USING EVAPOTRANSPIRATION DATA TO SCHEDULE IRRIGATION OF FORAGES

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ABSTRACT

Forage irrigation scheduling is affected by soil-water-plant relationships and harvest operations. Irrigation timing and amount depends on soil water holding capacity, weather, and crop growth processes. Evapotranspiration is affected by weather conditions and crop growth stage. However, an irrigation scheduling thus determined should be modified to accommodate harvest schedules to enhance curing of hay and to reduce soil compaction. This paper includes a discussion of crop coefficients and a list of available web based irrigation scheduling resources.

Key Words: Alfalfa, Irrigation, Crop Coefficients, Et data

INTRODUCTION

Irrigation scheduling is the process of determining when to irrigate and how much water to apply. It depends upon design, maintenance, and operation of the irrigation system and the availability of water. The objective of irrigation scheduling is to apply only the water that the crop needs, taking into account seepage, runoff losses, and leaching requirements. Scheduling is especially important to pump irrigators if power costs are high. Common irrigation scheduling approaches include the following:

1. Irrigation on fixed intervals or following a simple calendar, i.e., when a water turn occurs or according to a predetermined schedule.
2. Irrigating when the neighbor irrigates.
3. Observation of visual plant stress indicators.
4. Measuring (or estimating) soil water by use of instruments or sampling techniques such as probes.
5. By following a soil-water budget based on weather data and/or pan evaporation.
6. Some combination of the above.

As a general rule, field crops should be irrigated whenever the soil water depletion approaches 50 percent of the available water in the root zone. In the peak crop water use period in an arid area, the occurrence of rain is often neglected in determining an irrigation schedule.

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ESTIMATION OF CROP ET AND USE IN IRRIGATION SCHEDULING

Calculation of consumptive use is made by using climate and/or real-time weather data in a two-step process in which a modified Penman combination equation (or other similar equation) is used to compute the evapotranspiration of a reference crop and then a crop coefficient is applied to determine crop water use at specific stages of growth. Specific reference crops that have been used are alfalfa and clipped grass (Wright, 1982; Doorenbos and Pruitt, 1977; Allen et. al, 1998). Alfalfa reference crop evapotranspiration (Etr) is defined as the Et from a crop of alfalfa with extensive, uniform fetch, which is actively growing, is completely shading the ground, has at least 30 cm (12 inches) of top growth, is standing erect, and is not short of water (Jensen et al, 1990). Grass reference crop evapotranspiration (Eto) is defined as the Et from a crop of evenly clipped grass with extensive, uniform fetch, which is actively growing, is completely shading the ground, has 8 to 15 cm of top growth, and is not short of water (Doorenbus and Pruitt, 1977). Fetch refers to the extent of similar vegetation surrounding the site, particularly in the upwind direction.

The general form of the reference Et crop coefficient (two-step) approach to consumptive use equations is:

$$Et = Kc\ Et_{ref} + Ews \qquad (1)$$

where Et is the estimated crop evapotranspiration; Kc is an empirically determined crop coefficient relating crop Et to reference crop Etr; Et_{ref} is calculated Et for the reference crop (alfalfa or grass as described above); and Ews is an estimated wet soil surface evaporation adjustment to account for conditions occurring following an irrigation or significant rain. This adjustment is made in the early growth stages of a row crop or following a cutting of alfalfa. Ews should be ignored in situations where the Kc factor includes the effect of a wet soil surface on Et. However, the irrigation schedule should approximate that of the site where the Kc values were determined.

An alternate form of Eq. 1 is:

$$Et = Kcm \times Et_{ref} \qquad (2)$$

where Kcm is a "mean" crop coefficient (Wright, 1981 and Jensen et al., 1990) that includes the effect of evaporation from a wet soil surfaces from a typical irrigation schedule for the given crop. Crop coefficients are dependent upon the planting and harvest dates of the crop and each crop's specific growth characteristics. The alfalfa crop curve derived from data at Kimberly, ID is shown in Figure 1. Local planting or beginning growth, effective cover, and harvest dates are fundamental to properly characterizing crop coefficients. At the beginning of the season, the alfalfa green-up (when field looks green from pickup window) date may be known, but the effective cover and harvest dates will be estimated from previous years experience. These estimated dates should be revised as the season progresses. Field-observable conditions relating to forage crop effective cover are that alfalfa is about 12 - 15 inches tall, or about 20 to 25 days prior to the next cutting.

