Agricultural Water Management xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Agricultural Water Management

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

Soil water balance correction due to light rainfall, dew and fog in Ebro river basin (Spain)

R. Moratiel[a,b,*], A. Martínez-Cob[c], A.M. Tarquis[b], R.L. Snyder[d]

[a] Department of Plant Production, Technical University of Madrid, Avda. Complutense s/n, 28040 Madrid, Spain
[b] CEIGRAM, Centro de Estudios e Investigación para la Gestión de Riesgos Agrarios y Medioambientales, C/Senda del Rey 13, 28040 Madrid, Spain
[c] Estación Experimental de Aula Dei (CSIC), Avda. Montañana 1005, 50059 Zaragoza, Spain
[d] Department of Land, Air and Water Resources, University of California Davis, CA 95616, USA

ARTICLE INFO

Article history:
Received 4 September 2015
Received in revised form
10 December 2015
Accepted 12 December 2015
Available online xxx

Keywords:
Soil Water Balance
Evapotranspiration
Dew
Fog
Light rainfall

ABSTRACT

Accumulated daily crop evapotranspiration (ET_c) generally provides good estimates of cumulative soil water depletion between irrigation of well drained soils. If the canopy is wet due to fog, dew, or light rainfall, however, energy contribution to surface evaporation will reduce transpiration and hence soil water losses. When surface evaporation occurs, the ET_c overestimates the soil water depletion by an amount approximately equal to the surface water evaporation. Moratiel et al. (2013) proposed a method to estimate the contribution of surface water to ET_c based on the time of canopy drying. The first method assessment was done with California data, and this evaluation was conducted in the Ebro basin, Spain, to appraise the method in a higher latitude in area with a somewhat different climate. Differences between the California and Spain corrected models were less than 10% and depended mainly on the time of canopy drying. The comparison showed that the model is robust and useful to estimate the fraction (F) of ET_c coming from the soil under dew, light rainfall, and fog conditions.

1. Introduction

Three main mechanisms, which are often neglected, that provide water for evapotranspiration are fog interception, dew formation, and light rainfall. Fog occurs when water vapor (in the atmosphere) reaches saturation and condenses on aerosols regardless of the surface conditions. Dew occurs when the surface temperature reaches the dew point temperature, and the water vapor from the air in contact with the cold surface condenses to form dew. Light rainfall is often insufficient in magnitude to cause tipping bucket raingauges to tip and it is difficult to measure in standard rain gages. All three of these sources of water will wet a crop canopy, and contribute to evapotranspiration, so it is important to consider the contributions in water balance calculations. There are few studies dealing with the contribution of fog and dew to the soil water balance of crops. Dew deposition provides a relatively small contribution to crop evapotranspiration (ET_c), it depends on microclimate at night, and it varies to a great extent even within the same region (Moro et al., 2007). In coastal regions, fog can provide a considerable fraction of the annual water (Dawson, 1998). The majority of studies dealing with the fog contribution were developed for natural ecosystems (Kidron, 1999; Moro et al., 2007; Prada et al., 2009; Mildenberger et al., 2009; Kataka et al., 2010), while only a few studies investigated the contribution of dew and fog to the water balance of crops (Cosh et al., 2009; Kabela et al., 2009). In this paper, the model developed using California data to estimate the reduction in soil water losses due to the evaporation of fog, dew, and light rainfall interception by crop canopies is further tested in Spain at higher latitude than California. Quantification of dew, fog, and light rainfall contribution to ET_c is important for efficient water usage in irrigated agriculture.

In regions with high evaporative demand, the contribution of fog, dew, or light rainfall is relatively small, however, in locations and times when ET_c rates are small, the surface water contribution becomes important. For irrigation scheduling based on the soil water balance, the goal is to calculate the soil water depletion (S_D) using ET_c, deep percolation, and runoff of precipitation and irrigation applications, water Table contributions, and surface water supplied by fog, dew, and light rainfall. For well-drained soils and well-managed irrigation systems, there is no water Table contribution to ET_c and the sum of deep percolation and runoff are relatively easy to estimate. Estimating the contribution of surface water,

* Corresponding author. Fax: +34 915449983.
E-mail address: ruben.moratiel@upm.es (R. Moratiel).

