Supporting Irrigation Management Strategies through the Web: an application to the Portuguese Alentejo region

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Abstract

It has been built in the South of Portugal a dam that is going to allow in the long run for the transition of 110,000 ha of land from dry to irrigated agriculture. This major shift has social, economical and environmental impacts and to deal with this change it was created an Operational and Technological Irrigation Centre (COTR) in 1999 which has amongst other objectives to stimulate the scientific and technique information in the domain of the irrigated crops. In this sense COTR has been developing several R&D projects and is making an effort to take advantage of ICT potential to build information services to support farmers in their irrigation decisions.

In this work we will present COTR irrigation advisory service, a Web decision support system which is supported by a network of automatic weather stations and taking in account user information input (location, soil, crop, irrigation technology and seeding date) supplies an online real time optimal irrigation calendar and the farmer’s real one if the user inputs its one water supplies. The information delivery has multiple output options, namely trough the Internet with a Web interface or a personal digital assistant and trough mobile phone with the short message service.

Irrigation scheduling through crop evapotranspiration calculation follows FAO Irrigation and Drainage Paper 56 guidelines and the information system is supported by a relational database where the weather stations and users data is stored and where information characterizing the region most common soils, crops and technologies is also kept. This last information is also resulting from other R&D projects undertaken by COTR.

Key words: Irrigation scheduling, Web DSS, Web Information Services.

1 Introduction

In the traditional conception of a decision support system (DSS), the relative knowledge to one determined domain becomes a more or less complex mathematical model, being necessary to support the decision to introduce local data characterizing the problem. In some cases the necessary data to support the decision support system is collected and managed from external sources and, when these data are refreshed frequently, it can not be viable to transfer to the user the task of updating them. In these cases a system with a distributed architecture is necessary being the use of the Internet an obvious option between the participant partners (Jensen and Thysen, 2002).

There are, in literature, numerous examples of DSS in agricultural management, as for example for the fertilization and irrigation of parcels or for the treatment of plants diseases. The DSS that can take in consideration local conditions, as for example soil, meteorological information, etc., are more interesting for farmers than the generic systems, since they allow for a more accurate and personalized support to the decisions that the farmers has to take.
In systems developed to be integrally executed in personal computers in an entirely independent form, the user has the responsibility of supplying all the data necessary in the correct format. These DSS data feeding can be made by manual introduction or with batch processing. In this model, since the introduction and management of the data are users responsibility, the amount of data that a DSS based on personal computers requires can imposes some restrictions.

When a DSS demands the supply of data with high update frequency, for example, hourly or daily meteorological information, daily water consumption, it is not acceptable for farmers to manually feed such data. It is necessary that the DSS connects directly to a network that allows for their automatic updates. These data can be originated from local data collectors (agro-meteorological stations, measuring of volume) as well as from external sources.

In this context Web applications are of increased importance as form of making available DSS to potential users, since they make possible to reach global audiences at extremely reduced costs. Also and in the case of the DSS extremely important, they allow for all the processing to be made on the server side, so that launching of new versions and support databases updates possible without any intervention of the final user. In irrigation management, where the multiplicity of involved variables is, many times, an impediment for the generalization of its use, these solutions offer an interesting approach, because they make possible for the users to use updated meteorological databases in real time, crops, soil and irrigation technologies data, many times of difficult characterization for the farmer.

According to Jensen and Thysen (2002) one of the more interesting DSS groups for agricultural decision support includes, necessarily, the Internet-based, Dynamic, Personalized Decision Support System (I-DSS), that is, those that requires the dynamic introduction of data of external origin. The distributed architecture of a I-DSS will count at least with a user and an external supplier of dynamic data, being able, however, to contain several agents: data suppliers, models, processed data and information, besides the users. This flow, since data until information, involving several agents, is illustrated in Figure 1 where the column more on the left shows the originary raw data from different places and sources. The raw data, added from different sources, is processed models into data with bigger informative value. For example, registred meteorological data in determined moments and places can be interpolated and be added to get daily average and maximum values for places where data does not exist. Other models can be used to process further information previously processed. For example, the processed meteorological data can be used in agricultural models to calculate the crop water needs, the risk of the occurrence of illnesses, etc. In an I-DSS type model is used data from external sources and data supplied by the user so that the information for decision support is given in a personalized form, in a flow since raw data until personalized decision support, that these authors call information processing chain.

