CROP WATER REQUIREMENT OR IRRIGATION WATER REQUIREMENT

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INTRODUCTION

Crop water requirement refers to the amount of water that is used by a crop to meet the environmental demands of evaporation and transpiration (evapotranspiration or ET). This water requirement may be supplied by stored soil moisture, natural precipitation, or supplemental irrigation. However, irrigation systems are not perfect, loss of water will occur, and this is generally related to the efficiency of that system. Stored soil water has limits on availability, natural precipitation may not come at the proper time or in the proper amounts, and irrigation systems will have losses of water from the crop production system and nonuniform application. The net result is that in crop production systems that require supplemental irrigation two cases will exist, (1) Full Irrigation - the actual amount of water that must be pumped from the water source will be greater than the net irrigation requirement of the crop (considering rainfall and stored soil water); and (2) Deficit Irrigation - the net irrigation water requirement of the crop will not be satisfied. In either case, the uniformity of water application and efficiency of the irrigation system should be known in order to asses the irrigation water requirement that is appropriate for the crop water requirement with the given system.

EFFICIENCY DEFINITIONS

Efficiency can be defined in many ways related to irrigation and crop water use. Specific terms may include "water use efficiency", "reservoir storage efficiency", "conveyance system efficiency", and "irrigation application efficiency". In general, the term "irrigation system efficiency" (E_s) refers to the ratio of the volume of water that is of beneficial use to the volume of water that is delivered by an irrigation system and combines the effects of the last three terms listed above. Water that is of beneficial use can have many meanings. For example, it may only refer to water that is readily available to the crop for direct use. However, other beneficial applications of water that include portions not directly used by the crop include water for leaching requirements, seed germination, dust control, or other uses. Therefore, in order to properly assess how "efficient" a particular system may be depends upon the way in which efficiency is defined.

Water Use Efficiency

Water use efficiency may be defined relative to the crop or to the irrigation system. For example, "crop water use efficiency" is typically used to define the ratio of the crop yield to the volume of water used to produce the crop. While crop yield is easily defined,

the volume of water used to produce the crop may be the total crop water use from stored soil water, precipitation, and irrigation, or it could be defined on local level for comparison purposes as simply the volume of water pumped to produce that crop. With the latter definition, low irrigation inputs can result in high levels of crop water use efficiency, even when yields are relatively low. This brings up the term "irrigation water use efficiency" which may be defined as either (A) the ratio of the volume of irrigation supplied water that is of beneficial use to the crop to that which was withdrawn from the water source by the irrigation system; or (B) the ratio of the increase in crop yield relative to nonirrigated yields to the volume of water withdrawn from the water source by the irrigation system. Another method used to express definition (B) may use the increase in economic return over dryland conditions rather than crop yield for comparing the value added to different crops from supplemental irrigation.

Reservoir Storage Efficiency

Reservoir storage efficiency (E_r) is the ratio of the volume of water that is available from an irrigation reservoir to the volume of water delivered to that reservoir. If a reservoir is not used in the irrigation system, then a value of 1.0 would be used for this term. When reservoirs are used, this term is almost always less that 1.0 due to losses from percolation through the soil, evaporation from the water surface, and transpiration of reservoir water from aquatic and riparian plant species. Methods are available to control or minimize these losses. Whether these are economically feasible alternatives depends upon the specific conditions, uses, and constraints associated with each reservoir system.

Conveyance System Efficiency

Conveyance system efficiency (E_c) is the ratio of the volume of water delivered for irrigation by the system to the volume of water introduced into the conveyance system. Conveyance systems include open channels and closed conduits (PVC or aluminum pipelines). Open channel systems will always have E_c values less than 1.0 due to similar percolation, evaporation, and transpiration losses that can occur with reservoirs. Using channel liners and removing vegetative growths can help to increase the efficiency of these systems. Pipeline systems may have Ec values that approach 1.0 when proper solvent cementing and gasket sealing procedures are used. However, with time, joints and seals on some systems may leak and result in decreased E_c values.

Irrigation Application Efficiency

Irrigation application efficiency (E_a) is the ratio of the volume of irrigation water that is available to the crop for use (evapotranspiration) to the volume of water that was delivered to the crop by the irrigation system. Actual and potential values of E_a depend upon crop, soil, and irrigation system design and management parameters such as rooting depth, water holding capacity, hydraulic conductivity, irrigation system application uniformity, and irrigation scheduling. This particular efficiency term is a very difficult one to quantify. The previously listed parameters have biological system influences (plants,

soils, human design, installation and management) as well as manufacturing influences (product uniformity). Therefore the net result is generally a best guess as to the value of the E_a term. Values can range from 0.20 to in excess of 0.90 and will vary for a given irrigation system within a crop production season or during an individual irrigation cycle.

Irrigation System Efficiency

Irrigation system efficiency (E_s) accounts for the combined effects of reservoir, conveyance, and application efficiencies. Therefore E_s may be expressed as

$$E_s = (E_r) \times (E_c) \times (E_a) \quad (1)$$

where all terms are as previously defined.

WATER REQUIREMENTS

Water requirements can be defined as those needed by the crop or those that need to be withdrawn from the water source by the irrigation system. As previously defined, crop water requirements depend on the evapotranspiration demand on the crop which is primarily influenced by solar radiation, wind, temperature, humidity and crop characteristics. These parameters are used to estimate a reference crop evapotranspiration (Et_r) that is then related to the water requirement of the crop of interest (Et_c) by a crop coefficient (k_c). Crop coefficients depend upon the type of crop, cultural conditions, and stage of crop growth and development. Values typically range from 0.10 to 0.20 early in the growth cycle and from 0.90 to 1.10 at peak growth and development.

The net irrigation requirement (I_{net}) refers to the net amount of water that must be supplied by irrigation that must be completely available to meet the needs of the crop. This requires knowledge of the current soil water status and remaining available storage, the crop water requirements, and any precipitation that has or will occur. The gross irrigation requirement (I_g) will depend on I_{net}, the irrigation system efficiency E_s, and other system needs such as a leaching requirement when soil and/or irrigation water salinity levels are of concern.

The actual amount of water that is scheduled to be delivered to the crop at any irrigation will also depend on the availability of the water source and any limitations on its use. This leads into either full or deficit irrigation scheduling. Under full irrigation scheduling, the water source is sufficient and available to meet all crop and system needs. Thus, one needs to monitor crop needs and available soil water storage and to apply amounts that will fit within these criteria. Under deficit irrigation scheduling, the water supply is not sufficient to meet all irrigation demands, and the water must be scheduled for application to be available during the most sensitive crop growth periods.

SUMMARY

Differences between crop water requirement and irrigation water requirement were discussed. Crop water requirements depends on type of crop, stage of growth and development, and atmospheric conditions. Irrigation water requirement depends on crop water requirement and characteristics of the irrigation system such as uniformity of application and overall efficiency. While accurate information on the values of these different components is helpful to develop irrigation scheduling guidelines, most values are estimates and can vary from the true value by 5%, 10% or even more, and will change with time, even during the irrigation cycle. Therefore, one should incorporate proper field monitoring of stored soil moisture as a feedback source of information to adjust the irrigation schedule to meet the requirement of the overall system.