NebGuide

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Evapotranspiration (ET) or Crop Water Use

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What must irrigators consider in the most efficient use of water? Read on.

Irrigators in the Great Plains have two major challenges in the years ahead:

1. Maintain groundwater quality by adjusting management to minimize the leaching of agri-chemicals from the crop root zone;
2. Continue profitable production in the face of a less abundant and increasingly costly water supply.

Irrigators must learn to convert water to grain in the most efficient manner possible. Applying only enough water to meet full evapotranspiration (ET) of the crop is one key to efficient water use (ET is also called crop water use).

Since ET is directly related to yield, the goal for irrigation management is to supplement rainfall with just enough water to meet full ET unless the water supply is inadequate. If irrigation along with rainfall is insufficient to meet ET demand, yield reduction is likely. Irrigating too much can cause percolation of excess water below the root zone, conveying nitrate nitrogen and other agri-chemicals to the groundwater.

There are immediate short range operating costs to the irrigator for either excess irrigation or less than full irrigation. For ***each*** acre-inch of excess irrigation, operating costs can increase for:

1. Nitrogen loss of 5 lbs. or more per acre;
2. Yield loss or extra fertilizer to compensate for nitrogen leaching;
3. Extra energy for pumping, $2 - $4 per acre.

These factors can increase operating costs by $4 - $17.50 per acre for each excess inch of irrigation.

For ***each*** acre-inch of irrigation less than full ET demand by the crop, corn yields can be reduced by 6-10 bushels per acre; pumping costs will be $2 - $4 per acre less. The net effect on operating costs is $10 - $21 per acre for each inch of irrigation under full ET.

The long range costs of over-pumping the aquifer, excessive percolation, or runoff of water and chemicals are more difficult to assess. One way to avoid these long run or short run costs is to match irrigation to crop needs.

Irrigators in Nebraska and bordering states have an important information resource available to them through the area-by-area gathering of weather information that is translated along with local crop information into ET estimates. This ET information can serve a key role in irrigation management decisions.

What Is ET?

Water from precipitation or irrigation can enter the soil where it comes into contact with the crop root system. Evapotranspiration is the water removed from our soils by soil evaporation and plant transpiration.

Soil evaporation is a direct pathway for water to move from soil to the atmosphere as water vapor. Over the course of an irrigation season, soil evaporation is 20-30 percent of total ET. Soil evaporation rates are highest after irrigation or rainfall. At those times the soil surface is wet and the water readily evaporates. As the soil dries the soil evaporation rates decline.

Plant transpiration is evaporation of water from leaf and plant surfaces. Transpiration is the last step in a continuous water pathway from soil, into plant roots, through plant stems and leaves, and out into the atmosphere. Water conditions "drive" the system by pulling the water "uphill" through the entire pathway. Since water in this pathway also carries nutrients, transpiration is an essential process in plant life.

Both evaporation and transpiration are driven by a tremendous drying force the atmosphere exerts on soil and plant surfaces. *Figure 1* shows the relative forces that exist in water as it is drawn through the plant or directly from the soil.

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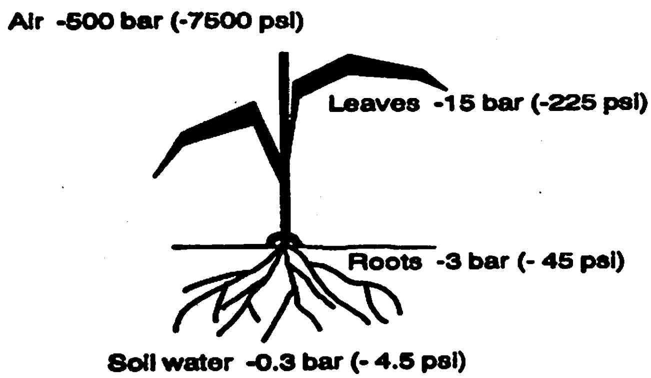

Figure 1. The change in water tension from the soil, through the plant and into the atmosphere.

Water moves from higher to lower pressure. The "bars" (1 bar = 15 psi) noted in *Figure 1* are negative pressure, or tension, terms. Water is drawn or "pulled" by more negative pressure as it moves from the soil, through the plant and into the atmosphere.

