A TOOL FOR DETERMINING SEASONAL WATER NEEDS AND IRRIGATION REQUIREMENTS OF CROPS IN SOUTH CAROLINA

J. Payero
Clemson University, Edisto Research and Education Center
Blackville, South Carolina

Abstract

Information on seasonal water needs and irrigation requirements of crops is needed for a variety of reasons, such as irrigation system design and regional water planning. The objective of this project was to develop an online tool to calculate seasonal water needs and irrigation requirements of crops in South Carolina. Therefore, the South Carolina Water Requirement Calculator (https://etcman.shinyapps.io/CropWaterUse/) was developed. The online tool uses historical daily rainfall and grass reference evapotranspiration (ETo) data to determine daily and seasonal crop water use and irrigation requirements for a variety of crops. The system allows users to choose the county, crop, soil type, planting date, and irrigation efficiency and produces a series of graphical outputs for each year of available weather records.

Introduction

Local data on the seasonal water needs and irrigation requirements of crops are needed for a variety of reasons. These reasons include watershed hydrological studies, irrigation system design, local and regional water planning, irrigation scheduling, and development of water policies and regulations, among others. Although seasonal water needs and irrigation requirements of crops could be obtained from local measurements, the reality is that local measurements are usually lacking since they are difficult to make and require very specialized and expensive instrumentation (Payero and Irmak, 2008; Payero and Irmak, 2013). Therefore, a more practical approach is to estimate the water needs and irrigation requirements of crops from local weather data using mathematical modeling approaches (Chauhan et al., 2013; Payero, 2018; Payero et al., 2011). Direct measurements, however, are still useful for evaluating and calibrating the model estimates. Therefore, the objective of this project was to develop an online tool to calculate seasonal water needs and irrigation requirements of crops in South Carolina.

Materials and Methods

The online tool, called the South Carolina Water Requirement Calculator was developed using the R (R Core Team, 2017) package "Shiny" (https://shiny.rstudio.com/) developed by R Studio. Shiny is an R package that facilitates building interactive web Apps taking advantage of the capabilities provided by the R language. The tool uses the available historical daily grass-reference evapotranspiration (ETo) and rainfall values for each of the counties in South Carolina to conduct a daily soil water balance. The (ETo) and rainfall values, which are updated daily, are obtained from the CRONOS database (http://climate.ncsu.edu/cronos/) provided by the North Carolina Climate Office. The daily soil water balance estimates the soil water in the crop root zone by calculating the daily water inputs (rain and irrigation) and the water outputs (evapotranspiration, runoff, and deep percolation). Irrigation is applied when the soil water content in the crop root zone reaches the threshold defined by the depletion fraction (p) for the crop.

The tool calculates daily values of crop evapotranspiration sing the FAO-56 single crop coefficient procedure as (Allen et al., 1998):

$$ETp = Kc \times ETo \quad (1)$$

$$ETa = Kc \times ETo \times Ks \quad (2)$$

where, ETp = crop evapotranspiration with no water stress (in day-1), ETa = crop evapotranspiration with water stress (in day-1), Kc = crop coefficient (unitless) and ETo = grass-reference evapotranspiration (in day-1), and Ks = transpiration stress coefficient, which is a factor describing the effect of water stress on crop transpiration (unitless). Daily runoff is determined following the SCS runoff equation (USDA/NRCS, 1999), as:

$$Q = (P - 0.2\ S)2/(P + 0.8\ S) \quad (3)$$

$$S = (1000/CN) - 10 \quad (4)$$

Where, Q = daily runoff (in day-1), P = daily rain (in day-1), and CN = curve number. The CN values for each soil type was selected from Table 2 in USDA/NRCS (1999), assuming a "row crop" with "straight rows" plus "crop residue cover" with "good" hydrologic condition. Daily deep percolation is calculated from the soil water balance when the water inputs exceed the field capacity of the soil in the effective crop root zone. Table 1 shows the availability of rain and ETo data for each of the counties in South Carolina. Table 2 and Table 3 show that crop and soil parameters used in the calculations.

Table 1. Availability of daily rain and ETo data from the CRONOS weather database for each county in South Carolina ("X" indicates that data records are available).

