

The ASCE Standardized Equation Based Bushland Reference ET Calculator

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ABSTRACT

Accurate daily reference evapotranspiration (ET) values are needed to estimate crop water demand for irrigation management and hydrologic modeling purposes. The Bushland Reference ET Calculator was developed by the USDA-ARS Conservation and Production Research Laboratory at Bushland, Texas for calculating hourly and daily grass and alfalfa reference ET. The user-friendly interface for the calculator was developed using .NET programming. The calculator uses the ASCE Standardized Reference Evapotranspiration (ET) Equation for calculating both grass and alfalfa reference ET at hourly and daily time steps. Users have the option of using a single set or time series weather data to calculate reference ET. Daily reference ET can be calculated either by summing the hourly ET values for a given day or by using daily averages of the climatic data. Although the Bushland Reference ET Calculator was designed and developed for use mainly by producers and crop consultants to manage irrigation scheduling, it can also be used in educational training, research, and other practical applications. This paper demonstrates use of the Bushland Reference ET Calculator that is available from the USDA-ARS Conservation and Production Research Laboratory web site to interested users at no cost.

INTRODUCTION

In agriculture, evapotranspiration (ET) is a major consumptive use of irrigation water and precipitation. Reliable and accurate estimates of ET or crop water use, which includes water evaporation from land and water surfaces and transpiration by vegetation, are essential to optimize irrigation management. Water use by a

specific crop (ET_c) can be estimated by multiplying daily reference ET (ET_r) calculated using meteorological data including solar radiation (R_s), wind speed (U_2), air temperature (T_a), and relative humidity (RH), by an appropriate crop coefficient (K_c) derived from lysimeter studies (Marek et al., 2010), i.e. $ET_c = K_c * ET_r$ under the assumption that weather conditions for the reference crop surface are similar to those in the surrounding region. The ASCE-EWRI standardized reference ET equation (Allen et al., 2005) is one of the widely adopted methods for estimating ET_r in the United States. The standardized reference ET (ET_{sz}) equation is given as:

$$ET_{sz} = \frac{0.408 \Delta (R_n - G) + \gamma \frac{C_n}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma (1 + C_d u_2)}$$

where: ET_{sz} is the standardized reference ET for grass (ET_G) or alfalfa (ET_A) crop surfaces (mm d^{-1} for daily or mm h^{-1} for hourly time steps), R_n is the net radiation at the crop surface ($\text{MJ m}^{-2}\text{d}^{-1}$ for daily or $\text{MJ m}^{-2}\text{h}^{-1}$ for hourly time steps), G is the soil heat flux density at the soil surface ($\text{MJ m}^{-2}\text{d}^{-1}$ for daily or $\text{MJ m}^{-2}\text{h}^{-1}$ for hourly time steps), T is the mean daily or hourly air temperature at 2-m height ($^{\circ}\text{C}$), u_2 is the mean daily or hourly wind speed at 2-m height (m s^{-1}), e_s is the saturation vapor pressure at 2-m height (kPa), calculated for daily time step as the average of saturation vapor pressure at maximum and minimum air temperatures, e_a is the mean actual vapor pressure at 2-m height (kPa), Δ is the slope of the saturation vapor pressure-temperature curve ($\text{kPa } ^{\circ}\text{C}^{-1}$), γ is the psychrometric constant ($\text{kPa } ^{\circ}\text{C}^{-1}$), C_n is the numerator constant that changes with reference type and calculation time step ($\text{K mm s}^3 \text{Mg}^{-1} \text{d}^{-1}$ or $\text{K mm s}^3 \text{Mg}^{-1} \text{h}^{-1}$) and C_d is the denominator constant that changes with reference type and calculation time step (s m^{-1}), and units for the 0.408 coefficient are $\text{m}^2 \text{mm MJ}^{-1}$. The ASCE-EWRI standardized reference ET equation is very complex for producers and crop consultants to use. Recently, the ASCE-EWRI ET Task Committee identified a need for a user-friendly ET calculator targeting advanced producers and crop consultants.

