

CONVERTING REFERENCE EVAPOTRANSPIRATION INTO TURF WATER USE

Paul Brown and Dave Kopec

Introduction

Accurate estimates of turf water use are required to effectively manage a turf irrigation system. In Volume I of this series entitled "Basics of Evaporation and Evapotranspiration (ET)," we indicated that actual turf water use (ET_t) is rarely measured in the real world. Instead, we use meteorological data and a mathematical model known as the Penman-Monteith Equation to estimate reference evapotranspiration (ET_o) — the ET from a tall, cool-season grass that is supplied with adequate water. In the lower elevations of Arizona the ET_o value would seem of limited value since we rarely grow turf that is equivalent to the reference surface. However, we get around this problem by adjusting the ET_o value to account for differences in turf type, quality and stage of development. This document describes the procedures used to adjust ET_o for use on managed turf surfaces in Arizona.

Estimating Turf ET From ET_o

An adjustment is necessary to convert ET_o values to estimates of turf ET (ET_t; Fig. 1). The adjustment process is actually quite easy and consists of multiplying ET_o by an adjustment factor known as a crop coefficient (K_c):

$$ET_t = K_c \times ET_o$$

The procedure can be completed in seconds with spreadsheet software or a hand calculator provided you have access to an ET_o value and an appropriate K_c value for your turfgrass.

Reference ET values can be obtained from a private, on-site weather station or a public weather network such as the Arizona Meteorological Network (AZMET) that provides daily ET_o

values for 28 Arizona locations via the Internet at <http://ag.arizona.edu/azmet>. Given that information on ET_o is readily available, the problem of estimating ET_t becomes one of selecting an appropriate K_c value for your turf.

Crop Coefficients (K_c)

A variety of factors impact the K_c value for turf. Among the most important are type of turf (cool vs. warm season grasses); turf quality; stage of turf development; and to a lesser degree, turf height. As a general rule, K_cs are higher for cool season grasses than for warm season grasses, and increase with turf quality and turf height. Stage of turf development refers mainly to time of the season. For example, water use of bermudagrass is lower (relative to ET_o) during the spring and fall transition seasons than during midseason. Specific details on K_c selection are provided below.

Crop Coefficients For Warm Season Grasses

The appropriate mid-season K_c for bermudagrass turf maintained at a mowing height of 5/8 – 1" (1.6–2.5 cm) rests somewhere in the range of 0.6–0.8 (Fig. 2 and Tables 1 & 2). The low end of the range would be appropriate for areas where traffic is low, rapid regrowth is not required and fertilization levels are low. The upper end of the K_c range would be appropriate for areas of high quality turf where fertilization regimes are high and rapid regrowth is required (e.g. high profile sports turf). Research studies indicate the K_c range recommended in Fig. 2 should be applicable to other warm season grasses, including Zoysia and St. Augustine grass (Kneebone and Pepper, 1982).

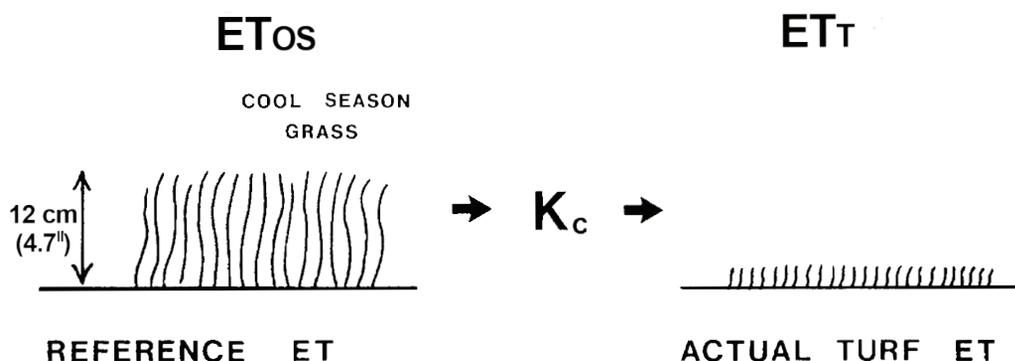


Figure 1. Reference Evapotranspiration (ET_o) must be adjusted with a crop coefficient (K_c) to estimate turf ET (ET_t).

