EFFIDRIP: a tool kit for scheduling and supervising irrigation in tree crops

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ABSTRACT

Sustainable use of irrigation requires delivering the optimum amount of water according to weather conditions and the status of trees and soil. Diverse existing technologies can be used in this topic but practical application in commercial orchards is limited by the lack of an integrated system. Within this context, EFFIDRIP provides a tool kit for cost-effective services in automated supervision and control of localized irrigation. The central part is a web-based application that monitors the crop through a wireless sensor network, uses meteorological data, and adjusts the forthcoming irrigation schedules without the need of user intervention. Compared to existing decision support systems, EFFIDRIP takes the next steps in automating irrigation control. First, it integrates commercial equipment deployed in the field, i.e. soil or plant sensors and irrigation controllers, to a higher level system. Second, it makes autonomous operative decisions and communicates machine-to-machine with the diverse components based on information and communication technologies. The system is being evaluated at three test sites (Portugal, Greece, Spain) in terms of improving water and fertilizer use efficiencies without impairing yield. Labour effort and the capacity to detect and cope with incidences are also analysed.

Keywords: fertigation, sensors, decision support system, wireless, simulation

1. INTRODUCTION

Efficient use of irrigation water, fertilizers and pumping energy requires planning the seasonal strategy as well as controlling the execution of such plan. Several technologies exist that can contribute to an effective management of sustainable irrigation. Execution of the irrigation schedules and low level management of the irrigation setup can be delegated to irrigation controllers, an electronic device in charge of commanding pumps, valves and other hydraulic parts. However, the schedules must be manually specified by the user. Meanwhile, several decision support tools exist that can be used for calculating the irrigation needs at different times of the season. For instance, WISE (Leib et al., 2001), AQUACROP (Steduto et al., 2009), CropIrri (Zhang and Feng,

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2010), RIDECO software (Zapata et al., 2012). At the same time, sensor and wireless communication technologies have been developed which can facilitate acquiring data for supervision and control of irrigation processes. Examples are soil water sensors and IEEE802.15.4 modules for low-rate wireless networks, respectively. Nevertheless, irrigation controllers, decision support tools and sensor systems have evolved independent of each other and a combined use of these resources for irrigation control is unpractical because of the labour, skills and perseverance required.
Here we focus in localized irrigation of tree crops, which presents some particular challenges. In tree crops water requirements show large variability within the same species, as affected by factors such as canopy traits and crop load. Localized irrigation involves specific dynamics of soil water, dominated by wet bulbs which form below the emitters, affecting the basics of irrigation control, as well as the sensor measurement and interpretation of soil water content.
Within this context, the EFFIDRIP project proposes to adapt different existing technologies to meet the specific requirements of this topic and integrates them in a layer of Information and Communications Technologies (ICT). The goal of EFFIDRIP is to provide a tool kit to SMEs for offering cost-effective services to farmers and technicians regarding scheduling and supervision of localized irrigation. The central part of the tool kit is a web-based application that monitors the crop through a wireless sensor network and adjusts the forthcoming schedules without the need of user intervention.

2. DESIGN OF THE EFFIDRIP SYSTEM

Basically, the EFFIDRIP system consists of a web-based application, complemented with hardware deployed in the field, which controls the irrigation schedules of the registered plots and offers the user a high level agronomical view of the irrigation process. After specification of a Seasonal Plan, set up with the help of the user, the system can operate autonomously to keep optimized schedules through the season. All repetitive tasks such as acquiring data, analysing them and deciding the next schedules are done automatically and are transparent to the user; details are available to the user upon request. If required, the user may modify the Seasonal Plan during the growing season.

2.1 Overall organization

The EFFIDRIP system is composed of diverse elements that communicate with the application server through internet (Figure 1). Namely, there are commercial irrigation controllers, wireless sensor networks, external services as well as the devices with which users can communicate using a browser.
Commercial irrigation controllers are used in the field for the local coordination of the hydraulic parts, i.e. valves, pumps, etc. The EFFIDRIP system communicates once a day with the irrigation controllers. The daily dose as calculated by EFFIDRIP is

transferred to the irrigation controller, which then manages the hydraulic network and copes with constraints specific of each farm. So far, EFFIDRIP has developed drivers for communicating with Hidra XIO (Macraut Ingenieros, S.L, Vigo, Spain) and Agronic 4000 (Sistemes Electrònics Progrès, Bellpuig, Spain). EFFIDRIP is not restricted to be used with these two controllers, as drivers for other controllers can be easily developed.

