Agricultural Water Management 195 (2018) 180–186

Contents lists available at ScienceDirect

Agricultural Water Management

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

Measuring short-crop reference evapotranspiration in a humid region using electronic atmometers

Zachary Straatmann[a], Gene Stevens[a,*], Earl Vories[b], Pat Guinan[c], John Travlos[d], Matthew Rhine[a]

[a] University of Missouri, Division of Plant Sciences, Fisher Delta Research Center, P.O. Box 160, Portageville, MO 63873, United States
[b] USDA-ARS Cropping Systems and Water Quality Research Unit, Fisher Delta Research Center, P.O. Box 160, Portageville, MO 63873, United States
[c] University of Missouri, Department of Soil, Environmental, and Atmospheric Sciences, 103 Anheuser-Busch Natural Resources Building, Columbia, MO 65211, United States
[d] University of Missouri, Department of Agricultural and Applied Economics, 325 Mumford Hall, Columbia, MO 65211, United States

ARTICLE INFO

Article history:
Received 12 April 2017
Received in revised form 4 October 2017
Accepted 10 October 2017

Keywords:
Atmometer
ETgage
Evapotranspiration
Weather station
Irrigation scheduling
Phone app

ABSTRACT

The Crop Water Use phone app is a weather-based program developed by the Missouri Extension Service to help farmers with irrigation scheduling. A limitation of the program is that it only works on Missouri fields. The app is linked to the state agricultural weather station network which supplies daily standardized, short-crop evapotranspiration (ET_o). For farmers outside the network, the cost of installing and maintaining appropriately maintained weather stations is cost prohibitive. A less costly option would be to install atmometers within the field of interest. The objective of this study was to compare ET_o data from atmometers to electronic weather stations with traditional sensors. In 2015 and 2016, electronic atmometers were installed at three locations in Missouri. Atmometers were placed near electronic weather stations programmed to calculate daily ET_o. Each atmometer ceramic cup was fitted with a disposable paper wafer and #30 diffusion canvas cover and wired to an event data logger to record daily ET_o measurements. Regression analysis showed a close relationship between ET_o measured with atmometers and weather station across locations and years ($R^2 = 0.74$). However, ET_o from atmometers averaged 15% lower than weather stations. Regional or localized calibration equations may be required before using ET_o from atmometers in irrigation scheduling apps, but additional research is needed to determine if the observed differences impact recommended irrigation intervals.

1. Introduction

Water is an important management factor for row crop production, especially in regions where irrigation is applied to supplement rainfall. Farmers are encouraged to maximize irrigation efficiency in fields to reduce input costs, conserve water resources, and minimize nutrient runoff to streams (USDA-Natural Resources Conservation Service, 2015). Irrigation scheduling programs are useful tools for improving water efficiency. Several state extension services have developed mobile phone apps linked to electronic weather station networks to calculate evapotranspiration used for irrigation scheduling (Andales et al., 2015; Migliaccio et al., 2016; Peters, 2015).

ET is a critical element in irrigation scheduling and helps calculate a running soil water balance in crop fields. ET is the combination of transpiration from the crop and evaporation of the water from the soil or plant surfaces (Scherer et al., 1999). In the central United States, the climate is humid but periods of low rainfall are common in the summer months when crops are growing. Irrigation is often applied in fields to prevent water stress and increase crop yields. The University of Missouri Extension Service maintains an agricultural weather station network (mesonet) which provides weather data to farmers for managing irrigation. The weather stations meet standards approved by the American Society of Agricultural Engineers (ASAE, 2004). Each weather station is equipped with a datalogger (Campbell Scientific, Logan, UT), 3-cup anemometer and direction vane (RM Young, wind sentry set, Traverse City, MI), temperature/relative humidity probe (Vaisala, Vantaa, Finland) housed in a 12-plate gill solar radiation shield (RM Young), tipping bucket rain gauge (Texas Electronics, Dallas, TX), silicon pyranometer (Li-Cor, Lincoln, NE; Model LI200S-X),

* Corresponding author.
E-mail address: stevensw@missouri.edu (G. Stevens).

https://doi.org/10.1016/j.agwat.2017.10.007
0378-3774/

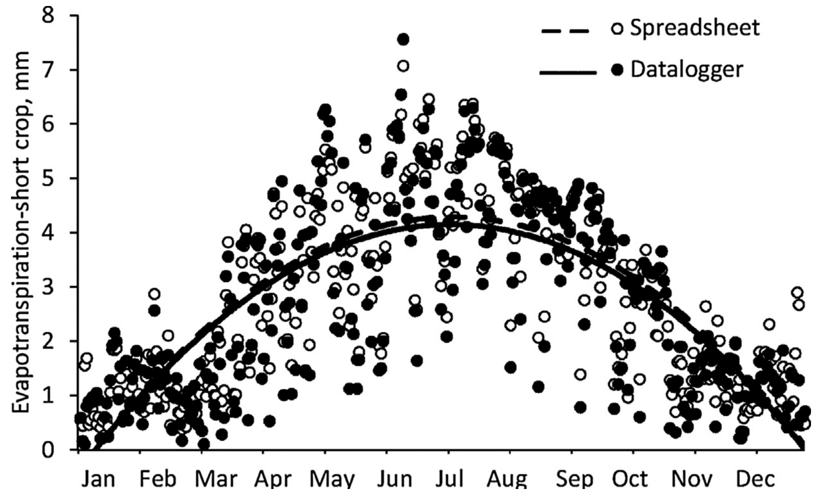

Fig. 1. Comparison between daily short crop evapotranspiration (ETo) at Portageville in 2015 calculated with standardized Penman-Monteith equation by a CR-1000 datalogger in a Campbell Scientific weather station versus a Excel spreadsheet using daily solar radiation, temperature, humidity, and wind.