County	Rain	ETo	County	Rain	ETo	County	Rain	ETo
Abbeville			Darlington	X	X	Lee		
Aiken		X	Dillon			Lexington	X	X
Allendale			Dorchester		X	Marion	X	X
Anderson	X	X	Edgefield			Marlboro	X	X
Bamberg			Fairfield		X	McCormick		
Barnwell	X	X	Florence	X	X	Newberry	X	X
Beaufort	X	X	Georgetown	X	X	Oconee	X	X
Berkeley	X	X	Greenville	X	X	Orangeburg	X	X
Calhoun			Greenwood	X	X	Pickens		X
Charleston	X	X	Hampton			Richland	X	X
Cherokee	X		Horry	X	X	Saluda		
Chester	X	X	Jasper			Spartanburg	X	X
Chesterfield	X	X	Kershaw		X	Sumter	X	X
Clarendon	X	X	Lancaster	X	X	Union	X	
Colleton		X	Laurens	X	X	Williamsburg	X	X
						York	X	X

Table 2. Crop coefficients, length of development stages, effective rooting depth (ERD), and depletion fraction (p) for each crop (Adapted from Table 11 and Table 12 in Allen et al., 1998).

	Crop Coefficient			Length of Development Stages (days)					ERD (in)	p
Crop	$K_{c\ ini}$	$K_{c\ mid}$	$K_{c\ end}$	L_{ini}	L_{dev}	L_{mid}	L_{late}	Total		
Cotton	0.35	1.18	0.60	30	50	55	45	180	53	0.65
Corn	0.30	1.20	0.35	30	40	50	50	170	53	0.55
Soybeans	0.40	1.15	0.50	20	35	60	25	140	38	0.50
Peanuts	0.40	1.15	0.60	35	35	35	35	140	30	0.50
Sorghum	0.30	1.10	0.55	20	35	45	30	130	59	0.55

Table 3. Field capacity (FC), permanent wilting point (PWP), Curve Number (CN), and minRain by soil texture (FC and PWP were adapted from Table 19 in Allen et al., 1998, and CN and minRain, from USDA/NRCS, 1999). The minRain is the minimum rain needed to produce runoff.

Texture	FC	PWP	CN	minRain (in)
Sand	0.12	0.05	64	1.2
Loamy Sand	0.15	0.07	64	1.2
Sandy Loam	0.23	0.11	75	0.8
Loam	0.25	0.12	75	0.8
Silt Loam	0.29	0.15	82	0.4
Silt	0.32	0.17	82	0.4
Silt Clay Loam	0.34	0.21	85	0.4
Silty Clay	0.36	0.23	85	0.4

Results and Discussion

Figure 1 shows a screenshot as an example of the inputs and outputs of the South Carolina Crop Water Requirement Calculator. The system allows users to choose the county, crop, soil type, planting date, and irrigation efficiency and produces a series of graphical outputs for each year of available rainfall and ETo data. The system produces a series of outputs summarized by days after panting, weeks, months, years and by growing season. Some of the sample outputs are shown in Figures 2 and 3.

