IRRIGATION MANAGEMENT SERIES

What is ET?

An Evapotranspiration Primer

Danny H. Rogers
Extension Irrigation Engineer
Biological and Agricultural Engineering

Mahbub Alam
Extension Irrigation Engineer
Southwest Research and Extension Center

Kansas State University
Agricultural Experiment Station and
Cooperative Extension Service
Manhattan, Kansas

The term **Evapotranspiration** (ET) combines the concepts of evaporation (E) from soil and plant surfaces with transpiration (T) from plant leaves to describe the total water escaping from a crop to the air.

The process of water-molecule transfer from any moist surface to the air is called **evaporation**. All surfaces having water in contact with air evaporate water, including lakes, moist soils, and wet plant leaves. Water molecules evaporate as long as the air is not saturated with water vapor.

Transpiration, on the other hand, refers to the water vapor escaping from plant leaves through tiny pores (called stomata) scattered over the leaf surface. It is different from evaporation because stomatal opening or closing occurs in response to environmental conditions. Water moves from moist soil into plant roots, through the plant, and finally out through leaf stomata. The evaporation and transpiration processes are illustrated in Figure 1.

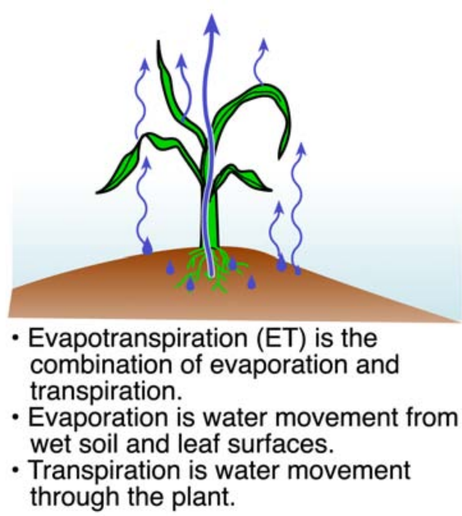


Figure 1

How does weather affect ET?

Evapotranspiration increases with:

- higher air temperature,
- more solar (light) energy,
- lower humidity, and
- faster wind speed.

Evapotranspiration is often referred to as "crop water use" because the two processes are so closely entwined and difficult to separate. Both evaporation and transpiration processes are driven by energy from solar radiation, air temperature and wind. Major energy processes are illustrated in Figure 2. There would be more ET occurring on a hot, sunny, windy day then on a cool, cloudy, calm day. The amount of ET that occurs can be measured by installing weighing lysimeters, but is estimated more conveniently and quite accurately by using equations. Climatic data, such as solar radiation, air temperature, relative humidity, and wind run, are used in these equations.

Early in the season, when plants are small, most water loss is from soil evaporation. When plants are large, most ET is from plant transpiration.

Why is crop water use important?

Crop water use determines how much water is needed that may be provided by rain, irrigation, or both. Too little water can reduce crop yield. Too much irrigation can:

- waste water,
- waste energy,
- waste nutrients, and
- unnecessarily deplete the source of water.

Smart irrigation management begins with knowing crop water use. The goal is to give plants exactly what they need when they need it. If a crop does not get enough water to meet its maximum demand, yield will decline. In fact, crop yield increases as water availability increases to the level of peak

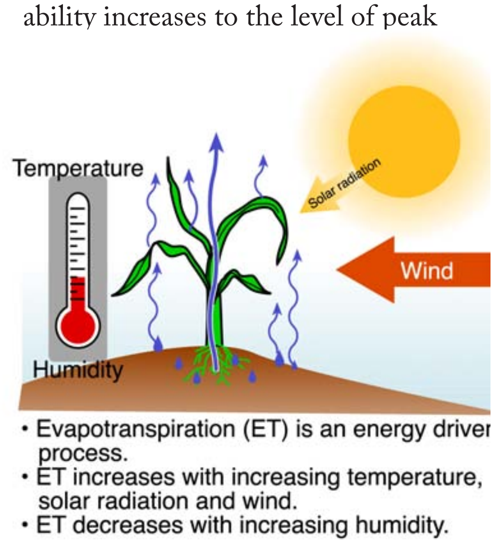


Figure 2

crop water use. More irrigation beyond this level does the crop no good, and may actually cause harm. Increased pumping and water costs erode profits. Excess irrigation water may run off or percolate below the root zone, removing nutrients and chemicals from where they are needed. Irrigating at a level less than maximum crop water demand lowers operating costs, but can decrease profitability because yield is proportional to crop water use relative to crop ET. To attain the highest profits for most crop and situations, irrigation must be managed to prevent both crop water stress and excess irrigation.

