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Irrigation System Comparison Guidelines

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Abstract. Individuals, organizations, and agencies often want to compare irrigation systems in order to determine which system option might be best suited to meet certain goals. Such goals might be: which is most cost effective, which is most efficient, or which would minimize a given environmental impact. Often, irrigation efficiency is a major concern, however table values often migrate to the upper theoretical limits of a particular type of irrigation system and therefore do not account for the specific site and management conditions needed to achieve that efficiency level. Still comparisons are useful for planning and evaluating options. An irrigation system comparison rating methodology that assigns “value” to certain system attributes and management flexibility ability is under development as a possible framework to improve irrigation system comparisons as an alternative to irrigation efficiency numbers.

Keywords. Irrigation systems, Irrigation Efficiency, Comparison Guidelines, Ratings

Introduction

ASAE S526.2, the Soil and Water Terminology Section of ASABE Standards, defines irrigation efficiency as “The ratio of the average depth of irrigation water that is beneficially used to the average depth of water applied, expressed as a percent. Beneficial uses include satisfying the soil water deficit and any leaching requirement to remove salts from the root zone.” The ASAE S526.2 definition for application efficiency (Ea) is “The ratio of the average depth of irrigation water infiltrated and stored in the root zone to the average depth of irrigation water applied, expressed as a percentage. Also referred to as AE.”

Irrigation Efficiency (Ei) is then more broadly defined than water application efficiency (Ea) in that irrigation water may have more uses than simply satisfying crop water requirements. Heermann et al, 1990, included in the list of potential beneficial uses of irrigation water as crop water use, salt-leaching, frost protection, crop cooling, and pesticide or fertilizer applications. For Kansas conditions, providing the crop water is the primary beneficial use. Chemical applications using the irrigation system and water are also a common practice but at a significantly less volume requirement and only occasionally would the water used to apply chemicals not be able to be stored in the crop root zone for future crop water use.

For practical purposes, in Kansas, irrigation efficiency and application efficiency are used interchangeably. Another short fall of applying efficiency definitions to field conditions is that irrigation efficiency is not a constant. There is considerable temporal and spatial variations that occur and not easily identifiable or measurable. In addition, the definitions assume the irrigation event to be of practical importance as pointed out in Keller and Bliesner, 2000; “…., Ea (the Classical Field Application Efficiency” gives no indication of the adequacy of irrigation and with exaggerated under irrigation, it can equal 100 percent.”

The USDA NRCS in the National Engineering Handbook (NEH, 1997) also defines various irrigation efficiency and uniformity terms, as described previously. The NRCS also has responsibilities to provide guidance design, review, and/or recommendations for various state and federal programs dealing with soil and water (irrigation) issues.

Kansas State Research and Extension Bulletin MF-2243, “Efficiency and Water Losses of Irrigation Systems” (Rogers et al, 1997), has a summary of many definitions associated with irrigation water distribution and also discusses the importance of distribution uniformity for irrigation water. It also discusses where water losses (relative to “beneficial” crop water use) can occur for various irrigation systems.

Ranges of application efficiency are noted for the general system types of surfaces, sprinkler, and microirrigation, rather than a single efficiency value.

In spite of the limitations and misunderstanding associated with “efficiency” related terms, they are still often used to compare irrigator systems. Comparisons of irrigation systems without regard to field and management conditions can result in unfair comparisons, illogical generalizations, poor economic choices, and unsound policies.

Assigning a single efficiency value to represent a general type or class of irrigation system lends itself to criticism. Usually the assignment of an efficiency value, the value assigned with “qualified” words such as “typical”, “potential”, “attainable”, “acceptable” or so forth and in qualified also with the assumption that the systems are managed with best management practices (BMP’s). BMP’s that can be utilized in a particular irrigated field is impacted by the irrigation system. No-till cultural practices, for example, are not compatible with furrow irrigation systems.

Irrigation efficiency tends to be associated with the in-season watering events. However, as declining well yield in the Ogallala Aquifer irrigated areas increase, limited and deficit irrigation practices become more important. Under these circumstances, the total water budget, including off-season precipitation usage, soil evaporation supervision with crop residue, and increased natural precipitation utilization become more importance. The ability of an irrigation system to perform well under those criteria is not adequately addressed by an irrigation efficiency term.