http://dx.doi.org/10.1016/j.agwat.2015.12.013
0378-3774/

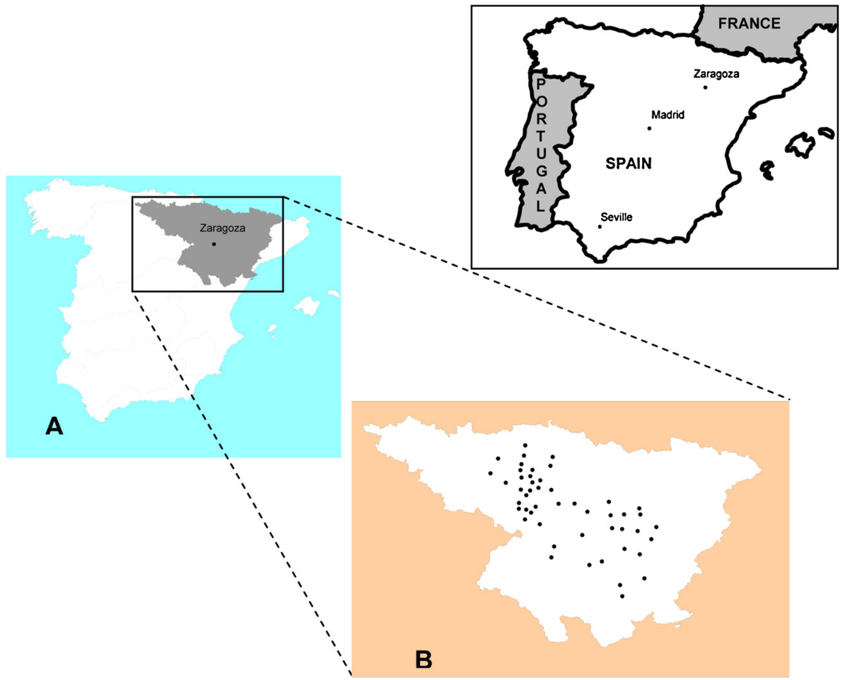

Fig. 1. (A). Location of the Ebro basin. (B). Location of the ometeorological stations of the Ebro basin.

however, is more difficult. When the plant foliage is wet, surface evaporation reduces transpiration losses because the energy that would contribute to transpiration is used to vaporize water from the leaf surfaces. Thus, surface vaporization (V_S) causes a reduction in soil water losses to ET_c roughly equal to the V_S contribution.

Proper irrigation scheduling requires information on the soil water depletion (S_D) within the crop root zone, application uniformity and efficiency, and application rate. The soil water depletion (S_D) is the difference between the volumetric water content at field capacity and the soil volumetric water content, where field capacity is the soil water content reached after drainage of the gravitational water. For well-drained soils, the two main methods to determine S_D are based on (1) gravimetric water content sampling and (2) cumulative crop evapotranspiration (CET_c) estimate. Assuming the other gains and losses of soil water are small, most of the soil water loss is due to ET_c.

The crop coefficient method is commonly used to estimate ET_c from the standardized reference evapotranspiration for short canopies (ET_0), where ET_c= $ET_0 \times K_c$. Crop coefficient (K_c) values are determined by calculating the ratio of measured ET_c to the ET_0, which is calculated using data from an agrometeorological station and equations described by Allen et al. (1998) and Allen et al. (2005). For a well-watered crop, the ET_c mainly depends on the energy available for vaporizing water on the plant surfaces, from the soil (evaporation), and from water vaporized inside the plant leaves (transpiration). Clearly, if the plant surfaces are wet, then some of the ET_c comes from surface vaporization rather than from transpiration.

There are few studies regarding the contribution of water from dew, fog, and light rainfall to the crop. Recently, Moratiel et al. (2013) reported a method to separate ET_c into S_D and V_S contributions for 30 California weather stations. The aim of this study was to evaluate the method under the semiarid conditions of the Ebro river basin (Spain), which is at higher latitude than California, to develop appropriate monthly models for this area, and to use the information to improve water balance calculations under dew, fog, and light rainfall conditions.

2. Material and methods

2.1. Study area: Ebro basin

The Ebro basin is located in Spain between meridians 4°W and 2°E and the parallels 40° and 43°N (Fig. 1). The basin surface area is 85,362 km^2 and it is located mostly in Spain (98.9%) with small areas in Andorra and France. The ring of mountains that surround the basin formed a depression in the central zone where most of the irrigated area is located. The Ebro basin originated during the Tertiary period. The central sector of the Ebro Tertiary Basin is characterized by Oligo-Miocene sediments deposited in evaporite and carbonate shallow lakes in a continental environment, disconnected from the sea (Gutiérrez Elorza and Gutiérrez Santolalla, 1998). The bedrock mainly consists of sub-horizontal evaporites of the Oligo-Miocene Zaragoza Gypsum Formation with laminated and nodular gypsum alternating with marls and lutites (sedimentary rocks, which are composed of silt-size sediment, clay-size sediment, or a mixture of both). Consequently, in the middle of the Ebro River Basin, the soils and surface water, which is the main source of irrigation water in the area, have the potential to contribute to salinity. Most of the soils in the irrigated areas are classified as Xerosol Gypsic and Xerosol Calcic, while the soils near the river are classified as Fluvisol Eutric (Salvador et al., 2011). The predominant climate is Mediterranean Continental. The average precipitation in the basin is 622 mm per year, concentrated in autumn and spring, but the average precipitation in irrigated areas is usually between 300 and 500 mm per year (Martínez-Cob and GarcíaVera, 2004). In the central part of the basin, the climate is semiarid or arid with annual ET_o in the range of 840–1500 mm, with an average value of 1150 mm (Salvador et al., 2011).

The Ebro Basin has 783,948 ha of irrigated land. The irrigation systems used in the basin are surface (69%), sprinkler (19%), and drip (12%). Surface water comprises 91% of the water use in the basin (CHE, 2012). The main field crops are: alfalfa (*Medicago sativa* L.), 121,499 ha, about 56% of the national alfalfa crop area; grain corn (*Zea mays* L.), 105,694 ha; barley (*Hordeum vulgare* L.), 83,550 ha; wheat (*Triticum aestivum* L.), 69,026 ha; peach orchard

Please cite this article in press as: Moratiel, R., et al., Soil water balance correction due to light rainfall, dew and fog in Ebro river basin (Spain). Agric. Water Manage. (2015), http://dx.doi.org/10.1016/j.agwat.2015.12.013