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Using Evapotranspiration Information and Soil Moisture Storage Capabilities to Improve Irrigation Scheduling

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Climate and evapotranspiration (ET) data can be very useful in irrigation scheduling. Data used in ET models can be obtained from many sources, including networks of dedicated weather stations. ET network data may be provided through public access Internet sources, such as the Lubbock-based Texas South Plains ET Network, http://lubbock.tamu.edu/irrigate/weatherdata.html; the Amarillo-based Texas North Plains ET Network, http://amarillo2.tamu.edu/nppet/petnet1.htm; or the South Texas area Texas ET Network, Texaset.tamu.edu. Other ET information delivery mechanisms include subscription-based fax delivery, subscription-based Internet delivery, and direct phone modem access to weather stations.

Since most ET networks were developed independently and for different audiences, there are differences in delivery methods, data formats, and even models used in estimating evapotranspiration from basic climate data. However with ongoing standardization efforts, increasing Internet access, and continuing research to acquire water demand data for more crops and in more locations, ET information is becoming a more widely used irrigation scheduling tool. Combined with in-field soil moisture and/or plant water status observations, ET information can help irrigators optimize irrigation applications for greater water use efficiency, crop yield and quality.

Information Available from ET Networks

Because basic climate information, such as (maximum and minimum) air temperatures, humidity, solar radiation, and wind are used in the calculation of reference crop evapotranspiration, these data are often made available along with the ET values. Also commonly presented are Heat Units (Growing Degree Days) and soil temperatures, used in crop growth models, integrated pest management applications, and planting decisions.

What is evapotranspiration (ET)? Evapotranspiration is a combined term used to describe crop water demand by combining evaporation and transpiration, depicted in Figure 1. Evaporation is the process through which water is removed from moist soil and wet surfaces (such as standing water or dew on leaves). Transpiration is the process through which water is drawn up through the plant (roots extract water from the soil, and water is eventually removed through stomata on the leaves.) Evaporation and transpiration are affected by climate demand (air temperature, wind, humidity, and solar radiation); crop-specific water demand characteristics (corn vs. cotton); and growth stage of the crop (cotton at full canopy and full bloom uses more water than seedling cotton).

What is Reference ET (PET)? An important value used in the calculation of crop-specific evapotranspiration is the *Reference (Crop) Evapotranspiration* or *Potential Evapotranspiration.* Potential Evapotranspiration (PET) and Reference Evapotranspiration (ETr or ETo) are the same value - an estimate of the (maximum) potential water use for a well-watered reference crop under the given climate conditions. The term, "PET", long used by many networks, is being replaced with the term, "Reference ET", to conform to standard terminology.

Evapotranspiration = Evaporation + Transpiration

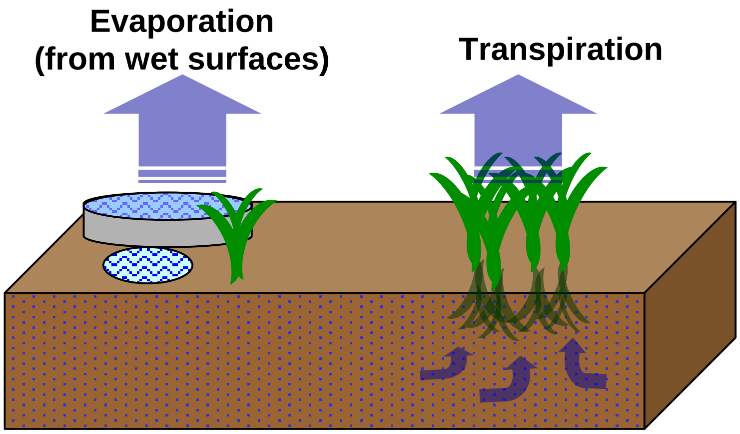


Figure 1. Evapotranspiration

Reference crop evapotranspiration is an estimate of water requirement for a well-watered reference crop. The alfalfa or cool-season grass reference crop is essentially an idealized crop used as a basis for the ET model. Reference ET is calculated by applying climate data (temperature, solar radiation, wind, humidity) in a model (equation). It is helpful to note that reference ET is only an estimate of the water demand for this idealized crop, based upon weather station data at a given location.