Real time ET_r and/or ET_c estimates are available for growers for irrigation scheduling in a very few parts of the world such as California Irrigation Management Information System (CIMIS) and Texas High Plains ET (TXHPET) Network due to resource constraints. This is expected to worsen in the near-future. For example, the TXHPET provided ET_r and ET_c on a daily basis to producers and crop consultants at no cost. However, this service was recently terminated due to the lack of funding support. Therefore, there is an immediate need for a simple reference ET calculator that can be used by crop consultants and producers to estimate accurate reference ET and representative crop water use with locally available weather data for irrigation scheduling purposes, thereby implementing the latest water conservation and best management practices. Therefore, the objective of this study was to develop a simple reference ET calculator to assist producers and agronomic consultants.

METHODOLOGY

The reference ET calculator designed and developed in this study is named the “Bushland Reference ET Calculator (BET).” The BET uses the ASCE-EWRI standardized reference ET equation (Allen et al., 2005) for calculating both grass and alfalfa ET_r at hourly and daily time steps. Since clear-sky solar radiation needed for implementing the standardized equation, BET uses a more complex equation provided in the Appendix D of the ASCE-EWRI ET manual.

BET was developed using the Visual Basic .NET programming language for calculating both ET_G and ET_A . It was designed to provide users with an option of using a single set or time series weather data to calculate ET. Daily ET_G and ET_A can be calculated either by summing the hourly ET values for a given day or by using daily averages of the climatic data. Therefore, it consists of two static and four user-friendly interactive pages. Two static pages were used to provide BET version, citation contact information for technical support and USDA disclaimer. Figure 1 illustrates the cover page of the BET.

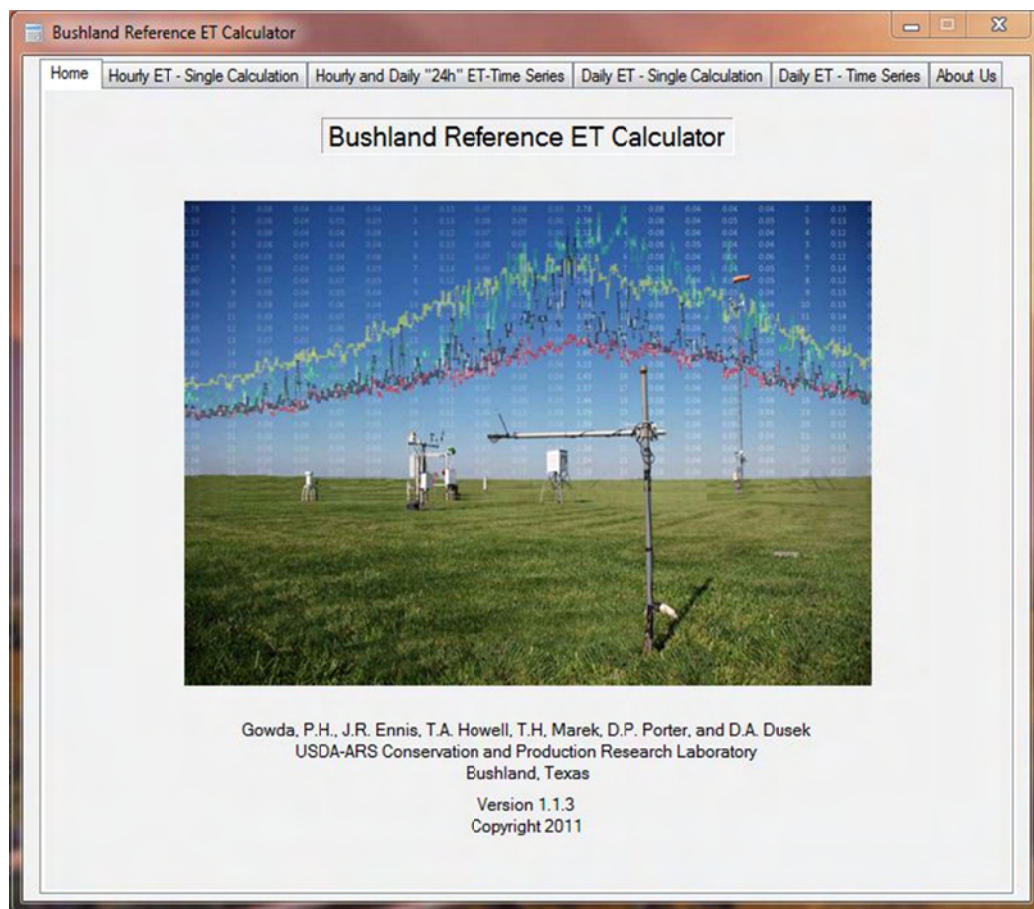


Figure 1. Front page of the Bushland Reference ET Calculator (BET).