The junction of these concepts, the Web applications and the irrigation management support systems, led us to idealize a solution that made available to the farmers with Internet access an irrigation management support tool based on the meteorological data from a regional network of automatic weather station (SAGRA), associated with local crops, soil and technologies data, this last ones in great measure resulting from the experimentation work that it carried out by the COTR.
2 System Drawing

2.1 Information Architecture

The information system was developed in a client-server architecture on a Web server in a three layers model: data access layer; logical business layer; and presentation layer.

In this case all the information processing is done in the server side allowing, thus, dynamic pages generated automatically without any necessary processing in the local computers to be presented to the users (clients).

Associated with the Web server there is a databases server, which in this system coexist physically in the same machine. If the future use of the system justifies it, it could be necessary to promote the separation of the Web server and the databases server in two different machines.

![DSS scheme](image)

Fig.2 DSS scheme

2.2 Data Access Layer (Data Model)

The DSS is supported by a relational database where the data of the weather stations and the users is stored. In this database there is, also, stored information that characterizes soil, the physical parameters for water retention, depth of the profile and the texture characteristics of the superficial layer that influence the soil evaporation. There is also stored information about the fraction of soil surface wetted by irrigation and data about the most common crops of the region, related with the length of growth stages and associated basal crop coefficients, root depth, crop height and depletion fraction. These last information, that characterizes the regional reality result, basically, on R&D projects carried out by COTR.
2.3 Logical Layer of Business

One way to determine the irrigation opportunity consists in the use of the evapotranspiration. This can be done according to the methodology recommended by FAO "Irrigation and Drainage Paper" 56. In this method and starting from the knowledge of the crop physiological characteristics and respective date of catch-crop, the soil data and the irrigation technology used, it’s possible to shape the daily process of water use by the crop using daily meteorological information, as well as date and amount of the water applied. The related publication, available integrally in the Internet, presents a reference and crop evapotranspiration calculation procedure based on the Penman Monteith method, accepted by the scientific community as a valid method and with a great adherence to reality.

As mentioned, the calculation algorithm used to support the DSS is based on the methodology proposed by the FAO "Irrigation and Drainage Paper" 56. The system was developed in Active Server Pages, a programming language that functions with the server in the client-server architecture of the Web applications. This approach allows that the pages are presented to the user without the necessity of any Plug-in or special requirement in the user’s browser.

The interconnection between this DSS and the SAGRA, allows for the automatic feeding of the meteorological data that support the crop irrigation demands calculation method, guaranteeing the maintenance of the real time information available. The original data from SAGRA is concentrated once a day in a COTR central server and processed automatically to be integrated in the database that supports the described information system. These data also feeds the institutional COTR Web site, where several reports show the evolution of the main climatic variable and the evapotranspiration of the main crops of the region are available. Another functionality that this agrometeorological database supports consists in the possibility of the visitors, by means of a process of previous registration, to download the data in a opened format suitable for local use.

2.4 Presentation Layer

The access to the decision support tool is made from the COTR Web site home page (www.cotr.pt), being necessary to follow a registration procedure and only after it’s validation by the administrator, with the consequent attribution of an username and password, the user will be able to access the service.

When starting a session in the information system and after the validation of the user supplied information it is offered to the user the possibility to create new crop cases and, from there, to make use of the optimal and real irrigation schedules for the specific crop case.

To create a new crop case the user, in a first step, based in lists of limited options (Figure 3 - 1), selects the crop, the respective seeding date, the closest automatic weather station from the list of stations that compose the SAGRA, the soil based in a list of possible textures and the irrigation technology.

Based on that information, the system starts a query to the supporting databases for the basal crop coefficients, to the characteristics of the soil and the irrigation technology, constructing dynamically a second form (Figure 3 - 2) where are presented the values of the variables which will be used in the irrigation schedule construction. In this step the user will be able to modify any of the values (if he has more refined information) or, in contrary, to use the considered values that correspond to the ones considered normal for the combination of the selected crop/soil/technology.

In the first page of the system, besides the possibility of creating new crop cases, a list of the already existing ones is presented to the user. There is the possibility to modify the information related to each one of them trough the access at any time to any step of the crop case creation and to correct or to test some different variable input values used in the simulation, as well as proceeding to it’s elimination.

