University of Nebraska Lincoln EXTENSION

Know how. Know now.

EC733

Variability of Reference Evapotranspiration Across Nebraska

Suat Irmak, Extension Soil and Water Resources and Irrigation Specialist
Kari E. Skaggs, Research Associate, Biological Systems Engineering

Reference evapotranspiration is a critical variable used to determine the actual water use of a crop. It is necessary to make irrigation management decisions and has many other applications in water resources management. Alfalfa reference evapotranspiration (ET_{ref}) is a measure of the rate of water that would be lost by evaporation and transpiration from a healthy alfalfa surface if it were not limited by availability of water. Since ET_{ref} is not limited by water availability or plant function, ET_{ref} depends on the ability of the environment to extract water from the surface. As such, ET_{ref} varies significantly throughout the year and growing season as a function of climate. (For more information on this method see the UNL Extension Circular EC765, *Magnitude and Trends of Reference Evapotranspiration Rates in South Central Nebraska*.) Furthermore, ET_{ref} varies significantly across Nebraska as climate varies significantly from the eastern to the western edge of the state.

This publication provides information about the differences in ET_{ref} for five Nebraska locations — Mead, Clay Center, North Platte, Champion, and Scottsbluff — and provides data and analysis of the long-term average daily, monthly, growing season (May 1–September 30), and annual (January 1–December 31) variability in ET_{ref}. It also discusses why long-term average ET_{ref} values may not be accurate enough to be used for effective irrigation management decisions in the current growing season.

How Crop Water Use Values Are Calculated

The common way to calculate actual crop water use (ET_a) for a given agronomic crop is to adjust ET_{ref} to a particular crop using a crop-specific coefficient (K_c). Each crop has a different set of crop coefficients that represents the percent (more or less) of ET_{ref} that the particular crop will use ($ET_a = ET_{ref} \times K_c$). The use of this method to estimate crop water is detailed in the UNL Extension NebGuide G1994, *Estimating Crop Evapotranspiration from Reference Evapotranspiration and Crop Coefficients*.) ET_{ref} can be measured directly using evaporative demand measurement systems, such as atmometers (ET_{gage}™), or calculated from weather variables such as solar radiation, air temperature, relative humidity, and wind speed. Other advanced evaporative flux measurement systems are used in research settings. (For more information on ET gauges see UNL Extension NebGuide G1579, *Using Modified Atmometers (ET_{gage}™) for Irrigation Management*.)

Appropriate ET_{ref} values are the basis for informed and timely irrigation management decisions to meet crop water demand. In some cases, Nebraska averages or values from across the state or neighboring states are used rather than local values. However, these ET_{ref} values may not accurately represent local values since ET_{ref} is a function of climate, and Nebraska's climate is highly variable.

IANR

Extension is a Division of the Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln cooperating with the Counties and the United States Department of Agriculture.

University of Nebraska–Lincoln Extension educational programs abide with the nondiscrimination policies of the University of Nebraska–Lincoln and the United States Department of Agriculture.

Table I. Location, elevation, and years of data used for each station.

Station	*Years*	*Latitude*	*Longitude*	*Elevation (ft)*
Mead	1983-2003	41° 09' N	96° 29' W	1,200
Clay Center	1983-2003	40° 57' N	98° 13' W	1,811
North Platte	1983-2003	41° 05' N	100° 46' W	2,824
Champion	1983-2003	40° 24' N	101° 43' W	3,375
Scottsbluff	1991-2003	41° 53' N	103° 40' W	3,962

Daily Distribution and Variation of Reference Evapotranspiration

Long-term weather data from stations at Mead, Clay Center, North Platte, Champion, and Scottsbluff were used in the analyses. The coordinates and elevation of weather stations used to calculate reference evapotranspiration values are provided in *Table I*. Daily ET_{ref} values were calculated using the standardized Penman-Monteith equation from the American Society of Civil Engineers Environmental and Water Resources Institute and daily weather data from the High Plains Regional Climate Center website at *www.hprcc.unl.edu*. ET_{ref} varies daily at each location and across the state. The standard deviations in ET_{ref} were calculated as indicators of variability with greater standard deviations indicating more variability.

