IMPROVEMENTS IN IRRIGATION EFFICIENCY

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INTRODUCTION

Efficiency is the name-of-the-game these days. We are constantly reminded that we must be more efficient with our time, our money, our skills, and our resources. Yet, the working definitions of the various efficiencies that each of us use may be quite different. Sometimes the correctness of the appropriate use of an efficiency term is entirely related to one's perspective. The topic of this presentation is irrigation, so let's look at two important efficiency terms in irrigation and look at how the terms interact.

WATER USE EFFICIENCY *(WUE)*

Water use efficiency *(WUE)* is typically defined as the crop yield divided by the amount of water used. Algebraically it can be expressed as

$$WUE = M_{crop} / V_{wuse} \qquad \text{Eq. 1.}$$

where M_{crop} is equal to the mass of the crop and V_{wuse} is equal to the volume of water used. It is easy to see that increases in WUE can be accomplished either by increases in M_{crop} <u>relative</u> to V_{wuse} or by decreases in V_{wuse} <u>relative</u> to M_{crop}. Whereas both techniques increase the beneficial use of water, only the second technique results in water conservation directly. It is important to note that manipulation of either term must be <u>relative</u> to the other term in the equation. Reducing water use is not beneficial if crop yield is reduced to the same extent.

WATER APPLICATION EFFICIENCY *(E_a)*

The water application efficiency (E_a) definition as reported by Heermann et al. (1990) is algebraically expressed as

$$E_a = V_{soil} / V_{field} \qquad \text{Eq. 2.}$$

where V_{soil} is equal to the volume of irrigation water needed for crop evapotranspiration to avoid undesirable water stress and V_{field} is equal to the volume of water delivered to the field. E_a is often incorrectly confused with the water storage efficiency which is the fraction of an irrigation amount stored in the remaining available crop root zone following an irrigation event. The use of water storage efficiency is discouraged by Heermann et al. (1990) because of the difficulty of determining the crop root zone and because the water storage efficiency can still be quite low while sufficient water is provided for crop production. It is easy to manipulate V_{field} so that E_a can be equal to 1 or 100%. It should be noted that any irrigation system from the worst to the best can be operated in a fashion to achieve 100% E_a if V_{field} is low. Increasing E_a in this manner totally ignores the need for irrigation uniformity. For E_a to have practical meaning, V_{soil} needs to be considered to avoid undesirable water stress.

INTERACTION OF WUE AND E_a

Algebraically it has been shown that either efficiency term can be maximized through manipulation of the various terms in the equations. However, some of these manipulations are not beneficial to the irrigator and perhaps, also not beneficial to the economic vitality of the state. Consideration of both terms is necessary to optimize beneficial use of water for crop production.

In a thorough review of crop yield response to water, Howell et al. (1990) enumerated four methods of increasing water use efficiency: 1) increasing the harvest index (ratio of crop economic yield to total dry matter production); 2) reducing the transpiration ratio (ratio of transpiration to dry matter production); 3) reducing the root dry matter amount and/or the yield threshold required to initiate the first increment of economic yield; or 4) increasing the transpiration component relative to the other water balance components, for example, through reductions of evaporation, drainage, and runoff.

Clearly, some of these four methods are more difficult than others. Tanner and Sinclair (1983) in a review of studies from the early 1900's to the 1980's conclude that there is very little hope for appreciably improving the transpiration ratio (Method 2). Some say that plant breeders and agronomists have made great strides in increasing the harvest index (Method 1) for many of the more important crops. Corn yields have increased an average of 2.5 bu/acre annually for the last 40 years in Thomas County, Kansas due to improvements in corn hybrids and cultural practices. The actual water used by the corn has not changed appreciably although the water use efficiency has increased. The yield threshold (Method 3) varies somewhat depending on the locale and the annual weather conditions. However, it does not appear practical that it can be manipulated to an appreciable extent. Improved irrigation systems and practices can increase both WUE and E_a by Method 4, increasing the transpiration component relative to the other water balance components.