The list of registred crop cases also allows to access, for each one of them, to the optimal and real irrigation schedule (Figure 4), where the difference between the two is in the fact that, in the real schedule is the user who manages the irrigation, including the date and amount of water supplies (including to create, modify or eliminate), and, in case it exists, to include real data about soil water content.
The optimal irrigation schedule has as main function to support the analysis of the potential crop water consumption based in the principle that the crop in the different growing stages would be at the maximum activity extracting from the soil the maximum amount of water needed. This situation is possible since it considers that the crop it’s free from water, nutricional or pathology stresses.

On the other hand, the system simply admits the fulfilment of the reservoir after the allowed deplection have been achieved (blue limit in the graph of figure 4), however in certain situations, this deplection could be about 100 mm, meaning that only after depleting these same 100 mm of water from the soil an irrigation of 100 mm is advised to restitute the soil water content. In terms of irrigation management this is not be the ideal situation, in such a way irrigation management now a days is based in more frequent and smaller applications and the majority of the irrigation systems hasn’t capacity for refill such amounts in such short intervals. It would be also a risk to allow for such amount of depletion because if the system suffers some malfunction during the needed water supply the crop might suffer from water stress.
The real irrigation schedule allows the user to see the behavior of its irrigation management options, and then, decide about the irrigation opportunity. Here the main goal will be allow for the user to become the irrigation manager in such a way that he should keep the line of current depletion (green line of the graph of figure 4) half way between the zero depletion level (field capacity) and the allowed depletion level. This situation aims two main purposes; one which is extremely important in irrigation management is related with the water reserve available in the soil. If the system damages during the water supply, it can be used until the system is repaired, without affecting the crop yield level. The other one which is less significant in the Alentejo irrigation management conditions, is related with the fact that keeping the depletion level in the soil very low (near field capacity) it doesn’t allow for water storage from rainfall that can occur during the irrigation season.

The irrigation schedules, beyond the numerical daily information made available, like temperature, crop evapotranspiration, the irrigation need or the applied irrigation (if optimal or real schedule, respectively), etc., also supplies a graphical presentation where it is possible to observe the evolution of the allowed and current depletion.

2.5 Further Developments

In order to test the possibilities offered by the incorporation of geographic information concerning the farmers parcel location so that the Weather station and soil selection could be made automatically a prototype of the system supported by a Web GIS was built (screenshot in figure 5).

Although fully functional and with a very friendly user interface the lack of supporting digital data in freely basis didn’t allow to make this approach available for the public in general but only for the cases where the COTR had trial fields under observation. Nevertheless the feedback from the users and the potential to minimize the user data input required in the crop case stage make the use of a Web GIS interface a promising approach.

Another development of the system was made considering the high adoption rate of mobile phones verified in Portugal (values above 90%). In this sense it was launched an alert mechanism through the mobile phone short messages service. This service is well received by the farmers since it follows a push approach and they don’t have to carry out any action to receive it. Nevertheless, since SMS service use has cost implications if it grows in the future we must reach some kind of cost sharing with the farmers.
In order to take advantage of the mobile phone potential in the case they supply Internet connection possibilities it was developed an interface for mobile platforms (Figure 6). This interface was developed in such a way that the system can be used directly from the field, if the farmers or technician has a digital personal assistant (PDA) with an Internet connection.

4 Conclusions

In the beginning the information system was used internally in a process of internal validation by means of the comparison with other methods of irrigation needs calculation, having the results obtained been very satisfactory.

Nowadays the Web DSS is available to be used by the public in general. On the other hand and in the scope of the Agro-Environmental Measures, more specifically in the Measure for Chemical Reduction in Agro-chemical products Leaching to the aquifers, enclosed in the Group of the Measures for the Environment, Soil and Water protection and improvement, the COTR has come to celebrate protocols with farmers associations in Alentejo.

Furthermore, the attention that the developed system is receiving from other agricultural regions of Portugal has lead to the launch of the service in an application service provider approach where by integrating weather data from other regions sub-systems are made available to the public. Nowadays this is already a reality for the Algarve Region, in a partnership with the Regional Direcção of Agriculture of the Algarve, to act as an Irrigation Advisory Service (IAS) through the emission of irrigation advises.

5 References


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