ET and Crop Yield

ET is important to irrigation management because crop yield relates directly to ET. This linear or "straight line" relationship is shown in *Figure 2*. Since yield increases linearly with ET, maximum yield will not be reached unless the maximum ET level is reached.

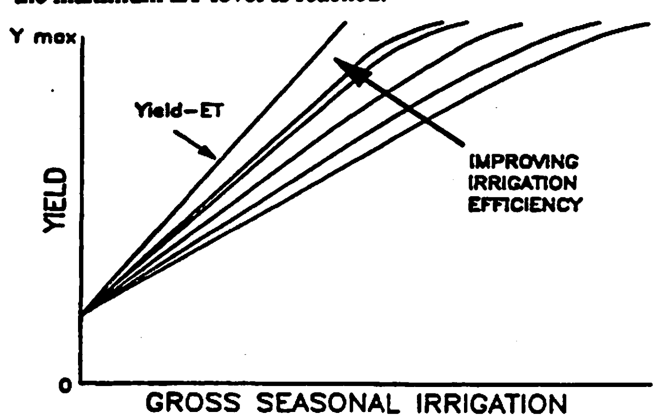

Figure 2. Yield - ET and Yield - Irrigation relationships.

Irrigators who are working to achieve maximum yields need to apply water to meet the crop's ET demand. Applying extra water beyond ET demand will not translate into extra yield. A particular crop variety responding to a particular climate has only so much capacity to transpire water.

The goal for irrigation managers is to convert water to ET and ultimately to yield. However, the curved lines in *Figure 2* represent inefficiencies in irrigation systems. It is not possible to convert *all* water into ET and yield. Furthermore, it takes more irrigation water to reach the same yield level from an inefficient system than a more efficient one. By improving system efficiency the yield-irrigation *curves* can come closer to the yield-ET *straight line.*

Factors That Affect ET

Weather. The power of the atmosphere to evaporate water is the driving force for soil evaporation and crop transpiration. Weather factors that have major impact on this evaporative power include: air temperature, humidity, solar radiation, wind. High air temperatures, low humidity, clear skies and high winds cause a large evaporative demand by the atmosphere.

The crop may or may not be able to satisfy the atmosphere's evaporative demand, but the weather factors set the *potential* for ET. This potential for ET, governed by weather factors, is the starting point for estimating ET from weather data.

Day-to-day variations in weather cause day-to-day variations in daily potential ET. The actual crop ET (or crop water use) also responds to these weather variations, as illustrated in *Figure 3*.

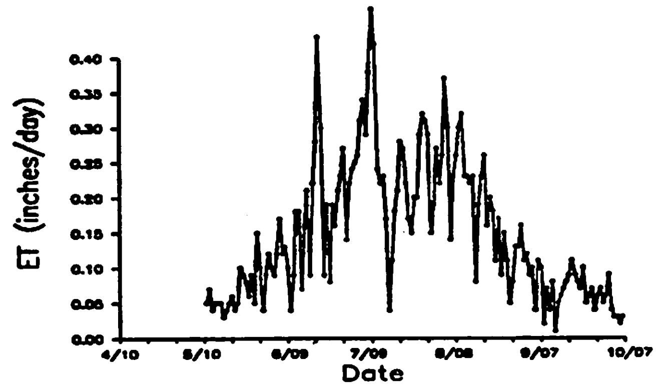

Figure 3. Example of daily variation in ET for corn.

Crop Type. Different crops use different amounts of water over the course of the growing seasons. *Table I* shows total growing season ET requirements for Nebraska crops. Crop planting times and water use patterns are somewhat different among the crops listed. Alfalfa is harvested 3-4 times each season and is unique since it is always in the vegetative stage. Winter wheat requires 2-3 inches of water from emergence to dormancy. Differences in water use among corn, sorghum and soybeans are mainly due to planting time and days to maturity. The range in ET values in *Table I* shows the year to year variation in ET due to differences in weather patterns.

Table I. Seasonal crop water use (ET) in Nebraska.

