MANAGING FURROW IRRIGATION SYSTEMS

Dean E. Eisenhauer, Associate Professor
University of Nebraska, Department of Biological Systems Engineering

David L. Varner, Extension Agent, Lancaster County

C. Dean Yonts, Extension Irrigation Engineer
University of Nebraska Panhandle Research and Extension Center

Wayne Liesemeyer, State Irrigation Engineer, Soil Conservation Service

Summary: Proper furrow irrigation practices can minimize water application, irrigation costs, and chemical leaching, and can result in higher crop yields.

Irrigating the entire field as quickly as possible is often the goal of a furrow irrigator. In many situations, irrigators are satisfied just to get the water to the end of the furrows, but consideration should be given to how much water is being applied and how it is distributed.

The number of gates opened or tubes set, the set size, has a significant impact on how fast the water advances across the field and the amount of water being applied. Set size should change during the season and between years to match changing soil intake conditions. Operating too few gates or tubes and using a long set time can result in a large amount of runoff. On the other hand, operating too many gates or tubes can result in slow water advance along the furrow and can cause poor distribution of water and deep percolation losses (Figure 1a). Both of these conditions result in reduced irrigation efficiency.

Efficient irrigation is obtained by almost filling the effective crop root zone each irrigation, applying water uniformly (Figure 1b), and by either minimizing or utilizing run-off. For furrows, runoff and the uniformity of the water infiltrated along the furrow are related to soil intake rate and the irrigator's management practices.

EVALUATING AND CHANGING CURRENT PRACTICES

The correct amount of water to apply at each irrigation depends upon the amount of soil water used by the plants between irrigations, the water-holding capacity of the soil, and depth of the crop roots. The rate at which water goes into the soil varies from season to season and from one irrigation to the next during the season. One common problem in furrow irrigation is that too much water is applied, especially during the first irrigation.

In general, you should apply water when about one-half of the available water capacity in the root zone has been used by the crop. When water is applied, don't completely fill or overfill the root zone. Overfilling the root zone leaches chemicals, such as nitrate-nitrogen; wastes water; and increases costs. Leave room in the soil for storing about one-half to one inch of rainfall that might occur soon after you irrigate.

Corn is furrowed for irrigation when it is about 24 to 30 inches high. At this stage of growth the roots have penetrated about 18 to 24 inches into the soil, so irrigation water should not be applied deeper than 18 inches. During a normal season in Nebraska, precipitation has replenished the soil profile below this depth and additional moisture is not needed for plant development. Usually, on medium-textured soils, 1.5 to 2.0 inches of water is all that is necessary to replenish the soil moisture in the top 18 to 24 inches of soil.

To evaluate present practices, you must estimate the gross depth and uniformity of application. The gross depth of water being applied can be figured as follows:

Stream size (gpm per furrow) = Pump discharge (gallons per minute) ÷ set size (number of furrows)

Gross depth of water applied (in) = 1155 x Stream size x Hours water applied ÷ Length of furrow (ft) ÷ Distance between furrows (in)

<u>Example</u>: Pump producing 750 gallons per minute (gpm)
Set size (number of furrows) = 100
750 gpm ÷ 100 = 7.5 gpm stream size
Water is applied for 12 hours
Rows are 1320 feet long
Distance between watered furrows is 30 inches
Gross depth applied = 1155 x 7.5 x 12 ÷ 1320 ÷ 30 = 2.6 inches

Knowing this information will allow you to make better management decisions and improve the overall performance of your irrigation system. In general, to avoid completely refilling the root zone, gross application amounts of water on sandy textured soils should not exceed 1.5 to 2 inches and should not exceed 2.5 to 3 inches on medium to fine textured soils.

Applying the right amount of water to your irrigation set is necessary for, but does not guarantee, efficient irrigation. Water must also be uniformly applied from one end of the irrigation run (field) to the other. Crop yields can be reduced on both ends of the field if one end receives too much water and the other end receives too little water.

Set Time-Stream Size

Select a stream size appropriate for the slope, intake rate, and length of run. Runoff and the uniformity of water infiltrated along the furrow are related to the cutoff ratio, CR. CR is defined here as the ratio of the time required for water advance to the end of the furrow to the total set time used for the irrigation. A CR of 0.5 is desired. For example, for a 12-hour set time, the advance time should be about 6 hours. The easiest way to change the advance time is by altering the furrow stream size, i.e. by changing the size of the irrigation set. This will affect the CR and hence the uniformity of water application.

