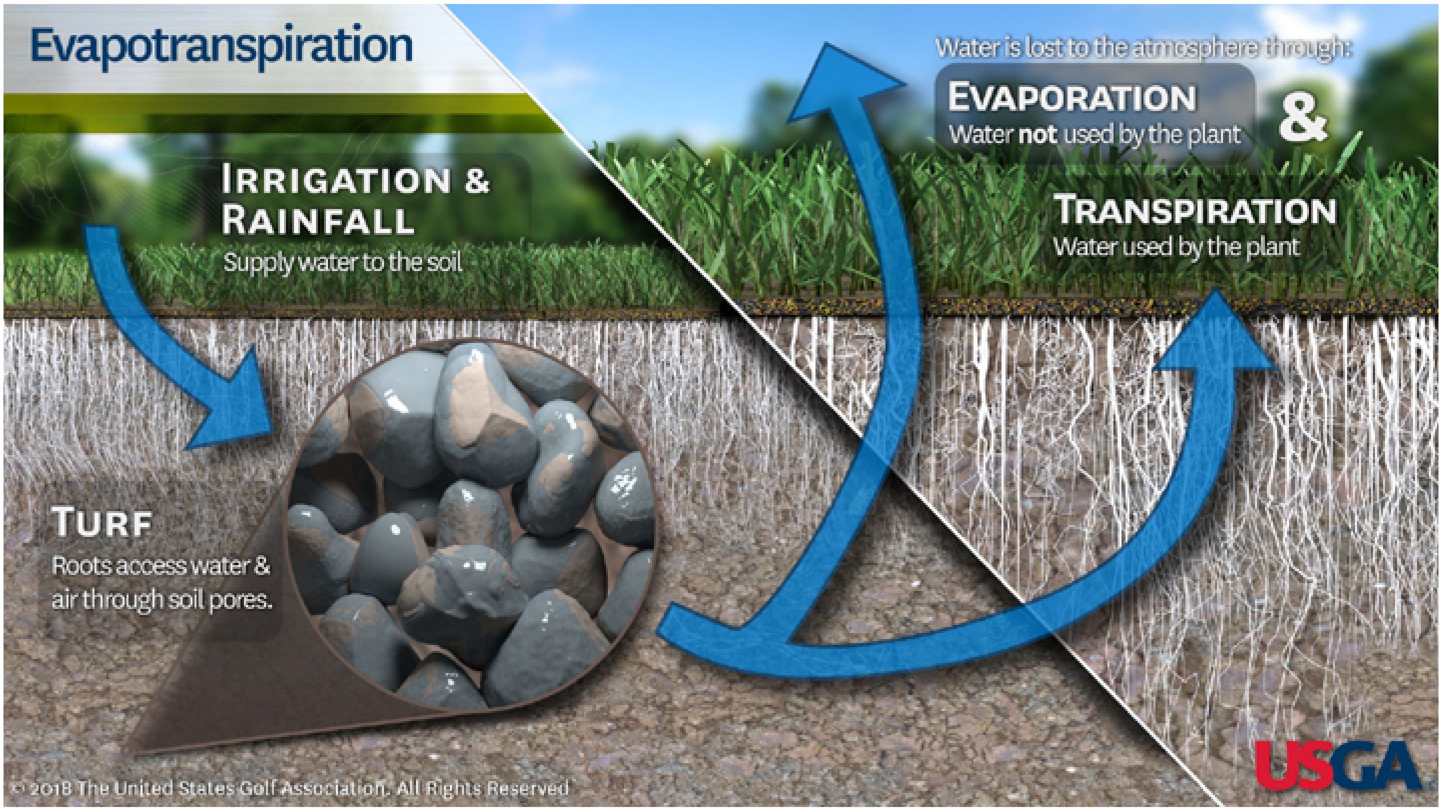
ET-Based Irrigation Scheduling

Using weather station data and crop coefficients to determine the water use rate of turf takes some of the guesswork out of irrigation programming decisions and leads to more efficient water applications.