Throughout the year, ET_{ref} will vary with the amount of energy that is considered available for evapotranspiration. The largest source of energy is from solar radiation from the sun. During winter, there is much less incoming shortwave solar radiation than in summer. Day-to-day variability also will be affected by the amount of incoming solar radiation from cloud cover. More solar radiation reaches the surface on sunny days than on cloudy days. Other factors that influence day-to-day variability of ET_{ref} are surface temperature, wind speed, and relative humidity. Generally, faster wind speeds, higher temperatures, and lower relative humidity are considered conducive to evapotranspiration, so ET_{ref} rates would be higher. These factors also influence spatial variability in ET_{ref} across Nebraska.

Table II presents some average weather conditions during the growing seasons (May 1–September 30) for each station. North Platte, Champion, and Scottsbluff have more cloud-free days (interpreted from less precipitation and lower relative humidity) during the growing season than Mead and Clay Center, and thus, would receive more radiation.

There also are differences in air temperature and wind speed across the state. For example, wind speeds average more than 1 mph faster at Champion than at the other locations. Relative humidity shows a decreasing trend from the eastern to western edge of the state. For example, the humidity at Scottsbluff is about 6 percent and 11 percent lower than at North Platte and Mead.

Figure 1 provides the daily distributions of ET_{ref} rates and standard deviations for each location along with the five-location average. *Table III* provides the average yearly maximum ET_{ref} rates for each location, as well as the greatest ET_{ref} rate recorded and the date on

Table II. Long-term daily averages of weather variables at each location during the growing season (May 1–September 30).

Station	*Wind speed (mph)*	*Maximum air temperature (°F)*	*Minimum air temperature (°F)*	*Relative humidity (percent)*	*Solar radiation (cal cm²/day)*	*Rain (in)*
Mead	6.7	81.7	59.4	72.2	469	17.8
Clay Center	6.4	80.8	58.6	71.6	478	18.8
North Platte	6.8	81.2	54.9	66.8	503	11.8
Champion	7.8	82.4	54.5	64.2	512	11.5
Scottsbluff	6.4	80.9	53.2	61.0	502	7.5

