service in ACTION

Colorado State University Cooperative Extension

no. 4.706

Irrigation scheduling with atmometers

Israel Broner[1]

Quick Facts

Atmometers supply a direct reading of reference ET, reducing the need for expensive weather stations.

ET estimation by an atmometer is acceptable for most irrigation scheduling purposes.

Operation of an atmometer is as simple as reading a rain gauge.

The atmometer can be used for irrigation scheduling by the water-balance method, which uses simplified tables of crop and soil coefficients and additional evaporation due to wet soil conditions.

An atmometer measures the amount of water evaporated to the atmosphere from a wet, porous ceramic surface. Atmometers have been used since the late 1800s to study plant transpiration. As its name implies, atmometers are an "atmospheric meter," and they measure evaporation rates as affected by weather conditions.

The modified atmometer[2] consists of a ceramic cup (Bellani plate) covered with a rough green canvas and mounted on top of a cylindrical water reservoir as shown in Figure 1. Distilled water is supplied to the ceramic cup from the lower part of the water reservoir by a conduit (suction tube). A check valve installed at the lower part of the suction tube prevents a back flow of water from the outside. A plastic sight tube is mounted on the side wall to indicate the water level in the reservoir.

By covering the ceramic cup with green canvas, the atmometer simulates water loss from a well-watered, vigorously-growing field of alfalfa. At full cover, transpiration accounts for nearly 95 percent of the total evapotranspiration (ET) (see Service in Action sheet 4.707, *Irrigation scheduling: the water balance approach*). In other words,

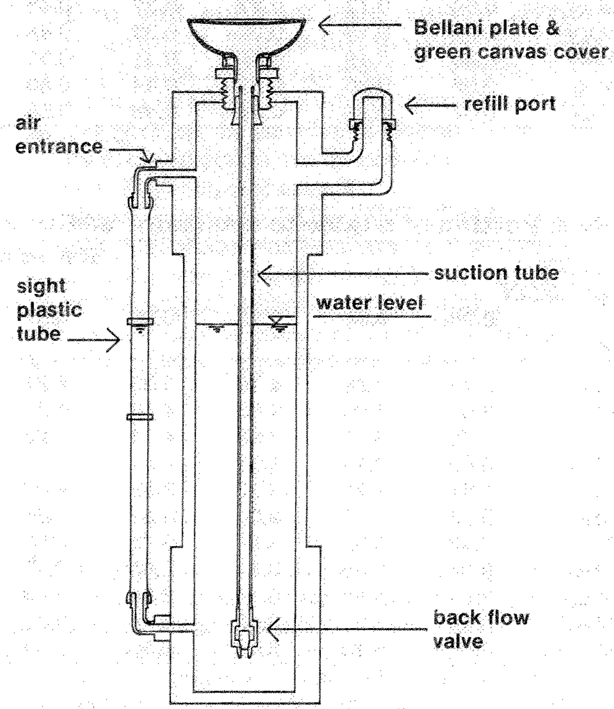

Figure 1: Schematic description of the modified atmometer.

95 percent of the total water vapor transferred to the atmosphere comes from the plants as opposed to the soil. Therefore, the amount of water evaporated from the modified atmometer can be used as a direct indication of alfalfa reference ET after full

[1]Israel Broner, Colorado State University Cooperative Extension agricultural engineer and assistant professor, agricultural and chemical engineering (3/90)

[2]Developed by Jon Altenhofen of the Northern Colorado Water Conservancy District.

[3]Duke, H. R., M. C. Crookston, E. R. Hamburg, M.E. Hess, I. Israeli, and T. L. Louden. 1987. Scheduling irrigation: A guide for improved irrigation water management through proper timing and amount of water application. ARS-SCS-ES, Fort Collins, Colorado.

cover has been achieved. Accuracy of daily ET data obtained by visually reading the plastic sight tube is limited. However, the atmometer is self-recording because it accumulates the ET once the reading has begun and the "reading errors" tend to average out. The accuracy of the modified atmometer for irrigation scheduling purposes was verified under local conditions.

Several studies were undertaken in which ET estimations using the atmometer were compared with more common methods under different field conditions in Colorado. A more formal study was conducted at the Agricultural Engineering Research Center in Fort Collins. ET estimations of four atmometers were compared to ET estimations by the Penman method. The results showed that the variability between atmometers spaced close together is small, and that the ET estimations by the modified atmometer were similar to those of the Penman method. These are only preliminary favorable results that indicate that the modified atmometer can be used as a tool to estimate alfalfa reference ET for irrigation scheduling purposes. It is recommended to periodically compare ET estimations by the atmometer to other methods to insure the atmometer reliability.

Installation and Operation

To install an atmometer place the instrument in a vertical position with the top of the ceramic cup 3.3 feet above the soil surface in a location with easy access within the irrigated field. The site should represent average field conditions. Do not install near wind shelters such as farm buildings, trees or tall crops. Detailed set-up and maintenance instructions are provided by the manufacturer with the atmometer. It is important to keep the green canvas clean by washing it periodically. It also is recommended to install a taller post next to the atmometer to discourage birds from perching on the atmometer.