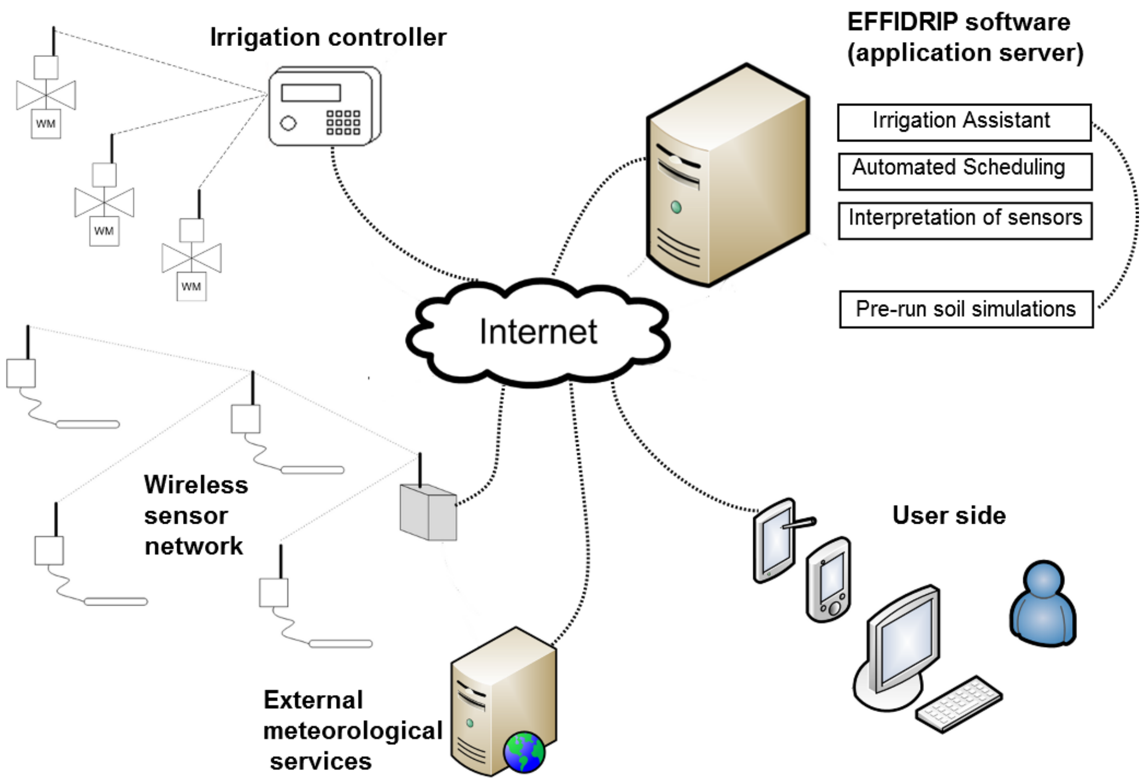

Figure 1. General layout of the EFFIDRIP system.

The wireless sensor networks are composed of remote sensor units which are in charge of measuring sensors and sending the data. A general packet radio service (GPRS) gateway on each network collects the data and uploads them to the platform. The remote sensor units have been designed specifically to optimize their performance and power consumption in the context of monitoring in tree crops. The types of sensors that are being used in EFFIDRIP test sites are weather sensors, probes for soil water content (alone or combined with electrical conductivity) and water meters.
Weather data can either be collected by sensors included in the wireless network or imported from external meteorological services. Some regional meteorological networks allow web service access to historical and current data. This can be a practical option which avoids farmers having to purchase and maintain their own instruments.