How do plants use water?

Water has four functions in plants:

- *cooling* — evaporation and transpiration cool leaves and help metabolic processes to continue.
- *nutrient transport* — dissolved nutrients move through plants along with water, and
- *hydration* — water in plant tissues keeps stems, leaves, and fruit firm.
- *photosynthesis* — water participates in photosynthesis and releases oxygen when oxidized by the chlorophyll system.

Crops use water for several purposes. During hot periods, the most important use is to cool the plant. Known as evaporative cooling, this process occurs in plants as it does in your body; water (sweat) evaporates from your skin and cools your body. Without evaporative cooling, the sun's energy would quickly overheat plant leaves, disrupt metabolic processes, and ultimately kill the plant. Cooling is such an important function that plants transpire more than 99 percent of the water they absorb during their lifetime.

A second function of water is to transport nutrients throughout plants. As water moves from soil into roots and then into leaves, nutrients also are carried along. Though nutrients are very important for crop growth, nutrient transport is considered a secondary function of water movement, because much more water is needed to meet a plant's cooling needs than to meet nutrient transport needs.

Depending on the crop, a good portion of water may remain in fruits and vegetables, while less than 1 percent of total water absorbed from soil may remain in the plant's other tissue. This may be surprising, because water makes up more than 90 percent of most crops' weight.

Finally, a vital function of water in a plant is providing an electron source for photosynthesis, which helps release oxygen and maintain an ecological balance of gases.

How is ET estimated?

Many formulas have been developed to calculate ET. Formulas used to estimate ET are called combination equations because they account for all the energy sources a plant has available to it. This includes energy from solar radiation and advective energy.

Advective energy is heat energy transported to a crop by wind. Because Kansas climatic conditions are very advective, ET formulas must account it. The amount of energy available to drive ET is routinely measured at a number of Kansas weather stations, which track such factors as temperature, relative humidity, solar radiation, and wind.

Reference ET values available today were developed by researchers who carefully measured weather conditions and water use by standard reference crops using weighing lysimeters to account for water use by plants during the growing season (Figure 3). Alfalfa and grass are two commonly used reference crops because they can be maintained at a certain height and stage of growth for long periods during a growing season.

Weighing lysimeters are essentially containers of soil mounted on a very accurate scale system. The reference crop of choice is then grown in these containers, surrounded by a field of the same crop to establish environmental equilibrium around the lysimeter. Where researchers used alfalfa as the reference crop, information on water-use rates was obtained when the crop attained a height of 15 to 18 inches, fully covering the ground and growing vigorously in the lysimeter in a well-watered condition. Weather data were collected during this growth stage.

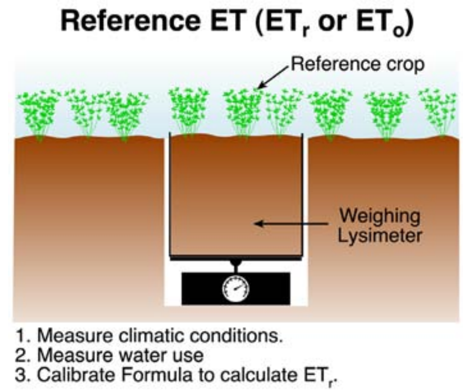


Figure 3

Researchers also used grass as a reference crop, grown to a height of 6 to 10 inches, fully covering the ground and having sufficient water to grow. Predictive equations were developed and calibrated using many sites and seasons to achieve the necessary accuracy.

Reference ET, when designated as ET_r, should refer to an alfalfa reference crop. Reference ET that refers to grass crops should be designated as ET_o. The term "potential evaporation" (PET) is sometimes used instead of reference ET, but this is an expression that is not well defined in the scientific community.

