SURFACE IRRIGATION EVALUATIONS UNDER CONVENTIONAL GATED PIPE IRRIGATION AND SURGE IRRIGATION[1]

Robert Schattin, Neysa A. Farris, Alan R. Mitchell

Abstract

On-farm field evaluations of conventional surface irrigation systems, and a surge irrigation system were performed by the Soil Conservation Service (SCS) and Oregon State University. The seven completed evaluations may be used to generalize the potential deep percolation resulting from surface irrigation as moderate (i.e. 2 inches per irrigation), although deep percolation may represent a substantial portion of overall water application (i.e. 30 to 50 percent). Some significant data measurement problems, particularly related to quantifying runoff, can make a greater reliance on this data difficult. The surge system evaluation presented a good opportunity to explore, on a commercial farm, this technology for the first time in Jefferson County.

Introduction

The objective was to evaluate on-farm conventional surface irrigation systems. These evaluations sought to quantify the extent of deep percolation from surface irrigation systems. A knowledge of deep percolation is important to quantify the potential leaching of nutrients into the vadose zone. Furthermore, a field evaluation of surface irrigation systems is important when determining proper surface irrigation design procedures.

Another objective was to evaluate improved surface irrigation systems technology, specifically surge-controlled surface irrigation systems. The principles of surge irrigation are described in another report on page 79. Two solar-powered Waterman Surge Irrigation control valves were evaluated for runoff, and irrigation efficiencies. This documentation of improved efficiencies may well lead to reduced deep percolation and subsequent agricultural loading of the vadose zone. Additionally, the SCS investigated Agricultural Research Service (ARS) design procedures for cablegation for on-farm use in Jefferson County.

Methods

Individual landowners, Mr. Don Boyle and Mr. Gary Harris, allowed data collection on their surface irrigated systems. The procedure used to evaluate deep percolation consisted of on-farm measurement of soil moisture before and after, total water applied, and runoff. Deep percolation was calculated as the unmeasured portion of the equation.

---

[1]This study was a cooperative effort of the USDA Soil Conservation Service, Oregon State University, and the Jefferson County Soil and Water Conservation District. It was supported by Oregon Department of Environmental Quality.

In general, the soil moisture measurement before and after irrigation was the highest quality data. Direct gravimetric soil sampling was used to evaluate the percent by weight, and a bulk density value of 1.25 Mg/m^3 was used to obtain percent by volume. This estimated bulk density corresponded well with SCS research values, and a modification of the estimated bulk density does not appreciably effect the subsequent computations.

Data collection of soil samples was very time consuming. An equally accurate result may have been obtained with fewer soil samples. Total soil moisture estimated in inches before and after is a function of the estimated root zone depth of the crop. For the purpose of this evaluation this was assumed to be 18 inches for garlic (Mr. Harris's field), and 24 inches for peppermint (Mr. Boyle's field). The assumption of a deeper root zone depth generally leads to less deep percolation calculated.

Direct gate measurements were made using a bucket and stopwatch. In general, a sampling of five to ten gates was made and multiplied by the total number of gates to calculate the amount of water being applied to a field. The computed water delivered to each row was in the 5.75 gal/min to 7.0 gal/min range. This corresponded well with typical system design values. Also the total gal/min serving a field was spot checked with the amount of water the landowner thought they were receiving and this check corresponded well. On some occasions the water delivered to an existing pipeline was estimated as the same as on the previous set for that field.

Runoff measurements were first tried using a cumulative flow meter placed at the end of the field. Shortly into trials these flow meters were found to plug up and proved unreliable. The Jefferson County Soil and Water Conservation District (SWCD) and SCS are pursuing design options to get full value out of these meters. A second limitation of the cumulative flow meters is the variability of head that they are subjected to. The initial runoff flows provided very little head and hence need a smaller meter. Subsequent runoff produced greater heads, corresponding flows, and the need for larger meters.

Runoff measurements were subsequently made using a V-notch corrugated weir. Several samples were taken at each measurement time and an average runoff per row multiplied by the number of rows showing runoff was used to calculate total runoff. These measurements were made periodically throughout the evaluations, and an average end area method was used to linearly interpolate between measurement points.

A general limitation to the runoff measurements was that they were not made after irrigation was discontinued. As a result, the attached summary table may tend to show less runoff than actually occurred, and a somewhat high computation of deep percolation. We decided to present the data as received with this note.

Overall direct gate measurements and runoff measurements were significantly complicated by dealing with an on-farm system. Lack of communication between landowners and data collectors sometimes resulted in missed measurements and/or unknown times of beginning and ending irrigation. To the extent possible, we have tried to screen the data provided based on reasonableness and with a thought to it's application. The data collectors and the irrigators who participated are to be commended for their efforts.