Interactive pages were designed for novice computer users to perform each of the following four tasks: (1) Hourly ET – Single Calculation, (2) Hourly and Daily ET - Time Series, (3) Daily ET – Single Calculation, and (4) Daily ET – Time Series. Efforts were made to design the interactive pages for intuitively entering the data input. Further, to ensure correct weather data is entered and submitted for calculating ET, validation controls were written into the code. When the program is executed with invalid, incomplete or missing data for performing a calculation, validation code resets the program and draws the user's attention by showing an exclamation (!) sign in red color on the right side of the input box with erroneous data. Also, codes were written to include and show boundary values for each of the input parameters when the mouse is moved over text boxes assigned for entering the data. An error message will be displayed when a calculation is performed with an entered input value for a parameter that is outside the set boundary values.

Figure 2 illustrates an interactive page for calculating a single hourly ET (mm) value from hourly weather data. This page prompts the user to provide the location of the weather station (latitude and longitude); year, day (Julian day), and time of the day; air and dew temperature ($^{\circ}\text{C}$); relative humidity (%); solar radiation (W m^{-2}); wind speed (m s^{-1}); barometric pressure (kPa); and elevation (m).

Figure 2. An interactive page in the Bushland Reference ET Calculator (BET) for calculating single hourly ET value.

Figure 3. An interactive page in the Bushland Reference ET Calculator (BET) for calculating single daily ET value.

Figure 3 illustrates the interactive page for calculating a single value of daily ET (mm) from daily average weather data. This page requires the user to provide the location of weather station (latitude and longitude); barometric pressure (kPa), and elevation (m) in addition to year and day of the year (Julian day); maximum and minimum air temperature ($^{\circ}\text{C}$); average dew temperature ($^{\circ}\text{C}$); average relative humidity (%); average solar radiation ($\text{MJ m}^{-2} \text{d}^{-1}$) and average wind speed (m s^{-1}). The user should note that the unit used for average solar radiation is different from that used in the calculation of hourly ET value.

Figure 4 illustrates an interactive page for calculating hourly and daily ET using hourly time series weather data. In this interactive page, the user provides time series hourly weather data in a text file. Sample input and output files are provided for assisting the user with preparation of to prepare weather data in a format required by the BET to calculate time series hourly and daily ET. The user can view the input and output sample files by clicking on the Sample Input Format and Sample Output Format buttons provided on the page (Fig. 4). BET calculates daily ET values when the input file contains hourly weather data for one or more days by summing hourly ET values for both grass and alfalfa reference crops. Input parameters required for calculating times series hourly and daily ET are the same as those required for calculating a single hourly ET value (Fig. 2).