Once the equation is calibrated, it is easy to obtain reference ET values by entering weather data into the equation. However, to be able to apply this for other crops, the reference ET needs to be adjusted to obtain actual crop ET. Actual crop ET is abbreviated as either ET_a or ET_c. Adjustment factors, known as crop coefficients (Kco), are obtained for crops of interest through similar research.

Figures 4a-c illustrate the process required to develop crop coefficients needed to translate reference ET into crop ET. Crop water use for the crop of interest is observed for all stages of growth in its life cycle. The coefficients are the ratio of observed crop water use to the reference ET.

Crop ET can be thought of as a percentage of a reference ET, as illustrated in Figure 5. Coefficient values may be greater than 1, however, if a crop's actual water use is greater than that of the reference crop. This is especially possible for grass reference ET values, because reference grass is short compared to many field crops.

Obtaining reference ET values is becoming easier in major irrigated areas of Kansas because radio, newspapers, and computer network services often report reference ET. These values are used in irrigation scheduling programs, which help irrigators minimize irrigation pumping costs without causing yield loss.

Irrigation scheduling computer programs have coefficient values embedded in them to modify the entered value of reference ET into actual crop ET. Reference ET values calculated using information from the K-State weather station network are available on the Kansas State University weather data library Web site (**www.oznet.ksu.edu/wdl**).

Does ET change as the crop grows?

Crop ET changes depending on:

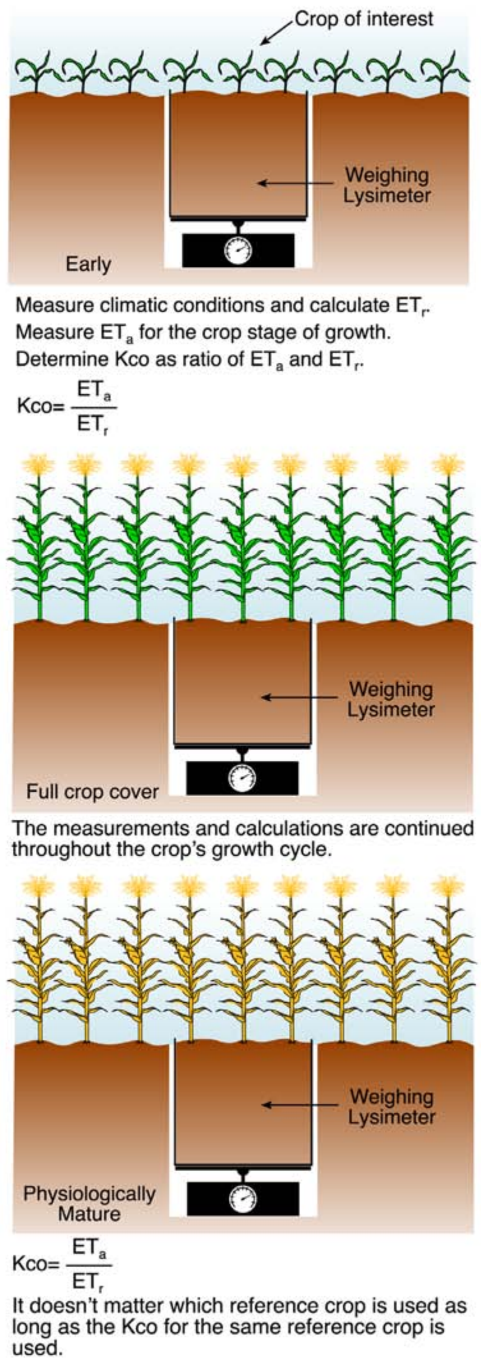
- canopy cover,
- crop type and variety, and
- plant maturity.

The crop coefficient reflects these differences and is used to estimate actual crop ET by multiplying reference ET by the Kco factor of the crop under consideration.

Different types and varieties of plants are capable of moving water at different rates. They also have different maximum rates of ET demand. Even the same crop has a different water use rate depending on the stage of growth or relative amount of canopy cover.