How is Crop Evapotranspiration calculated? Crop-specific ET is estimated by multiplying the Reference ET by a crop coefficient. The crop coefficient takes into account the crop's water use (at a given growth stage) compared to the reference crop. For instance, seedling cotton does not use as much water as the idealized grass reference crop, but during peak bloom cotton could actually use more water than the grass reference crop. The crop coefficient is understood to follow a pattern (curve); examples are shown in Figures 2 and 3.

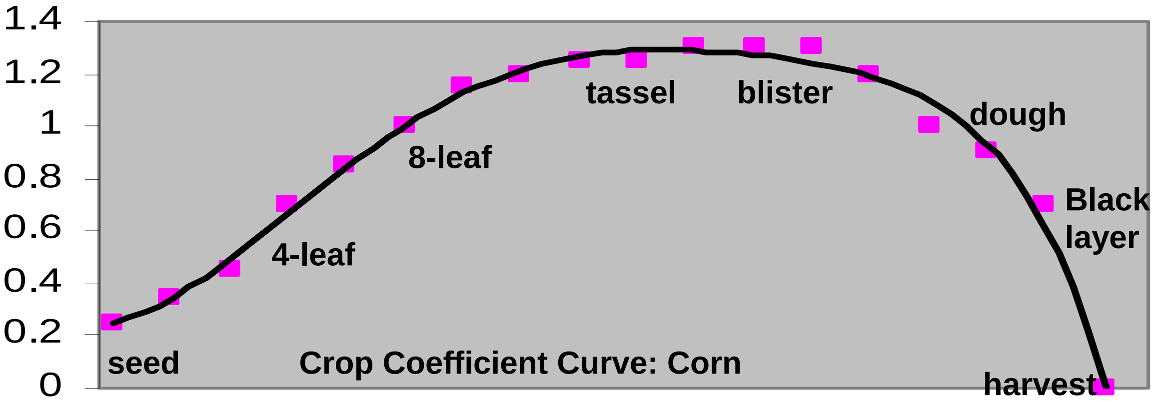


Figure 2. Crop coefficient curve for corn, Texas Southern High Plains.

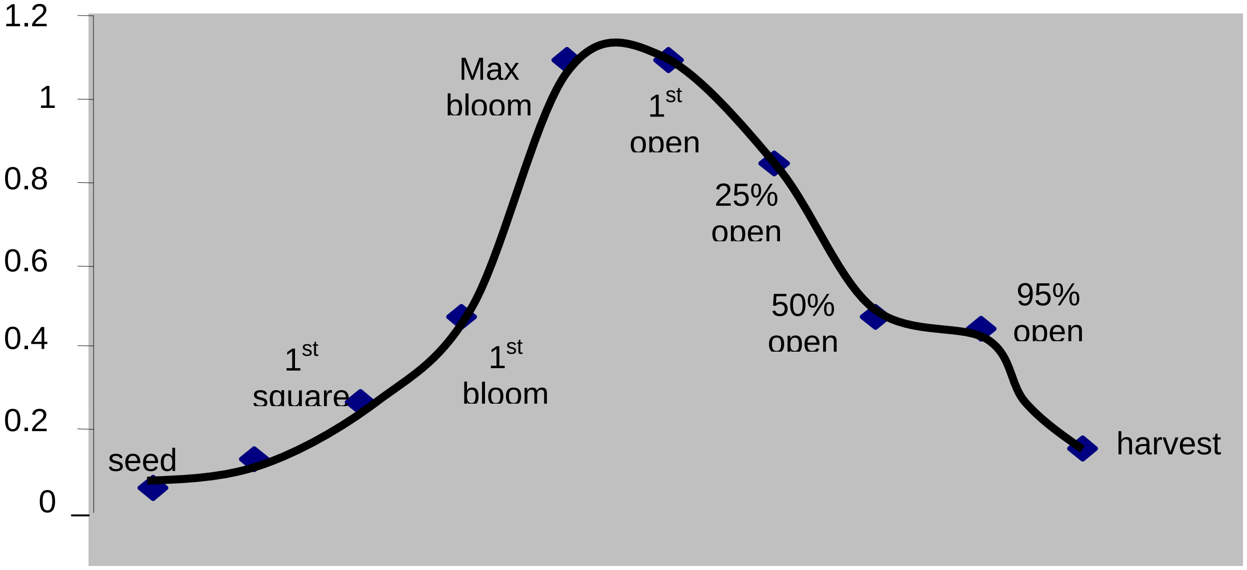


Figure 3. Crop coefficient curve for cotton, Texas Southern High Plains.

