Evapotranspiration and Precipitation in Kansas: Part I

Dale Bremer, Kansas State University

Published January 2003 in Turfnews, a Kansas Turfgrass Foundation Newsletter

Note: This is the first of a two-part series about evapotranspiration (hereafter referred to as ET) and precipitation in Kansas. The article in this issue discusses the fundamentals of ET and the water budget of a land's surface. In the next issue, we will examine precipitation and ET patterns in Kansas and discuss practical applications in turf management related to these topics.

The climate of Kansas has been described as having…"an annual mean temperature almost as high as that of Virginia, more sunshine than that of any state to the east, and generous summer rains which, in the eastern counties, average heavier than those of other states, except a few along the Gulf Coast" (from *Report of the State Board of Agriculture: Climate of Kansas*, 1948). I'm not sure what the significance of Virginia's climate is, but from the above description Kansas does sound like a great place to live. And maybe even a nice place to manage turfgrass.

Of course, Kansas is a great place to live, and on average the climate can be pleasant. To turf managers, climate is important because it determines ET and precipitation, among other things, which in turn affects irrigation amounts required for turfgrass.

However, averages which define our climate don't really mean much when you consider extremes that are typical to Kansas's continental climate. There is a saying: "Climate is what you expect, but weather is what you get". That is certainly true in Kansas. In fact, the weather does fluctuate significantly in Kansas. For example, Colby in 1941 received a whopping 4 1/2 inches of precipitation, while Manhattan in 1951 received over 60 inches. Temperatures in Phillipsburg reached 120^{o}F in July of 1936, and reached a low of -31^{o}F in Manhattan in January of 1947. These extremes have significant impacts on the health and even the survival of turfgrass, and consequently present challenges to turf managers in Kansas.

Precipitation and ET are important in turfgrass management not only because of their role in turf health and function, but also because they (precipitation and ET) involve water, which is a politically hot topic in Kansas and across the western U.S. States, including Kansas and its neighbors, are fighting over water and thus it is in the best interests of water users to understand water use and to find more efficient ways to use water. In turf management, efficient use of water probably begins with a fundamental understanding of precipitation and ET.

Just to refresh everybody's memories, ET is defined as the evaporation of water from the surface of leaves and the soil. Or as another definition puts it, ET is the opposite of precipitation, or the moving of water from the earth's surface back up into the atmosphere. ET is a large part of the "water budget" of a vegetated surface. For example, the Kansas Geological Survey reports that of the 27 inches of average annual precipitation in Kansas (statewide average), over 23 inches is lost to the atmosphere via ET. In other words, approximately 86% of precipitation in Kansas evaporates back into the atmosphere. The percentage is even higher in western Kansas, reaching about 99% in southwestern Kansas.

The equation for the water budget of a surface is:

Precipitation + Irrigation = ET + Runoff + Deep Drainage

where the water inputs onto a surface are from precipitation and irrigation, and losses of water from a surface are ET, runoff, and deep drainage (sometimes referred to as deep percolation). In non-irrigated watersheds in Kansas, the largest loss of water is from ET. In irrigated areas, the goal is to minimize losses from runoff and deep drainage, and apply only enough to supply the atmospheric demand for ET (minus the amount supplied by precipitation). By providing this amount of water, stress is reduced on turfgrasses without losing significant amounts from runoff and drainage.

There are several factors that significantly affect ET, including four major climatic variables and two properties of a land's surface.

The major climatic variables are solar radiation, air temperature, relative humidity, and wind speed. Solar radiation supplies the energy to evaporate water, so obviously ET is higher on sunny days compared to cloudy days. The capacity of air to evaporate and hold water increases exponentially as the air warms, so higher air temperatures result in higher ET rates. Relative humidity affects the "drying power" of the air and thus, dry air (low relative humidity) increases ET. Finally, wind speed mixes the air and carries water vapor away from a vegetated surface; hence, ET increases with wind speed. From this description, one can surmise that ET rates will be high on sunny, hot, and windy days with low relative humidity, and conversely, ET will be low on cloudy, cool, and calm days with high relative humidity. Potential ET, which is defined as the maximum theoretical amount of ET, can be calculated from weather station measurements of these climatic variables.

Actual ET, however, may be quite different from potential ET because of two features of a land's surface that may vary from place to place. Those two features are: 1) the amount of water in the soil, and 2) the type of vegetation. The amount of water in the soil is critical because even if climatic conditions predict high ET rates (high potential ET), the actual ET rates will be very low if soil water availability is limiting such as in a desert. Vegetation type also can make a difference because some plants restrict their rates of transpiration more than others and thus, reduce ET rates. Thus, even if soil water is plentiful, ET rates may be lower from a surface covered with low water-use plants compared to higher water-use plants. An example of this in turf would be warm season grasses (such as bermuda, zoysia, and buffalograss), which typically use less water than cool season grasses (such as Kentucky bluegrass, tall fescue, etc.).

Ideally we would like to know actual ET rates so we could have more precise estimates of the amount of irrigation to apply to turf (ET – precipitation = irrigation amount required). However, actual ET rates have proven quite difficult to measure and therefore, a multitude of methods have been developed to estimate actual ET. These include anything from using measurements of pan evaporation with "crop coefficients" developed for specific crops, to complex equations that use weather data and plant properties to estimate ET for specific crops or vegetation types. However, the variability in most of these methods is quite high depending upon the climate. The placement of weather stations and evaporation pans also may cause variability because weather data may be affected by local microclimatic factors. Consequently, estimates of actual ET may be quite inaccurate and may result in over- or under-irrigation of turf.

The Food and Agricultural Organization (FAO) investigated the various methods of estimating ET and now recommend a standard equation that can be used to estimate "reference ET" for a hypothetical, well-watered grass of uniform height that is about 5 inches in height. This equation is called the "FAO Pennman-Monteith equation", also known as the "FAO-56", and uses the climatic variables (solar radiation, air temperature, wind speed, and relative humidity) and properties of the plants to estimate ET from the surface. It was shown to be more reliable over a wider range of conditions than the other methods.

ET estimates from the above equations prove quite interesting when applied to Kansas climate, particularly since Kansas climate varies considerably from east to west and from year to year. In the next issue of TURFNEWS, I will describe various trends in precipitation and ET (actual, reference and potential) in Kansas, and discuss some of the practical applications of using weather data in turf management decisions.