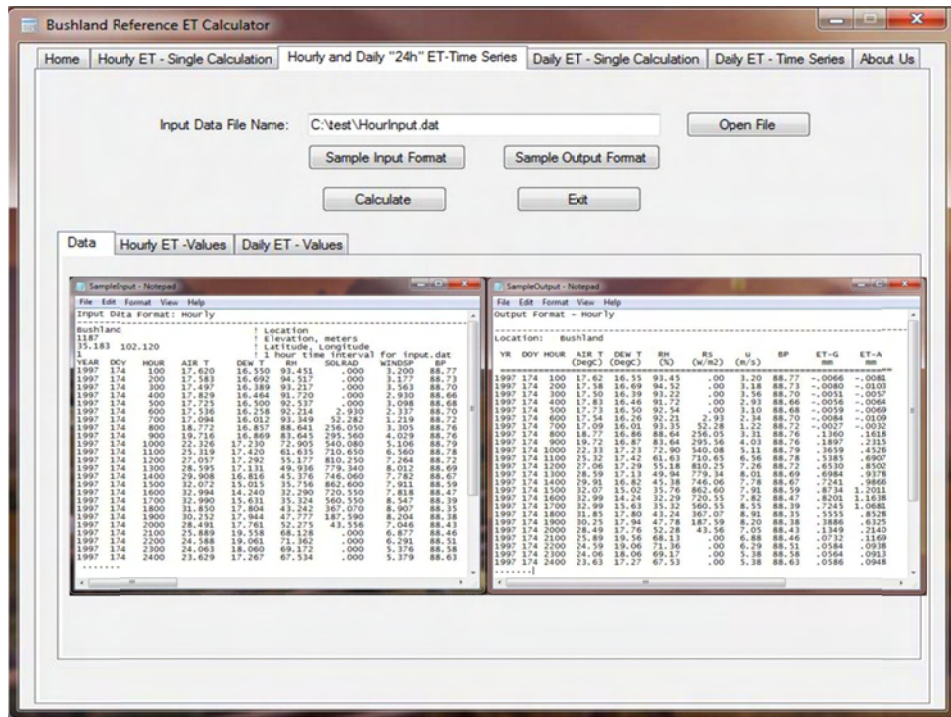


Figure 4. An interactive page in the Bushland Reference ET Calculator (BET) for calculating hourly and summed daily ET using hourly time series weather data.

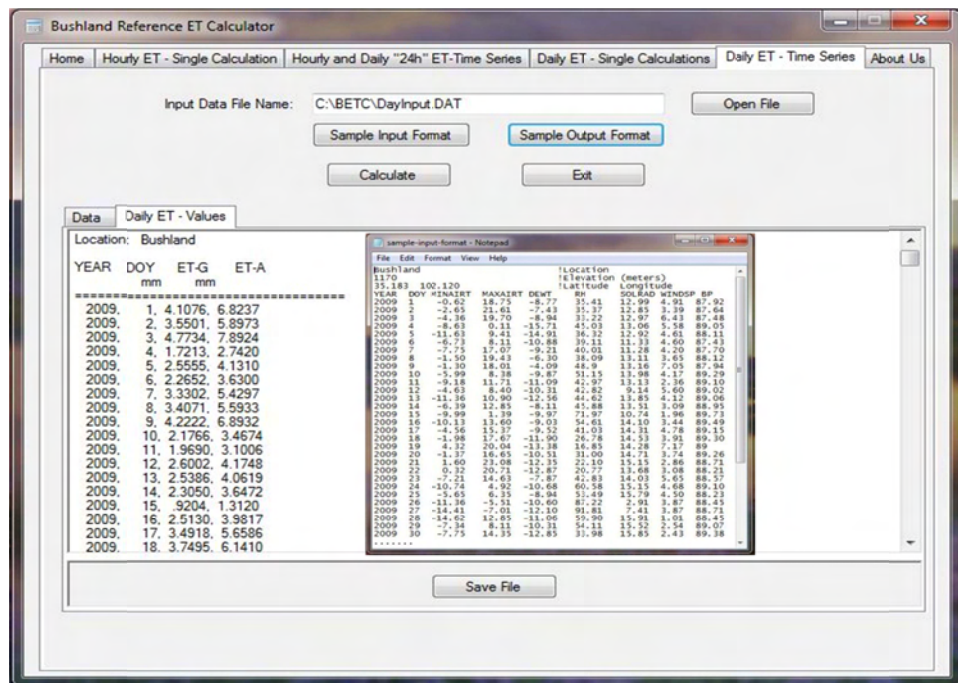


Figure 5. An interactive page in the Bushland Reference ET Calculator (BET) for calculating daily ET using daily time series weather data.

Figure 5 illustrates an interactive page for calculating daily ET using daily time series weather data. Input parameters required for calculating time series daily ET are the same as those required for calculating a single daily ET value (Fig. 3). This interactive page closely mimics the design used in the calculation of hourly and daily time series ET.

SUMMARY AND DISCUSSION



Figure 6. Preliminary design of the Bushland Reference ET Calculator for the smart phone platforms.

Reliable and accurate estimates of crop water use or crop ET are required for improving water use efficiency in irrigated agriculture. Crop ET is calculated by multiplying the grass or alfalfa reference ET by the appropriate crop coefficient. This paper demonstrates use of the Bushland Reference ET Calculator (BET) developed and distributed through the USDA-ARS web site (<http://www.cprl.ars.usda.gov/swmru-software-bretc.php>) to interested users at no cost. Although the Bushland Reference ET Calculator (BET) was designed and developed for use mainly by producers and crop consultants to manage irrigation scheduling, it can also be used in educational training, research, and other practical applications. At present, BET is made available for Windows 7, Windows XP and Windows Vista versions. Efforts are underway to develop BET for smart phone platforms such as iPhone and Android (Fig. 6) and enhance capabilities of Windows versions of the BET to include graphic visualization and statistical tools for quality assurance / quality control purposes.

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