BY PAUL JACOBS AND PAT GROSS



The keys to effective irrigation are applying water efficiently and in the proper amount. The obvious question is, what is the proper amount? One of the most important decisions a turf manager must make every day is how much water to apply. This decision has a significant impact on turf health and playability of the golf course. Additionally, the environmental concerns surrounding water use on golf courses elevate the importance of implementing and documenting efficient irrigation practices. So, how do you know how much water your golf course needs?

A variety of methods are used to determine how much water to apply to a golf course. Some superintendents rely on visual observations of turf. Others use soil probes to feel how much moisture is present. Still other methods depend on experience and gut feelings. Each of these methods is subjective and can lead to water waste. Today, many superintendents prefer to base daily irrigation decisions on weather data used to calculate evapotranspiration (ET).

Evapotranspiration values represent the amount of water lost from the soil due to evaporation in addition to the water used by plants under specific weather conditions. Evapotranspiration is typically calculated daily, and superintendents can use ET values to apply irrigation to replace a portion of the water lost. Using ET to guide irrigation decisions allows superintendents to take some of the guesswork out of the irrigation programming process by basing their decisions on data, research, and some simple math.

UNDERSTANDING EVAPOTRANSPIRATION

Evapotranspiration is the term that describes the total loss of water from evaporation and transpiration. Evaporation is the loss of water from the soil and transpiration is the amount of water used by plants for growth and other metabolic processes. Evapotranspiration is typically expressed in inches or millimeters of water per day.

Several methods have been used over the years to calculate and measure ET, including devices such as atmometers, evaporative pans, and lysimeters. Today, it is more common to use empirical mathematical models based on climate data. Evapotranspiration is a function of four different weather factors: solar radiation, wind speed, humidity, and temperature. The

Weather stations collect meteorological data used to calculate reference ET, a number that can be used to accurately estimate turf water use.

ET calculation is always made for the same reference crop — i.e., a well-watered cool-season grass maintained at 3 to 6 inches — is held constant so that any changes in ET are a result of weather factors (Brown and Kopec 2014). These ET calculations yield a number known as reference ET (ET_o).

OBTAINING ET INFORMATION TO DETERMINE TURF WATER REQUIREMENTS

Several sources can be used to obtain reference ET, including on-site weather stations, state weather station networks, and the National Weather Service. On-site weather stations, which have become commonplace at many golf courses, have the potential to provide more accurate information than off-site weather stations, which could be miles away. Weather stations at golf courses are typically linked to the computer software that controls irrigation schedules.

Some states have a network of weather stations that offer reference ET data free of charge online — e.g., the California Irrigation Management Information System and the Arizona Meteorological Network. Another free source of ET information is the National Weather Service at www.digital.weather.gov, which provides forecast reference ET for up to seven days based on weather patterns. Looking at forecast reference ET can provide a long-term estimate of water requirements and help better plan irrigation applications. It is important to note that different weather station manufacturers and irrigation control software compute reference ET differently, and the differences can be significant (Brown 1999). Using one source of reference ET data is recommended so that the methodology is consistent and irrigation programing decisions are more precise.

The actual turf irrigation requirement is known as the turf ET (ET_t). Two variables are used to calculate this number — the reference ET and a crop coefficient (K_c). Turf ET is calculated as follows:

$$ET_t = ET_o \times K_c$$

- ET_t — Turf ET is an accurate estimate for the water requirement of a specific turf species under particular conditions.

- ET_O — Reference ET is a baseline value obtained from weather station data. It represents the combined amount of water used by a reference crop and the amount of water lost from the soil through evaporation. The value is calculated based on climatic data, including temperature, humidity, wind speed, and solar radiation.
- K_C — The crop coefficient is an adjustment factor. It represents a percentage of the reference ET value. Research has shown that turf requires less water than what is calculated by reference ET; therefore, only a percentage of reference ET needs to be applied as irrigation to sustain healthy growth (Kneebone et al., 1992). Cool-season grasses generally have a greater water requirement than warm-season grasses and typically require 80 percent or more of reference ET. Warm-season grasses typically require 60 to 80 percent of reference ET.