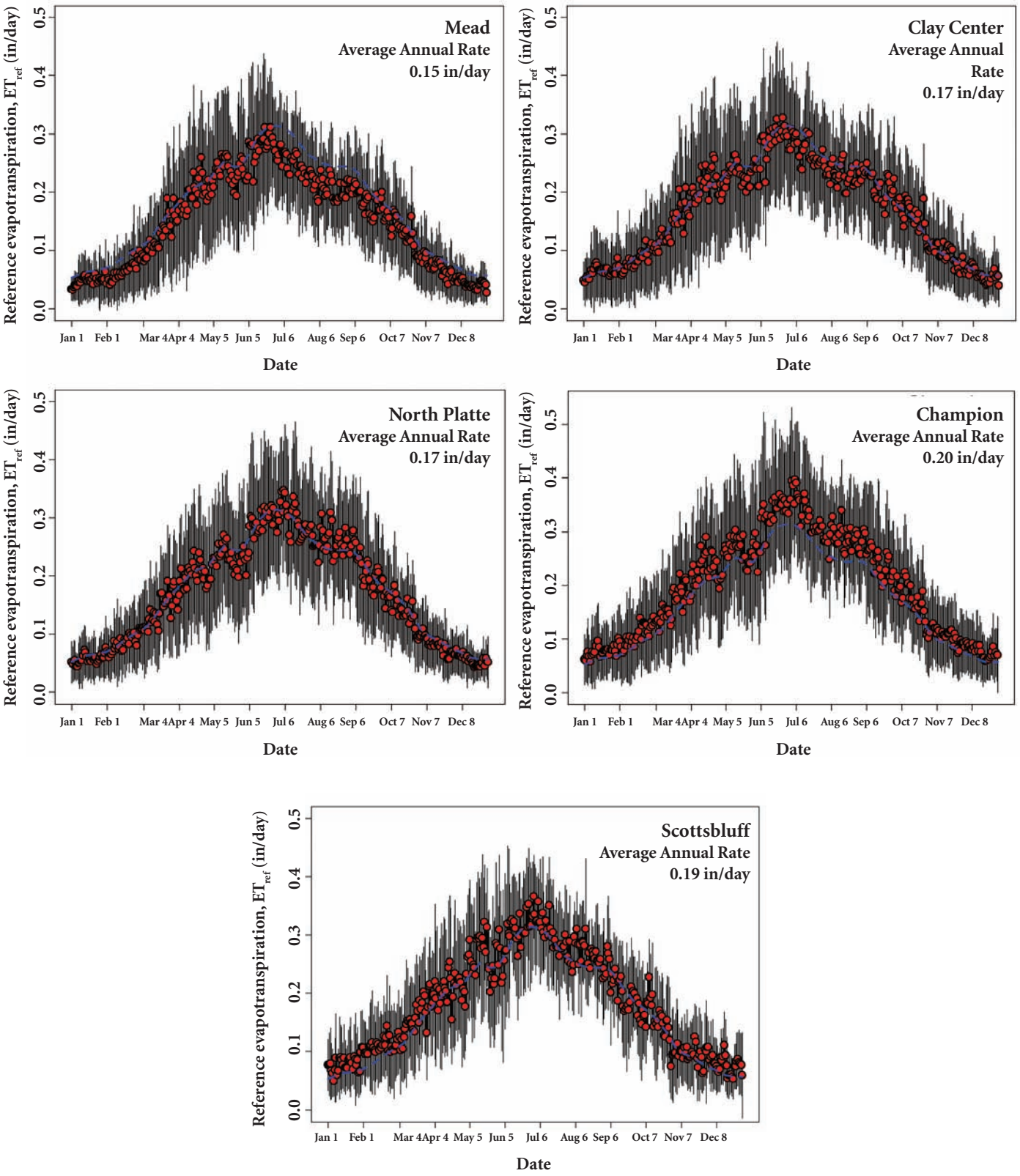

Figure 1. Distribution of daily average alfalfa reference evapotranspiration (ET_{ref}) rates (red points) for stations in Mead, Clay Center, North Platte, Champion, and Scottsbluff. The vertical bars indicate the standard deviations in ET_{ref} for a given day at each location. The dashed blue line represents average daily ET_{ref} rates of the five locations.

Table III. Long-term daily averages of growing season (May 1–September 30) ET_{ref} rates, average annual maximum ET_{ref} rates, and historical maximum ET_{ref} rates and dates for each station. Standard deviations of the average rates are in parenthesis.

Station	*Average growing season ET_{ref} (in/day)*	*Average maximum ET_{ref} (in/day)*	*Historical maximum ET_{ref} (in/day)*	*Date of historical maximum ET_{ref}*
Mead	0.23 (0.10)	0.53 (0.07)	0.69	June 8, 2000
Clay Center	0.25 (0.10)	0.54 (0.09)	0.75	June 21, 1988
North Platte	0.26 (0.11)	0.56 (0.07)	0.71	June 19, 1989
Champion	0.29 (0.12)	0.63 (0.08)	0.81	June 2, 1990
Scottsbluff	0.27 (0.09)	0.53 (0.05)	0.66	August 16, 2002

which it occurred. The greatest maximum rates were at Champion. Early in the year, average ET_{ref} values are low at all locations as is annual variation. ET_{ref} rates and standard deviations were least at Mead and greatest for Scottsbluff from January through February. The standard deviation on each day at each location is an indicator of the year-to-year variation of ET_{ref} at each location for that certain day.

Most locations had slight decreases in ET_{ref} during mid-May to early June from decreases in incoming solar radiation during the rainy season. ET_{ref} rates increased to maximums in late June to early July. After mid-July, ET_{ref} rates decreased until early August, leveled out for about a month, then continued to decrease through the rest of the year. The standard deviations at each location, generally increased as the ET_{ref} increased. Standard deviations were around 0.05 inch/day during the winter, 0.10 inch/day during the spring and early summer and 0.07 inch/day through the fall. Standard deviations were greater where ET_{ref} rates were greater, so Champion had the greatest standard deviations (0.03-0.18 inch/day) and Mead had the smallest standard deviations (0.01-0.14 inch/day). The standard deviations of the ET_{ref} rates were consistently between 1 percent (late summer–fall) and 3 percent (winter).

