IRRIGATION
MANAGEMENT
S E R I E S

Using Evapotranspiration Reports for Furrow Irrigation Scheduling

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Efficient irrigation with surface-irrigation systems is a tricky task—so most flood irrigators usually can improve irrigation efficiency. One management opportunity that should improve overall water-use efficiency is through irrigation scheduling with the use of local or regional evapotranspiration data.

WHAT IS EVAPOTRANSPIRATION?

Evapotranspiration is the term coined to describe the amount of water used by a growing crop (not the amount applied by an irrigation system). It is the combination of two words: evaporation and transpiration, and it is often referred to as ET. Any water, whether deposited by dew, precipitation, or irrigation, can be consumed by the crop to fulfill the ET requirement.

The amount of ET that occurs is influenced by climatic or atmospheric conditions such as temperature, relative humidity, wind, and solar radiation. In addition, crop conditions such as stage of growth and plant health affect ET. Procedures to calculate ET based on weather and crop data have been developed for many Kansas crops and are available for use.

In western Kansas, ET information may be available through radio and newspaper reports. However, if these sources are not available, other methods exist to estimate ET and to aid in developing a crop water budget and irrigation schedule.

HOW TO USE ET INFORMATION

Irrigation scheduling using ET information is like a checkbook accounting procedure. ET is the amount of crop water withdrawal that must be balanced against water deposits of rainfall and irrigation. The water balance must be kept within the limits of crop stress as determined by the field condition, irrigation capacity, and crop variety. Through the scheduling procedure, the amount of water application required and the time of application can be determined.

IRRIGATION SCHEDULING

To schedule flood irrigation using figures, you must follow these steps:

1. Determine the total crop water use (ET) since the last update of soil water status;
2. Determine the total effective rainfall and irrigation amount since the last update of soil water status;
3. Update the soil water status; and
4. Begin irrigation when the soil water depletion equals or exceeds the net irrigation application amount.

This procedure will maintain soil water at or above the allowable soil water depletion if the irrigation system has the capacity to supply water demanded by the crop at its peak rate of water use. If the system capacity is less, the crop will reduce soil water reserves unless rainfall replaces the deficiency. Periodic soil water sampling is recommended to ensure adequate soil water is being maintained. This should be done at various sites within a field.

The timing of the initial application of flood irrigation is not easily determined. Only a large application normally can be applied uniformly, and often the first irrigation must begin early in order to water the final set before it reaches critical soil water depletion. This means several of the first irrigation sets may be over-irrigated because of the early irrigation, and often full root development has not been achieved, reducing the effective total soil water storage.

Before scheduling can begin, the following preliminary information about field conditions must be determined:

A. DETERMINE THE ACTIVE CROP ROOT ZONE.

The active root zone of the crop is dependent on crop type, its stage of maturity, and soil conditions. Soil conditions, such as hard pans, may restrict root development. This example assumes corn grown on good soil and uses a managed root zone of 3 feet. The root zones of corn and other crops can exceed 3 feet, but since the majority of the roots and, therefore, the majority of water withdrawal is from 3 feet or less; a 3-foot root zone is commonly used. Any root development beyond 3 feet can be considered a safety factor. Early in the season, the root zone may be less than 3 feet and should be properly accounted for within the scheduling procedure. Production handbooks, available through your county extension agents, for the major Kansas crops can help determine various root development ranges.

B. DETERMINE THE AMOUNT OF SOIL WATER STORAGE CAPACITY IN THE ROOT ZONE.

The soil texture influences the water-holding capacity of the soil; the coarser the texture, the less the holding capacity. Holding capacities of some common Kansas soils are available in KSU Extension bulletin L-904, *Soil, Water and Plant Relationships*, county soil surveys, or the SCS Kansas Irrigation Guide. Contact a county extension agent for assistance. For this example, assume a silt loam type with a 2-inch per foot water-holding capacity. The total soil water available would be 2 inches per foot times a 3-foot root zone or 6 inches.

C. DETERMINE THE AMOUNT OF ALLOWABLE SOIL WATER DEPLETION BEFORE IRRIGATION IS STARTED.

Crops have differing levels of water depletion tolerance. Too much depletion stresses the crop and depresses yields; too frequent watering wastes water, fuel, and fertilizer and could also depress yields. A general irrigation guideline for most field crops is to maintain at least 50 percent of available soil water during the bulk of the growing season. Depletion of 60 to 70 percent late in the season may be permissible without yield loss. The allowable depletion for this example will be 50 percent of 6 inches total allowable storage for a 3-foot root zone, which equals 3 inches.