Table 1. Recommended Kc values for low desert turf systems in Arizona

Type of Turf	Turf Quality			
	Maximum ¹	Good ²	Acceptable ³	Minimum ⁴
Bermudagrass	0.80	0.70	0.60*	0.50*
Overseeded Ryegrass	0.83	0.75	0.68*	0.60*

¹: Highest quality golf and sports turf irrigated daily

²: High quality golf and sports turf irrigated every 2-3 days

³: Acceptable: parks & schools lawns where inputs and traffic are limited

⁴: Stressed turf: marginal turf quality

* Kcs at these values and below produce deficit irrigation regimes which over time could lead to salinity and/or sodium problems in turf soils

Table 2. Monthly crop coefficients (Kcs) appropriate for use with standardized reference evapotranspiration values (ETos) generated by the Arizona Meteorological Network (AZMET). The turf surface from October through May was overseeded 'Froghair' intermediate ryegrass. 'Tifway' bermudagrass served as the turf surface from June through September. Mean seasonal Kcs are provided in the columns labeled Winter and Summer. Turf was irrigated daily except on days with significant rainfall, and a maintenance regime was employed to maintain fairway quality turf.

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUMMER	WINTER
Kc ¹	0.78	0.79	0.86	0.89	0.85	0.78	0.78	0.82	0.83	0.83	0.83	0.80	0.80	0.83

¹: Reduce the Kcs by 0.1 if irrigating less frequently (e.g. every 3 days). Reduce Kcs by 0.1-0.2 for thin turf stands and areas receiving less intense management.

Recent Arizona-based research (Brown et al., 2001; Banuelos, et al., 2011) indicates the Kc of high quality bermudagrass varies with turf growth rate. As a result, peak Kc values develop during late summer when warm nights support rapid turf growth. Monthly adjustments in Kcs may therefore be appropriate for some high maintenance turf systems. Monthly as well as seasonal bermudagrass Kcs derived from this research are provided in Tables 1 & 2.

Water use of warm season grasses decreases during the spring and fall transition seasons when growth slows due to suboptimal temperatures. Crop coefficients run about 0.2 lower for warm season grasses during these transition seasons. For example, if you use a Kc of 0.7 for mid-season turf, a Kc value of 0.5 should be adequate during transition periods.

Once warm season grasses attain full dormancy in winter, grass water use essentially declines to zero. Evapotranspiration from dormant surfaces is therefore comprised of soil evaporation. There is little quantitative research on the evaporation rates from dormant warm season turf surfaces; however, factors such as thatch density, surface soil texture and irrigation frequency will certainly impact the evaporation rate. Research completed by Kneebone and Pepper (1982) and more recent lysimeter studies at the University of Arizona Karsten Turf Research Facility suggests Kcs for dormant warm season grasses run close to 0.5 when surface soil moisture remains relatively high (i.e. irrigated regularly). Lower Kcs approaching 0.2 should suffice with infrequent irrigation and/or low surface soil moisture

Crop Coefficients For Cool Season Grasses

Cool season (C-3) grasses typically use a higher fraction of ETos than warm season grasses when both are grown under similar conditions. While cool season grasses are rarely grown in the low deserts during the summer months, there have been a few Arizona studies that have examined the water requirements of tall fescue grown during the summer. Appropriate Kcs for tall fescue maintained at 1.5" (4 cm) during the summer months range from 0.80-0.95 (Albrecht, 1993; Brown, 2011) and support the general rule that cool season grasses use significantly more water than warm season grasses during the summer months (Fig. 3).

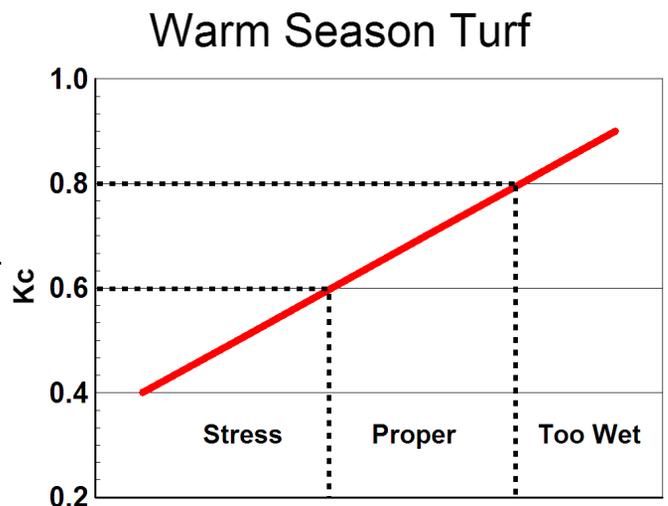


Figure 2. The appropriate Kc range for warm season grass is 0.6-0.8. Use of a Kc below 0.6 will likely produce water stress; use of Kcs above 0.8 will likely produce wet and/or muddy conditions.