When selecting the furrow stream size, consider furrow erosion. Use a furrow stream that does not cause serious erosion. In general, the maximum nonerosive stream size decreases as furrow slope increases. The stream size selected should be less than the value given in Table 1, but still large enough to obtain relatively uniform water application. With the proper CR and gross application, you can achieve uniform water application, minimize deep percolation, and minimize runoff. Try different combinations of furrow stream size and set-time. The best combination is the one which moves water to the end of the furrow within the requirements of the cutoff ratio, is less than the maximum erosive stream size, and results in gross applications that are not excessive.

Example:

Current Situation

System flow = 760 gpm
80 gates opened
Set time = 24 hours
Advance time = 18 hours (from observation)
Furrow stream size = 9.5 gpm/furrow (760 ÷ 80)
Furrow length = 2600 feet
Furrow spacing (distance between watered furrows) = 30 inches
Soil = silt loam
Current cutoff ratio = 0.75
i.e. 18 ÷ 24

As mentioned above, two items need to be evaluated. First, the cutoff ratio is too high and should be reduced from 0.75 to 0.50. Secondly, the gross water applied is:

$$\textit{Gross depth applied} = \frac{1155 \times 9.5 \times 24}{2600 \times 30}$$

$$= 3.4 \textit{ inches}$$

So, in addition to the cutoff ratio being too large, the gross depth applied is slightly excessive. One way of reducing the gross application is to reduce set time. In this example, we will increase the rate of advance by increasing the furrow stream size and decrease gross water applied by reducing the set time to 12 hours. Use Figure 2 to determine the number of furrows to irrigate for different advance times.

Recommended Changes:	Current Example	Your Example
Desired cutoff ratio =	0.50	_____
Thus, new advance time = i.e. (0.5 x 12)	6 hrs.	_____
Time Ratio = new time ÷ old time = 6 ÷ 18 =	0.33	_____
From Fig. 2 find furrow ratio =	0.58	_____
New number of gates = old number of gates x furrow ratio = 80 x 0.58 =	46	_____
New furrow stream size rate = 760 ÷ 46 =	16.5 gpm	_____
New gross depth applied = 1155 x 16.5 x 12 ÷ 2600 ÷ 30 =	2.9 inches	_____

For silt loam soils, 2.9 inches gross depth is within the allowable range. Also, if the furrow slope is less than 0.75%, the 16.5 gpm stream size is within the non-erosive limits. In this example, we have demonstrated how to improve the uniformity of irrigation by reducing the cutoff ratio and how the gross depth of application can be reduced by reducing the irrigation set time.

Length of Run

Irrigation runs which are too long result in water being lost by deep percolation at the head of the furrow by the time the lower end is adequately irrigated.

The length of irrigation runs should not exceed 600 feet on sandy soils and about 1300 feet on clay soils. However, on some low intake rate soils, the length of run may be as long as 2600 feet and the operator will still be able to distribute the water uniformly between the upper and lower end of the field.

The time required for advance increases dramatically with furrow length. This is illustrated for an example furrow in Figure 3. Here, the time to advance water 2600 feet is 3 times longer than the time for 1300 feet. Thus, if you have a problem getting rows through in a reasonable length of time (as determined by the cutoff ratio) and you are using the maximum allowable nonerosive stream size, shortening the row length is an alternative for reducing advance time.

Intake Rates

The rate at which water penetrates into the soil varies with the steepness of slope, soil texture, spacing of furrows, and soil compaction. The rate at which soil will absorb water varies with time. At first, water will penetrate into the soil rapidly but within one or two hours it will decrease to a rate which stays relatively consistent for the remainder of the irrigation. This fairly consistent rate is called "basic intake rate." In general if the basic intake rate is 0.5 inches per hour or less, the length of run can be at least 1300 feet long. Higher intake rates require shorter length of water runs.

EVERY OTHER FURROW IRRIGATION

When irrigation is required it becomes important to irrigate the entire field as quickly as possible. Irrigating every other furrow will supply water to one side of each row. The result is applying water to more acres than irrigating every furrow from a given water source in a given time. Irrigating every other furrow is often beneficial on soils with high infiltration rates and low water-holding capacities.

Often, irrigators encounter higher soil intake rates during the first irrigation. This can result in applying more water during the first irrigation than in subsequent irrigations and requires more hours to irrigate a field from a given water supply.