Surge Irrigation

Mr. Boyle agreed to allow data collection on his fields. Two sets were monitored under gated pipe irrigation systems controlled with solar powered surge valves. Different pre-programmed settings were tried throughout the season. A conventional gated pipe system was evaluated, directly adjacent to the surge sets, that had the same row spacing and length

Data collection methodology was the same as reported above. Many of the same problems, particularly related to runoff collection, were repeated during the surge systems analysis.

SCS performed an in-depth investigation of using ARS cablegation procedures on Mr. Dean Brooks' property. The conclusion was that the existing system of gated pipe irrigation did not readily lend itself to modification to cablegation. The cable plug is not designed to run through a gated pipe but rather an adjacent mainline. After analysis of Mr. Brooks' situation this retrofit to cablegation was not deemed cost effective. The SCS continues to look for an appropriate cablegation system candidate in Jefferson County and will pursue the use of local ASCS cost share dollars for its installation.

Results

Table 1 presents the data obtained during the conventional surface gated pipe irrigation evaluations. Some evaluations were not included in this summary because data omissions made final calculation impossible. A complete set of data and calculations is available for review at the SCS Bend Area Office.

The most conclusive statement, with respect to data quality, is that on several occasions the two irrigators began irrigation with relatively high available water contents. Also the irrigations were fairly uniform in their gross depths of application and were in line with average design values for Madras soils and approximately 50 to 60 percent efficiency. From recent laboratory data furnished by the Soil Survey Party Leader for the Upper Deschutes River Soil Survey, the estimated water content at field capacity of a Madras Loam is 31 percent by volume. From the data it is evident that this value was often exceeded following an irrigation. Soil moisture values greater than 31 percent may indicate a saturated soil held up by a relatively impervious layer underlying the shallow soils in the area. Hence, the relatively saturated soils may negatively affect crop production in addition to the implications of early watering on deep percolation and irrigation inefficiency.

A reasonable generalization is that the irrigation efficiencies were in the range of 30 to 45 percent without tail water recovery. A 10 to 20 percent increase in irrigation efficiency is expected with the installation of tail water recover systems. These values would further increase if a deeper rooting depth was assumed. Caution is required when extrapolating the limited test results to a larger area.

An estimate of deep percolation in the range of one to three inches per irrigation is reasonable. For the majority of the crops irrigated in Jefferson County this would approach four irrigations per season, or approximately eight inches of deep percolation. It is noted that this estimate of deep percolation is in the context of a natural precipitation zone of nine inches annually.

No correlation between length of run and irrigation efficiency is evident. This may be in part related to the moderately deep Madras Loam, which is estimated at 24 inches and is underlain by basalt. SCS computational procedures, based on uniformly deep soil, would estimate much higher deep percolation for the lengths of run analyzed.

Surge Irrigation

Table 2 presents the data obtained during the surge irrigation evaluation. Some evaluations were not included in this summary because data omissions made final calculation impossible. A complete set of data and calculations is available for review at the SCS Bend Area Office.

Efficiencies were shown to improve under the surge irrigation systems. Irrigation efficiencies in the range of 50 to 60 percent are reasonable to expect using the surge systems. Many more set times are possible than the ones tried. SCS will continue working with Mr. Boyle on improved surge valve use.

Again, the irrigations began with relatively wet soils. Due to the complexity of measuring runoff data by row, no estimates were made to indicate the relative amount of system inefficiencies allocated to deep percolation or runoff.

There is a clear difference between expected runoff under conventional (continuous) or surge systems. Actually, some of the highest rates of runoff were found under the surge systems. This is indicative of improper operation, as the main aim of the surge systems is to reduce runoff. The movement of water to the end of the row occurs much more quickly under the repetitive levels as shown on the graph. However if an individual surge level is on too long this can lead to excessive runoff. From the data we conclude that secondary surges on Mr. Boyle's fields should not exceed two hours. Often these surge times exceeded four hours.

Additional surge system data, would be useful to quantify the exact time that runoff begins. With one exception, no data during the initial two hours of surge were obtained. This information could be used to better design the surge durations.

The runoff data under surge irrigation will be used to refine the design of surge duration next year as the SCS continues to work with Mr. Boyle.

Conclusion

The seven evaluations do not provide adequately sufficient data to be applicable to Jefferson County as a whole. The evaluations may be used to generalize the potential deep percolation resulting from surface irrigation as moderate (i.e. 2 inches per irrigation), although deep percolation may represent a substantial portion of overall water application (i.e. 30 to 50 percent). Some significant data measurement problems, particularly related to quantifying runoff, make a greater reliance on this data difficult. Also the limited number of evaluations performed must be considered when reviewing this data. For the irrigations evaluated, irrigation water management may be the single most effective irrigation system improvement. For the evaluations, the lowest initial soil moisture resulted in irrigation efficiency approaching 75 percent and was often in the 90 percent range.

