FURROW IRRIGATION

Harry L. Manges
Professor Emeritus, Department of Biological and Agricultural Engineering
Kansas State University
Manhattan, Kansas 66506-2906

INTRODUCTION

Water is conveyed over the land surface to the point of infiltration in furrow irrigation. Irrigation is accomplished as water flowing down or ponded in furrows infiltrates into the soil profile. The driving force for infiltration into the wetted area is gravity. After the water has entered the soil, it is redistributed by forces other than gravity such as capillary forces.

In conventional furrow irrigation, water is delivered to the head end of the furrow continuously during an irrigation. When water reaches the lower end of the furrow, infiltration has just begun at that point but has progressed to some depth at the upper end (Figure 1). As irrigation continues to refill the soil water reservoir, runoff occurs.

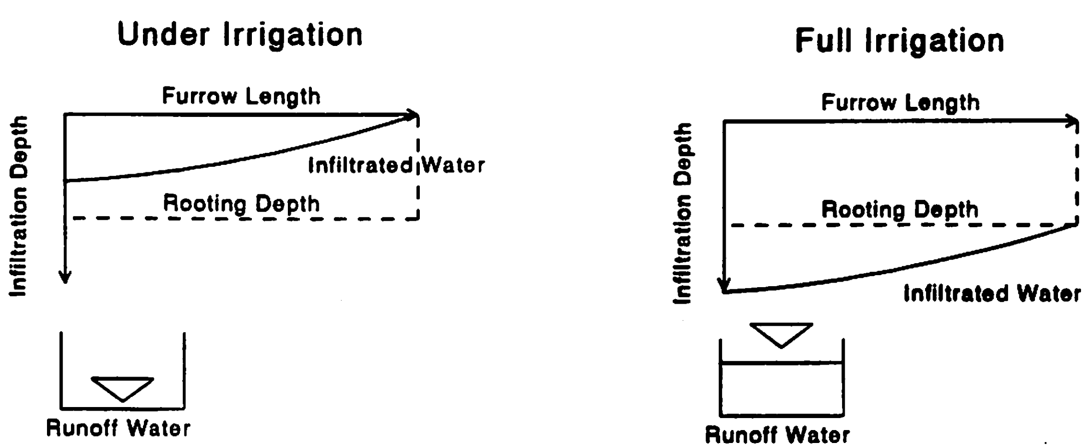

Figure 1. Typical results of furrow irrigation.

The volume of runoff depends on how complete the soil moisture deficit in the crop root zone is satisfied (Figure 1). For efficient water application at full irrigation, either the runoff water is caught and utilized by a tailwater reuse system or runoff is minimized by some management technique such as surge irrigation or cutback irrigation. This paper assumes continuous inflow to a furrow throughout an irrigation event, unless otherwise specified, with runoff recycled through a tailwater reuse system.

INFILTRATION

Infiltration is the movement of water into the soil. Conditions at the surface control the rate water enters the soil during an irrigation and affects the rate flow advances down a furrow. For a given inflow rate, advance rate is low on soils with a high infiltration rate because depth of water causing flow is low. Conversely, advance rate is high where infiltration rate is low.

Infiltration rate is high when irrigation is initiated and decreases with time, approaching a constant rate referred to as the basic infiltration rate. The numerical value of the SCS intake family is this basic infiltration rate in in/hr.

Infiltration is a complex process dependent not only on soil properties but also on other factors including initial soil moisture content, previous wetting history, cultivation practices, freezing and thawing during winter, and irrigation practices such as surge irrigation.

Infiltration of water into a dry soil is very rapid, especially in those soils with a high enough clay content to crack on drying. Wet soils have a low initial infiltration rate and the basic infiltration rate is reached soon after irrigation begins. Rainfall or an irrigation smooths and compacts the soil surface. Infiltration rate is reduced for irrigations subsequent to either of these events.