Another consideration is the ability to store rainfall in a soil that was recently irrigated. If the water has been applied to every furrow, the entire root zone may have been refilled to field capacity prior to rainfall. Irrigating every other furrow and applying less water per irrigation may provide more storage space within the root zone for the added rainfall.

Figure 4 shows the lateral and downward infiltration of water for two soil types where every other furrow is irrigated. When the watered furrow spacing is too wide, there will be a dry area in between the furrows and the crop may not get enough water. The distance between watered furrows should never exceed 6 feet.

Research indicates that every other furrow irrigated field yields compare very closely to every furrow irrigation. Table 2 shows corn yields on various soil textures when irrigating every furrow and every other furrow with a manually operated surface irrigation system with 12 hour irrigation sets.

Irrigation water application may be reduced 20 to 30 percent by implementing every other furrow irrigation. Infiltration is not reduced by one-half compared to watering every furrow due to more lateral infiltration when using the every other furrow irrigation.

Plant nutrient availability may be hindered in the dry rows when irrigating every other furrow. This is expecially important in dryer years. To improve the availability of these nutrients, the irrigator can alternate the wet and dry furrows for each irrigation.

Every other furrow irrigation should not be used on steep slopes or on soils with low intake rates. On steep slopes, the water flowing down the furrow is in contact with only a limited amount of soil surface, causing low intake rates.

REUSE

Recirculating irrigation runoff water is a method of making more effective use of irrigation water and labor. Reuse of runoff water decreases the amount of water that needs to be pumped or delivered and can be used to improve water application efficiencies by approximately 20 percent.

Reuse systems are essential for efficient surface irrigation. Growers who don't have reuse systems often cut the stream size in the furrow to a very small flow in order to minimize runoff. Again, an uneven water distribution pattern can result.

The economic value of runoff water will often be the deciding factor in installing a reuse system. However, irrigation runoff is prohibited by law in Nebraska. Reuse of irrigation runoff water often is more feasible than the use of additional labor to accomplish efficient irrigation and yet prohibit runoff.

OTHER MANAGEMENT PRACTICES FOR FURROW IRRIGATION

A relatively new technique for managing furrow irrigation is called surge flow irrigation. With this technique, water is applied intermittently, through the use of an automatic valve, rather than continuously to the irrigation furrows. This method frequently reduces both runoff and water infiltration. For more information, see NebGuide G90-___.

Irrigation scheduling is always important for good water management. With furrow irrigation, it is particularly useful so that irrigations are not started too early. Irrigating too soon leads to deep percolation losses due to infiltrated depths that exceed the soil moisture deficits. The following two NebGuides provide useful information for properly timing water applications: G85-753, Irrigation Scheduling Using Crop Water Use Data; and G84-690, Estimating Soil Moisture by Appearance and Feel.

Table 1. Maximum furrow stream to minimize erosion for various slopes (from the Soil Conservation Service).

Slope (%)	Stream Size (gpm)
0.20	50.0
0.40	30.0
0.75	17.0
1.25	10.0

Table 2. Corn yields on various soil textures when irrigating every furrow and every other furrow with a manually operated surface irrigation system with 12-hr. irrigation sets.

Soil	Every furrow	Every-other furrow (same)	Every-other furrow (alternate)
	----------	bu/acre	----------
Albaton - clay loam	157	154	----
Luton - silty clay loam	152	159	----
Crete - silty clay loam	153	156	----
Holdrege - silt loam	179	177	174
Sarpy - sandy loam	140	143	----
Ortello - loamy sand	118	119	120
O'Neill - loamy sand	114	107	----