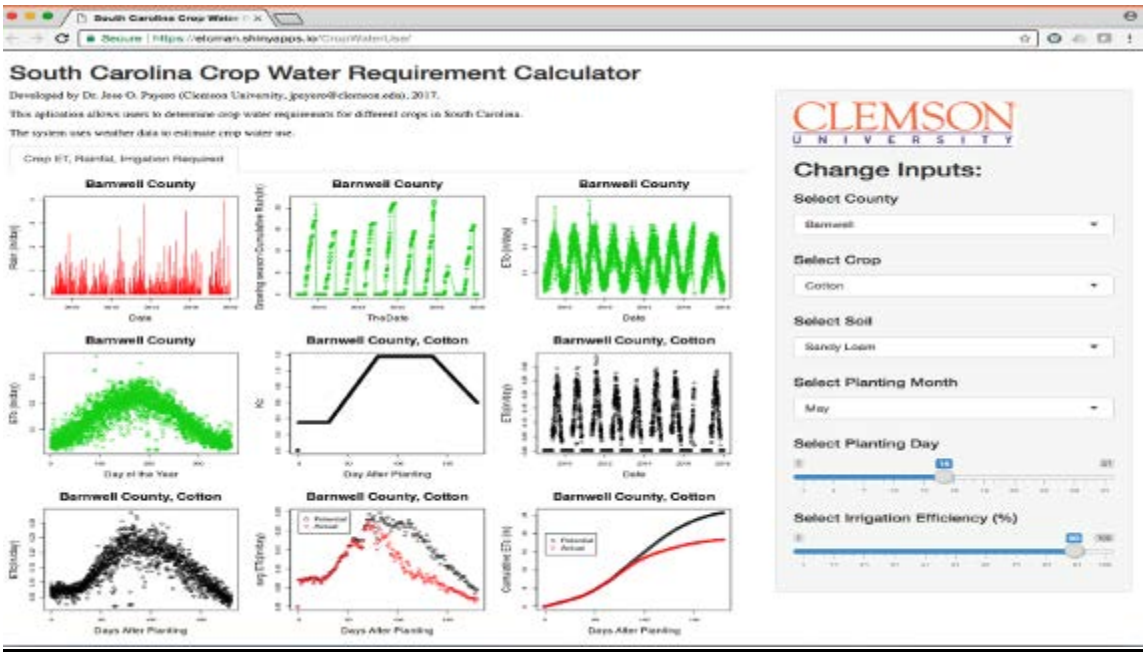

Figure 1. Sample inputs and outputs of the South Carolina Crop Water Requirement Calculator.

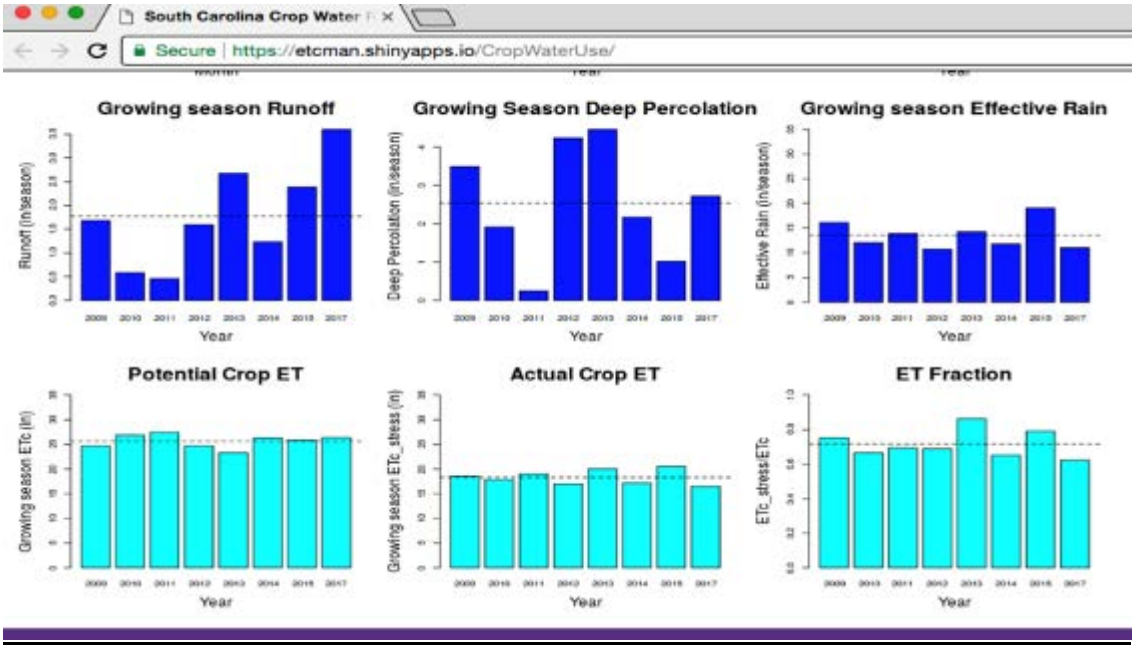

Figure 2. Sample output of the South Carolina Crop Water Requirement Calculator.