Distribution of Annual Total Reference Evapotranspiration

Yearly total ET_{ref} for five Nebraska locations are presented in *Figure 2*. From 1983 to 2003, ET_{ref} annual totals were greater at Champion than at Mead, Clay Center, and North Platte. From 1991 to 2003, ET_{ref} at Champion also was greater than ET_{ref} at Scottsbluff for each year except 1993 and 1996. For every year except one (1988), lowest ET_{ref} totals were at Mead. Years 1997

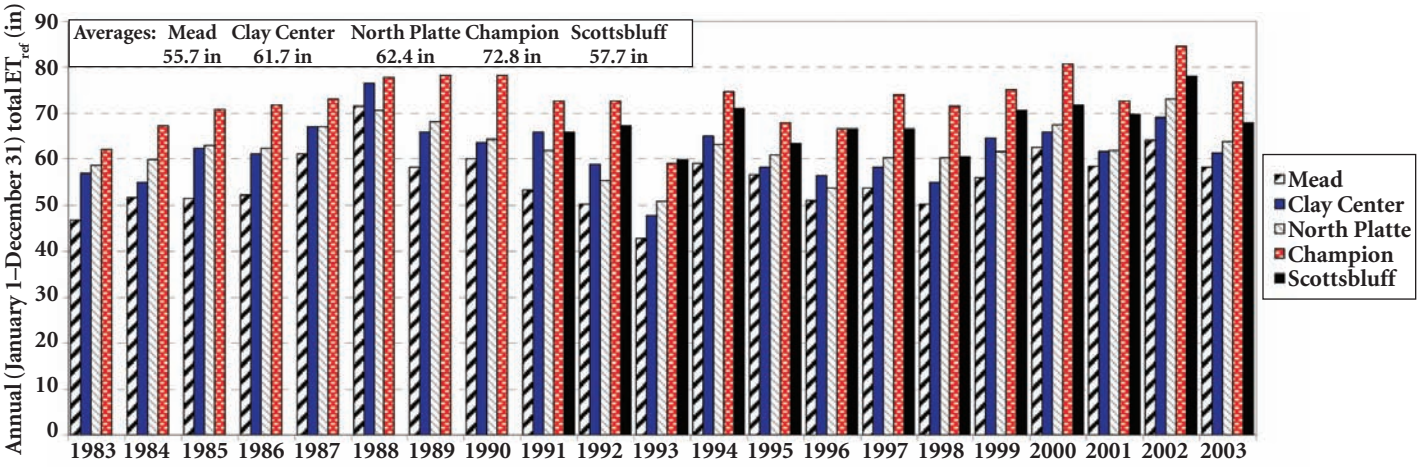

Figure 2. Annual total alfalfa-reference evapotranspiration (ET_{ref}) for Mead, Clay Center, North Platte, Champion, and Scottsbluff for1983-2003 (1991-2003 only for Scottsbluff). Each bar represents the total ET_{ref} from January 1 to December 31 of each year.