One more item to note is that the reference crop ET model and the crop coefficient curves were developed from long-term research. Data may have been compiled from various sources to develop these relationships. Actual crop water demand can be affected by many factors, including soil moisture available, health of the crop, and likely by plant populations and crop variety traits. These factors generally are not taken into account by the models. Hence, ET data provided by on-line networks are probably best used as guidelines for irrigation scheduling and (where applicable) integrated pest management and integrated crop management. Predicted growth stages and estimated water usage should be checked with in-field observations. Actual crop water use is likely to be somewhat less than the predicted ET value.

How is estimated ET used to schedule irrigation? There are a variety of ET-based irrigation scheduling methods, models and tools available. Many are essentially based upon a "checkbook" approach: Water stored in the soil (in the crop's root zone) is withdrawn by evapotranspiration and deposited back into the soil through precipitation and irrigation. When soil moisture storage falls below a given threshold value, irrigation is applied to restore the moisture.

The amount of water extracted to the threshold value is often termed, "allowable depletion"; it is generally between 40% and 60% of the plant available water storage capacity of the effective root zone. Hence, when approximately 50% of the plant available water has been extracted through evapotranspiration, an irrigation application would be delivered to replenish the soil moisture storage. Under managed deficit irrigation management, irrigation applications would be adjusted, perhaps to a) fill only a portion of the depleted water storage; or b) allow greater soil moisture depletion but schedule the irrigation to better meet crop water demand during the most critical growth stages for the particular crop.

How should soil conditions be taken into account? Soil properties and conditions affect how much water can be retained, and at what rate the water can enter the soil. Some critical soil properties that should affect irrigation management are permeability, soil moisture characteristic, and hydraulic conductivity.

Permeability is the rate at which soil can take in water through infiltration. A soil with low permeability cannot take in water as fast as a soil with high permeability; the permeability therefore affects the risk for runoff loss of applied water. Hence permeability is an important consideration in selecting irrigation application rates. Permeability is affected by soil texture, structure, and surface condition. Generally speaking, fine-textured soils (clays, clay loams) have lower permeability than coarse soils (sand). Surface sealing, compaction, and poor structure (particularly at or near the surface) limit permeability.

Hydraulic conductivity, closely related to permeability, describes the ease with which water moves within the soil. As water is extracted through evaporation and transpiration, soil moisture can be re-distributed, as water moves from wetter areas in the soil to drier areas. Following irrigation or rainfall events, hydraulic conductivity affects how quickly and how well the added water is distributed in the soil profile. Hydraulic conductivity affects drainage (gravity flow of water), as well as lateral and vertical distribution of water in the soil. Hydraulic conductivity can be especially important in alternate furrow irrigation applications (including LEPA) and subsurface drip irrigation applications in which water is applied to a relatively small cross-section of the soil profile with the expectation that the water will be distributed beyond the point of application to supply the root zone.

Soil moisture characteristic, also referred to as a *soil moisture release curve* or *soil moisture retention curve* (depicted in Figure 4), is the relationship of how much water is retained against a given pressure potential (suction). It is essentially a representation of energy required to extract water from the soil over a range of soil moisture conditions. Critical levels of suction are *field capacity* and *permanent wilting point*. *Plant available water* is that which is stored between field capacity and permanent wilting point (see Figure 5). Some soils can store more water than others. At field capacity, sandy soil may be expected to hold 0.6 to 1.25 inches of available water per foot of soil; a clay loam may hold 1.5 to 2.3 inches of water per foot of soil. Because the soil's moisture holding capacity is limited, excess water applications will result in deep percolation and/or runoff losses.