These differences are reflected in crop coefficients. The crop coefficient reflects how one crop's ET compares with the ET of a reference crop. For

Developing a Crop Coefficient (Kco) to Determine Actual Crop ET (ET_a)



Figures 4a-4c

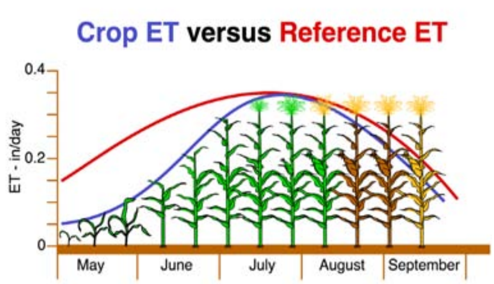


Figure 5

example, corn in the early growth stage uses less water than an alfalfa crop with a full canopy. The crop coefficient is the ratio of actual ET to reference ET. Thus, if reference ET is known, we can use crop coefficients for corn or other crops to quickly estimate crop ET.

Are soil water and crop water use related?

The amount of available soil water is determined by:

- soil water storage capacity,
- soil water availability,
- root zone depth, and
- crop and residue cover.

If water is not available in the root zone, no ET can occur. The goal of irrigation is to keep soil water availability from limiting crop ET.

Water stored in soil is transported into the plant by root hairs in contact with the water in soil pores. It moves up the stem to the leaves and thus forms a continuum. Dry air is continuously pulling that water. At the same time, plants need cooling to function, so they transpire. Soil, water, and plant relations are critical factors to consider for effective irrigation management. Soil characteristics determine how much and how tightly water is held in the soil, as well as how quickly water can move to plant roots to replace transpired water. Rooting depth determines the volume of soil water a plant can access. Together, these factors control the amount of water available to a crop.

These relationships are discussed in detail in K-State Research and Extension Bulletin L-904, *Soil, Water and Plant Relationships*. Soil-water-plant relationships provide the basis for developing a crop water budget or an irrigation schedule.

Irrigation scheduling refers to the procedure to determine when and how much irrigation water should be applied to meet a specific management goal. A common irrigation goal is to prevent yield loss due to deficient levels of available soil water. An additional goal may be to prevent excess irrigation.

An ET-based irrigation schedule uses ET information to determine crop water withdrawals from the crop root zone, which can retain a fixed amount of water based on root depth and soil type. The withdrawals by the crop are offset by additions of water by rain or irrigation. This water balance is illustrated in Figure 6.

KanSched is an ET-based irrigation scheduling software program that has been developed by K-State Research and Extension irrigation specialists to assist irrigators wishing to use ET-based scheduling. KanSched is available via the Web at **www.oznet.ksu.edu/mil**.

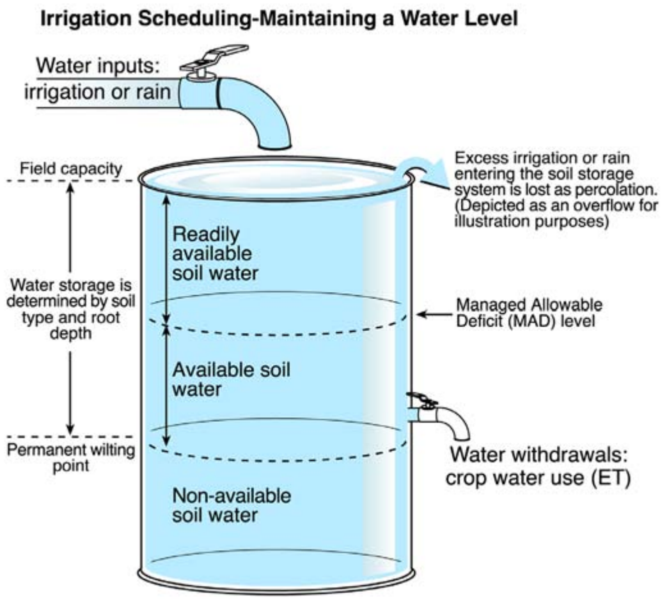


Figure 6

Summary

1. Evapotranspiration, or ET, is a term that describes crop water use due to evaporation from both plants and soils and transpiration from plant leaves.

2. Plants need water to meet ET requirements. If ET demand is not met, crop yield suffers. Knowing ET helps in determining when and how much to irrigate.

3. Weather conditions determine how fast a crop transpires and water evaporates from crop field. Different crops may have different ET for the same weather conditions.

4. ET can be determined on a daily basis by using weather data to help producers make irrigation decisions.

Authors

Danny Rogers and Mahbub Alam, Extension Agricultural Engineers

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