E3A: System Performance and Efficiency

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STEP 4

Steps in the Irrigation Series

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How effective the system delivers water to a field from a water source is a major contributor to the performance of an irrigation system. Several terms, including water conveyance efficiency, water application efficiency, soil water storage efficiency, overall irrigation efficiency, and effective irrigation efficiency, have been used to assess the performance of a system (Irmak et al., 2011). Less-efficient systems usually require greater irrigation amounts to meet crop evapotranspiration (ET) demands due to water loss between the source and the crop as compared to more efficient systems. This results in increased energy use and operational cost for the producer. Several efficiency terms will be described; however, the reader is directed to the references below for further information regarding different efficiency terms.

Top mounted sprinklers on a pivot can be less effective due to evaporation and wind affecting uniformity.

Pivot sprinkler system in Idaho. NRCS photo – photographer: Howard Johnson. For more info: http://photogallery.nrcs.usda.gov/netpub/server.np?find&catalog=catalog&template=detail.np&field=itemid&op=matches&value=4003&site=PhotoGallery

Water Application Efficiency

Water application efficiency evaluates how well an irrigation system delivers water from the conveyance system to the crop and is calculated as:

$$E_a = \left(\frac{V_s}{V_f}\right) \times 100\%$$

(Equation 5)

where, E_a is application efficiency (%), V_s is volume of irrigation water stored in the crop root zone (acre-inch), and V_f is the volume of irrigation water delivered to the farm or field (acre-inch). In terms of irrigation efficiency "point-of-view," E_a is used to evaluate crop yield response. Water application efficiency is always less than 100% due to water loss from various pathways. Figure 4 illustrates the water cycle for a center pivot-irrigated field. The contributing factors that reduce E_a are runoff, deep percolation below the crop root zone, wind drift, and evaporation from droplets, crop canopy, and the soil surface; however, if runoff is captured and reused, then V_f should be adjusted to account for the recovered water.

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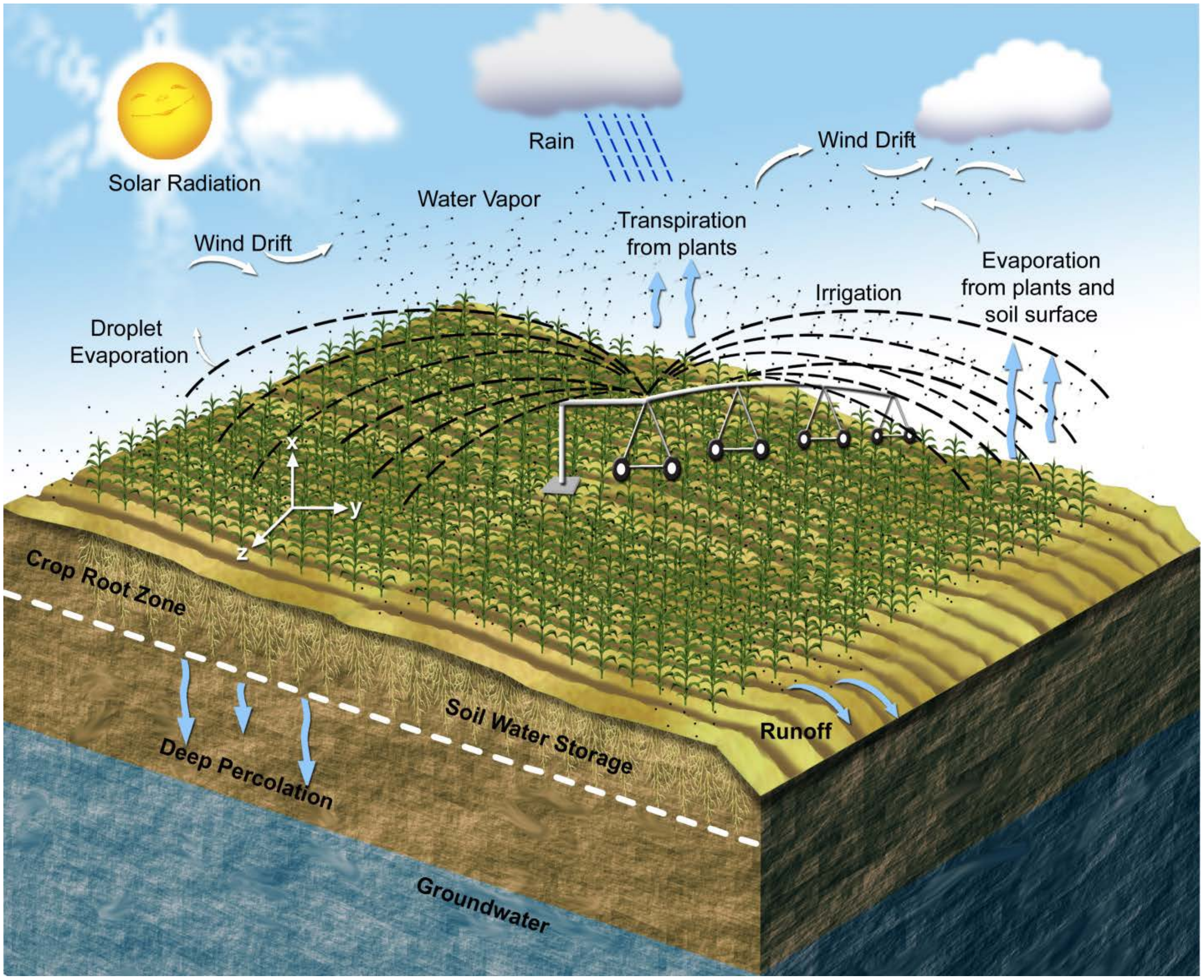

Figure 4. Components of the water cycle for a center pivot irrigated field as it relates to water application efficiency (E_a) [Adapted from Irmak (2009)].

