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Software for the automatic control of irrigation using weighing-drainage lysimeters

J.A. Vera-Repullo[a,*], L. Ruiz-Peñalver[b], M. Jiménez-Buendía[a], J.J. Rosillo[b], J.M. Molina-Martínez[b]

[a] Electronic Technology Department, Universidad Politécnica de Cartagena, Cartagena 30202, Spain
[b] Research Group: Ingeniería Agromótica y del Mar, Universidad Politécnica de Cartagena, Campus Alfonso XIII, ETSIA, 30203 Cartagena, Spain

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ABSTRACT

Among all the existing methods to study crop water requirements, necessary for an efficient irrigation management, the most accurate is the one based on the use of weighing lysimeters. The best known lysimeters are those used for crops in bare soil, with similar dimensions to the plantation frame of the measured species. These lysimeters are buried in the ground, require civil works, have a high cost and are commonly used in experimental plots to determine crop coefficients. There are cheaper and smaller scale lysimeters used to monitor water balance in pots without civil works. Although crop coefficients obtained from these lysimeters are not comparable to those obtained from crops in the ground, they may be useful to accurately determine the plants water needs so they can be used as a reference to irrigate the rest of potted plants of the plot.

The objective of this work was to develop and evaluate a software system to optimize irrigation using weighing lysimeters in a potted crop. The software was programmed in a compact embedded controller using the LabVIEW graphical programming language with the Real-Time module. This controller receives data from the lysimeters throughout a Modbus/RS-485 communication network, processes them and realizes the calculations to control the irrigation valves in real time. The system was tested in an experimental plot owned by the “Escuela Politécnica Superior de Orihuela” with *Vitis Vinifera* L. cv Bobal. The software allowed the acquisition and data logging as well as irrigation scheduling based on water balance obtained from weighing lysimeters i.e. based exclusively on actual crop water needs.

1. Introduction

Nowadays, in the food and agriculture sector of the southeast of Spain, the use of different agromotic systems for the management of water and energy resources is spreading because water availability is low and its cost is very high. These systems provide a valid response to the control requirements of productive processes (El-Gafy and El-Ganzori, 2012; Faye et al., 1998; Wellens et al., 2013).

The most important goal of these systems is to minimize water consumption while maximizing production, maintaining the vegetative state of the plant. This decrease in water consumption also means a reduction in pumping energetic costs. To achieve this reduction a control system to perform an efficient irrigation scheduling should be implemented. This system must answer two basic questions: (i) when to irrigate? And (ii) what volume of water should be used?

The first question (when?) implies the determination of the irrigation period, i.e. time between two irrigations. The second (how much?), requires to define the dose (volume, height, or type of application) of water. To perform a successful irrigation scheduling, some basic data and knowledge (sometimes formalized in “models”) must be taken into account (see Fig. 1). Either the farmer or the automatic irrigation system (computer or embedded controller with watering algorithms) will determine the dose and irrigation frequency using a set of decision rules.

1.1. Scheduling methods

Mainly three irrigation scheduling methods are distinguished in the literature (Fandiño et al., 2012; Rosa et al., 2012a, 2012b; Van Leeuwen et al., 2009) based on: climate data, soil water conditions and crop water conditions.

* Corresponding author. Tel.: +34 968 325475; fax: +34 968 32 5345.
E-mail address: jose.vera@upct.es (J.A. Vera-Repullo).

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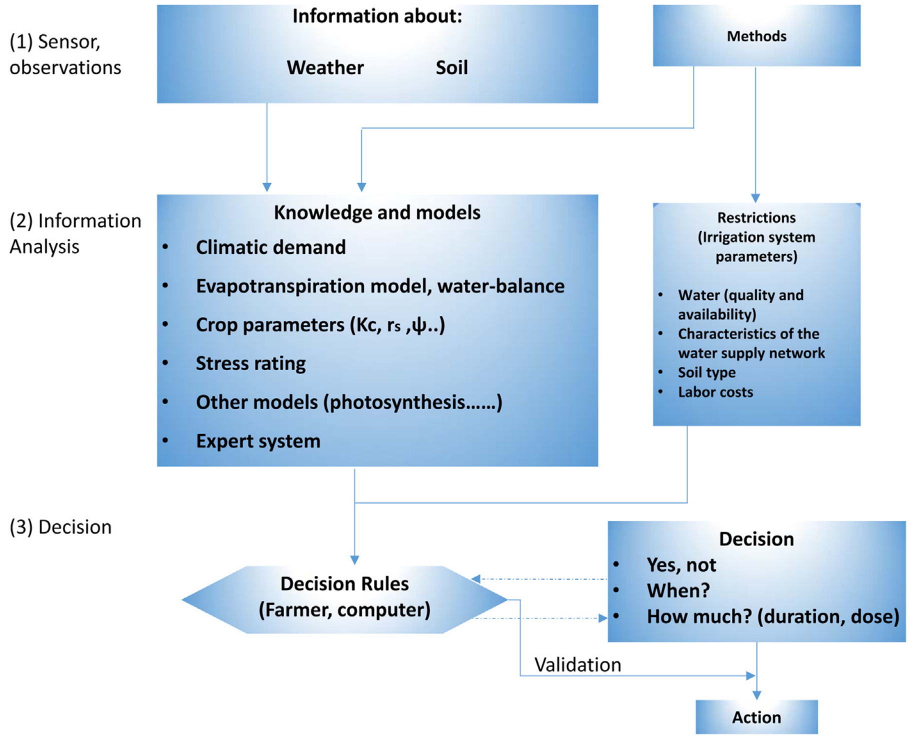