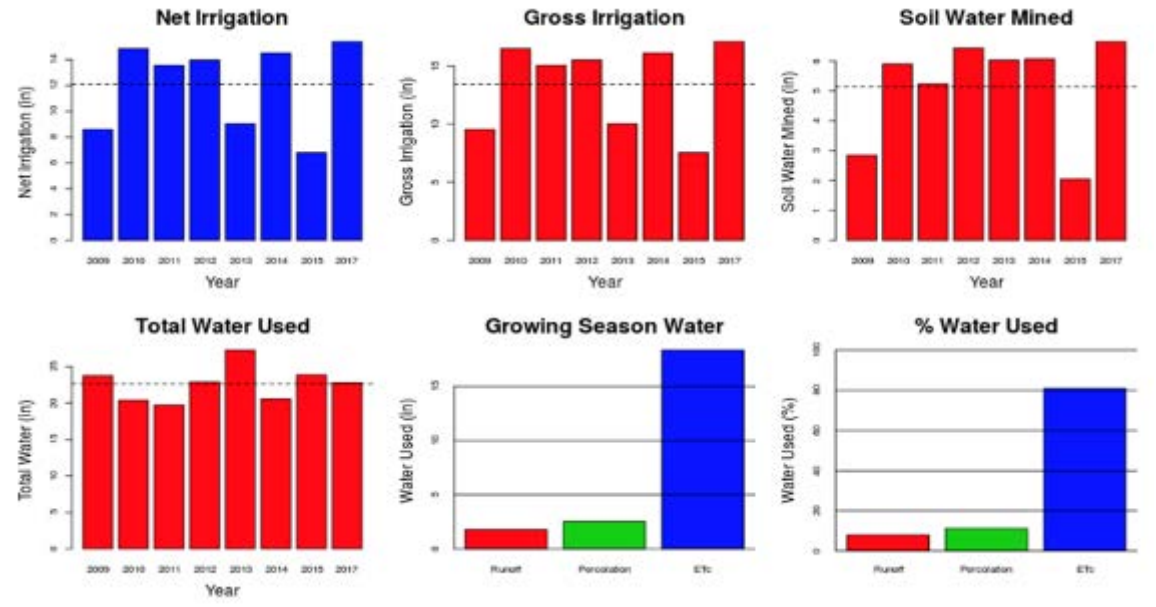

Figure 3. Sample output of the South Carolina Crop Water Requirement Calculator.

Summary

In this study, an online tool to calculate seasonal water needs and irrigation requirements of crops in South Carolina called the South Carolina Water Requirement Calculator (https://etcman.shinyapps.io/CropWaterUse/) was developed. The online tool uses historical daily rainfall and grass reference evapotranspiration (ETo) data, which is available in the CRONOS database, to determine daily and seasonal crop water use and irrigation requirements for a variety of row crops. Currently, only major row crops (cotton, corn, soybean, peanuts, and sorghum) have been included, but additional crops can be added as needed. One limitation of the current system is that some of the counties in South Carolina do not have historical rainfall and/or ETo records. The intend is for the tool to be used as water planning tool to obtain basic information for applications such as irrigation system design and for guiding water policy decisions.

Acknowledgements

The author would like to acknowledge the North Carolina Climate Office for maintaining the CRONOS database and for providing the weather information online. The author would also like to acknowledge the financial support provided by USDA-NIFA (Hatch Project No. SC-1700540).

References

Allen, R.G, Pereira, S., Raes, D., and Smith, M. 1998. Crop evapotranspiration-Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. FAO, Rome.

Chauhan, Y.S, Wright, G.C., Holzworth, D., Rachaputi, R.C.N., and Payero, J.O. 2013. AQUAMAN – a web-based decision support system for irrigation scheduling in peanuts. Irrigation Science, 31: 271–283.

Payero, J.O. 2018. An online tool for estimating evapotranspiration and irrigation requirements of crops in South Carolina. Journal of South Carolina Water Resources, 5(1):69-73.

Payero, J.O., D. Singh, G. Harris, S. Vriesema, J. Hare, L. Pendergast, and Y.S. Chauhan. 2011. Application of a new web-based tool (CropWaterUse) for determining evapotranspiration and irrigation requirements of major crops at three locations in Queensland, p. 295-318, In L. Labedzki, ed. Evapotranspiration. InTech. (Available at: http://www.intechopen.com/books/show/title/evapotranspiration).

Payero, J.O., Irmak, S. 2013. Daily energy fluxes, evapotranspiration and crop coefficient of soybean. Agricultural Water Management, 129:31-43.

Payero, J.O. and Irmak, S., 2008. Construction, installation, and performance of two repacked weighing lysimeters. Irrigation Science, 26: 191-202.

R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

USDA/NRCS. 1999. Engineering Hydrology Training Series: Module 205-SCS Runoff Equation. 27 pp.