Crop	*Western*	*Central*	*Eastern*
		inches/year	
Corn	23-26	24-27	25-28
Soybeans	20-22	21-23	22-25
Dry Beans	15-16	—	—
Sorghum	18-20	19-22	20-23
Winter Wheat	16-18	16-18	16-18
Alfalfa	31-33	32-35	34-36
Sugar Beets	24-26	—	—

Crop Growth Stage. During the course of the growing season, ET from crops depends not only on the potential ET demand from the atmosphere, but also on the crops' stage of growth. ET is related to leaf surface area, so small plants transpire less water than large ones.

Due to growth patterns of different crops, maximum ET occurs at different times during the calendar year. Generally, crops grown in Nebraska reach maximum ET just prior to their reproductive growth stage. As crops continue through reproductive processes and approach maturity, ET decreases. Average daily crop ET data are shown in *Figure 4*. These lines represent the general trend in crop ET over the course of the growing season. The average maximum ET for corn,

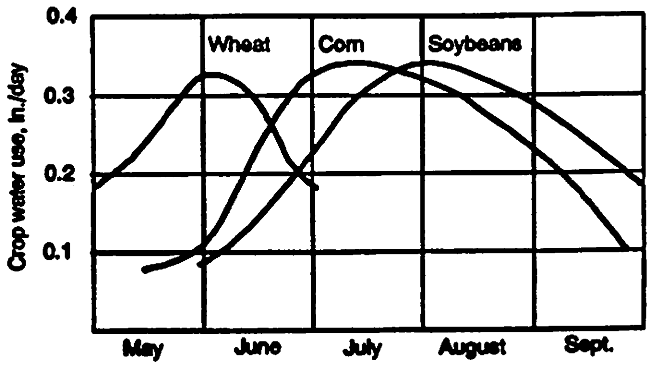

Figure 4. Example of average daily ET during the growing season.

sorghum, soybeans and wheat is approximately 0.30 to 0.35 inch per day. Individual daily ET could reach 0.45 - 0.50 inch per day.

Crop Variety. The relative maturity range of a particular variety has the most impact on seasonal crop ET. At the same location, a corn variety with maturity of 120 days will use more water than an 85 day variety. However, if both varieties are able to mature fully, the grain produced for each inch of ET is approximately equal.

Longer season corn varieties use more water, but they also produce more grain if the heat units and water supply are available. The difference in water use is due to total days of water use, not a difference in daily water use.

Crop Population. Plant population in a sparsely planted crop like corn can influence crop ET. Dryland farmers may grow 12,000-15,000 plants per acre, while a neighboring irrigator may use 25,000-30,000 plants per acre. Irrigators often wonder whether or not decreasing corn population will result in less ET and irrigation requirements.

Irrigated research plots in Nebraska have shown that savings in transpiration from fewer plants per acre have been used up by increases in evaporation. Less shading from fewer plants resulted in more evaporation.

ET requirements decreased when irrigated corn populations were less than 18,000 plants per acre. Dryland farmers can take advantage of lower ET requirements with lower populations. Irrigators needs to plant for higher populations to optimize yields.

Surface Cover and Tillage. The amount of soil surface cover influences soil evaporation. When the soil surface is wet, evaporation depends on the amount of radiant energy at the soil surface. Lowest evaporation rates occur from shaded and mulched soil surfaces. Crops shade more and more of the soil as they grow, but soil evaporation continues. However, crop residues can reduce soil evaporation by 1-3 inches during the irrigation season.

Availability of Soil Water. Research shows soil water content cannot be considered alone as the single factor controlling whether crop ET is reduced below its potential rate. The ability of soil to transmit water to plant roots and the actual evaporative demand for a given day also are important.

For progressively drier soil, actual crop ET is below the demand rate. The drier soil is unable to transmit water to the roots fast enough to satisfy higher potential ET demand.

When the soil is very dry plants may not experience reductions in ET, if the potential ET demand is low. Controlling factors are the potential ET demand and the soil's ability to transmit water to the roots. This transmitting ability is different for every soil and for a given soil it depends on the water content.