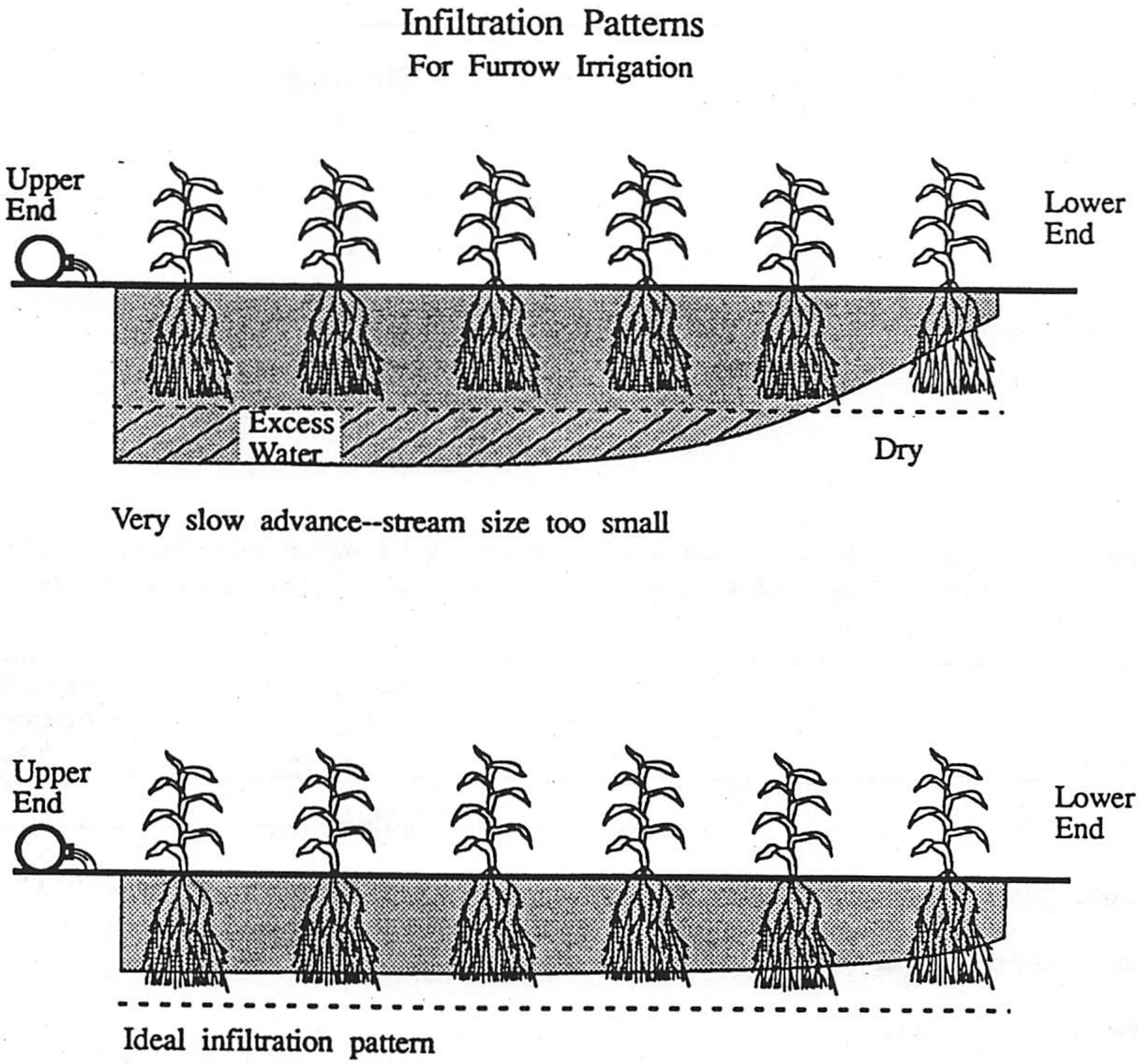

Figure 1. Infiltration patterns with furrow irrigation.