In addition, it is highly recommended that soil water monitoring be used as a backup to supplement the ET information and the effective amount of rainfall-ensuring soil water reserves are being maintained. General irrigation guidelines for various crops are available in Extension publications. For additional information on soils and soil water monitoring, ask a county extension agent about bulletins from the Irrigation Water Management Series and crop production handbooks.

D. DETERMINE THE IRRIGATION APPLICATION AMOUNT.

The irrigation application amount can be calculated by the following formula:

$$\text{Gross Irrigation Application (inches)} = \frac{Q \times T}{450 \times A}$$

where: Q = flow rate, gpm*
T = length of application, hours
A = area being irrigated, acres

450 is a conversion constant:
450 gpm = 1 acre-inch/hour
* gpm = gallons per minute

The area being irrigated, A, is determined using the following formula:

$$A = \text{Set size or area (acres)} = \frac{N \times R \times L}{43{,}560}$$

where: N = number of wetted furrows
R = width between wetted furrows, feet
L = row length, feet

43,560 is a conversion constant:
43,560 square feet = 1 acre

Gross application represents the total amount of irrigation water delivered to the set. The important amount in scheduling is the net irrigation amount, which is gross irrigation minus losses such as deep percolation and runoff. Use the best estimate available for system efficiency (Net irrigation = gross irrigation × system efficiency). Periodic soil water sampling can be used to adjust the soil water figures and help determine system efficiency. Table 1 lists expected irrigation efficiency ranges for various levels of surface irrigation management.

EXAMPLE CALCULATION FOR IRRIGATION APPLICATION AMOUNT

Required information:
Flow rate = Q = 1125 gpm
Row width = 30 inches or 2.5 feet
Alternate rows are watered therefore R = 5 feet
Number of gates open = N = 50
Set time = T = 12 hours
Length of run = L = 1300 feet

Surge flow without reuse:
Efficiency estimate= 75%
Field size = 150 acres

Set Size Area =
$A = N \times R \times L / 43560$
$= 50 \times 5 \times 1300/43560$
$= 7.5$ acres

Gross Irrigation = $(Q \times T)/(450 \times A)$
$= (1125 \times 12)/(450 \times 7.5)$
$= 4$ inches

Net Irrigation = Gross Irrigation × Efficiency
$= 4 \times 0.75$
$= 3$ inches

Another important item to note is the total time to complete one irrigation. In this example, 7.5 acres/set are irrigated and two sets/day can be completed. Therefore, for the 150 acre field, 10 days are needed to complete one irrigation.

E. COMPARE THE NET IRRIGATION APPLICATION AMOUNT TO THE ALLOWABLE SOIL WATER DEPLETION.

The net irrigation amount should be no more than the allowable depletion. If it is larger, the set times must be reduced or the area irrigated increased to reduce the application amount. This may require other management changes to accomplish a uniform application of a smaller irrigation. Possible actions might be furrow smoothing and packing prior to irrigating or the use of surge irrigation.

SCHEDULING EXAMPLE

After all the preliminary information has been determined and filled in at the top of the “Soil Water Balance Worksheet” (Table 2), irrigation scheduling can begin.

Step 1. Determine the total ET since the last update of the soil water status.

Obtain the amount of ET that occurred during this period. This can be done on a daily basis and recorded on a water balance sheet as shown in Table 2. The amount of ET may be reported as either reference ET (ETr) or actual ET. If actual ET information is obtained, record it directly into the column marked crop ET on Table 2, and ignore the columns marked ETr, Stage of Growth, and Crop Coefficient. ETr is the expected ET from a uniform, green, actively growing reference crop (i.e. alfalfa) due to atmospheric demand. Actual ET is usually less than ETr since plant characteristics of other crops and stage of growth reduce the amount. If ETr is used, it must be modified to reflect the crop type and maturity. Figures 1 and 2 are graphs of crop coefficients for corn and grain sorghum.

Using these graphs, the ETr can be modified to reflect a field's growth.

Record the crop coefficient (Kco) into the appropriate column. Multiply ETr by the Kco to obtain ET for your crop.

Step 2. Determine the amount of effective rainfall.