Tilling tends to reduce the density of the soil leading to an increase in infiltration rate. Smoothing and compacting the soil surface will reduce infiltration rate. Minimum tillage practices which leave considerable quantities of crop residues on the soil surface will lead to increased infiltration rates. Freezing and thawing during winter will help build favorable soil structure with the same effects on infiltration rate as tillage and minimum tillage practices.

Surge irrigation is a practice which often increases the rate of advance down a furrow and decreases infiltration rate.

TAILWATER REUSE SYSTEMS

Runoff results if the soil water reservoir is refilled during irrigation by graded furrows with continuous inflow to the furrows. Legislation prohibits the discharge of runoff from irrigation into drainageways at the farm boundary in most areas where water is pumped from an underground aquifer. A tailwater reuse system will recycle the runoff water and with good management result in a water-application efficiency of 85% (Soil Conservation Service, 1985).

A typical tailwater reuse system consists of a drainage ditch, an earthen tailwater reservoir, a pump, and a pipeline. Runoff is collected in the drainage ditch and carried to the tailwater reservoir for temporary storage. The pump delivers water from the tailwater reservoir through the pipeline back to the field where runoff is generated or to another field.

Alternative types of tailwater reuse systems include continuous pump, intermittent pump, rainfall and tailwater storage, and cycling sump (Hay and Pope, 1977).

Continuous Pump System

The system utilizes a reservoir with a storage capacity equal to 1 day's runoff from irrigation. Pumping is continuous with few interruptions and water is normally delivered back to the field where it is generated. Furrows are irrigated with water from both the irrigation pump and the tailwater pump. Management is easy compared to a system with a more erratic pumping rate.

Intermittent Pump System

The tailwater reservoir has a large enough volume to hold the runoff from multiple irrigations over several days. Water is stored until a complete irrigation set can be watered with runoff from irrigation. A tailwater pump with a greater pumping rate than for a continuous pump system is required. This system is suited to sites where the irrigation runoff from one field is used to irrigate another field.

Rainfall and Tailwater Storage System

A storage reservoir is built to hold both irrigation runoff and runoff from rainfall. This type of system is best adapted to areas with small capacity irrigation wells and large watershed areas with significant runoff from rainfall.

Cycling Sump System

A small sump, usually a vertical concrete or steel tube 48 inches in diameter, serves as the reservoir. Operation of the pump is automatically controlled by a water level switch. The pump must be capable of pumping the highest rate of runoff as the storage volume is small. The runoff water is pumped back into the irrigation stream giving an erratic rate of flow to the furrows. This type of system is an economical way to control runoff where the volume of runoff is small or the value of land is high and it isn't desirable to construct a larger reservoir.

Harvesting Rainfall Runoff

All reservoirs in tailwater reuse systems will collect runoff from rainfall in addition to runoff from irrigation. Volume of rainfall runoff collected and utilized for irrigation is highly dependent on reservoir size. Mao (1977) and Manges and Mao (1978) have reported the results of a study on sizing tailwater reservoirs for utilizing runoff from rainfall. A tailwater management model for a continuous pump system was developed to predict volume of runoff from rainfall on irrigated land and the portion of the rainfall runoff that could be utilized in irrigation. Predictions were made for corn grown on SCS intake families 0.3 and 0.5 soils at Garden City and Larned for a 25-year period (1949-1973). Criteria for pumping from the tailwater reservoir included 1) pumping would take place only when the reservoir was full, 2) the soil could hold the water applied, 3) climatic conditions allowed for irrigation, and 4) irrigation water-application efficiency was 85%. Table 1 gives average annual rainfall runoff and the amount utilized for irrigation with various sizes of reservoirs. Average annual runoff from rainfall was higher at Larned than at Garden City because of it's higher average annual rainfall, 24.35 inches at Larned and 18.61 inches at Garden City. Volume of rainfall runoff utilized for irrigation increases as reservoir size increases. Using 1977 prices, it wasn't economically feasible to build a reservoir larger than that required to hold 1 day's runoff from irrigation.

