Agricultural Water Management xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Weighing lysimetric system for the determination of the water balance during irrigation in potted plants

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ARTICLE INFO

Article history:
Received 30 May 2016
Received in revised form 2 October 2016
Accepted 8 October 2016
Available online xxx

Keywords:
Agromotic systems
Evapotranspiration
Irrigation monitoring
Lysimeter

ABSTRACT

In years, the availability of water for irrigation is one of the main problems in Mediterranean Agriculture. That is why new technologies must be used to achieve proper irrigation management which is the main determinant of the quality and quantity of harvests and involves determining crop water needs. This paper presents a study for the development and implementation of an instrumentation system capable of accurately determining water balance during irrigation periods using a weighing lysimeter for potted crops. The mechanical structure of the lysimeter was designed and validated by our research group in previous works. In the design, the main requirements were high precision and low cost to make it affordable to most farmers. For this reason, the system was implemented using an open source platform and precision instrumentation to ensure accuracy of the measurements. A high-precision flowmeter was used to monitor the supplied irrigation water. The system was also capable of sending data wirelessly to a server in the cloud so they could be later queried from any device with Internet access. Field trials were conducted in order to collect data in both irrigation and non-irrigation periods. The application of filtering techniques was required, so a Savitzky-Golay smoothing algorithm was selected to obtain reliable data of instantaneous evapotranspiration. In the data analyzed, a decrease between 10% and 20% was observed in the hourly evapotranspiration during the irrigation intervals.

1. Introduction

Water scarcity is one of the main problems of the Mediterranean agriculture, especially in semiarid regions of the southeast of Spain. In addition, the progressive worsening of weather conditions, more and more extreme as a result of the impact of droughts and climate change, further underscores the need for adaptation developing efficient methods to optimize the use of water (Pérez-Sánchez and Senent-Aparicio, 2015). To do this, new technologies need to be exploited making them affordable to farmers with limited economic resources. In this context is framed the Spanish National Strategic Plan for Sustainable Modernization of Irrigation (MAGRAMA, 2014) whose main objective is the consolidation and modernization of existing irrigation systems in order to increase water savings through technological development applied to management of available water resources and, ultimately, to the optimum irrigation scheduling.

The region of Murcia, in particular, is severely hit by a gradual and progressive desertification. Low rainfall, and the use of saline water call for new strategies and methods for a region mainly engaged in irrigation agriculture (over 200,000 ha). The water management and irrigation scheduling methods used by most of the farmers are outdated; they are based mostly on humidity and salinity measurements within the roots zone, and a free decision making from the interpretation of these data (Bachand et al., 2014).

To make a proper irrigation scheduling it is necessary to determine the plant water needs. For this purpose different methods are used, such as models obtained from meteorological variables, soil sensors, as well as through direct measurement of the water balance with weighing lysimeters (López-Urrea et al., 2014; Ruiz-Peñalver et al., 2015; Vera-Repullo et al., 2015). Meteorological variables and soil sensors do not provide accurate calculation of the crop evapotranspiration (ET_c) since it is estimated indirectly by established formulas such as the Penman-Montheith (Allen et al., 1998). Image processing has also been used to obtain good estimates of the ET_c at a reduced cost (Escarabajal-Henarejos et al., 2015; García-Mateos et al., 2015), but a comprehensive calibration process is required for each particular species. Nevertheless,

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http://dx.doi.org/10.1016/j.agwat.2016.10.006
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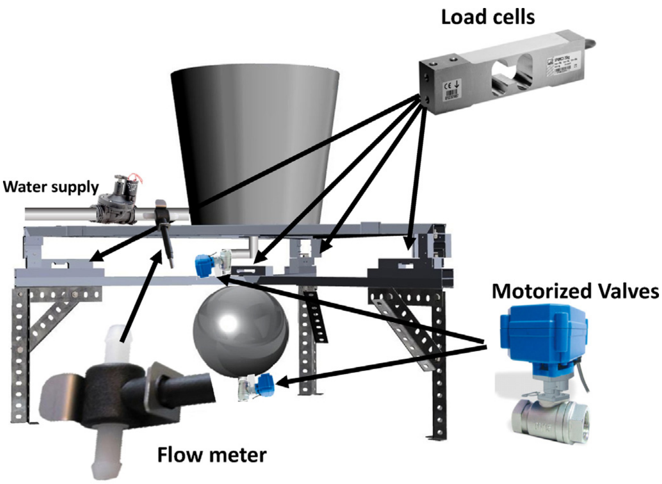

Fig. 1. Overview of the weighing lysimeter.

weighing lysimeters can be used to directly determine the ET_c (previously making a calibration and validation of the equipment), and thus establish the exact amount of water needed by a crop. Since data obtained from weighing lysimeters are more accurate and reliable, these are frequently used to validate data obtained with other methods (López-Urrea et al., 2006; Vaughan et al., 2007).