The solar-powered surge irrigation valves improved overall irrigation efficiencies compared to the results obtained under conventional gated pipe irrigation systems. The measurements of runoff were insufficient to allocate system inefficiencies to either deep percolation or runoff. This runoff data indicates the surge durations may have been too long. The data collectors encountered many of the same runoff measurement problems reported earlier, although these were further complicated by the fact that many more periods, the on and off surges, existed during an irrigation. Since some superior irrigation efficiencies were obtained with the surge valve it is warranted to continue their evaluation in Jefferson County, with particular attention paid to the surge cycle time. At this time a wholesale recommendation to adopt surge irrigation technology in Jefferson County can not be made.

Recommendations

The on-farm evaluation of surface irrigation systems in Jefferson County represented a real challenge to the SCS and OSU team. A great deal was learned relative to flow measurement, coordination with landowners, the need for detailed soil sampling, and measurement of flows on-farm. It is recommended that SCS and the SWCD continue to monitor, on a regular basis, at least two irrigators per year to fully develop the skill to monitor real on-farm situations.

A shortcoming of this past year's evaluation was the limited time and money spent. Improvements, particularly related to flow measurement, would likely mean some trial structural measures. Additionally, the time required to fully monitor a 24 hour irrigation set (and be out there every hour) is significant. To be most useful, future evaluations need to focus more carefully on the time and equipment needed.

The most obvious focus for future SCS program activity may be irrigation scheduling, followed by tailwater recovery systems, and then followed by system conversion, e.g. shortening of run lengths.

Table 1. Field efficiency test for conventional surface, gated pipe irrigation systems, Madras, OR 1993.

FIELD	Acres	Length of Run Ft.	Soil	Crop
Harris - S2	7.21	1086	Madras Loam	bluegrass
Harris - S4	3.85	617	"	garlic
Boyle - Cont.	3.53	1280	,,	peppermint

IRRIGATIONS

H-S2-I1	Harris Set 2 Irrig.	B-CO-Il	Boyle Continuous Irrig. #1
H-S2-I2	Harris Set 2 Irrig.	B-CO-I2	Boyle Continuous Irrig. #2
H-S4-I1	Harris Set 4 Irrig.	B-CO-IS	Boyle Continuous Irrig. #5
H-S4-I2	Harris Set 4 Irrig.		

Event	Gross Appl.	Water Content* before	Water Content* after	Crop depleted	Field efficiency**	Runoff (est.)***	Deep Percolation
	--in--	--percent--		--in--	-percent-	--in--	--in--
H-S2-I1	5.3	27.3	35.3	1.4	27-37	1.5	2.3
H-S2-12	2.7	27.3	32.6	0.9	35-39	0.8	1.0
H-S4-I1	4.2	22.4	32.1	1.7	42-50	1.6	0.8
11-54-12	3.1	28.3	30.3	1.1	35-99	2.2	0.0
B-CO-Il	4.8	30.1	32.7	0.6	13-17	1.2	2.9
B-CO-I2	3.8	22.5	26.0	0.8	21-29	1.0	2.1
B-CO-I5	4.1	33.1	33.0	0.0	0-0	0.7	3.4

* From recent laboratory data of the Upper Deschutes River Soil Survey (not yet published) the Madras loam volummetric water content at field capacity is 31 percent.
** Field efficiency - the first value is efficiency assuming no collection of tail water, the second value assumes efficiency assuming 100 percent tail water recovery.
*** Some data collection discrepancies were found in the above sampling. Refer to the complete report before using this data.

Table 2. Field efficiency test for the surge irrigation system, Madras, OR, 1993.

FIELD	Acres	Run Length Ft.	Soil	Crop
Boyle - Continuous	3.53	1280	Madras Loam	Peppermint
Boyle - North Surge	7.1	1280	Madras Loam	t,
Boyle - South Surge	7.1	1280	Madras Loam	"

Field-irrigation

BO-NS-I1	Boyle North Surge Irrigation #1
BO-NS-I2	Boyle North Surge Irrigation #2
BO-NS-I5	Boyle North Surge Irrigation #5
BO-SS-I1	Boyle South Surge Irrigation #1

Event	Gross Appl.	Water Content* before	Water Content* after	Crop depleted	Field efficiency**	Runoff (est.)***	Deep Percolation
	--in--	----percent----		--in--	-percent-	--in--	--in--
BO-NS-I1	1.7	28.80	33.70	1.2	68.0		
BO-NS-I2	2.1	22.94	27.38	1.1	50.4		
BO-NS-I5	2.3	31.28	35.57	0.9	38.0		
BO-SS-I1	3.4	23.45	31.39	1.4	42.0		

* From recent laboratory data of the Upper Deschutes River Soil Survey (not yet published) the Madras loam volummetric water content at field capacity is 31 percent.
** Some data collection discrepancies were found in the above sampling. Refer to the complete report before using this data.
***Insufficient data was collected during surge trials to accurately allocate system inefficiency due to runoff or deep percolation components.