Operation of the modified atmometer is as simple as reading a rain gauge. To determine the equivalent depth of water evaporated read the plastic sight tube graduated in inches to find the variation in water levels during the considered period of time. When the water level in the reservoir drops to approximately two-thirds of the reservoir add distilled water. Set-up instructions explain how to fill the atmometer with distilled water. An important procedure in the set-up and refill of the modified atmometer is to maintain continuity of water through the ceramic cup and the suction tube. A lateral spout on the upper portion of the cylindrical reservoir is used to refill the water reservoir whenever necessary. Reliability and accuracy of atmometer readings can be increased by installing more than one device at the same site. In case of significant differences in reading between instruments, the cups should be cleaned and checked or the manufacturer should be contacted.

Water Balance with the Atmometer

The modified atmometer can be used for irrigation scheduling by providing daily estimates of alfalfa reference ET. Reference ET is used in the water-balance method (see SIA 4.707) as an estimation of the potential water loss from a reference crop. ET estimation is the difficult portion of the water-balance method, and usually it is done by calculating ET from measured weather parameters. The modified atmometer facilitates the ET estimation by supplying a direct reading of reference ET. Consequently, no cumbersome weather measurements and calculations are required. In some areas of Colorado, daily ET values based on climatological data are published by Cooperative Extension agents or Soil Conservation Service (SCS) personnel and can be used for the soil water-balance calculations. However, these values represent average conditions of the area and not local conditions at each farm.

Water-balance tables (WBT) were developed to manually calculate soil water balance and further facilitate the use of the modified atmometer for irrigation scheduling. At the start of the season, soil water-balance tables can be generated by a local Cooperative Extension agent or SCS office and filled in manually during the growing season. The WBT and look-up tables for soil and additional evaporation coefficients for a particular field are generated by a computer program.

The input information needed to generate the WBT and look-up tables is as follows:

1. Dates of planting and root development (germination date).
2. Number of days from planting to full cover and from full cover to harvest.
3. Initial root depth (inches)—usually assumed to be 6 inches.
4. Maximum root depth (inches).
5. Available water capacity (in/in).
6. Management allowable depletion (MAD) (percent). Three different levels of MAD are allowed.
7. Crop coefficients in the form of coefficients of a four degree polynomial equation. The program has built in crop coefficients from Duke et al.[3] (1987) for the following crops: alfalfa, corn, dry beans, pasture, potatoes, sorghum, soybeans, small grains and sugar beets. These coefficients show up on the data screen when the name of the crop is entered. The crop coefficients were developed for use with alfalfa reference ET in the western United States.

The WBT (Table 1) consists of nine columns, and the number of rows is the number of days in the growing season. Dates, crop coefficients (KC) and MADs are calculated and inserted in the WBT. The rest of the columns are filled out by the user during the growing season. Actual ET is found by multiplying the reference ET by the given crop coefficient, a soil coefficient and an additional evaporation coefficient. These last two coefficients are taken from the look-up tables.

The soil coefficient (KS) look-up table (Table 2) is the possible depletion levels for each day of the growing season with a corresponding soil coefficient (KS). The additional evaporation coefficient (KW) look-up table (Table 3) is possible values of KW for each day of the growing season for corresponding values of KS.

The WBT (Table 1) can be updated on a daily or weekly basis following the steps listed below.

1. Enter reference ET in column 2 (Table 1) and rain and/or irrigation depths in column 7.
2. Find soil coefficient (KS) value that corresponds to the previous day's depletion from the look-up table (Table 2). Enter the KS value in column 4. For example, assume the soil water depletion on 14 May was 0.34 inches. Table 2 for 15 May, shows the corresponding KS value is 0.90.
3. If the soil surface is very wet from a rain or irrigation within the last one to three days, find the additional evaporation coefficient KW value (Table 3) that corresponds to the soil coefficient KS value found in the previous step. Enter the KW value in column 5. Take the KS value found in step 2 and look up Table 3 or 15 May. It shows that the corresponding KW value is 3.85. If the soil surface is dry, the value of KW is 1.0.
4. Calculate actual ET by multiplying reference ET by the crop coefficient, soil coefficient and additional evaporation coefficient. Enter the result in column 6.
5. To find today's depletion add today's actual ET (column 6) to the previous day's depletion and subtract rain and/or irrigation (column 7). The result is today's soil water depletion and is entered in column 8. If the result is negative, enter zero in column 8.
6. Irrigation is needed if today's soil water depletion (column 8) is equal to or exceeds the MAD in column 9.

A short version of the WBT (Table 4) also is available that does not include the soil and additional evaporation coefficients, thus ignoring the effect of the actual water content on the actual ET. For this version the user only needs to enter reference ET and does not need the look-up tables.

Table 1: Long version of the soil water-balance table.