2.2. User interface

Users can interact with the platform using any web browser on any type of device connected to the internet. The major functionalities of the user interface are registering new plots, using the Irrigation Assistant to plan the next irrigation season and supervising irrigation.
Supervision is intended to facilitate the management of a large number of plots by the same user, with minimum time and effort. The user is offered a synoptic view of his/her plots where all remarkable information is concentrated and visible at a rapid glance (Figure 2). This includes icons (e.g. traffic lights for general plot status: green = OK, orange = attention required, red = error) indicating the state of compliance with the Seasonal Plan or the occurrence of some event. The irrigation applied the last seven days is shown graphically. More detailed data, including graphics with the output of the sensors are shown at the user's request.

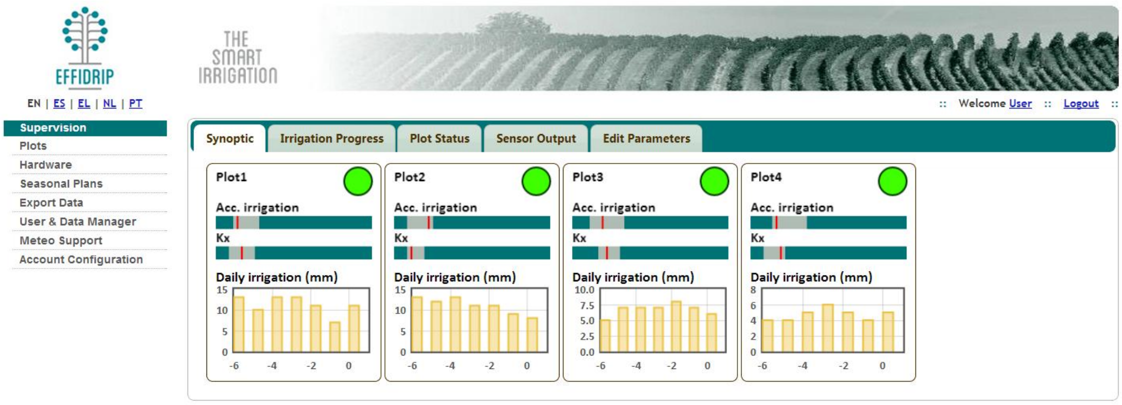

Figure 2. The EFFIDRIP user interface for supervising irrigation.

2.3 Workflow in the automated scheduling system

The user must participate in providing information that describes the context of the plots and outline the strategy to follow during the irrigation season. This has to deal with defining the scenario, its goals and priorities. Later on, the system can work autonomously with the data collected from the sensors and external services, making by its own the appropriate decisions regarding day-to-day response to crop development, weather conditions and major perturbations. This is illustrated in Figure 3.

