Irrigation Efficiencies of Surface Systems

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Efficiency rating of any engine, such as, air conditioners, water heaters, furnaces, etc., is of great importance to us. It is an indicator for cost of operation and quality of performance. Similarly, knowledge of irrigation efficiency of a system is important not only to evaluate post construction performance, but also to be able to design and determine the feasibility of a system prior to installation. Each system has its inherent capacity of performance; the lined canal will have greater efficiency due to reduced seepage when compared to an unlined ditch.

Let us consider a field with a crop growing on it. Using irrigation scheduling techniques and soil water monitoring devices we can determine the required depth of irrigation application that is the net amount of water to apply for proper growth and yield. The objective is to refill the root zone to field capacity, the maximum amount that the soil within the root zone will hold for plant use. The required depth for an irrigation event is expressed as an average depth of water to be applied over the entire field.

The required depth as mentioned is the 'net' amount of water to be applied. Diverting or pumping the net amount only will require that the farmer or irrigator must spread the water over the field without any loss, and therefore, achieve 100% efficiency. But in reality the irrigator has to deal with losses and to overcome the loss he has to work with a 'gross' amount. The farmer or the irrigator has the opportunity to influence only the gross amount of water applied. Hence, there is a need for a performance related term which states a relationship between the 'net' requirement and the 'gross' application.

A system that will perform at 100% efficiency may not be feasible economically and attainable operationally. The actual cost of water or return from crop production must be considered to justify changing to an efficient but costly system.

There are many efficiency terms to describe system performances. Although a single definition that describes irrigation efficiency for comparison of all systems is desirable, it is difficult to express the same by one definition to cover physical, economical, and biological evaluations. As a result a multitude of expressions have come about to express different aspects of efficiency. It is necessary for us to familiarize with the expressions. In this write up we will deal only with management and physical efficiency aspects of surface irrigation systems.

Definitions:

Water Conveyance Efficiency (E_c) : The percentage of source water that reaches the field.

$E_c = 100\ (W_f / W_d)$

W_f= water delivered to field

W_d= water diverted from a source

The source of water may be a stream, reservoir, or underground aquifer. The amount diverted or pumped from the source may not reach the field depending on the conveyance and distribution system. Conveyance efficiency is generally a concern for irrigation districts that supply water to a group of farmers through a system of canals and open ditches. Irrigation water in most of Kansas is pumped and carried in closed pipes or conduits, and the conveyance efficiency is expected to be nearly 100%.

Water Application Efficiency (E_a) : The percentage of water available for crop use to the water delivered to field.

$E_a = 100\ (W_a\ /\ W_f)$
W_a= water available for crop use
W_f= water delivered to field

Water application efficiency gives a general sense of how well an irrigation system is performing its primary task of getting water to meet crop needs. This, however, may mislead as to how well the crop is doing. Water application efficiency can be very high in a situation where the soil profile or root zone has not been filled, although all the water delivered is available for use by the crop. The crop need have not been met and crop failure or a reduced yield may result. It is also possible to have a high E_a , but the irrigation water so poorly distributed that crop stress exists in areas of the field.

Water Storage Efficiency (E_s) : The percentage of water stored in the root zone to the water required to fill the root zone to field capacity (Hansen et al.,1980; Walker and Skogerboe, 1987).

$E_s = 100\ (W_s\ /\ (W_c - W_a))$
E_s = water storage efficiency
W_s= water stored in a root zone
W_c= available water storage capacity in the root zone (amount between field capacity and wilting point).
W_a= water available in the root zone at the time of irrigation

It is difficult to define the root zone which changes during the season and is different for each crop. This also requires determination of available soil water at the time of irrigation application. When E_a is high the E_s may be low. If a large irrigation is given to raise E_s then E_a may go down. It is recommended that this definition be discontinued from usage (Heermann, et al, 1992). However, for surface irrigation systems the water storage efficiency may be useful if the objective is to minimize the number of irrigation and labor cost.

Irrigation Efficiency (E_i) : The percentage of water delivered to the field that is used beneficially (ASCE, 1978).

$E_i = 100\ (W_b\ /\ W_f)$
W_b= water used beneficially
W_f= water delivered to field

Irrigation efficiency is more broadly defined than water application efficiency in that the irrigation water may be applied for more uses rather than to satisfy crop water use (ET) only. Other beneficial purpose may include salt leaching, frost protection, crop cooling, and pesticide or fertilizer applications. Most irrigation systems of Kansas are single-purpose (supply water for crop use), which allows water application efficiency and irrigation efficiency to be used interchangeably.

Two other terms may be useful to evaluate a system from the management point of view where water quality degradation may occur due to deep percolation or water loss from run off. These are deep percolation and run off ratios.

Deep Percolation Ratio is defined (Walker and Skogerboe, 1987) as:

$$DP_r = W_{dp} / W_f$$

where, DP_r = the deep percolation ratio

W_{dp} = water percolated below the root zone, and

W_f = water delivered to the field.

This is usually evaluated in conjunction with water application or irrigation efficiency determinations. In many instances this water may not be recovered by a crop. It is significant a term where high water table or leachate may cause water quality deterioration. For a Kansas irrigator this may be important to avoid groundwater contamination and immediate loss of valuable pumped water.

Tailwater Run off Ratio is defined (Walker and Skogerboe, 1987) as:

$$TW_r = W_{ro} / W_f$$

where, TW_r= the tailwater ratio

W_{ro} = water run off from field

W_f = water delivered to the field.

Tailwater is normally reused by pumping from a recovery pit in the same field or adjacent fields. It is of concern if the water is lost, or has the potential to degrade the water quality, or is prohibited by law. Kansas irrigators generally reuse the water by pumping from a tailwater pit and may not be a concern except for additional pumping cost.

Range of Application Efficiencies for Surface Irrigation Systems

System Type	Application Efficiency Range (%)
Basin	60 - 95
Border	60 - 90
Furrow	45 - 80
Surge	60 - 90

References

ASCE, 1978. Describing irrigation efficiency and uniformity. *ASCE Journal of Irrig. and Drain. Div.* 104(IR1): 35-41.

Hansen, V.E., O.W. Israelsen and G.E. Stringham. 1980. *Irrigation Principles and Practices,* 4th. ed.New York: John Wiley & Sons.

Heermann, D.F., W.W. Wallender and M.G. Bos.1992. Irrigation efficiency and uniformity, In: *Management of Farm Irrigation Systems,* ed. G.J. Hoffman, T.A. Howell and K.H. Solomon. 2nd print, 125 - 149. ASAE, St.Joseph, Michigan.

Walker, W. R. and G.V. Skogerboe. 1987. *Surface Irrigation, Theory and Practice.* Engewood Cliffs, NJ: Prentice-Hall, Inc.

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Application Efficiency versus Distribution