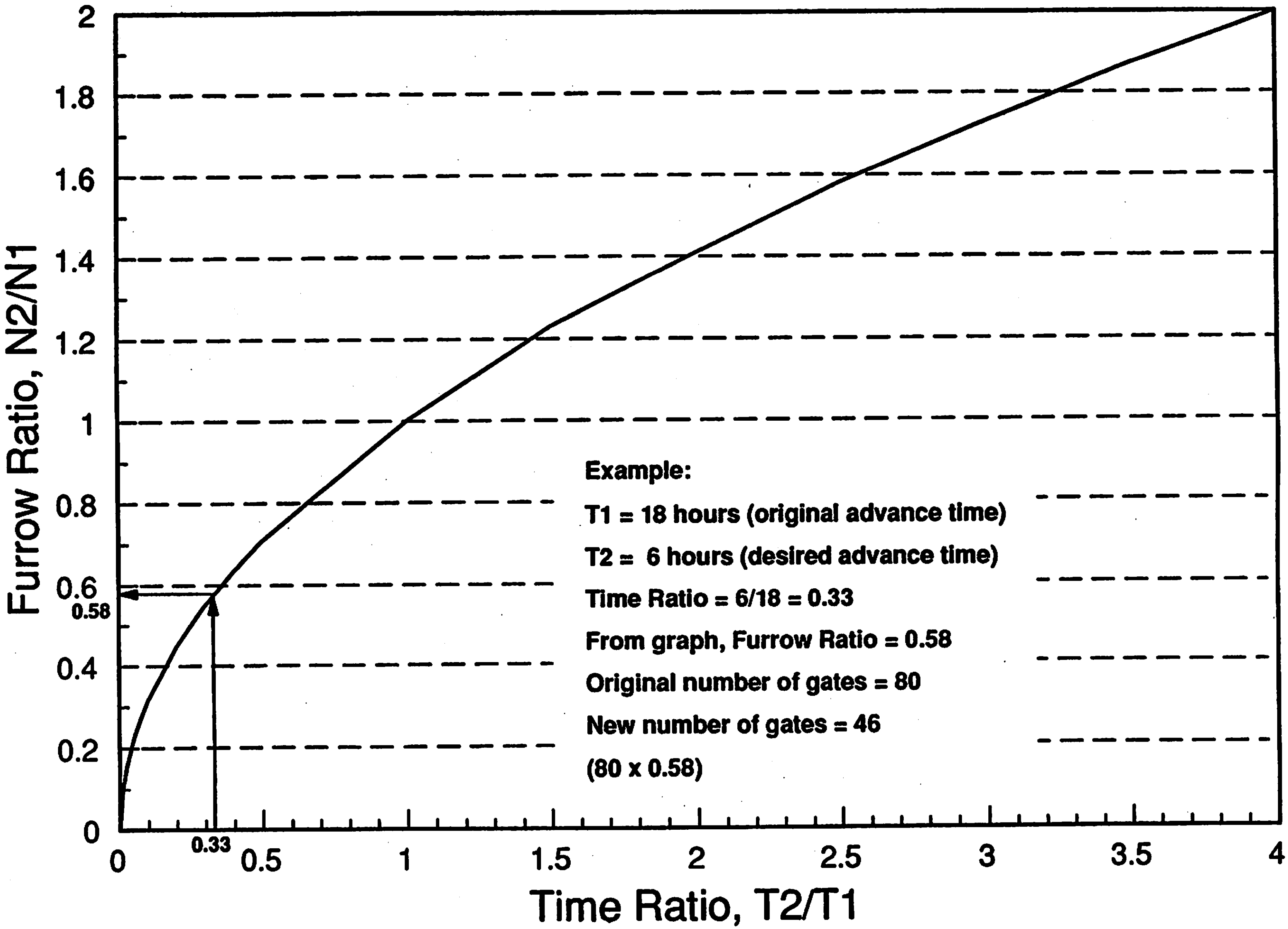

Figure 2. Graph for determining proper set size.

