IMPROVING FLOOD IRRIGATION MANAGEMENT IN ALFALFA

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ABSTRACT

F Alfalfa is the largest water user crop in the state of California grown on approximately one million acres of irrigated land (USDA, 2006). Alfalfa is the dominant crop in the Imperial Valley where more than 120,000 acres of alfalfa are grown using flood (surface) irrigation systems. Alfalfa crop water requirement under surface irrigation systems is in excess of 6 acre-feet/acre per year. Almost 40% of this water is used during the summer season during which alfalfa evapotranspiration requirements are high due the extreme summer temperatures. Improvements in surface irrigation efficiency can be achieved by minimizing water losses associated with surface irrigation systems.

Key Words: alfalfa, irrigation, efficiency

INTRODUCTION

Forage crop production accounts for the majority of water use in several western states including California. Alfalfa is the largest water user in the state of California grown on over one million acre of irrigated land. Alfalfa production also dominates water use in the Imperial Valley as it is a perennial crop regularly planted on nearly 25% of the Valley irrigated acreage (Imperial County, 2009). In 2009, more approximately 120,000 acres of alfalfa were grown in the low desert region. In the low desert region of California, approximately 25-35% of applied irrigation water is used for the production of alfalfa. As competition for water resources intensifies, it is important to improve the efficiency of surface irrigation systems and have a better understanding of the water use associated with forage crop production in the region. A significant amount of water could be saved by the implementation of irrigation management practices to improve the efficiency of surface irrigation systems.

SURFACE IRRIGATION SYSTEMS EFFICIENCY MEASURES

The main objective of evaluating any irrigation system is to identify management practices that can be implemented to improve water use efficiency. Evaluating the performance of a surface irrigation system is often tedious and time consuming. Irrigation efficiency can be evaluated by several performance measures such as application efficiency (AE), application uniformity or distribution uniformity (DU), deep percolation ratio (DPR), and runoff ratio (ROR). The

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formulas that are commonly used to evaluate the efficiency of an irrigation system are defined below:

Water-Conveyance Efficiency (WCE)

WCE= 100*Wd/Wi

where Wd is water delivered by a distribution system and Wi is water introduced into the distribution system. Example of water losses in a distribution system: seepage and evaporation.

On-farm Efficiency Measures

Application Efficiency (AE)

AE=(Average depth of water added to the root zone)/(Average depth of applied water)

Distribution Uniformity (DU)

DU=(Average volume (or depth) of water stored in the lowest quarter of the field)/(Average volume (or depth) stored in soil profile)

Deep Percolation Ratio (DPR) and Runoff Ratio (ROR)

DPR=(Volume (or depth) of deep percolation)/(Volume (or depth) of applied water)

ROR=(Volume (or depth) of runoff)/(Volume (or depth) of applied water)

AE+DPR+ROR=100%

Irrigation Water Requirements (IR)

IR= Crop ET/AE

Example

If an average of 5 inches of water were applied to a field and if we assume 4 inches of water were stored in the root zone (based on crop water requirements for that period), any amount of water in excess of 4 inches is lost to deep percolation and/or runoff.

AE = 4/5 = 80%

Application efficiency refers to the ability of surface irrigation system to match crop water needs with the amount of applied water. Uniformity refers to the ability of the irrigation system to distribute the applied water throughout the field.

FLOOD IRRIGATION SYSTEM MANAGEMENT MEASURES

The advantage of flood irrigation system method is that it is inexpensive, both in terms of system costs and energy costs. The disadvantage is that its performance depends strongly on soil properties such as the infiltration rate and soil type. It is the most difficult irrigation method to manage efficiently because of its dependence on soil properties and its performance characteristics, and thus, a trial-and-error approach is normally used in its management.

Border or flood irrigation designs have several common features. They usually have slopes from 0.1% to 0.2% (1 to 2 ft per 1000 ft of run), include small 'border checks' (or small levies) 6-20" high, which confine water to an area from 10 to 200 feet wide so that water moves down the field. Field length in the direction of flow varies, but is usually determined by field constraints and soil characteristics. Sometimes flood systems are combined with 'corrugated' or 'bedded' systems which facilitate water movement and drainage on heavy soil.

Design variables for flood irrigation include slope, border length, border inflow rate, surface roughness, and infiltration rate. Recommended field lengths for various slopes, soil types and check The rate at which the water flows down the field depends on the inflow rate of water into the check, slope, length of the border check, soil infiltration rate, and surface roughness. The flow of water across the field is characterized by the advance curve, which shows the time at which water arrives at any given distance along the field length. The recession curve shows the time at which water no longer ponds on the soil surface at any given distance along the field length. The difference between advance time and recession time at any distance along the check length is the time during which water infiltrates the soil or the infiltration time (Fig. 1). These infiltration times vary along the field length, resulting in more water infiltrating in some parts of the field compared to other areas.