The amount of rainfall that actually enters the root zone is the effective rainfall. The best estimation of effective rainfall will be based on observation of the intensity and duration of the rainfall event. High intensity rainfall events exceed the soil infiltration capacity and increase runoff potential. High intensity rainfall, coupled with long duration, would indicate large runoff volumes and result in low effective rainfall. Low intensity rainfalls are desirable since they more closely match the soil infiltration rate, thus more rain is effective. Long duration rainfalls have increased runoff potential since soil intake capacity decreases as water content increases. Precipitation of less than 0.25 inches is usually ignored, and large events may require soil sampling to determine the soil water levels to record on the water balance sheet. In this example, the only rainfall event noted in Table 2 is 0.67 inches occurring on 7/17.

Step 3. Update the soil water status.

The irrigation amount recorded on Table 2 is net irrigation. The net irrigation will be based on the application rate as influenced by the irrigation efficiency. Irrigation efficiency is influenced by set length, time, furrow condition, furrow stream size, length of run, tailwater reuse, and other factors. The net irrigation will be the gross application amount multiplied by the application efficiency of the system. Periodic soil sampling and general experience with a field will help an irrigator estimate net irrigation efficiency. In this example net irrigation application was calculated in Step D and was determined to be 3.0 inches. The two columns of Table 2 labeled Location 1 and Location 2 represent soil water conditions of the first and last set. The soil water depletion for the day is found using this formula:

Soil Water Depletion = Previous day's soil water depletion + Et - Net Irrigation – Effective Rainfall

The example in Table 2 begins on June 29 with existing soil water depletion at both location 1 and 2 of 1.16. The calculation for June 30 is:
6/30 depletion = 1.16 + 0.07 - 0 - 0 = 1.23. Example calculation for July 4 is depletion = 1.81 + 0.30 - 3.0 - 0 = -0.89, which shows the net irrigation of 3 inches. The negative value indicates excess irrigation application that cannot be stored in the root zone. Record 0.00 depletion for the date. Note in the net irrigation column that the number of days to finish the entire irrigation is shown along with the net irrigation amount that is recorded when the location receives the water.

Step 4. Begin irrigation when the allowable soil water depletion occurs.

Table 2 also illustrates the difficulty in timing of the first irrigation. This difficulty is primarily due to the uniform soil water condition of the field at the beginning of the first irrigation. Once the first irrigation is completed, the soil water across the field is staggered and, unless enough rainfall is received to refill the soil profile, it will remain staggered throughout the remainder of the irrigation season.
In the example, the average of the five previous days ET are used as the predictor of starting the irrigation. The average ET from June 24 to June 28 (data not shown) was 0.13 inches per day. If, for example, 10 days are required to apply a 3-inch net application, the estimated soil water withdrawal would be 0.13 × 10 = 1.3 inches. In order to prevent soil water depletion below the allowable limit of 3 inches, irrigation should begin before 1.7 inches of depletion (3.0 minus 1.3) occurs in the last set. The irrigation is started on July 4, the first day after location 2 had a depletion greater than

Table 1. Probable Range of Surface Irrigation Efficiency under Various Management Procedures*

Management Procedure	Probable Efficiency Range (%)
Continuous flow, no tailwater recovery	50 to 60
Continuous flow, tailwater minimized	60 to 70
Continuous flow, tailwater reuse	70 to 85
Surge flow, tailwater minimized	70 to 85
Surge flow, tailwater reuse	75 to 90

*Length of run, furrow stream size, soil type, slope, set time, etc. greatly influence irrigation efficiency. These efficiency ranges are guideline estimates.

Figure 1. Corn Crop Coefficient vs. Stage of Growth

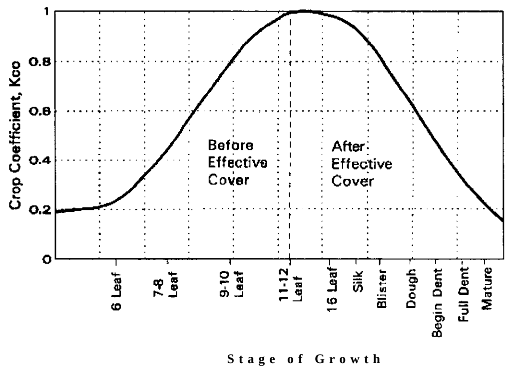
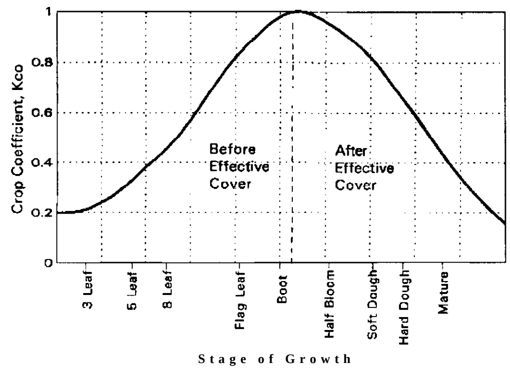


Figure 2. Grain Sorghum Crop Coefficient vs. Stage of Growth



1.7 inches (7/3 depletion was 1.81). Note the prediction of when to begin was an under-estimation and the last set exceeded the allowable depletion from July 8 to July 11, due to much higher than predicted ET demand.

