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Four Decades of Progress in Monitoring and Modeling of Processes in the Soil-Plant-Atmosphere System: Applications and Challenges

IRRINET: large scale DSS application for on-farm irrigation scheduling

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Abstract

IRRINET is an expert system for irrigation scheduling developed by the CER (Emiliano-Romagnolo Canal Irrigation Consortium), implementing the results of more than 50 years of research on plant/water relation and sustainable irrigation management. The IRRINET project was supported and co-funded by the Emilia-Romagna Region with the aim to progressively reduce water use for irrigation all over the region. IRRINET is among the tools provided to the farmers in the frame of Emilia-Romagna Regional Action Plan for Rural Development 2007-2013. The service started in 1984, on the Videotext network, and, nowadays, IRRINET is spreading in other 6 regions of Italy, with IRRIFRAME project. The following step after the 1984 was in 1999 when IRRINET service was developed on WEB. The IRRINET service is freely available on Internet and provides an 'irrigation advice' for the main water demanding crops. The system provides a real-time irrigation scheduling: day-by-day information on how much and when to irrigate farm crops.
The aim of present paper is describe the evolution of IRRINET service, the sub-models of IRRINET water balance model and the main development trends. With special attention is analyzed the future development needs in precision irrigation context.

Keywords: IRRINET, irrigation scheduling service,water saving

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Introduction

An improvement on suitable management of water losses in agriculture is the irrigation scheduling [1], that directly leads to water saving of 9-20%. Although an overabundant amount of software tools and technologies for irrigation scheduling has been developed in the last 30 years, only few successful attempts to transfer those knowledge to farmers have been made [2]. Despite the huge number of irrigation scheduling system, the majority of farmers is not yet using those tools. Different studies [3,4] point out that the reasons for non-adoption of irrigation scheduling by farmers are (1) the difficulty of applying complex technology in practice and (2) the perception by the users of the little benefit to use them.

Nowadays, some irrigation scheduling services are focusing on the implementation of DSS irrigation service based on web-database interface. Some example of irrigation DSS are, as well as IRRINET service: IrriSatSMS (Australia), ISS-ITAP (Albacete, Spain), BEWARE (Crete, Greece), Anglia river Basin (UK), IRRISA (France), IrriSat (Campania Region, Italy). The communication between DSS and farmers is a key topic on the implementation of irrigation scheduling service. Different technologies' can be used such as e-mail, fax, online-bulletin but short message service (SMS) communication platform offers to the irrigation DSS the possibility of providing simpler and more suitable mobile decision support to farmers [5]. With 3.3 billion of users [6] the mobile phones technology allows to reach every one in all the countries. The SMS communication allows to provide growers with an easy to use and understandable information on how much water their crop has used and how long they need to run their pump or drip system during irrigation.

IRRINET is the free-irrigation scheduling service of CER. This service is operating since 1984. Nowadays the service is applied in 12500 parcels all along the Italian country.

1. Evolution of IRRINET service

The first attempt to transfer of irrigation scheduling knowledge to famers by CER were carried out in 1984. The extension service provided a form to about 100 farmers for the application of checkbox scheduling method. The last method was based on monthly average evapotranspiration. The first meteorological station was installed in 1985 by Regional Board, and the needs of meteorological data for irrigation scheduling where overcame providing to farms a pluviometers and 40 class-A pan evaporimeters in every homogeneous area. The required meteorological data were measured by farmers and transmitted to the irrigation service. Always in 1985 the irrigation scheduling service became operative in Videotext network (Figure 1). So, in the same year, two approaches were followed in order to obtain a certain diffusion of the service. The main reason was that not all the farmers were able to manage some technologies.

In 1986 the regional system of meteorological stations was installed and for the calculation of soil-water balance of irrigation scheduling service was used the data base of the Regional Meteorological Service (SMR). The irrigation scheduling service on Videotext was dropped for lack of technical service from telecommunication management society.

Figure 1: Videotext pages of irrigation scheduling service (1984), with input videotext page to communicate the meteorological data measured by the farmers (pluviometer) and with information on irrigation depth and length of run.

In 1999 was carried out by CER a project for the development of new software for irrigation scheduling with a web interface, called IRRINET. During the development of the first prototype of IRRINET, a new database for data acquisition and storage was designed, a robust system for interaction with GIAS (Global Information System for Agriculture in Emilia-Romagna) web-data base platform was created and new parameters for crops and irrigations scheduling were developed. In 2004 the IRRINET system were improved developing the web-GIS interface for the interaction of calculation procedure with soil data base and, in 2007, with shallow groundwater table monitoring system[6]. Since 2009 IRRINET has evolved in IRRINET Plus which implement economic calculation of the irrigation profitability, providing farmers with further information other than optimal irrigation volume and time, such assessing the economic benefit related to the next irrigation.

From 2011 the IRRINET service is applied in 25 Drainage and Irrigation Consortia of six Italian regions (IRRIFRAME Project of National Association of Drainage and Irrigation Consortia - ANBI). The system is improved taking into account in the calculation the real water availability in irrigation supply channel or pipeline or, for other application, providing to the water boards an information on the water needs of irrigation districts.

2. Description of the service and ICT infrastructures

IRRINET system provides to farmers a day-by-day information on how much and when to irrigate crops, implementing a real-time irrigation scheduling. Climatic and meteorological data are gathered on daily basis on the web-DB server from several acquisition and elaboration systems. Irrigation scheduling is determined applying a mathematical model based on daily water balance of soil-plant-atmosphere system [8]. The structure of system is reported in Figure 2.