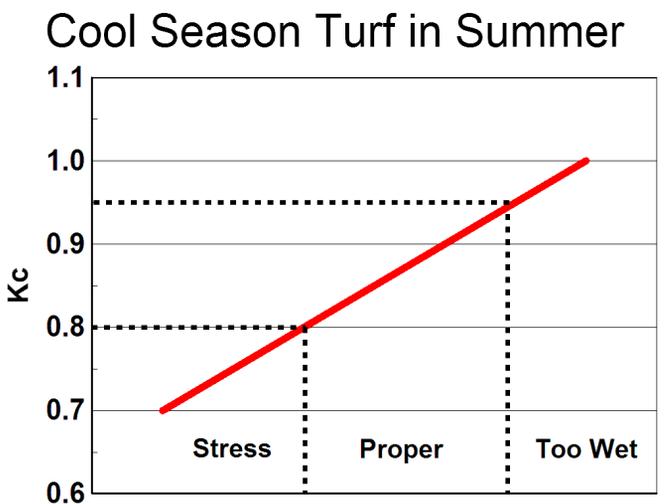


Figure 3. The Kc range for cool season grasses (e.g. fescue) during summer is 0.80-0.95. Use higher Kcs for high quality turf and turfs with less heat tolerance. Lower Kcs suffice for lower quality turf or for more heat tolerant varieties.

Overseeded Ryegrass

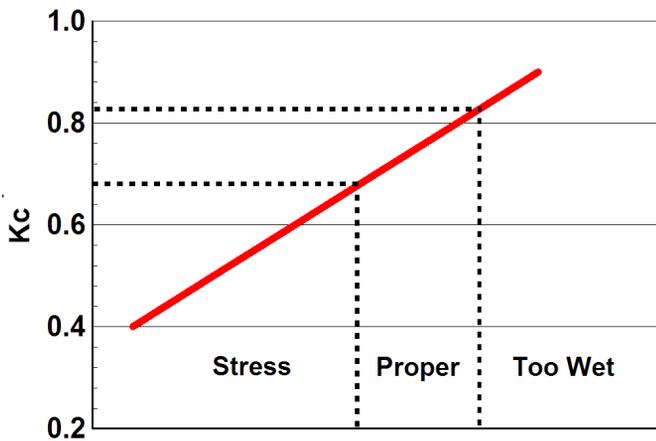


Figure 4. The Kc range for overseeded perennial rye is 0.68-0.83. Higher Kcs are required for high quality turf and warm weather. Lower Kcs suffice for cooler weather and lower quality turf.

Cool season grasses (annual and perennial ryegrasses) are commonly overseeded into bermudagrass during the fall to maintain a green, winter turf surface. Appropriate Kcs for overseeded ryegrasses maintained at a height of 7/8–1.25" (1.7– 3.0 cm) range from 0.68-0.83 (Fig. 4; Table 1). Lower Kcs are appropriate for less dense stands and during colder periods when frosts are common. Higher Kcs are appropriate for the warmer months and where high rates of fertilization generate dense, fast growing stands of turfgrass.

Adjusting Kcs For Turf Height

Turf height is another factor that can impact Kc value. Taller turfs use a little more water because they interact more effectively with the wind and absorb more solar radiation (a result of increased leaf surface). However, definitive research results showing the impact of turf height on water use are not available for Arizona. In lieu of such research reports, we recommend caution when adjusting Kcs for turf height and suggest increasing the Kc by 0.05-0.1 if the mowing height is doubled relative to the heights listed above. It is important to remember that ETos is an estimate of the water use of a tall (4.7") cool season grass. The maximum Kc for most managed turf systems should therefore run below 1.0.

Computing ETt – Some Examples

The computation of ETt can be divided into three simple steps: 1) obtain a local ETos value, 2) select an appropriate Kc value and 3) multiply the ETos by the Kc to obtain ETt. Please note that AZMET generates two reference ET values each day. Use the one identified as STD. REF. EVAPOTRANSPIRATION for estimating turf ET. The following examples clarify this procedure.