In addition to scheduling using ET information, it is recommended that soil water monitoring be included as part of the management program. Different soil water monitoring techniques are discussed in KSU Extension bulletin L-795, *Soil Water Measurement: An Aid to Irrigation Water Management.*

SUMMARY

Scheduling irrigation by use of ET should be beneficial to irrigators by providing additional management information on their crop needs. Irrigation scheduling is a method of determining both the time of irrigation application and, within the limits of the flood system distribution, the size of application to make the most efficient use of water. Table 3 of this bulletin could be photocopied and used for scheduling irrigation using the method described. Additional information on improving application efficiency of furrow systems is available in KSU Extension bulletin L-912, *Surge Irrigation* and L-913, *Managing Furrow Irrigation Systems.*

Table 2. Soil Water Balance Worksheet

Field ______Example______ Crop ______Corn______

Root Zone Depth ______3______ feet Root Zone Available Water Holding Capacity ______6______ inches

Soil Type ______Silt Loam______ % Allowable Depletion ______50______ %

Available Water Holding Capacity ___2.0 inches/foot___ Allowable Depletion ______3.0______ inches

Date	Effective Rainfall Inches	Net Irrigation Inches	ETr Inches	Stage of Growth	K_{co} Crop Coefficient	Crop ET Inches	Soil Water Depletion Location 1	Soil Water Depletion Location 2	Comments
6/29			0.56	6 leaf	0.28	0.16	1.16	1.16	Irr. begins 7/4 to prevent
6/30			0.22	6 leaf	0.30	0.07	1.23	1.23	excess depletion att
6/31			0.34	7 leaf	0.33	0.11	1.34	1.34	location 2. See step 4
7/l			0.22	7 leaf	0.38	0.08	1.42	1.42.	for more detail.
7/2			0.24	7 leaf	0.42	0.10	1.52	1.52	
7/3			0.62	7 leaf	0.47	0.29	1.81	1.81	
7/4		1 3”	0.59	8 leaf	0.50	0.30	0.00	2.11	
7/5		2	0.49	8 leaf	0.57	0.28	0.28	2.39	
7/6		3	0.49	8 leaf	0.61	0.30	0.58	2.69	
7/7		4	0.36	9 leaf	0.68	0.24	0.82	2.93	
7/8		5	0.35	9 leaf	0.71	0.25	1.07	3.18	
7/9		6	0.22	9 leaf	0.77	0.17	1.24	3.35	Average 5-day ET =
7/10		7	0.25	9 leaf	0.81	0.20	1.44	3.55.	0.22+.34+.2+.17+.25
7/11		8	0.40	10 leaf	0.85	0.34	1.78	3.89	= 1.18, 1.18/5 = .24
7/12		9	0.25	10 leaf	0.87	0.22	2.00	0.89	.24×10 = 2.40”
7/13		10 3”	0.31	10 leaf	0.89	0.28	0.00	1.17	3.00-2.40 = 0.6”
7/14		1 3”	0.35	11 leaf	0.91	0.32	0.32	1.49	allowable depletion @
7/15		2	0.37	11 leaf	0.93	0.34	0.66	1.831	location 2. Begin
7/16		3	0.20	11 leaf	0.95	0.19	0.85	2.02	irrigation immediately
7/17	0.67”	4	0.41	11 leaf	0.97	0.40	0.58	1.75	0.89>0.6 for location 2.
7/18		5	0.36	12 leaf	1.00	0.36	0.94	2.11	
7/19		6	0.35	12 leaf	1.00	0.35	1.29	2.46	

Table 3. Soil Water Balance Worksheet

Field ____________________ Crop ____________________

Root Zone Depth __________ feet Root Zone Available Water Holding Capacity __________ inches

Soil Type ____________________ % Allowable Depletion ____________________%

Available Water Holding Capacity __________ inches/foot Allowable Depletion ____________________inches

							Soil Water Depletion		
Date	Effective Rainfall Inches	Net Irrigation Inches	ETr Inches	Stage of Growth	K_{co} Crop Coefficient	Crop ET Inches	Location 1	Location 2	Comments

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