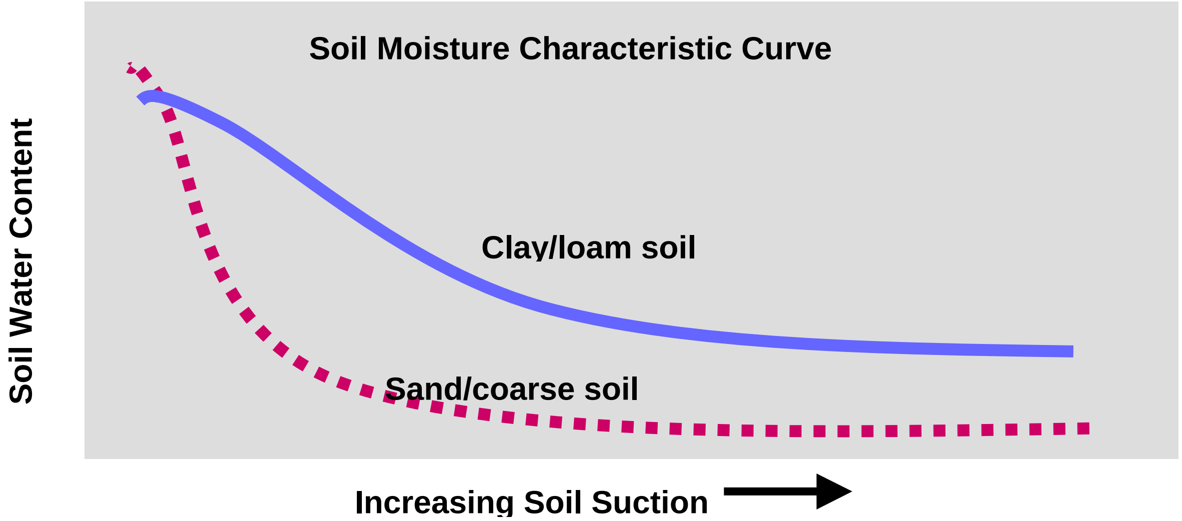


Figure 4. Soil moisture release with increasing suction.

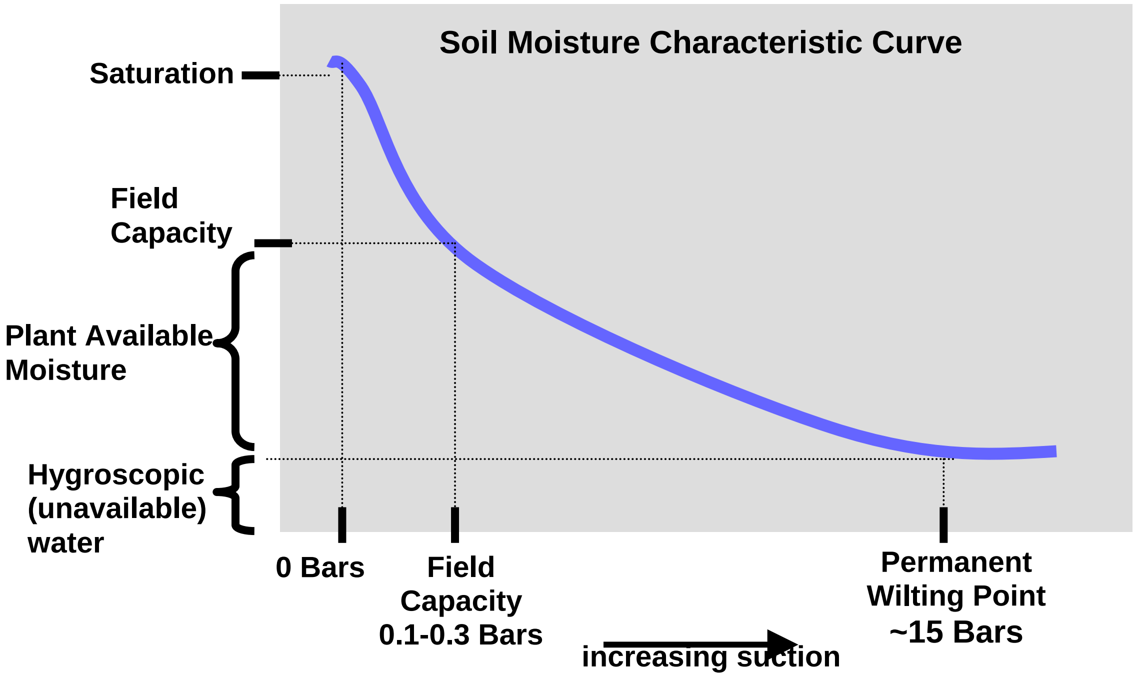


Figure 5. Soil moisture release with increasing suction.