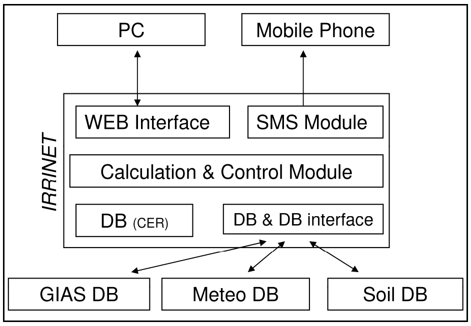

Figure 2: IRRINET system, DB and user' interaction module

The programming language has been upgraded on .NET 4 64 bit and MS SQLServer2000 for server environment and it is composed by 3 main modules: Web application, External data importation module, IrriSMS module. The external data importation module accepts a XML file as input data. The system returns a XML file with the irrigation scheduling results as output [9]. The application has a three-level implementation design:

- Web Interface (ASPX)
- Data access layer (ADO.NET) for the data base access
- Business layer (VB) which includes the water balance algorithms

The application uses a relational database that includes more than 70 tables. The database is organised in informational areas (Table 1).

Table 1.description of database settings.

Knowledge base area	Area information	User and farm description	GIS data
Model configuration parameters Model and crop parameters (Kc, crop stages..)	Meteorological data Water table depth data	Detailed crop description User data: • Water table depth data • Start and stop crop date	Soil map Shallow groundwater map
Lookup lists (managed crops, irrigation systems..)	Soil information		
	User information (registered users only)		

The GIS maps are managed on a Geodatabase. The polygon identifiers of the maps are dynamically linked to the information stored in the database (*e.g.* meteorological and water table stations, soil units) . The users of the IRRINET service can access to the service in different way and, from the web interface, they can totally interact with the system and parameters. The access to the service can be managed by web browser, IRRIMANAGER scenario and external system. The system has been developed focusing on the possible and future needs of the users and it allows *e.g.*:

- interact with the users with SMS communication protocol, that are automatically sent to the users registered in the service (Figure 3);
- store data on yearly, monthly and daily basis of crop stages, evapotranspiration and others parameters;
- store and evaluate in text or chart format actual data on evapotranspiration, next irrigation date, irrigation water depth and others.

Figure 3: Description of the information displayed with IrriSMS module

The common SmartPhone can display and interact with the web pages of the system.
IRRIMANAGER, one of the possible way to access to IRRINET service, represents the evolution of the service for Drainage and Irrigation Consortia. It is a client application that allows to create complex irrigation scenarios *e.g.* to manage the water diversion, conveyance and distribution infrastructures, as explained in the previous paragraph.

3. Water Balance Model

The irrigation model has been developed by CER and has been validated locally over 50 years of field trials. The processes simulated in IRRINET model (Figure 4) can be assembled in 4 groups:

- Water dynamics in soil. The hourly calculation of soil-water content is carried out considering three soil layer: soil surface layer, rooted layer, bottom layer. According to Driessen [10], the amount of water which moves between the layers of the soil profile is the water that exceeds single layer water storage.
- Crop growth. It represents the phenological development of the crops and the growth of the root system.
- Crop water requirements. The crop evapotranspiration is calculated for standard and no-standard condition according to Doorenbos and Pruitt [11].
- Water table contribution. The capillary rise is calculated as fraction of ETm through empirical function developed by CER after nine years of field trials. [12, 13, 14, 15].

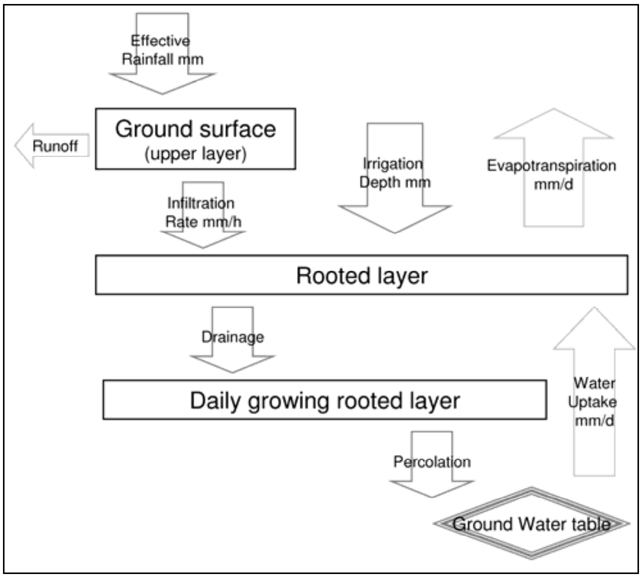

Figure 4: Schema of soil-water IRRINET model

The result of the simulation is an assessment of irrigation depth, depending on irrigation methods.

4. Conclusion and future application needs

With IRRIFRAME project, the IRRINET service is applied in 12500 parcels all over the Italian country. The service has been improved year-by-year following the needs through users' feedback and applying the field research results. Each parameters used in the model for the calculation have been calibrated during field trial for 50 years, in order to evaluate the variability of the crops, soil and climate condition. It makes IRRINET a robust system that can respond efficiently to the majority of agricultural local condition.

The improvement of the IRRINET system is based both on soil-water model and on ICT infrastructures. The platform has been developed allowing a total customization of the service *e.g.* soil-water sensor integration, user specified crop coefficient (from local trial or remote sensor system) and actuators control. Everything is connected thorough web server to the input web-db.

Some problems for the service diffusion are related to the availability of meteorological data (daily min, max and average temperature and hourly rain) that are not always presented. In the same way, a georeferenced soil map can reduce the input needs for soil parameters estimation, but is not always in electronic format.

The next challenges for the service will be the integration with sensor and actuator systems, as well as input crop coefficient data provided by remote sensing, to cope with both few information provided by user or available on the area and the needs of more accuracy in soil water content calculation.

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