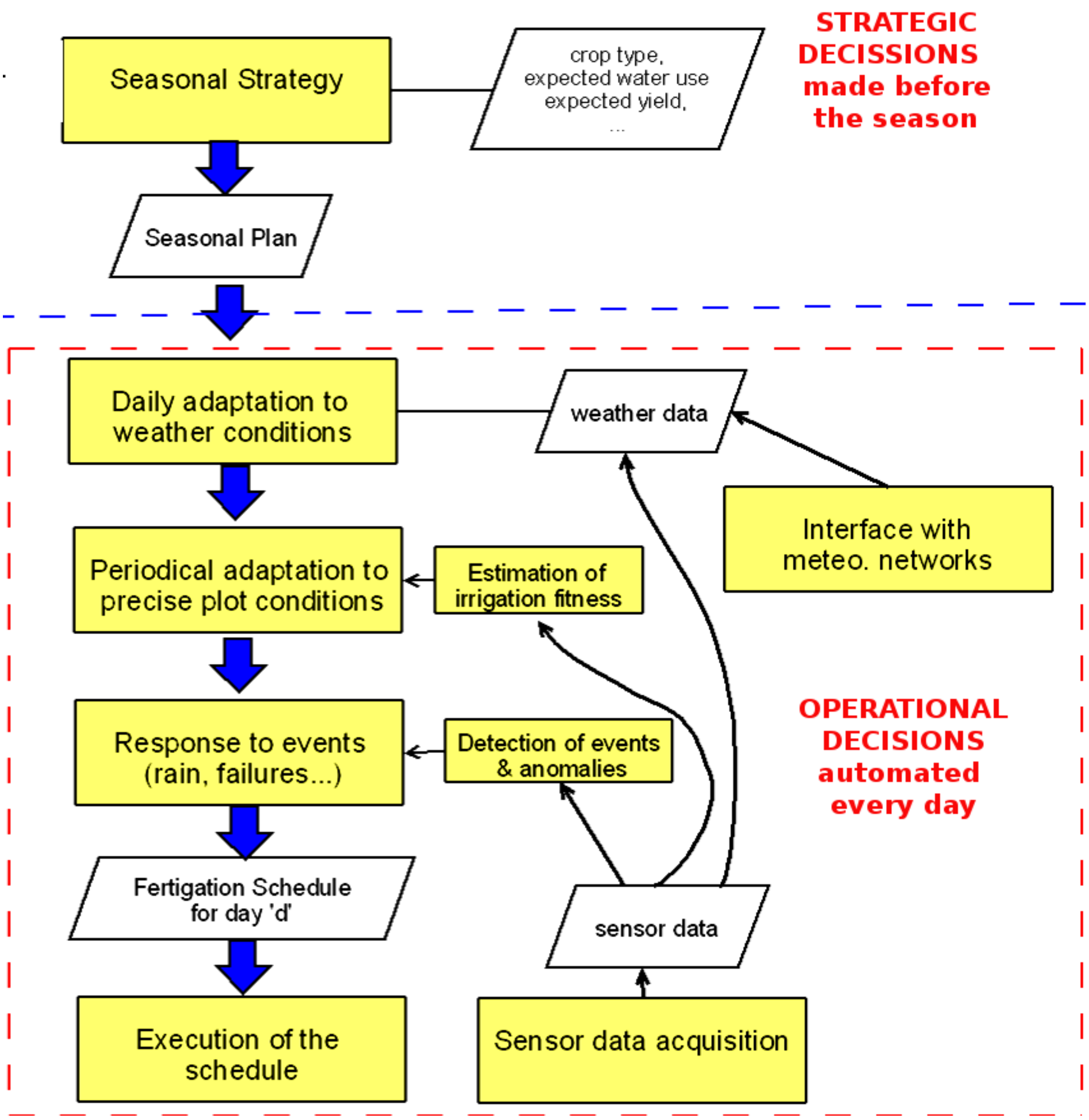

Figure 3. Workflow in the EFFIDRIP scheduling system.

2.4 Seasonal Plan

The Seasonal Plan is a key element for linking the EFFIDRIP's features on supervision and control of irrigation with the user's expectations on what has to be done on each plot during the forthcoming growing season (Figure 3). It is defined for each plot before starting to irrigate and specifies the acceptable range for accumulated irrigation at different times during the season, as well as the acceptable range for operational parameters that will be automatically tuned by the system. First, this is a way for

defining the strategy to follow and let the system execute this with enough flexibility for responding to the encountered conditions. Second, it facilitates defining seasonal objectives for the irrigation process and consequently it facilitates supervising during the season how the performance of irrigation progresses towards the objectives.
To help users to build the Seasonal Plan, the platform is equipped with an Irrigation Assistant, which asks information regarding the crop, expected calendar, layout and dimensions of the trees, characteristics of the irrigation setup, type of soil, allocated volume for irrigation and productive goals by the user. With this information the Irrigation Assistant builds a Seasonal Plan and presents it to the user for its approval (Figure 4).