Irrigation System Comparative Rating

A possible way to improve the ability to compare irrigation system types would be to try to incorporate important BMP’s into the rating of a particular system type. In the following example, four comparison categories are used to rate general irrigation system types. The four comparison categories are: 1) irrigation efficiency, 2) the surface soil distribution, 3) soil evaporation and 4) scheduling (depth of application) control.

An example spreadsheet is shown in Figure 1 using the four adjustment factors and “assigned” adjustment values. If such a comparison system were developed further, the major system class could be expanded to the desired number of base systems. In the KS652.0605 State Supplement (for Kansas), Table KS6-1 has seventeen different base systems categorized by an “attainable farm efficiency”.

As mentioned previously, deficient irrigation systems, as do improved dryland cropping systems, conserve soil water by reducing soil disturbances (tillage). Three soil disturbance levels are shown as an example for this criteria. In this instance, the adjustment factor was determined by looking at the potential impact a water loss by soil tillage could have on a crop water budget of 24 inches. For example, a heavily tilled field may have losses of 4 inches. The adjustment factor assigned to represent this condition was calculated by dividing the crop water use (24) by the losses plus crop water use (24 + 4). If a no-till program was in use, the adjustment factor is “1”. Surface systems require tillage to maintain good furrows, while sprinklers and CP can easily handle no-till practice. Rodent habitat control using a light tillage pass is a potential recommended BMP practice for SDI systems, so a some water loss was used for this example.

Soil evaporation losses can very between system types. Most sprinkler and CP systems nozzles that result in the entire surface being wetted; surface systems may only wet a fraction of the soil surface, while SDI systems should have no surface wetting due to irrigation. To some extent, this issue is covered by the irrigation efficiency rating. However, in Kansas, even when irrigation is used, a significant portion of the crop water budget is supplied by in-season rainfall. This factor helps to account for differences in the soil surface conditions of the system types and their general receptivity to infiltrating rainfall.

The final scaling factor for the irrigation system comparison rating is termed scheduling control. It might also be termed depth of application control. SDI systems have very precise control over the application depth, with little loss of efficiency. Center pivots and other sprinkler systems can also apply very light applications but usually at a loss of “efficiency” since a fixed amount of each application is subject to rapid evaporation to the atmosphere from the wetted crop or soil surface. Surface systems typically do not have much flexibility in applying a light application. In the case of early season surface irrigation, when irrigation needs are the least, the heaviest application depth must be applied to fill up the furrows to allow the irrigation water advance. The last irrigation of the season may also be another opportunity for sprinkler and SDI systems to more closely match the remaining water need of a crop verses a larger minimum application depth required by a surface system.

The final comparison rating is made by multiplying the adjustment factors together to a amount less comparison number. A higher number would indicate an irrigation system advantage over a lower number irrigation system rating in terms of the system’s ability to utilize water, whether for irrigation or rainfall. In the case example, surface systems have a low rating as compared to sprinkler systems, which have a lower rating then center pivots and SDI. SDI systems have a slight comparative advantage over center pivots in this example.

Conclusion

Generalized comparison of irrigation systems is difficult because site specific conditions and the degree of management have major influences. However, comparisons based only on irrigation efficiency values have often been found to be inadequate and sometimes misleading. This paper discussed several comparison factors that might help establish or improve comparison methodology.

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Figure 1: Example irrigation system comparison rating using form comparison factors and assigned adjusting factors.

Major System Class		**Base Efficiency %**	
Surface Irrigation		65	
Sprinkler Irrigation (Non-pivot or linear)		70	
Center Pivot or Linear Move		85	
SDI		95	

Soil Profile Disturbance	**System Options**	**Calc. Adj. Factor**	**Total Water Budget:** 24
Disturbed Soil Profile	Surface	0.86	Disturbed soil water loss 4
Limited Soil Profile Disturbance	SDI	0.96	Limited soil water loss 1
Undisturbed Soil Profile (no till)	Sprinkler, CP	1.00	No till loss 0

Soil Evaporation		**Adjustment Factor**
High Losses (all surfaces wetted)	Sprinkler & CPs	0.9
Medium Losses (Soil wetted)	Surface	0.96
Low Losses (no surface wetting)	SDI	1

Scheduling Control		**Assigned Scaling**
Limited	Surface	0.8
Fair	Sprinkler (non-CP)	0.9
Good	CP	0.95
Precise	SDI	0.98

Major System Class	**Comparison Rating**
Surface Irrigation	38
Sprinkler Irrigation (non-pivot or linear)	57
Center Pivot or Linear Move	81
Micro-irrigation	89