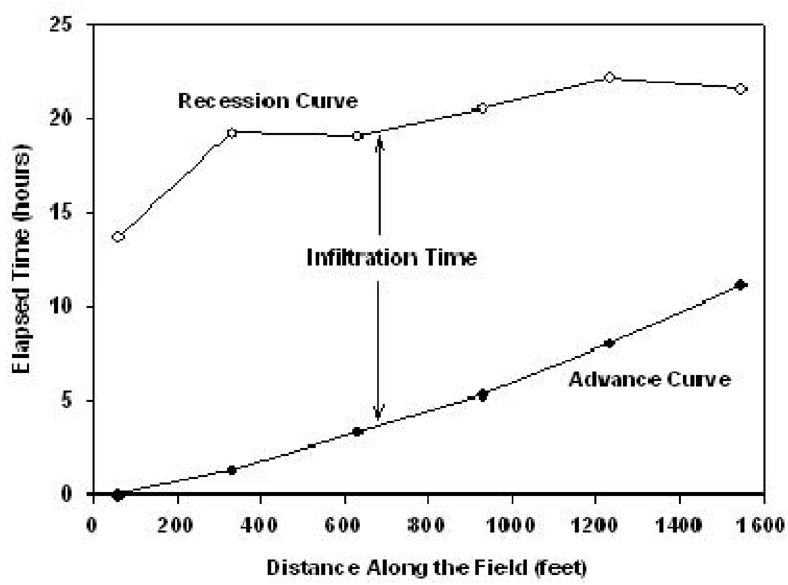

Figure 1. Advance and recession curves for a flood-irrigated field.

Improving Flood Irrigation Systems

Flood irrigation systems can be improved by reducing deep percolation below the root zone and reducing surface runoff. However, measures to improve flood irrigation can be competitive, i.e. measures that reduce deep percolation can increase surface runoff and vise versa. Some measures commonly recommended include the following:

Increasing check flow rate: This commonly recommended measure reduces the advance time to the end of the field, thus decreasing variability in infiltration times along the field length. However, caution should be exercised with this approach such that the increased flow rate does not increase soil erosion.

Reducing field length: This is the most effective measure for improving uniformity and for reducing percolation rate below the root zone. Studies have shown that shortening the field length by one-half can reduce percolation by at least 50 percent. The distribution uniformity (DU) of infiltrated water will be increased by 10 to 15 percentage points compared with the normal field length. The new advance time to the end of the shortened field generally will be 30 to 40 percent of the advance time to the end of the original field length. Thus, the irrigation set time must be reduced to account for the new set time. A major problem with the above measure is the potential for increased surface runoff, which could be 2 to 4 times more runoff for the reduced length compared with the original field length (Hanson, 1989).

Selecting an appropriate irrigation water cutoff time: The amount of surface runoff or tailwater can be greatly reduced by decreasing the cutoff time of the irrigation water. This is the most effective measure for reducing surface runoff. The cutoff time for a given field may need to be determined on a trial-and-error basis. The cutoff time should occur before the water reaches the end of the field except for sandy soils with high infiltration rates. However, the cutoff time should allow sufficient water to infiltrate the end of the field. Some guidelines, however, are to cut off the irrigation water when the water advance is about 60% of the field length for fine-textured soil, 70% to 80% for medium texture soil, and near 100% for coarse textured soil. Research in the Imperial Valley showed runoff to be about 2% of the infiltrated volume when the cutoff time occurred when the water advanced to about 70% of the field length in cracking clay soil (Grismer and Bali, 2001; Bali et al., 2001). A procedure for estimating the cutoff time for cracking clay soil has been developed by the University of California (Bali et al., 2001).

The effect of reducing the cutoff time on surface runoff is shown in Table 1, using data from evaluations of flood irrigation systems. The advance time to the end of this field was 670 minutes. A cutoff time of 800 minutes resulted in substantial surface runoff. Reducing the cutoff time to 600 minutes decreased the surface runoff by 82%, yet the infiltration time at the end of the field was adequate. However, a cutoff time of 500 minutes resulted in incomplete advance to the end of the field, and thus, no infiltration occurred at the end of the field. The effect of the decreasing cutoff times on the uniformity of infiltrated water was slight until cutoff times were much less than the advance time.

Table 7. Effect of cutoff time on applied water, surface runoff, and distribution uniformity (DU).

Cutoff Time (minutes)	Applied Water (inches)	Surface Runoff (inches)	DU (%)
800	12.8	2.8	89
700	12.1	1.6	87
600	11.2	0.5	82
550	10.7	0.06	78
500	9.8	0	62

Recover surface runoff: Recirculation systems (commonly called tailwater-return systems), or storage-reuse systems, can dramatically improve efficiency of flood irrigation systems. Recirculation systems involve collecting the surface runoff in a small reservoir at the lower end of the field and then recirculation the water back to the "head" of the field during irrigation, using a low lift pump and a buried or portable pipeline. The recirculated water should be used to irrigate an additional area of the field. Simply recirculating the runoff back to the same irrigation set that generated the runoff results only in temporarily storing the water on the field and will result in an increased rate of runoff.

Similarly, a storage/reuse system involves storing all of the surface runoff from a field and then using that water to irrigate another field at the appropriate time. This approach requires a farm with multiple fields, a relatively large reservoir, and distribution systems to convey surface runoff to the storage reservoir and to convey the stored water to the desired fields.

Care should be taken that water quality is not degraded from the storage-reuse systems. Pesticides have been found to infiltrate groundwater on some soil types, primarily from catchment basins, steps to seal basins from subsurface infiltration may be effective at preventing contamination.

CONCLUSION

Efficiency of surface irrigation systems can be improved by several practical measures. Improvements in surface irrigation efficiency can be achieved by minimizing water losses associated with surface irrigation systems. Most of water losses in surface irrigation systems can be reduced by managing surface runoff water. Irrigation cutoff time management practices could be used to reduce surface runoff and increase application efficiency.

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