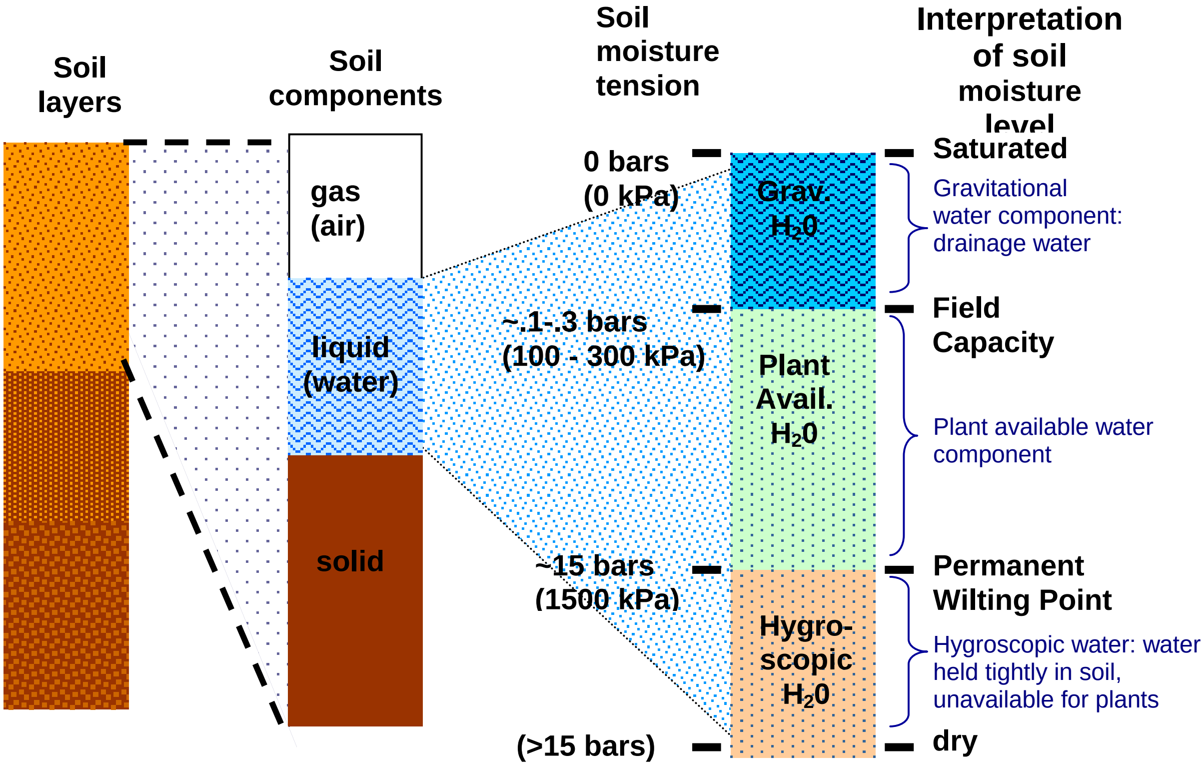


Figure 6. Components of soil and of soil water.