Example 1. Determine daily ETt for acceptable bermudagrass turf in Phoenix.

- Step 1. Obtain the ETos value from AZMET. From Fig. 5, the value is 0.3".
- Step 2. Select a Kc value. An appropriate Kc would be 0.60 (Table 1).

Step 3. Multiply the ETos value by Kc to obtain ETt.

$$\begin{aligned} ETt &= Kc \times ETos \\ &= 0.60 \times 0.3'' \\ &= 0.18'' \end{aligned}$$

Example 2. Determine daily ETt for high quality bermudagrass turf in Phoenix.

- Step 1. Obtain the ETos value from AZMET. Suppose ETos is again equal to 0.3" (Fig. 5).
- Step 2. Select a Kc value. An appropriate Kc value would be 0.80 (Table 1).
- Step 3. Multiply the ETos value by Kc to obtain ETt.

$$\begin{aligned} ETt &= Kc \times ETos \\ &= 0.80 \times 0.3'' \\ &= 0.24'' \end{aligned}$$

Example 3. Determine daily ETt for acceptable quality overseeded ryegrass in Phoenix.

- Step 1. Obtain the daily ETos value from AZMET. From Fig. 6, the value is 0.14".
- Step 2. Select a Kc value. An appropriate Kc would be 0.68 (Table 1).
- Step 3. Multiply the ETos value by Kc to obtain ETt.

$$\begin{aligned} ETt &= Kc \times ETos \\ &= 0.68 \times 0.14'' \\ &= 0.095 \text{ or } \sim 0.10'' \end{aligned}$$

Example 4. Determine daily ETt rate for high quality overseeded ryegrass in Phoenix.

- Step 1. Obtain the ETos total from AZMET. From Fig. 6, the value is 0.14".
- Step 2. Select a Kc value. An appropriate Kc would be 0.83 (Table 1).
- Step 3. Multiply the ETos value by Kc to obtain the daily ETt.

$$\begin{aligned} ETt &= Kc \times ETos \\ &= 0.83 \times 0.14'' \\ &= 0.116'' \text{ or } \sim 0.12'' \end{aligned}$$

Turf ET was computed on a daily basis in the previous examples. It is important to note that ETt can be computed for periods in excess of one day by simply summing the ETos for the period in question, then multiplying the resulting sum by an appropriate Kc.

The examples above clearly show the process of computing ETt is simple. Selection of an appropriate Kc value represents the major challenge when computing estimates of ETt, and turf managers will need to experiment a little to determine the proper Kc for their turf. For managers new to the concept of ET-based irrigation management we recommend starting with

a Kc value 0.70 for both warm and cool season grasses. Adjust the Kc upward or downward based on turf performance. More experienced managers may wish to fine tune their irrigation management by adjusting Kcs on a seasonal or monthly basis. Consult Tables 1 and 2 for recommended monthly and seasonal Kcs. Reduce the monthly Kcs in Table 2 by 0.1-0.2 for thin turf stands and areas receiving less intense management regimes (e.g. lower fertilizer rates).

Precautions When Using Non-AZMET Weather Stations

A number of companies now sell weather stations and software that provide turf managers with reference ET values. Individuals that use these stations should understand that the Kcs presented above may need some adjustment when used with non-AZMET stations. Crop coefficients should be developed for (or matched to) a specific Penman or Penman-Monteith Equation since each version of the equation produces a slightly different value for reference ET (under identical weather conditions). The Kcs presented in this document were developed for use with ETos as computed by AZMET which uses the new standardized computation procedure (Brown, 2005). Most weather stations manufactured in the past few years utilize the same ETos computation procedures as AZMET. The Kcs provided in this document should provide acceptable results when used with ETos from these stations.

Turf managers with access to reference ET computed by older Rainbird, Toro, and Motorola stations/software will likely need to adjust the Kc values presented here. Adjustment factors for

reference ET values computed by weather stations from other companies are not available at this time. Turf Managers are encouraged to upgrade their weather stations and/or irrigation management software to provide reference ET computed using this new standardized procedure so they can more effectively utilize future research on irrigation scheduling and management.