Table II. Grain yields, water use, and irrigation water use efficiencies (IWUE) for continuous corn grown at North Platte, NE, 1985-87. (Hergert et al)

	Dryland	*Limited Irrigation*	*Full Irrigation*
Irrigation (in)	0.0	6.0	13.8
ET (in)	13.5	19.1	25.3
Grain Yield (bu/ac)	59.0	135.0	178.0
Grain/ET (bu/ac-in)	4.3	7.1	7.1
IWUE* (bu/ac-in)	–	12.7	5.5

*IWUE = Irrigation water use efficiency

$$\text{IWUE (Limited)} = \frac{\text{Limited Irrigation Yield - Dryland Yield}}{\text{Limited Irrigation - Dryland Irrigation (0)}}$$

$$\text{IWUE (Full)} = \frac{\text{Full Irrigation Yield - Limited Irrigation Yield}}{\text{Full Irrigation - Limited Irrigation}}$$

Table II shows the effect of reduced soil water availability on the season ET for corn at North Platte, NE. Dryland crops received rainfall only, but limited irrigated crops received an additional 6 inches of irrigation. Fully irrigated crops were irrigated to replace all the water used for ET. Crop ET and grain yields were reduced when soil moisture became limiting. The limited irrigation was applied to give the most benefit to grain yield.

Crops including corn, winter wheat, and determinate soybeans need water during reproductive and grain filling growth stages. Indeterminate soybeans, which flower over a longer time, need water especially during grain filling. Little or no water was applied during vegetative growth.

When crops do not receive water to meet their ET demand, grain yields can be reduced. Limited water applications targeted to critical growth stages can be very effective for grain production.

Estimating ET

The University of Nebraska has developed a network of automated weather stations throughout Nebraska and bordering states (*Figure 5*). These weather stations measure and record the air temperature, relative humidity, incoming radiation, and wind speed. Weather information from each station is collected daily by a computer in Lincoln. These data are used to calculate potential ET which estimates crop weather use for the region around the weather station. The calculation is based on 45 years of research which has related these weather factors to evaporative demand.

The crop ET is calculated from potential ET. Growth stages of crops near the station are based on growing degree days accumulated since crop emergence. The growth stages combined with the potential ET from the weather station give crop ET estimates. Nebraska field research has furnished the relationships between potential ET from the weather stations and crop ET throughout the growing season.

Crop ET estimates assume soil water does not limit crop ET. The increased soil evaporation rates that occur immediately after rain and irrigation are not included in the estimates. These specific adjustments to crop ET vary from field to field and cannot be included in regional estimates.

Regional crop ET estimates are an excellent starting point for tabulating water use from a particular irrigated field. Periodic checks of soil moisture in each irrigated field are necessary to confirm the water use from that field.

Sources for ET Information

A computerized "bulletin board" is available from the University of Nebraska for public access of ET information. Contact the Department of Agricultural Meteorology, L.W. Chase Hall, University of Nebraska-Lincoln for information on the bulletin board. Irrigation specialists and Extension agents also retrieve regional ET information from the bulletin board for the news media.

Several newspapers, radio and television stations, and telephone recordings across Nebraska provide regional ET information. Usually, ET is reported in units of inches per day. To find the total crop ET over several days, multiply the reported ET by the number of days.

Using ET Information

An analogy to matching irrigation and rainfall amounts to crop ET is a bank account. The soil is the "bank" for water. Rainfall and irrigation are deposits to the account and ET is the withdrawal from the account. This approach has been called "checkbook" irrigation scheduling. A detailed guide for the procedure is available through: NebGuide G85-753, *Irrigation Scheduling Using Crop Water Use Data.* ET estimates are a key component for tracking how much water the crops are using, when to irrigate and how much to apply.