Fig. 1. Stages and agents involved in the irrigation decision process.

1.1.1. Scheduling based on climate data

This method performs an estimation of the water requirements of crops considering climatic conditions and estimation of the soil water balance (empirical formulas, evapotranspiration models, etc.). This approach, which is frequently used, is the recommended by the Food and Agriculture Organization of the United Nations (FAO) (Allen et al., 1998). It requires initial data related to the soil and crop components and either real time climate data or climate statistics and precipitation probability referred to an "average" year. Its main advantages are that neither soil nor plant water status are required and that it allows an average estimate, scalable to any plot size.

The accuracy of this method will depend on how precisely it can estimate the different elements that make up the soil water balance: estimation of the starting data (e.g.: initial soil water content), crop demand forecasts (crop evapotranspiration, ETc) and effective rainfall. The other parameters involved in the water balance, such as deep percolation, runoff and groundwater contribution are neglected. If all the data of the soil water balance could be accurately ascertained, the water balance determination would be a rigorous method of irrigation scheduling. Hence the importance of correctly estimating the different components, particularly the reference evapotranspiration (ETo) (Álvarez et al., 2004; Droogers and Allen, 2002; Hunsaker, 2011; Thysen and Detlefsen, 2006; Xu et al., 2011) and the crop coefficient (Kc) (Allen et al., 2011; Cruz-Blanco et al., 2014; Fandiño et al., 2012; López-Urrea et al., 2012).

1.1.1.1. Reference evapotranspiration. The FAO standardized method for the ETo estimation, based on the Penman–Monteith formula (Allen et al., 1998), has been widely adopted by different researchers and implemented as a basic tool in many applications for irrigation scheduling and automation. Several authors recommend its use (hereinafter, FAO-56 ETo) as it provides coherent results in different weather conditions (Allen et al., 1998; Itenfisu et al., 2003).

In addition to air temperature and solar radiation, the FAO-56 requires knowledge of the wind speed and vapor pressure deficit, which is generally obtained from nearby weather stations (Hoogenboom, 2000). Thus the use ETo from nearby stations is not suitable for precision agriculture where accurate models must be built in order to optimize the use of irrigation water. For this reason some research works propose the installation of agro-climatic stations in the crop itself (Hunsaker, 2011; Patel et al., 2012; Zhongshan et al., 2010). In this way, ETo can be worked out with much higher precision.

1.1.1.2. Crop coefficient. The crop coefficient (Kc) is used to work out the standard crop evapotranspiration (ETc). It takes into account the development stage of the crop species, the type of irrigation (sprinkler, located, etc.) and cultivation techniques, such as planting density and pruning among others. FAO proposes Kc values for a large number of species in standard crop conditions (Allen et al., 1998). The main disadvantage of using Kc values is that if actual conditions differ from the standard, so adjustment of these coefficients is required (Allen et al., 1998; Cruz-Blanco et al., 2014; Droogers and Allen, 2002). Such is the case of horticultural crops in greenhouses.

1.1.2. Irrigation scheduling based on soil water conditions

This schedule is based on measurements of the characteristics of the soil water conditions such as water content, water potential and water balance. Currently a large range of moisture and soil water potential sensors with analog or digital outputs is available for this purpose (Thompson et al., 2007). This is a widespread programming method used by farmers due to its simplicity, but it has the disadvantage of using localized soil measures, which can sometimes be unrepresentative of the whole plot.

1.1.3. Irrigation scheduling based on crop water conditions

It is a relatively recent and promising method, based on the assessment of the level of crop stress (stress index). For this, it