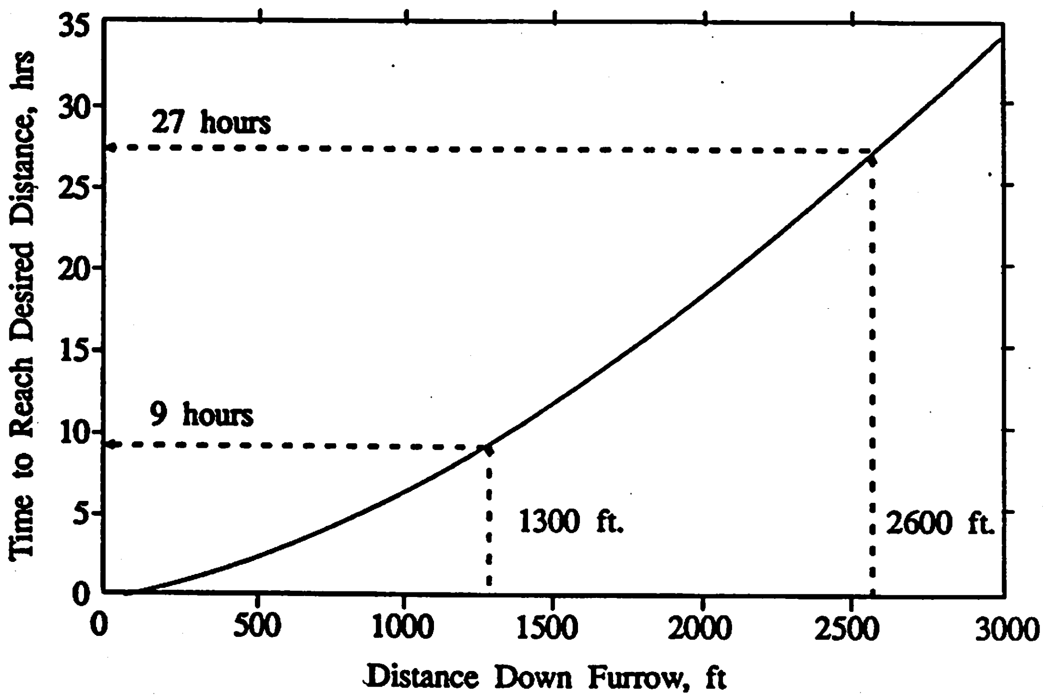

Figure 3. Advance of water across the field.

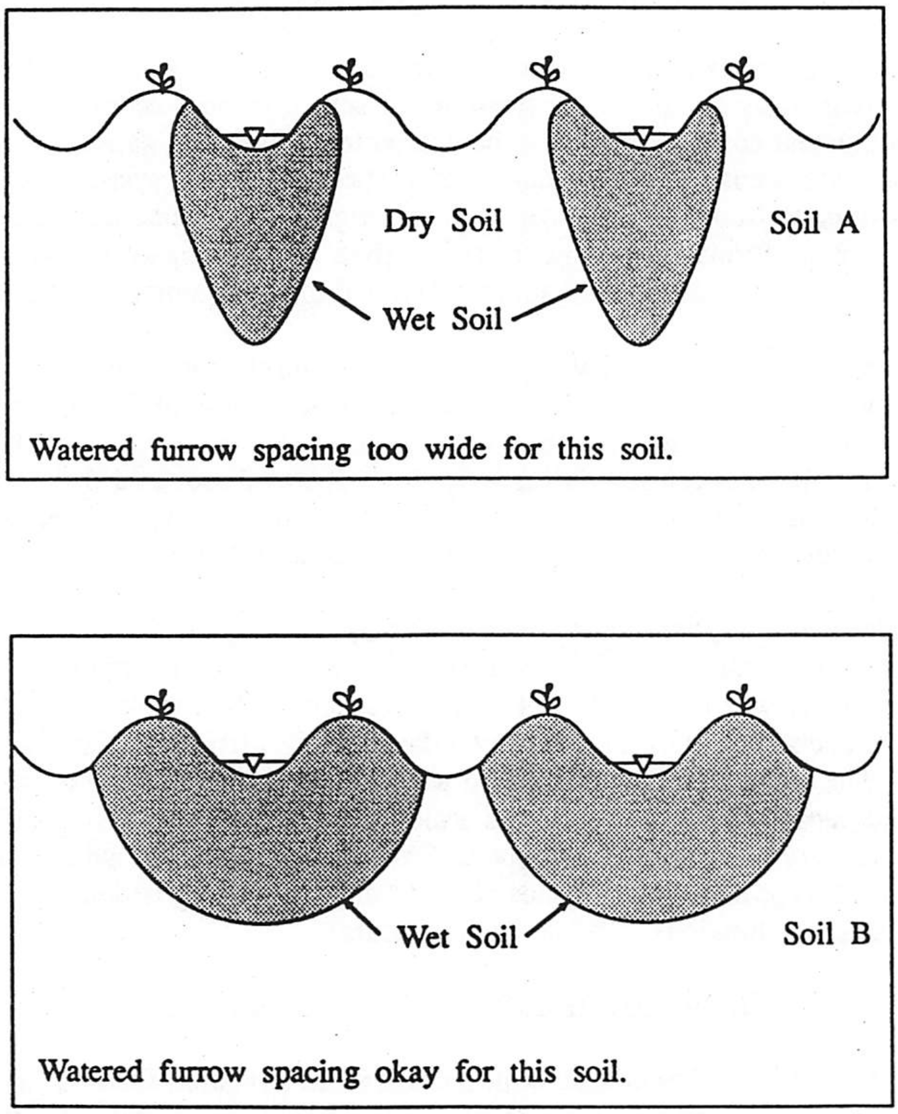

Figure 4. Wetting patterns from irrigated furrows.