Crop yield is linearly related to transpiration for many field crops from the point of the yield threshold through the point of maximum yield (Figure 1). However, the relationship of crop yield and total water use is usually curvilinear. The region between the dotted line and the curve represents the inefficiencies caused by the irrigation system and/or inappropriate irrigation/precipitation timing or amounts. Use of irrigation water beyond the point where the dotted line and the curve join at maximum yield represents wasteful overirrigation and should be eliminated immediately. All of the points on the rising dotted line have equal WUE, so all are equally beneficial in terms of WUE. However, most irrigators are practicing irrigation for the beneficial purpose of increasing crop yields and economically need to produce near the top of the rising leg. Lamm et al. (1993) analyzed 9 different resource allocation schemes for irrigated corn ranging from full irrigation to severely deficit irrigation. Full irrigation was found to be the most economical operating point. They concluded, *Irrigators wishing to continue to grow corn when irrigation is limited by physical (water supply) or institutional constraints should seriously consider reducing irrigated land area to match the severity of the constraint.*

Only reductions in the area between the dotted line and the curve (Figure 1) and obviously elimination of overirrigation should be considered as opportunities where improved irrigation systems and practices can increase WUE and E_a. Many irrigators are already upgrading irrigation systems and management of their present systems to *stretch* water. There are considerable opportunities for further water use reductions, but the ultimate reductions cannot be economically obtained overnight. The irrigation sector continues to search for economical ways to reduce inefficient water use in a manner that can optimize both WUE and E_a.

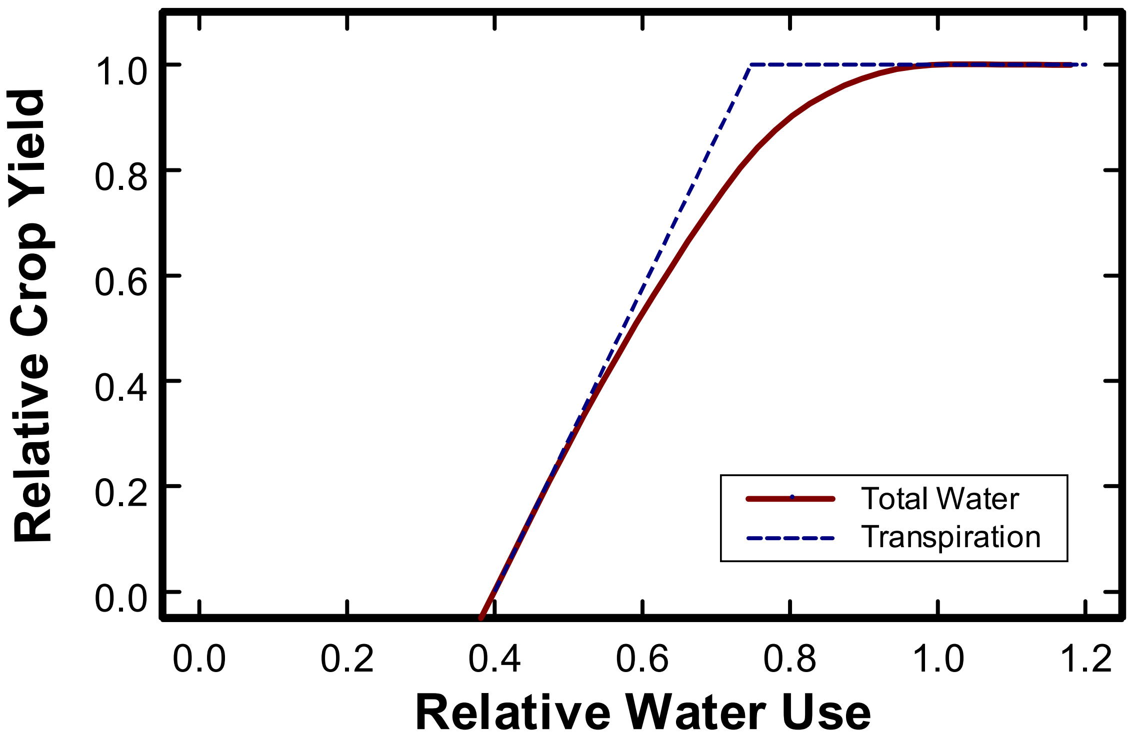

Figure 1. Hypothetical crop yield response to total water use and transpiration. Area between dotted line and curve is inefficiency. Use of irrigation water beyond where dotted line and curve rejoin (maximum crop yield) is wasteful overirrigation. Starting point for both lines is yield threshold. *Numbers shown for example only, actual values will vary.*

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Available at http://www.ksre.ksu.edu/irrigate/Reports/ImproveIrrEff.pdf