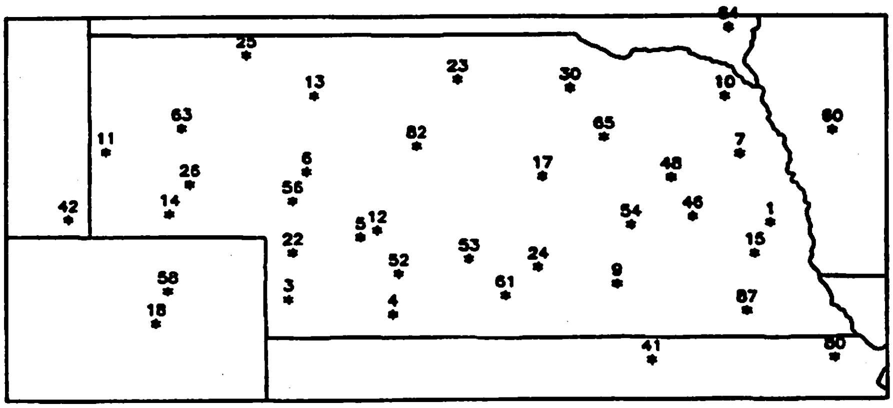

Figure 5. Weather station locations in and near Nebraska (1990).

Table III. Automated Weather Stations in and near Nebraska (1990).

#	Station Name	I.D.	El (m)	Lat.		Long.		Starting Mo/Day/Yr
1	MEAD	255369	366.	41	8	96	30	5/19/1981
3	CHAMPION	251599	1029.	40	22	101	43	5/20/1981
4	MCCOOK	255319	792.	40	13	100	34	5/21/1981
5	DICKENS	252319	945.	41	0	100	55	5/21/1981
6	ARTHUR	25 369	1097.	41	38	101	30	2/13/1982
7	WEST POINT	259209	442.	41	49	96	48	5/15/1982
9	SOUTH CENTRAL	257899	552.	40	31	98	8	7/14/1982
10	NORTH EAST	256019	445.	42	22	96	58	7/16/1982
11	PANHANDLE	256489	1244.	41	50	103	41	8/21/1982
12	NORTH PLATTE	256079	022.	41	4	100	44	9/15/1982
13	GUDMUNDSEN'S	253479	1049.	42	24	101	26	10/5/1982
14	SIDNEY	257839	1317.	41	13	103	0	12/1/1982
15	HAVELOCK	254699	351.	40	50	96	40	5/5/1983
17	ORD	256339	625.	41	36	98	56	7/10/1983
18	AKRON, CO	5 119	1384.	40	9	103	8	10/13/1983
22	GRANT	253399	975.	40	50	101	40	5/22/1984
23	AINSWORTH	25 59	765.	42	33	99	51	6/4/1984
24	GIBBON	253299	625.	40	41	99	0	12/4/1984
25	GORDON	253359	1109.	42	47	102	9	10/18/1984
26	SILVERTHORN	257849	1302.	41	31	102	47	9/1/1984
30	ONEILL	256299	670.	42	27	98	38	7/17/1985
41	SCANDIA, KS	147259	451.	39	47	97	47	3/28/1985
42	PINE BLUFFS, WY	487239	1554.	41	11	104	5	4/1/1985
46	RISING CITY	257119	375.	41	11	97	19	7/27/1985
48	TARNOV	258449	472.	41	34	97	33	6/4/1986
51	MEAD TURF FARM	255368	366.	41	9	96	30	7/29/1986
52	UNSTA CURTIS	252109	784.	40	38	100	30	8/5/1986
53	LEXINGTON	254669	731.	40	47	99	44	8/5/1986
54	CENTRAL CITY	251569	517.	41	6	98	0	9/4/1986
55	LINCOLN IANR	254809	383.	40	45	96	38	8/27/1986
56	ARAPAHOE PRAIRIE	25 259	1097.	41	22	101	40	2/2/1987
58	STERLING, CO	57959	1200.	40	27	103	1	4/9/1988
60	CASTANA, IA	131299	432.	42	2	95	48	5/19/1988
61	HOLDREGE	253919	707.	40	25	99	22	5/29/1988
63	ALLIANCE NORTH	25 148	1213.	42	4	102	51	5/29/1988
64	BERESFORD, SD	39 669	381.	43	4	96	55	1/1/1988
65	ELGIN	252599	619.	41	59	98	16	1/1/1988
80	POWHATTAN, KS	146539	365.	39	47	95	48	2/23/1989
82	HALSEY	253549	824.	41	54	100	19	8/13/1989
87	BEATRICE	25 629	376.	40	15	96	44	1/1/1990

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