HI for Irrigated Agriculture in the Southwest

IRRIGATION PRINCIPLES

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UC Center for Water Resources (http://www.waterresources.ucr.edu)
Nitrate Groundwater Pollution Hazard Index

Irrigation uniformity is an important irrigation management factor. Irrigation uniformity refers to how evenly water is distributed across the field. No irrigation is perfectly uniform. In all cases, some parts of the field receive more water than others. The degree of uniformity however, can be highly variable depending upon irrigation system and management. Non-uniform irrigation creates a major management tradeoff between maximizing crop production or minimizing potential ground water degradation. If a field is irrigated to achieve maximum production in the section receiving the least amount of water, the other parts of the field will be "over irrigated" creating much deep percolation from those sections of the field. In contrast, if the field is irrigated to avoid deep percolation on the section receiving the most water, the other parts of the field will be "under irrigated" leading to yield reduction. Achieving maximum yield without deep percolation is scientifically impossible with non-uniform irrigation.

Increasing irrigation efficiency (IE) is frequently cited as a positive goal, which can be misleading. One problem is that irrigation efficiency has different definitions. The most common (but not exclusive) definitions are the ratio of yield (Y) to applied water (AW) or the ratio of evapotranspiration (ET) to AW. Ambiguity exists with the term "applied water." Some define it as the amount of water delivered to the field and includes runoff from the field. Others subtract runoff and define applied water as the water that infiltrates the soil and is potentially available for crop use. Clearly a different irrigation efficiency number results depending upon which definition of applied water is used. For this particular discussion, we will define applied water as that which infiltrated the soil and irrigation efficiency as the ratio of ET to AW.

For non-uniform irrigation, 100% irrigation efficiency can be achieved by irrigating such that the water applied to the section of the field receiving most water does not exceed ET. This eliminates deep percolation from all parts of the field. The consequence is having reduced yield on much of the field. Therefore, high irrigation efficiency comes at the cost of production. This might still be considered as being efficient use of water. However, it is not efficient use of land. The land is not being used to its maximum productivity. Therefore, increasing irrigation efficiency is not always a positive goal and should not be promoted as such.

Clearly, irrigation efficiency numbers can be modified by changing the amount of applied water. A different approach is to improve irrigation uniformity. Higher yields (higher ET) and less deep percolation can be achieved for the same amount of applied water if the irrigation uniformity is increased. In this case, increase in irrigation efficiency is positive in every respect except possibly for the cost entailed in achieving the increased uniformity. From a technical point of view, increase in irrigation efficiency is not always a positive goal but increasing irrigation uniformity is. Therefore, we strongly urge the discontinuation of the term irrigation efficiency in the context of efficient resource utilization or potential ground water degradation.

Increasing irrigation uniformity is a positive goal. However, deficiencies exist in methods of measuring and reporting irrigation uniformity for different technologies. For simplicity, we will broadly classify irrigation technologies as furrow, sprinkler, or drip. Uniformity of furrow irrigation is determined by measuring the rate of water advance down the furrow. Since water is on the top end of the field longer than at the lower end of the field, the "opportunity" for water to infiltrate the soil decreases as it moves down the field. This creates a non-uniform distribution, which is associated with "opportunity time." Variations of soil properties that affect the infiltration rate across field, can also contribute to non-uniform irrigation. Non-uniformity associated with soil variability is not measured and therefore a significant source of non-uniformity, which could be as high as 50% of the total non-uniformity, is neglected in the computation. Allowing the water to flow longer after it has reached the end of the field can increase uniformity of irrigation associated with opportunity time. In other words, increasing the runoff contributes to increasing uniformity. This is one case where increasing uniformity may not be a positive effect in terms of chemical transport to ground water because the increased uniformity might come at the cost of increased deep percolation.

Placing containers in a geometric configuration and measuring the amount of water caught in each container typically measure uniformity of sprinkler irrigation systems. The amount of water collected in each container can be analyzed by various techniques to come up with a numerical value of irrigation uniformity. Wind greatly distorts sprinkler irrigation uniformity and thus complicates the evaluation. The results can be highly dependent upon the atmospheric conditions at the time of measurement. A further complicating factor related to sprinkler irrigation uniformity is that the numerical values can depend on the size of the containers used. In other words, distributing small containers usually results in a high computed degree of variability than distributing an equal number of larger sized containers. Note however that the "complete" extent of variability is captured by this technique during the time period of measurement.

Uniformity of drip irrigation systems is usually a combination of measuring the variability f emissions from individual emitters and pressure variations within the entire system. As with the sprinkler systems this method of measuring non-uniformity captures the entire degree of variability.

Comparison of measured uniformity for different irrigation technologies is misleading. Comparing a furrow irrigation uniformity value, which has a significant amount of non-uniformity missing, to sprinkler or drip where the full extent of non-uniformity is captured is not appropriate. Comparison of uniformity values within a given irrigation technology is reasonable. However, even in this case, comparison of computed furrow irrigation uniformity on one field to another field may be misleading if the soil variability on the two fields differs. The greatest utility of measuring uniformity of furrow systems is to guide the management on that particular field. Irrigation uniformity can be altered by length of furrow, rate of water application, and duration of irrigation. The management of a given furrow irrigation system can be materially enhanced by characterizing the uniformity.

Uniformity and the amount of water application are both important factors concerning ground water degradation. Both potentially contribute to the amount of deep percolation that transports chemicals. Sprinkler and drip irrigation systems have the advantage of allowing precise control on the amount of water applied by use of a valve. Furrow irrigation does not allow precise control on the amount of water that infiltrates the field, although it can be modified somewhat by duration of irrigation and other irrigation factors.

The performance of any irrigation technology is dependent upon appropriate design and management. A poorly designed and managed drip irrigation system with considerable pressure variation or clogged emitters can be very non-uniform. On the other hand, the potential for distributing the appropriate amount of water uniformity is greater for drip system than furrow. The potential for sprinkler system is highly dependent on wind factors.

The cost for drip systems is considerably higher than furrow. Unfortunately, water savings and/or higher yields do not always compensate the higher investment for drip system. Ground water degradation associated with agricultural production is usually external to the farmer's operation. If the cost of ground water degradation were internalized, the economics would provide an increased incentive for conversion of irrigation technology.