Water application efficiency is affected, in part, by irrigation management. Table 6 provides typical E_a values for well-designed and managed irrigation systems. It is possible to have high E_a values yet unsatisfactory system performance if the irrigation system does not meet crop ET demands. A small amount of irrigation under low atmospheric evaporative demand can result in minimal water loss (i.e., high E_a), yet not meet crop ET demand, resulting in crop water stress. Table 6 provides a good estimate of the upper limit achievable for different system types under well-managed conditions in which crop ET demands are met. Other factors to consider when calculating and assessing E_a are the accuracy of measuring stored irrigation water, effective crop rooting depth, and spatial variability in E_a. Spatial variability in E_a can be, in part, attributed to poor water distribution of an irrigation system. Reporting both E_a and water distribution uniformity provides a better indication of overall irrigation system performance. Additional readings, listed below, will provide further information on factors impacting E_a.

Irrigation Efficiency

Irrigation water may be applied to satisfy other objectives than meeting crop ET. Table 7 presents different uses of irrigation water between beneficial and non-beneficial as well as between consumptive and non-consumptive. Irrigation efficiency (E_i) is commonly used to assess the effectiveness of the irrigation system in delivering water for beneficial uses. It is defined as the ratio of the volume of water beneficially used (V_b, acre-inch) to the volume of irrigation applied (V_f, acre-inch) and is expressed as:

$$E_i = \left(\frac{V_b}{V_f}\right) \times 100\%$$

(Equation 6)

Similar to E_a, irrigation management decisions can also impact E_i. In addition, E_i is subjected to personal biases in the term beneficial water use. We recommend one explicitly defines their interpretation of the beneficial use of irrigation, when using E_i to evaluate the irrigation system performance.

Table 6. Potential water application efficiencies (E_a, %) for well-designed and managed irrigation systems. Adapted from Irmak et al. (2011).

Irrigation System	*"Potential" Application Efficiency (%)*
Sprinkler Irrigation System	
LEPA	80 – 90
Linear move	75 – 85
Center pivot	75 – 85
Traveling gun	65 – 75
Side roll	65 – 85
Hand move	65 – 85
Solid set	70 – 85
Surface Irrigation Systems	
Furrow (conventional)	45 – 65
Furrow (surge)	55 – 75
Furrow (with tailwater reuse)	60 – 80
Basin (with or without furrow)	60 – 75
Basin (paddy)	40 – 60
Precision level basin	65 – 80
Micro-Irrigation Systems	
Bubbler (low head)	80 – 90
Micro-spray	85 – 90
Micro-point source	85 – 90
Micro-line source	85 – 90
Subsurface drip	> 95
Surface drip	85 – 95

Note: LEPA (Low energy precision application)

Overall Irrigation Efficiency

The overall irrigation efficiency (E_o) represents the efficiency of the entire system to deliver water from a water source to a crop. It can be calculated by multiplying either water application efficiency (E_a, as decimal) or irrigation efficiency (E_i, as decimal) by the water conveyance efficiency (E_c, as decimal) calculated as:

$$E_c = \left(\frac{V_f}{V_t}\right) \times 100\%$$

(Equation 7)

where, E_c is conveyance efficiency (%), V_f is the volume of irrigation water that reaches the farm or field (acre-inch), and V_t is the total volume of water diverted from the water source (acre-inch). The conveyance efficiency will decrease as a result of water losses, including canal seepage, canal spills, evaporation from canals, and leaks in pipelines. For center pivot irrigation, E_c can be as high as 100% since there is minimal water loss in closed/pressurized conveyance systems. The selection between E_a and E_i to calculate E_o will depend on the purpose or objective of irrigation, and the equation to calculate E_o is:

$$E_o = [(E_a \ or \ E_i) \times E_c] \times 100\%$$

(Equation 8)

Table 7. Partition of irrigation water use between beneficial and non-beneficial as well as consumptive and non-consumptive.

	Consumptive Use	**Non-Consumptive Use**
Beneficial	Crop evapotranspiration Plant evapotranspiration for windbreaks Germination of seeds	Water for leaching Softening soil crust for emergence Evaporation for cooling Evaporation for frost protection
Non-Beneficial	Phreatophyte evapotranspiration Weed evapotranspiration	Wind drift and droplet evaporation Evaporation from soil and plant surfaces Reservoir and canal evaporation Deep percolation Surface runoff Operational spill

References and Further Readings

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Notes

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