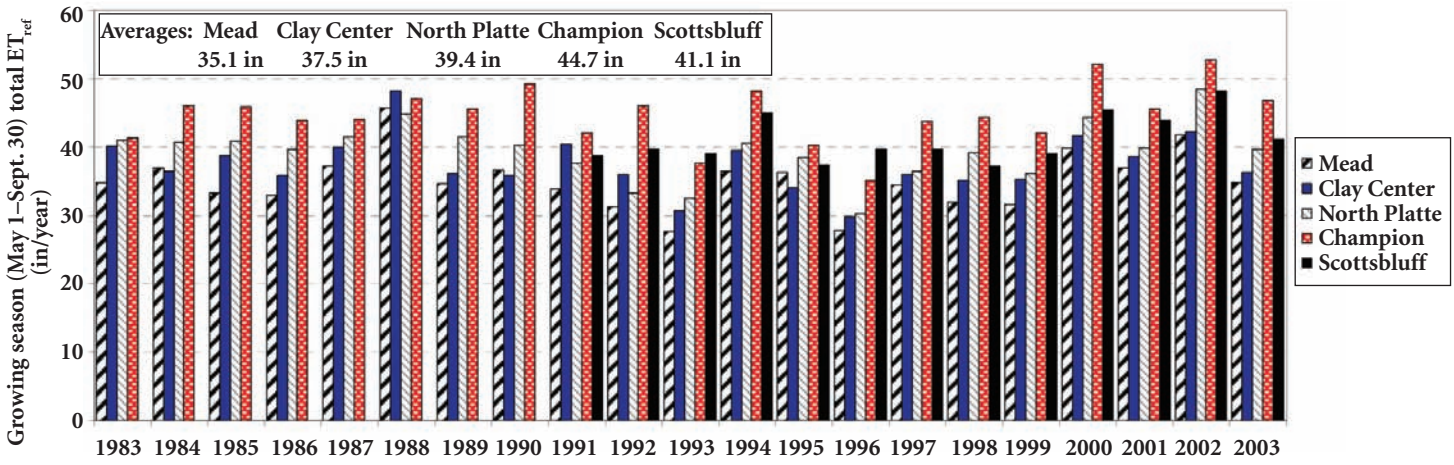

Figure 3. Growing season (May 1–September 30) total alfalfa-reference evapotranspiration (ET_{ref}) for Mead, Clay Center, North Platte, Champion, and Scottsbluff for1983-2003 (1991-2003 only for Scottsbluff).

and 2003 are good examples of near average years for all five locations.

The inter-annual trends in yearly total ET_{ref} are similar for all locations. For example, if one location has below average ET_{ref} during the year, all locations usually would have below average ET_{ref}. Although in some years, this does not hold true. For example, in 1992, Scottsbluff and Champion had average ET_{ref} totals, while Mead, Clay Center, and North Platte had below average ET_{ref} totals. From 1991 to 2003, the maximum yearly ET_{ref} total occurred during 2002 at 64.1, 69.0, 73.2, 84.6, and 78.1 inches for Mead, Clay Center, North Platte, Champion, and Scottsbluff, respectively. In 1988, Mead and Clay Center had greater ET_{ref} totals at 71.5 and 76.5 inches. The minimum total ET_{ref} for each location occurred during 1993 which was a very wet year across the Midwest. ET_{ref} totals were 42.8, 47.6, 50.9, 59.3, and 59.8 inches for Mead, Clay Center, North Platte, Champion, and Scottsbluff, respectively. Annual ET_{ref} totals at Scottsbluff showed the least year-to-year variation, while Mead had the most year-to-year variation.

Growing Season Total Reference Evapotranspiration

Growing season (May 1-September 30) total ET_{ref} was greatest at Champion for all years except 1988 (greatest at Clay Center), 1993 (Scottsbluff), and 1996 (Scottsbluff). Growing season ET_{ref} was least at Mead for all years except 1984 (least at Clay Center), 1988 (North Platte), 1990 (Clay Center), and 1995 (Clay Center). On average, growing season ET_{ref} totals follow the same distribution as annual totals. Growing season ET_{ref} contributes the most to the annual total at North Platte with an average 63.1 percent of the annual total coming from the growing season, followed by 63.0 percent at Mead, 61.5 percent at Champion, 60.8 percent at Clay Center, and 60.7 percent at Scottsbluff.

Monthly Total Reference Evapotranspiration

Long-term average monthly total reference evapotranspiration (*Figure 4*) is highest for Champion during all months except the winter months of December, January, and February when monthly ET_{ref} at Scottsbluff is higher. During winter months, Scottsbluff was the warmest and least humid location, averaging 0.6°F warmer and 5 percent less humid than Champion. During the spring, summer, and fall months, temperatures were never the greatest at Champion, but incoming solar radiation was always greatest, averaging about 23 cal cm^{-2} d^{-1} higher than other locations because of its most southern location.