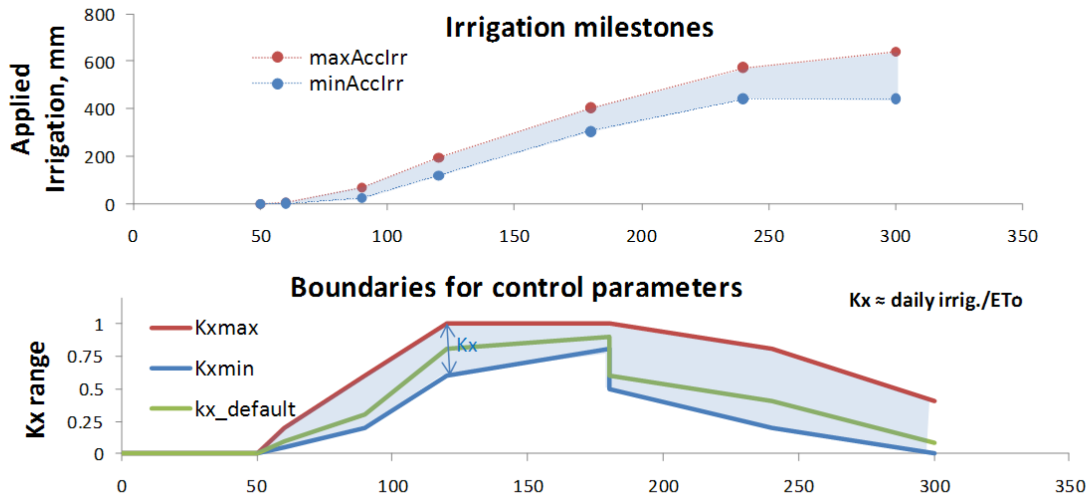

Figure 4. Example of a Seasonal Plan specifying the acceptable range for irrigation in a given plot managed by EFFIDRIP.

2.5 Soil simulations

To cope with the uniqueness of each orchard, the platform is equipped with a database containing pre-run simulations of soil water dynamics under different combinations of soil properties and configuration of the irrigation setup. For this purpose, the FUSSIM soil model (Heinen, 2001) has been adapted to the context of localized irrigation and a collection of soil-emitter scenarios has been simulated. These are used by the Irrigation Assistant for foreseeing the dynamics of soil water and estimating some components of the water balance on a particular plot.

2.6 Determination of irrigation doses

The daily irrigation dose (DID) is determined from reference evapotranspiration (ET_o) multiplied by a control parameter (K_x) which is tuned by feedback from the observed effect of previous irrigation doses, following an approach described in Casadesús et al. (2012):

$$\text{DID} = ET_o * K_x$$

K_x is initialized as the expected crop coefficient for that crop (Allen et al., 1998). Later, it is iteratively adjusted by the control system according to the following two aspects. On one hand, the fitness of irrigation to the actual crop water needs, interpreted from the trend of soil water content. On the other hand and with higher priority, it attends the adherence to the Seasonal Plan considering the projected irrigation until the end of the season.

3 RESULTS / CONCLUSIONS

Some distinctive features of the EFFIDRIP toolkit include its specialization in localized irrigation, whose particularities use to be oversimplified in other tools, the way sensor data is integrated in the whole scheme, as well as the focus in following an agreed plan aimed at some seasonal goal. The way sensors are used is original in that, first, they are automatically interpreted in non-trivial terms which refer to irrigation fitness and occurrence of events. Second, this interpretation is used by the control system combined with estimations of irrigation requirements and integrated within the Seasonal Plan. These features address the control system to reach seasonal objectives with agronomical interest rather than immediate arbitrary targets. In addition, they increase the fault tolerance of the system in case of sensor malfunctions.
Compared to existing decision support systems, EFFIDRIP takes the next step in automating irrigation control. It integrates commercial equipment deployed in the field, i.e. soil or plant sensors and irrigation controllers, to a higher level system. It makes autonomous operative decisions and communicates machine-to-machine with the diverse components based on information and communication technologies. These features contribute a higher sense of control that may facilitate adoption of efficient irrigation practices. The user's participation is focused in those occasional tasks that cannot be automated while the bulk of routine tasks are undertaken by the platform. The EFFIDRIP platform is currently being evaluated at three test sites, in olives (Portugal), citrus (Greece) and apples (Spain). The evaluation looks for quantifying improvements in water and fertilizer use efficiencies without impairing yield. Labour effort and the capacity to detect and cope with incidences are also analysed.

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