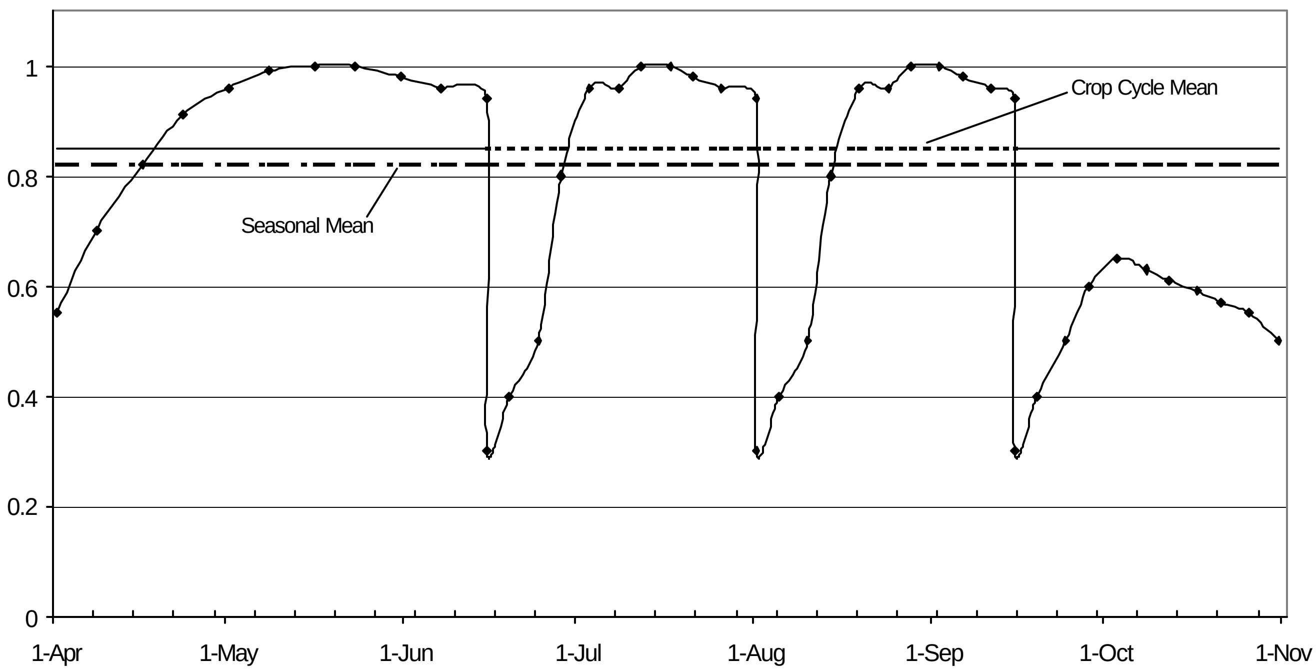

Figure 1. Alfalfa Mean Crop Coefficients Curve (after Wright, 1981, and Jensen et. al, 1990) with Harvest Dates Typical to Southern Idaho.

Crop coefficients have been developed for a wide variety of crops for use with either an alfalfa or grass reference crop. In general, these crop coefficients are not interchangeable between reference crops. Jensen et al. (1990) stress that the same reference Et values should be used to estimate crop Et as were used in developing the Kc values. The field alfalfa crop coefficient values shown in Figure 1 are for use with calculated alfalfa reference Et, Etr. If the publicly available reference Et data is for a grass reference, Eto, then the value of the coefficient from Figure 1 must be multiplied by 1.2 to produce the equivalent crop Et. This is due to the average relationship between Etr and Eto as: Etr = 1.2 Eto (Wright, 1996). The value of a crop coefficient (Kc or Kcm) at a particular growth stage depends on plant transpiration as well as evaporation from the soil surface. Care must be exercised in applying values from one research site , i.e. Kimberly, ID, a semi-arid intermountain western USA research site, to other sites with different conditions, specifically with respect to spring precipitation events and normal irrigation practices (Jensen et al., 1990).