Table 1. Annual Runoff Produced and Utilized for Various Reservoir Sizes for Different Locations and Soil Types.

Reservoir Size		IV[1]	2V	3V	4V	5V
		Garden City, SCS Intake Family 0.5				
Reservoir Volume	ac-in	13.15	26.61	40.00	53.37	67.15
Runoff Produced	in	1.55	1.55	1.55	1.55	1.56
Runoff Utilized	in	0.42	0.69	0.87	1.01	1.12
Runoff Utilized	%	27.00	44.50	56.10	65.20	71.80
		Larned, SCS Intake Family 0.5				
Reservoir Volume	ac-in	13.15	26.61	40.00	53.37	67.15
Runoff Produced	in	2.46	2.46	2.47	2.48	2.50
Runoff Utilized	in	0.60	0.98	1.23	1.44	1.60
Runoff Utilized	%	24.40	40.00	49.80	58.00	64.00
		Garden City, SCS Intake Family 0.3				
Reservoir Volume	ac-in	17.49	35.41	53.37	71.83	89.46
Runoff Produced	in	2.67	2.68	2.70	2.72	2.72
Runoff Utilized	in	0.70	1.17	1.48	1.70	1.88
Runoff Utilized	%	26.20	43.60	54.80	62.50	69.10
		Larned, SCS Intake Family 0.3				
Reservoir Volume	ac-in	17.49	35.41	53.37	71.83	89.46
Runoff Produced	in	4.10	4.12	4.13	4.15	4.17
Runoff Utilized	in	1.07	1.74	2.18	2.53	2.79
Runoff Utilized	%	26.10	42.20	52.80	61.00	66.90

1-V is the volume for 1 day's runoff from irrigation.

Alternative Tailwater Reservoirs

Manges (1987) proposed replacing the drainage ditch in a tailwater reuse system with an underground drainline to reduce water losses and minimize waterlogging and subsequent crop losses. For a continuous pump system, annual cost of the drainline was 5 to 7 times the savings in energy costs for pumping irrigation water. Drainline costs can be reduced by the use of surge irrigation which would reduce peak runoff rate and thereby the size of the drainline required.

Earthen tailwater reservoirs remove land from cultivation and lead to seepage and evaporation losses. They interfere with farming operations and harbor weeds and insects. Manges et al. (1993) suggested replacing the drainage ditch and tailwater reservoir with an underground drainline. The drainline would carry runoff water to the tailwater pump while serving as a storage reservoir. Drainline diameter would be minimized through the use of surge irrigation to keep runoff from irrigation to a minimum. Replacement of drainage ditches and earthen tailwater reservoirs with an underground drainline and a sump may make use of tailwater reuse systems more attractive to farmers.

SUMMARY

In furrow irrigation, water is conveyed over the land surface to the point of infiltration. Rate of infiltration is controlled by soil properties as well as initial soil moisture content, previous wetting history, cultivation practices, freezing and thawing during winter, and irrigation practices. Various types of tailwater reuse systems operated in conjunction with the furrow irrigation system can lead to water-application efficiencies of 85%. All tailwater systems will trap runoff from rainfall which will reduce the need for irrigation water. The volume of irrigation water saved will depend on the size of the tailwater reservoir. A continuous pump system with a reservoir capacity of 1 day's runoff from irrigation can utilize an average of 0.42 and 0.60 inches of rainfall runoff annually for SCS intake family 0.5 soil at Garden City and Larned, respectively. For SCS intake family 0.3 soil, an average of 0.70 and 1.07 inches of rainfall runoff can be utilized annually at Garden City and Larned, respectively. Larger volumes of rainfall runoff can be utilized by building large tailwater reservoirs. Utilization of rainfall runoff will reduce the volume of water pumped from the underground aquifer. Tailwater reuse systems may be made more acceptable to farmers if drainage ditches and earthen reservoirs can be replaced by a buried pipeline.

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