Factors such as turf species, height of cut, turf quality, and stage of development all influence water requirements and crop coefficient values. As mowing height increases, crop coefficient values also increase (Brown and Kopec, 2014). Additionally, turf stands with high nitrogen fertility rates will typically have greater crop coefficient values and require more water (McGroary et al., 2011). Turf species, and even cultivars within a given species, exhibit a wide variation in crop coefficient values. Optimizing irrigation applications depends on selecting correct crop coefficients that are matched to the reference ET calculation procedure (Brown, 1999).

PUTTING ET TO WORK

When irrigating a golf course, each superintendent does things a little differently. Some rely heavily on site-specific knowledge and their feel for conditions, while others have been using ET-based calculations for years. Certainly, local knowledge and an understanding of how a golf course responds to different irrigation regimes is required even when using ET. However, relying strictly on feel can be problematic because it relies upon using turf appearance as a gauge of water use efficiency. This approach may be effective at ensuring turf does not suffer from a water shortage, but how do you know if too much is being applied? To optimize water use efficiency, ET should be used as part of the decision-making process. The following steps will help walk you through using ET to make irrigation decisions:

Step 1: Gather reference ET information. Obtain reference ET information from an on-site weather station, the National Weather Service, or a state weather station network. Some superintendents prefer to irrigate daily, while others like to accumulate ET values for several days and schedule heavier irrigation cycles at less frequent intervals. Such decisions are site-specific and must take into account soil factors, turf species, and operational issues at the golf course.

Step 2: Determine the crop coefficient. Crop coefficient values change throughout the year due to temperature, day length, and turf growth cycles. Comparing crop coefficient values between different

Cultivars of the same turf species can have very different crop coefficients.

TABLE 1
Example of monthly crop coefficients for cool-season and warm-season turf in Riverside, California (Adapted from Meyer et al., 1985)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Cool-season grasses	.61	.64	.75	1.04	.95	.88	.94	.86	.74	.75	.69	.60
Warm-season grasses	.55	.54	.76	.72	.79	.68	.71	.71	.62	.54	.58	.55

climatic regions is difficult because crop coefficient values are lower in arid environments than in wet environments (Carrow, 1995). For better precision, it is ideal to obtain monthly crop coefficient values from a local university extension specialist. An example of monthly crop coefficient values for warm- and cool-season grasses is presented in Table 1. Unfortunately, such information is not available in all parts of the country, which presents an opportunity for further research. In the absence of monthly crop coefficient values, using 0.8 (80 percent) for cool-season grasses and 0.6 to 0.7 (60 to 70 percent) for warm-season grasses as baselines and making adjustments based on seasonal growth rates is recommended.

Step 3: Calculate turf water use. To calculate turf water use, multiply reference ET by the crop coefficient. This gives us an accurate estimate of the water used by turf. The equation is:

$$ET_o \times K_c = ET_t$$

Example 1: Determine the daily turf water use for a perennial ryegrass fairway maintained to high standards of turf quality. Assume, hypothetically, that the perennial ryegrass reference ET for the day was reported to be 0.15 inch and the crop coefficient was determined to be 0.80:

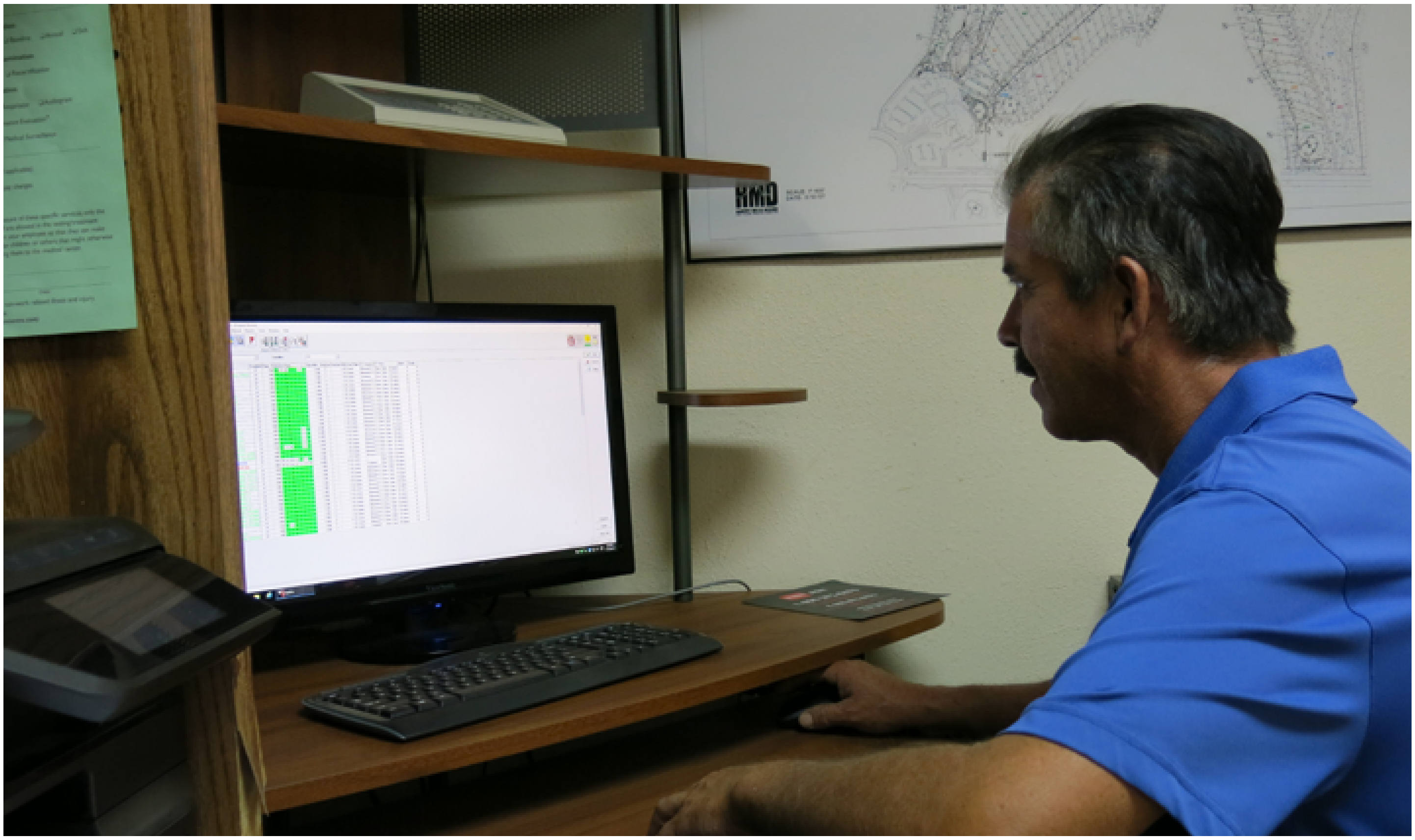
$$0.15 \text{ inch} \times 0.80 = 0.12 \text{ inch}$$

Example 2: Determine the daily turf water use for a bermudagrass fairway maintained to high standards of turf quality. Assume, hypothetically, that the bermudagrass reference ET for the day was reported to be 0.22 inch and the crop coefficient was determined to be 0.70:

$$0.22 \text{ inch} \times 0.70 = 0.154 \text{ inch}$$

Step 4: Adjust for uniformity and site conditions. Once turf water use is calculated, it can serve as a reasonable estimate of the amount of water that needs to be applied. However, irrigation system uniformity must be considered when determining how much water to apply. Also, keep in mind that salts can accumulate in the soil during prolonged periods of drought, especially under deficit irrigation. Both factors can increase the actual amount of water required. To accurately make

Crop coefficients change throughout the year as turf enters different stages of growth. During winter, dormant bermudagrass requires very little water while overseeded turf requires additional water.



Optimizing water use requires daily adjustments to an irrigation program. Using ET to guide irrigation decisions removes some subjectivity from the process.

adjustments, an irrigation system audit and chemical water tests should be performed. An irrigation system that is not uniform will use more water than a uniform system when trying to ensure that even the driest areas receive adequate irrigation.