and battery charged with a solar panel. The wind anemometers are installed 3 m above the ground. The datalogger and battery are stored in a weather-resistant enclosure. Most of the 34 stations in the mesonet have a Campbell Scientific^{TM} CR-1000 data logger which is programmed to calculate standardized short-grass evapotranspiration called ET_o (Campbell Sci., 2015). For farmers calculating daily crop ET for irrigation scheduling, ET_o is multiplied by a coefficient (K_c) specific to the crop in the field. In the Northern Hemisphere, ET_o is usually highest in June, and July when days are longer (Fig. 1). ET_o varies from year to year which is a limitation for irrigation scheduling from printed charts that rely on long-term weather averages.

A modified Penman-Monteith equation is commonly used to calculate ET_o (Monteith, 1985). Campbell Scientific weather stations use a standardized version of the equation developed by the Task Committee on Standardization of Reference Evapotranspiration and included in their Technical Committee Report to the Environmental and Water Resources Institute of the American Society of Civil Engineers (Campbell Sci., 1999; Walter et al., 2000).

Most farmers do not have time to manually calculate daily crop ET and soil water deficits from weather data for their fields. In 2015, the University of Missouri Extension Service released an irrigation app for mobile phones called the Crop Water Use app which uses daily ET_o from the state mesonet (Stevens et al., 2016). Many of the equations in the Missouri program including crop coefficients were modified from the Arkansas Irrigation Scheduler (Cahoon et al., 1990; Vories et al., 2009). Most state extension irrigation scheduling apps, including Missouri's program, make recommendations using the water balance approach (Andales et al., 2011). Lack of ET_o data is a limitation for farmers wanting to use these apps for irrigation scheduling. Some states in the region have mesonets, but do not calculate ET_o, while other states are data sparse when it comes to the number of weather stations that do calculate it. One of the largest systems for sharing weather data among universities and government agencies operates in the Western region. The *Irrigation Scheduler Mobile* phone app developed at Washington State University accesses ET_o from AgriMet-Pacific Northeast, a group of 270 weather stations maintained by the Bureau of Reclamation, and mesonets in Washington, Montana, Colorado, Arizona, North Dakota, South Dakota, and California (Palmer and Hamel, 2009).

In Georgia and Florida, developers of an irrigation app for cotton called *Cotton SmartIrrigation* are testing novel ways to provide ET_o values to farmers using their program in other states (Vellidis et al., 2016). An experimental forecast ET tool (FRET) produced by the National Weather Service was evaluated as a substitute for local weather station generated ET. A shortcoming of the FRET tool is that the National Weather Service predicts ET_o for tomorrow and the near future but does not calculate ET_o values from actual weather from the past. Vellidis et al. (2016) found that FRET often overestimated ET_o, which could lead to recommendations for unnecessary irrigation applications. Hopefully, FRET and similar tools will improve with time.

Another approach is to install more weather stations in states without mesonets, but appropriately equipped and remotely accessible electronic weather stations are expensive to install and keep maintained. In Missouri, each electronic weather stations with sensors for ET calculation costs about $10,000 US. Communication equipment and annual maintenance add another $3000 to the cost. Electronic modified atmometers (Model E, ETgage Co., Loveland, CO), which cost about $1000 US, may be a less expensive way to supply daily ET data to farmers in places that they do not have an established mesonet. As with conventional weather stations, a modem or radio would be needed with an atmometer to remotely upload weather data; however, less-expensive manually read versions of the ETgage are also available if remote access is not required.

Little research has been reported in humid environments comparing electronic atmometers to weather stations with sensors for solar radiation, wind, temperature, and humidity. A few experi-

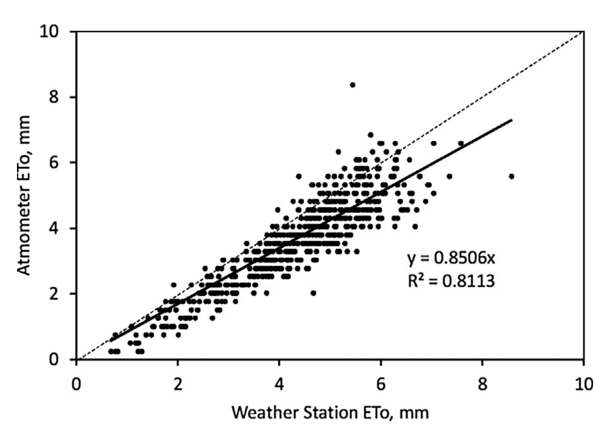

Fig. 2. Comparison between ET_o values at three Missouri locations in 2015 and 2016 measured with atmometers compared to calculated amounts from Campbell Scientific weather stations.