Lacking locally calibrated crop coefficients, the mean Kimberly, ID coefficients are acceptable for most purposes; however, caution must be exercised. If the anticipated field irrigation frequency is different from the schedule at the research site (in this case Kimberly, ID), then adjustments to account for a different evaporation from a wet soil surface may be appropriate. This would be particularly true for high frequency irrigation by center pivots.

Irrigation Scheduling

The purpose of an irrigation scheduling model is to estimate current and future soil water contents. When the soil water content drops to a specified level, the program indicates that irrigation is needed. Estimated soil water (SW) content is determined by:

$$SW_2 = SW_1 + Irr + Rain - Et - DP \quad (3)$$

Where SW_1 and SW_2 are the beginning and ending total available soil water contents, respectively; Irr and Rain are the respective amounts of infiltrated irrigation and rain; Et is calculated crop water use, or evapotranspiration; and DP is deep percolation or drainage out of the root zone. The time interval (update period) between Points 1 and 2 is generally 1 week, although it could be as short as one or two days. During the harvest cycle of alfalfa, irrigation, rain (hopefully) and deep percolation are zero, thus the soil water depletion is equal to Et.

The minimum time between the last irrigation prior to cutting and clearing the bales off the field could be as little as five or six days (cut two or three days after irrigation plus three days curing, baling, and hauling) on a sandy soil with mid-summer conditions. If average Etr is 0.3 in/day for this period, and using the Kcm values from Figure 1, the soil water depletion could be about 1.2 inches. This is getting close to 50 percent depletion in a five foot deep sandy soil rootzone and indicates that irrigation should be initiated soon. One Utah grower, in these conditions, sets his center pivot to apply one-half inch for the first irrigation to get around quickly, and then slows it down to get deeper water penetration subsequently.

The use of daily crop coefficients during the harvesting is not necessary as there is no irrigation until the field is cleared and replenishing the accumulated soil water depletion afterwards is the goal. Thus, a harvest cycle average Kcm value could be used after the first cutting. This is shown in Figure 1 as “crop cycle mean” for Etr as Kcm = 0.85 (for Eto, Kcm = 1.2 x 0.85 = 1.02).

SCHEDULING IRRIGATION FOR FORAGE HARVEST OPERATIONS

Insufficient time between an irrigation event and subsequent forage harvesting operations can lead to increased opportunity for soil compaction and harvest operation difficulties. Typical grower harvest traffic reduced field alfalfa yields about 13 to 17 percent below non-trafficked plots in two and three year old stands in a Shafter, CA, study (Rechel, et. al., 1991). They state that “alfalfa yields were significantly reduced both by harvest traffic and compaction.” Depositing swathed hay on wet soil, lengthening out the curing process, is of more concern to many farmers.

The interval between alfalfa cutting and the previous irrigation depends on soil texture, weather, method of irrigation, and harvesting equipment. Lighter textured sandy and loamy sand soils dry out quicker following irrigations than do the heavier loam and clay loam soils. The interval after an irrigation prior to the harvest event changes with the time of year, being a little longer in the spring and fall, and shorter in the summer when the weather conditions are hotter and drier. Alfalfa is cut about two weeks following surface irrigation (4 inch application) on heavy clay soils in central Utah. If hot, dry windy conditions exist then it could be a couple of days less. Whereas on lighter soils with wheelmove sprinklers (2 inch application) the cutting can be about a week after irrigation, and with center pivots on sandy loam soils two or three days may be enough delay. On the silt loam soils located in southern Idaho, if the soil surface is too wet at the

Table 1. Days Between Irrigation and Subsequent Alfalfa Harvest for Typical Soils and Various Daily Et rates.