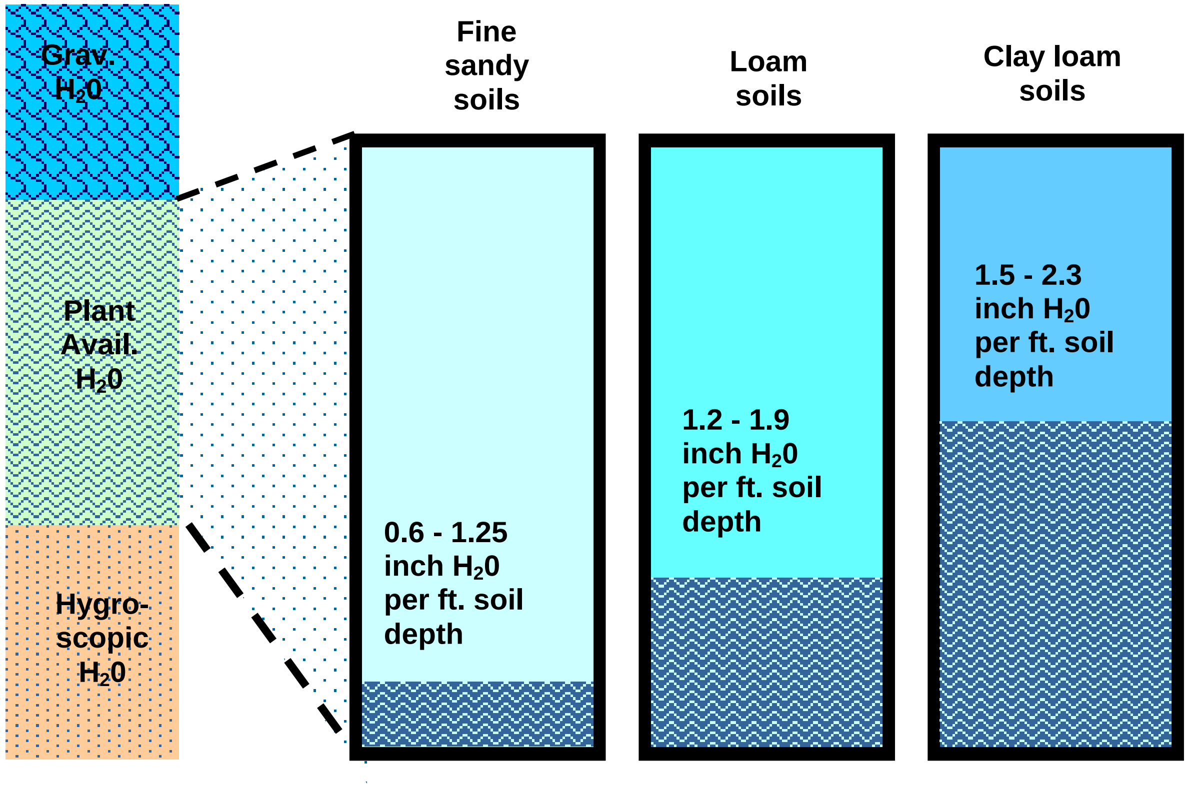
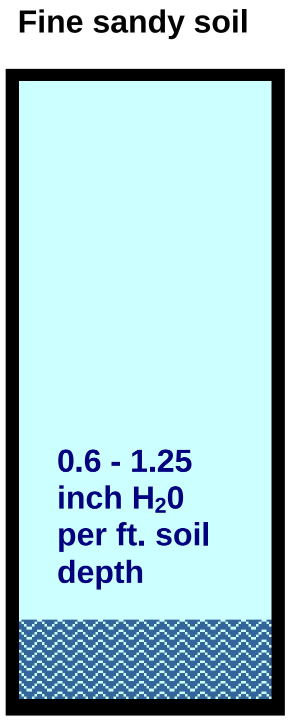


Figure 7. Available water storage by soil type.



Estimating available water in root zone:

Example: Amarillo soil
(loamy fine sand/fine sandy loam)

Available water by soil depth:

Soil layer Location	Soil layer depth	Avail. H_20 per inch soil	Avail. H_20 Storage in soil layer
0-14 in	14 in	0.08 in/in	1.12 in
14-46 in	32 in	0.15 in/in	4.80 in.
46-80 in	34 in	0.13 in/in	4.42 in

If the crop's root zone depth is 4 feet (48 inches), the water available at field capacity is (14 X 0.08) + (32 X 0.15) + (2 X 0.13) = 1.12 + 4.80 + 0.26 = 6.18 inches of water

Figure 8. Estimating water holding capacity in the root zone.