A relatively low-cost way of determining the uniformity of an irrigation system is to conduct a catch-can test. To do so, place shoebox-sized containers on the ground about 10 feet apart between sprinklers. Run all the sprinklers that affect the test area for a minimum of three rotations. Then, measure the volume of water in each container. Finally, calculate the scheduling coefficient (SC) using the following formula:

$$SC = \frac{\text{average water volume}}{\text{volume from driest area}}$$

For example, if the average volume collected per container was 6 ounces and the container with the least amount of water contained 4 ounces, the scheduling coefficient would be 6/4 or 1.5. In this case, you would need to multiply the value for turf water use by 1.5 to ensure that the driest areas receive adequate irrigation.

This simple method of measuring irrigation uniformity can be performed with basic supplies and effectively shows how poorly some antiquated irrigation systems apply water. However, a scheduling coefficient typically is not used to determine actual irrigation requirements because if adjustments are made to adequately irrigate dry spots, then other areas will be overirrigated.

Moisture meters can also be used to identify inefficiencies in an irrigation system. Using moisture meters allows irrigation adjustments to be made based on soil moisture content instead of irrigation system uniformity or scheduling coefficients calculations. Regardless, additional scheduling adjustments will be necessary based on site conditions — e.g., south-facing slopes may require more water and shaded areas may remain wet longer than areas in full sun. Adjustments typically can be made by adjusting the run times of individual stations. For a more thorough evaluation of an irrigation system, conduct a complete irrigation system audit.

Step 5: Programming the irrigation system. When programming an irrigation system, it is important to realize the correlation between water quantity and run time. Often, run times are based on multiples of the time required for an irrigation head to make one full rotation. This makes sense, but understanding the quantity of water that is applied in a given amount of time is most important.

If an irrigation system runs for 10 minutes, it is essential to know how much water is being applied during those 10 minutes. Performing a catch-can test or an irrigation audit is a great way to determine how much water is applied in a given amount of time. However, factors such as nozzle selection and water pressure influence precipitation rate, so changes to an irrigation system should be noted and accounted for in the central controller.

Water management is one of the most influential factors affecting turf health and playability.

CONCLUSION

As the adage goes, you can't manage what you can't measure. When it comes to efficient irrigation management, ET is an objective measurement that helps determine how much water should be applied to turf on a given day. It incorporates daily weather data — including solar radiation, wind speed, humidity, and temperature — and utilizes a crop coefficient to fine-tune the water requirement for a particular site and turf species. While ET-based irrigation scheduling has been used for decades, there is still work to be done to determine accurate monthly crop coefficient values that match local climate conditions and expectations for quality for all parts of the country. Evapotranspiration-based irrigation scheduling does not remove all local knowledge and feel from the decision-making process. It utilizes meteorological data and simple calculations to create an accurate estimate of turf water use. Using ET to guide irrigation decisions ultimately results in healthier turf, less water waste, and better playing conditions.

REFERENCES

Brown, Paul, and Dave Kopec. "Converting Reference Evapotranspiration Into Turf Water Use." The University of Arizona Cooperative Extension, 2014.

Brown, Paul. "Confused About Weather Station ET? Maybe You Should Be." USGA Green Section Record, vol. 37, no. 1, 1999, pp. 5-7.

Carrow, Robert N. "Drought Resistance Aspects of Turfgrasses in the Southeast: Evapotranspiration and Crop Coefficients." Crop Science, vol. 35, no. 6, 1994, pp. 1685-1690.

Kneebone, W. R., et al. "Water Requirements and Irrigation." Turfgrass, Agronomy Monograph 32, edited by D.V. Waddington et al., American Society of Agronomy, 1992, pp. 441-472.

McGroary, P. C., et al. "Water Use of St. Augustine Grass and Bahiagrass Under Varying Nitrogen Rates." Agronomy Journal, vol. 103, no. 1, 2011, pp.100-106.

Meyer, J. L., et al. "Irrigation of Turfgrass Below Replacement of Evapotranspiration as a Means of Water Conservation: Determining Crop Coefficient of Turfgrasses." Proceedings of the International Turfgrass Research Conference, edited by F. Lemaire, July 1985, pp. 357-364.

PAUL JACOBS *is an agronomist in the Northeast Region, and* PAT GROSS *is the director of the West Region.*

USGA