Soil Type	50 percent of available soil water in top two feet[a]	Average daily Alfalfa ET, inches per day 0.15	0.20	0.25	0.30	0.35
		Days to deplete 50 percent of SW in top two feet				
Sands and fine sands	0.63	4	3	3	2	2
Very fine sands, loamy sands	0.90	6	5	4	3	3
Sandy loam	1.35	9	7	5	5	4
Sandy clay loam	1.85	12	9	7	6	5
Loam, silt loam, silty clay loam, clay loam	2.00	13	10	8	7	6

[a] Average value for typical range of 50 percent of field capacity minus wilting point.

time of swathing, soil will ball up on the guards and cause difficulty in the harvest operation. In that area, the wait is a week or longer after a surface irrigation before swathing hay (J.L. Wright, personal communication 2002). Sometimes harvest operations are delayed until the soil surface has dried out, however, in nighttime conditions that are conducive to the formation of dew, the soil surface may not dry out very readily.

Wright (2002) further suggested that on the southern Idaho silt loam soil, accumulated Et should be approximately two inches after the irrigation and prior to the harvest to insure adequate soil drying. This could be summarized as a general rule of thumb by suggesting that the soil water should be depleted about 50 percent of available in the top two feet. The number of days to wait after irrigation prior to cutting will thus vary with soil water holding capacity and average crop Et for the period. This variation is shown in Table 1 for typical soils and daily alfalfa crop Et rates varying from 0.15 to 0.35 inches per day. The interval between irrigation and harvest varies from two days in lighter textured sandy soil at high summertime Et rate, to thirteen days in heavier clay soils at low Et rates, such as experienced in the spring and fall. Following the guidelines in Table 1, adjusted with local experience, could avoid much of the wet soil conditions causing curing problems at alfalfa cutting and potential soil compaction during the baling and hauling operations.

AVAILABLE IRRIGATION SCHEDULING DATA AND SOFTWARE

A variety of Et data is available on the worldwide web for use in irrigation scheduling. Some of these sites are listed in Table 2 along with a few crop Et/irrigation scheduling calculation software. A more comprehensive list is found on the Irrigation Association's hotlink at http://irrigation.org/about_et_list.htm. A summary discussion of irrigation scheduling programs is presented by Henggeler (2002).

Table 2. Internet Sites for Evapotranspiration Data and Other Information.

State	Website (URL)	Reference Et Type
Arizona	http://ag.arizona.edu/azmet	Eto
California	http://www.dpla.water.ca.gov/cgi-bin/cimis/main.pl	Eto
Colorado	http://ccc.atmos.colostate.edu	Etr
Kansas	www.oznet.ksu.edu/mil	Etr
Minnesota/ Wisconsin	www.soils.wisc.edu/wimnext./water.html	Eto
New Mexico Nevada Oklahoma	http://weather.nmsu.edu	Eto
Pacific Northwest California (North) Idaho, Montana, Oregon, Washington, Wyoming	http://mac1.pn.usbr.gov/agrimet/	Etr
South Dakota	http://abe.sdstate.edu/weather/	
Texas	http://texaset.tamu.edu http://texasweather.tamu.edu	Eto
Utah	http://nrwrt1.nr.state.ut.us/techinfo/consumpt/default.htm	Historical crop water use

Et Software/Calculators/Procedures		Contact Person (email)
Arizona	AZSCHED	Ed Martin (edmartin@ag.arizona.edu)
Colorado	Cropflex	Israel Broner (israel@engr.colostate.edu)
Kansas	KANSCHED	Danny Rogers (drogers@bae.ksu.edu)
Minnesota Et Checkbook	http:www.extension.umn.edu/distribution/cropsystems/DC1322.htm	Jerry Wright (jwright@umn.edu)
Utah	PCET	Bob Hill (bobh@ext.usu.edu)
Washington Et Calculator	WISE	Brian Leib (brian_leib@wsu.edu)

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For additional reading/resource material see:

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