Relative humidity was second lowest to Scottsbluff, and wind speeds were among the fastest. Average total ET_{ref} is lowest for Mead, except in May when both Clay Center and North Platte have lower average monthly ET_{ref} totals. Mead averages less incoming solar radiation during every month due to its northern location and cloudiness. In May, temperatures were lower and relative humidity was greater at Clay Center than at Mead, while North Platte had lower temperatures and slower wind speeds. Clay Center and North Platte have similar ET_{ref} totals except in July and August when monthly ET_{ref} is about an inch greater for North Platte. During July and

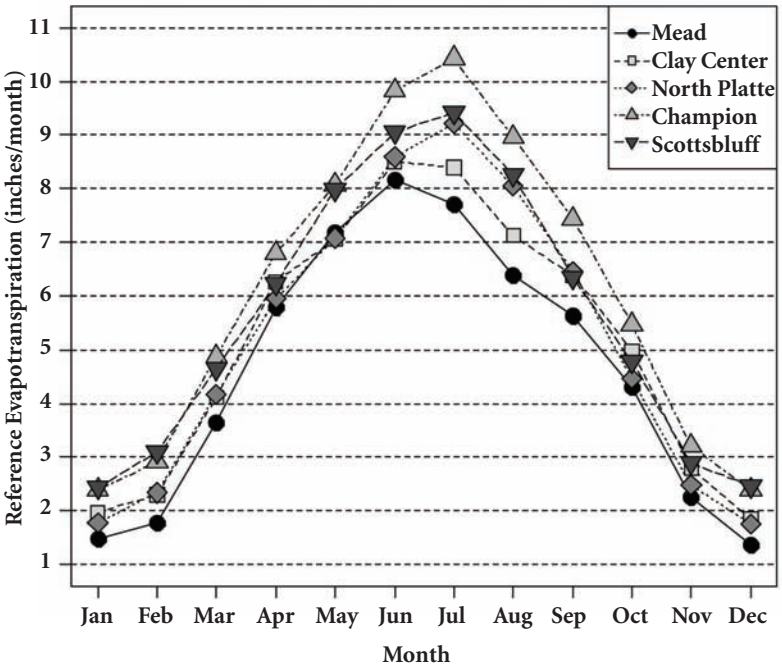

Figure 4. Long-term average monthly alfalfa-reference evapotranspiration (ET_{ref}) for Mead, Clay Center, North Platte, Champion, and Scottsbluff, Nebraska.

August, North Platte averages 5.5 percent lower relative humidity.

The peak month of ET_{ref} for Mead and Clay Center is June, while the peak month for North Platte, Champion, and Scottsbluff is July. After June in Mead and Clay Center, even though temperatures continue to increase, relative humidity increases and wind speeds decrease, resulting in a decrease in ET_{ref}. July is the warmest month, with somewhat lower relative humidity for the other three locations. December has the lowest ET_{ref} for Mead and Clay Center, while December and January have similarly low ET_{ref} for North Platte, Champion, and Scottsbluff. Relative humidity is greatest in December at Mead and Clay Center and in January at North Platte, Champion, and Scottsbluff. Incoming solar radiation is lowest in December, and average temperatures are lowest in January at all locations.

Recommendation

Based on the analysis of ET_{ref} from five Nebraska locations, it is recommended that where possible ET_{ref} measurements or estimations from the *current year* and a local source be used with proper crop coefficients to calculate actual crop water use for irrigation management. While using long-term average ET_{ref} values can be useful for water resource infrastructure design and development, using the current year's ET_{ref} data will provide for more accurate irrigation water management and will better account for how this year's climatic conditions are affecting crop water requirements.

Sources of Current, Local ET_{ref} Values

The ET_{ref} values in Nebraska are available from two main sources.

- The High Plains Regional Climate Center (*www.hprcc.unl.edu*) reports daily ET_{ref} values and other weather variables for about 60 automated weather stations in Nebraska as well as stations in North Dakota, South Dakota, Kansas, and Colorado.
- The Nebraska Agricultural Water Management Network (NAWMN) provides weekly ET_{ref} information from ET gauges at more than 200 locations across Nebraska on its website at *www.water.unl.edu/web/cropswater/nawmdn.*

This publication has been peer reviewed.

UNL Extension publications are available online at *http://extension.unl.edu/publications*.