A lysimeter is a device used in agronomy to measure the volume of incoming water (rainfall and irrigation) and water coming out (drainage, evapotranspiration) of a container containing an isolated mass of soil (Payero and Irmak, 2008). Different types of lysimeters are commonly used by agronomists for calculating evapotranspiration, such as volumetric lysimeters and weighing lysimeters. The latter are the only ones that allow us to calculate evapotranspiration directly using a mass balance. The main drawback of using weighing lysimeters is that they usually require civil work which entails high costs. Moreover, in the majority of cases, lysimeters determine the ET_c accumulated over hourly and daily intervals, but do not have enough accuracy for obtaining it in shorter time intervals. For these reasons, the Agromotic and Sea Engineering research group developed a lysimeter for crops in pots (Ruiz-Peñalver et al., 2015) based on an easily portable and fast installation light metal structure. This first equipment was installed and validated in different field experiments using both commercial data loggers (Campbell CR1000) (Ruiz-Peñalver et al., 2015) and ad hoc conditioning and electronic systems (Jiménez-Buendía et al., 2015). Data collected with this lysimeter made it possible to accurately obtain ET_c values daily, hourly and every minute at low cost. This increase in accuracy led to pose the following challenge: what happens to ET_c during irrigation? Within irrigation intervals, ET_c was assumed to follow a linear trend so it was estimated using a linear interpolation between values at the beginning and at the end of irrigation. That is why research continued in order to develop an instrumentation system that had sufficient accuracy to work out the ET_c in the aforementioned irrigation periods. It is in this context that this paper presents the design and development of the measuring equipment for pot lysimeters implemented with reliable, inexpensive, open-source hardware and software platforms. Special attention has been paid to the necessary instrumentation to accurately measure the water supply as it is essential in determining the water balance.

This paper is organized as follows. Section 2 describes the instrumentation and electronic devices, software programming tools and acquisition and filtering techniques applied during and after data collection. Then, Section 3 presents and discusses experimental results, and finally, Section 4 is devoted to the conclusions.

2. Materials and methods

2.1. Lysimeter

The system is based on a weighing lysimeter for potted plants formerly developed by our research group (Ruiz-Peñalver et al., 2015). As shown in Fig. 1, the triangular platform that supports the pot rests on three load cells located at their vertices and are used to measure the weight. A fourth load cell is responsible for measuring the weight of the drainage tank. The four load cells were constituted by temperature-compensated strain gauges (full Wheatstone bridge configuration). The model selected was the 108TA (Vetek Weighing AB, Väddö, Sweden): three 30-kg ones to weigh the pot and a 10-kg one for the drainage. These load cells have IP66 protection and comply with OIML R60 C3 regulations, up to 5000 divisions for scales class III (International Organization of Legal Metrology, 2000) with a nominal sensitivity of $2\,mV\,V^{-1}$ ±10%. With these specifications a weighing accuracy of 6 g for the 30-kg cells and of 2 g for the 10-kg ones was guaranteed.

To measure the irrigation water, a high-precision low-range flow meter was required, since irrigation was done with two compensated emitters of 2 l/h (irrigation flow was around 0.06 l/min). The Equflow 0045PHP01 (Equflow B.V., Ravenstein, The Netherlands) turbine flow sensor was selected as it provides a typical output of 100,000 pulses per liter (each sensor is delivered with its own calibrated K-factor). This gives a resolution of 10 μl/pulse for flow rates between 0.03 to 2 l/min, with an accuracy of 1%. Two 5 V voltage-controlled motorized electrovalves were used to empty the drainage tank.

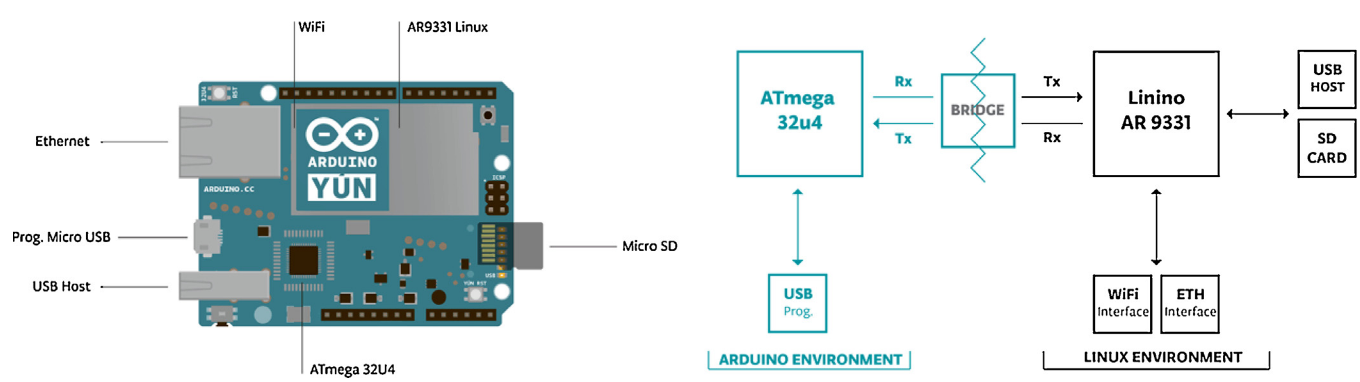

Fig. 2. Arduino Yun parts (left) and block diagram of its internal structure (right).

Source: http://arduino.cc.

Please cite this article in press as: Jiménez-Carvajal, C., et al., Weighing lysimetric system for the determination of the water balance during irrigation in potted plants. Agric. Water Manage. (2016), http://dx.doi.org/10.1016/j.agwat.2016.10.006