References

- Albrecht, W. 1993. Turfgrass Water Use in Northern Arizona. Extension Bulletin N. 93-03. The Arboretum at Flagstaff.
- Banuelos, J. J.L. Walworth, P.W. Brown and D.M. Kopec. 2011. Deficit Irrigation of Seashore Paspalum and Bermudagrass for Golf Course Turf. *Agron. J.* 103(6): 1567-1577.
- Brown, P.W. 2005. Standardized Reference Evapotranspiration: A New Procedure for Estimating Reference Evapotranspiration in Arizona. Ext. Rpt.1324. College of Agriculture & Life Sci., Univ. of Arizona, Tucson, AZ.
- Brown, P. 2011. Turfgrass Consumptive Use: Flagstaff, Arizona. Ext. Rpt. AZ1353. College of Agriculture & Life Sci., Univ. of Arizona, Tucson, AZ.
- Brown, P.W., C.F. Mancino, T.L. Thompson, M.H. Young, P.J. Wierenga and D.M. Kopec. 2001. Penman Monteith Crop Coefficients for Use with Desert Turf Systems. *Crop Sci.* 41: 1197-1206.
- Kneebone, W.R. and I.L. Pepper. 1982. Consumptive use by sub-irrigated turfgrasses under desert conditions. *Agron. J.* 74:419-423.

Figure 5. AZMET daily weather summary for Phoenix on July 3, 2013 showing ETos equal to 0.30".

AZMET Daily Weather Data: PHOENIX GREENWAY: Jul 3 2013						
	MAX.	MIN.	MEAN	TOTAL	UNITS	
TEMPERATURE	106.9	78.3	95.2		DegF	
RELATIVE HUMIDITY	51.3	13.4	25.1		%	
DEWPOINT			52.0		DegF	
ACTUAL VAPOR PRESS.			1.3		KPas	
VAPOR PRESS. DEF.			4.5		KPas	
SOIL TEMP. 4 in	94.1	87.8	91.4		DegF	
SOIL TEMP. 20 in	84.9	84.2	84.7		DegF	
WIND SPEED	17.9		4.3		MPH	
WIND VECTOR MAG.			1.8		MPH	
WIND VECTOR DIR.			147		Degrees	
SOLAR RADIATION				585.8	Langleys	
PRECIPITATION				0.00	Inches	
AZMET REF. EVAPOTRANSPIRATION				0.31	Inches	
STD. REF. EVAPOTRANSPIRATION				0.30	Inches	

Figure 6. AZMET daily weather summary for Phoenix on February 19, 2013 showing ETos equal to 0.14⁹⁹.

AZMET Daily Weather Data: PHOENIX GREENWAY: Feb 19 2013

	MAX.	MIN.	MEAN	TOTAL	UNITS
TEMPERATURE	69.6	43.9	57.6		DegF
RELATIVE HUMIDITY	59.8	12.1	27.8		%
DEWPOINT			22.3		DegF
ACTUAL VAPOR PRESS.			0.4		KPas
VAPOR PRESS. DEF.			1.3		KPas
SOIL TEMP. 4 in	62.2	52.3	57.0		DegF
SOIL TEMP. 20 in	56.3	55.9	56.1		DegF
WIND SPEED	15.2		4.5		MPH
WIND VECTOR MAG.			2.5		MPH
WIND VECTOR DIR.			176		Degrees
SOLAR RADIATION				426.9	Langleys
PRECIPITATION				0.00	Inches
AZMET REF. EVAPOTRANSPIRATION				0.17	Inches
STD. REF. EVAPOTRANSPIRATION				0.14	Inches



**THE UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE AND LIFE SCIENCES
TUCSON, ARIZONA 85721**

PAUL BROWN
Biometeorology Specialist

DAVE KOPEC
TURF/PASTURE GRASS SPECIALIST

CONTACT:
PAUL BROWN
pbrown@cals.arizona.edu

This information has been reviewed by University faculty.
cals.arizona.edu/water/az1195.pdf

Originally published: 2000

Other titles from Arizona Cooperative Extension can be found at:
cals.arizona.edu/pubs

Any products, services or organizations that are mentioned, shown or indirectly implied in this publication do not imply endorsement by The University of Arizona.

Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Jeffrey C. Silvertooth, Associate Dean & Director, Extension & Economic Development, College of Agriculture Life Sciences, The University of Arizona.
The University of Arizona is an equal opportunity, affirmative action institution. The University does not discriminate on the basis of race, color, religion, sex, national origin, age, disability, veteran status, or sexual orientation in its programs and activities.