evapotranspiration. *Journal of the Irrigation and Drainage Division*, 108(3): 225–230.

[6] Jones, H. G. 2004. Irrigation scheduling: advances and pitfalls of plant-based methods. *Journal of Experimental Botany*,, 55(407): 2427-2436.

[7] McCarthy, A. C., N. H. Hancock, and S. R. Raine. 2011. Advanced process control of irrigation: the current state and an analysis to aid future development. *Irrigation Science*, 31(3): 183-192.

[8] Rao, N. H., P. B. S. Sarma, and S. Chander. 1988. A simple dated water production function for use in irrigated agriculture. *Agricultural Water Management*, 13(1): 25-32.

[9] Romero, R., J. L. Muriel, I. Garcia, and Munoz del La Pena D. 2012. Research on automatic irrigation control: state of the art and recent results. *Agricultural Water Management*, 114: 9-66.

[10] Stewart, J. I., R. M. Hagan, W. O. Pruitt, R. E. Danielson, W. T. Franklin, R. J. Hanks, J. P. Riley, and E. B. Jackson. 1977. Optimizing crop production through control of water and salinity levels in the soil. Reports Paper 67. Utah Water Research Laboratory, USA, 191 pp.

[11] Todorovic, M. 2006. An excel-based tool for real time irrigation management at field scale. *Proc. Int. Symp. on Water and Land Management for Sustainable Irrigated Agriculture*, Adana, Turkey. 4-8 April, 2006. Çukurova University, Adana, Turkey.

[12] Todorovic, M., B. Karic, and L. S. Pereira. 2013. Reference evapotranspiration estimate with limited weather data across a range of Mediterranean climates. *Journal of Hydrology*, 481: 166-176.

[13] Zapata, N., R. Salvador, J. Cavero, S. Lecina, C. Lopez, N. Mantero, R. Anadon, and E. Playan. 2012. Field test o fan automatic controller for solid-set sprinkler irrigation. *Irrigation Science*, 31(5): 1237-1249.