Instructions to determine today's soil water depletion:
Insert atmometer ET or alfalfa reference ET in column (2). Multiply the ET in column (2) by the crop coefficient, KC, in column (3), the soil coefficient, KS, in column (4), and then the coefficient to adjust for recent irrigation or rain, KW, in column (5). Write the result in column (6), which is today's actual water use, AET. Insert rain or irrigation applied in column (7). Add the AET in column (6) with the previous day depletion in column (8) then subtract column (7) to get today's soil water depletion. Today's soil water depletion can be negative if rain and/or irrigation exceed the soil water depletion. In this case, enter a zero in column (8). Write today's soil water depletion in column (8) to record today's depletion. Now, compare the soil water depletion to the MAD, in column (9). If today's depletion is greater than the MAD, then irrigation is needed.

Field: SW-1
Crop: CORN

(1) Date	(2) Atmometer ET (in)	(3) KC	(4) KS	(5) KW (in)	(6) AET (in)	(7) Rain/ irrigation (in)	(8) Soil water depletion (in)	(9) MAD
10-May	*	0.20	*	*	=	—	→	0.30
11-May	*	0.20	*	*	=	—	→	0.33
12-May	*	0.20	*	*	=	—	→	0.36
13-May	*	0.21	*	*	=	—	→	0.40
14-May	*	0.21	*	*	=	—	→	0.43
15-May	*	0.22	*	*	=	—	→	0.46
16-May	*	0.23	*	*	=	—	→	0.49
17-May	*	0.23	*	*	=	—	→	0.52
18-May	*	0.24	*	*	=	—	→	0.55
19-May	*	0.25	*	*	=	—	→	0.59
20-May	*	0.26	*	*	=	—	→	0.62

Table 2: Portion of the table to determine soil coefficient value.

KS as a Function of the Previous Day Depletion

Field: SW-1
Crop: CORN

KS > Date	0.99	0.96	0.93	0.90	0.87	0.84	0.81	0.78	0.75	0.72	0.69	0.66
10-May	0.03	0.10	0.17	0.22	0.27	0.32	0.35	0.39	0.41	0.44	0.46	0.48
11-May	0.03	0.11	0.19	0.25	0.30	0.35	0.39	0.43	0.46	0.49	0.51	0.53
12-May	0.03	0.12	0.20	0.27	0.33	0.38	0.43	0.47	0.50	0.53	0.56	0.58
13-May	0.04	0.13	0.22	0.30	0.36	0.42	0.47	0.51	0.55	0.58	0.61	0.63
14-May	0.04	0.15	0.24	0.32	0.39	0.45	0.50	0.55	0.59	0.63	0.66	0.68
15-May	0.04	0.16	0.26	0.34	0.42	0.48	0.54	0.59	0.63	0.67	0.71	0.73
16-May	0.04	0.17	0.27	0.37	0.45	0.52	0.58	0.63	0.68	0.72	0.75	0.79
17-May	0.05	0.18	0.29	0.39	0.48	0.55	0.62	0.67	0.72	0.77	0.80	0.84
18-May	0.05	0.19	0.31	0.41	0.51	0.58	0.65	0.71	0.77	0.81	0.85	0.89
19-May	0.05	0.20	0.33	0.44	0.53	0.62	0.69	0.76	0.81	0.86	0.90	0.94
20-May	0.06	0.21	0.34	0.46	0.56	0.65	0.73	0.80	0.85	0.91	0.95	0.99

Table 3: Portion of a table to determine additional evaporation coefficient value.

KW as a Function of KS

Field: SW-1
Crop: CORN

KS > Date	0.99	0.96	0.93	0.90	0.87	0.84	0.81	0.78	0.75	0.72	0.69	0.66
10-May	3.86	3.98	4.10	4.23	4.37	4.52	4.67	4.85	5.03	5.23	5.45	5.69
11-May	3.81	3.93	4.05	4.18	4.31	4.46	4.62	4.79	4.97	5.17	5.39	5.62
12-May	3.76	3.87	3.98	4.11	4.25	4.39	4.55	4.71	4.89	5.09	5.30	5.53
13-May	3.69	3.79	3.91	4.03	4.17	4.31	4.46	4.62	4.80	4.99	5.20	5.43
14-May	3.61	3.71	3.83	3.95	4.08	4.22	4.36	4.52	4.70	4.89	5.09	5.31
15-May	3.52	3.63	3.74	3.85	3.98	4.12	4.26	4.42	4.59	4.77	4.97	5.18
16-May	3.43	3.53	3.64	3.75	3.88	4.01	4.15	4.30	4.47	4.64	4.84	5.05
17-May	3.34	3.44	3.54	3.65	3.77	3.90	4.03	4.18	4.34	4.51	4.70	4.91
18-May	3.24	3.33	3.44	3.54	3.66	3.78	3.92	4.06	4.21	4.38	4.56	4.76
19-May	3.14	3.23	3.33	3.44	3.55	3.67	3.80	3.93	4.08	4.24	4.42	4.61
20-May	3.04	3.13	3.23	3.33	3.44	3.55	3.67	3.81	3.95	4.11	4.28	4.46

Table 4: Short version of the soil water-balance table.

Instructions to determine today's soil water depletion:
Insert atmometer ET or alfalfa reference ET in column (2). Multiply the ET in column (2) by the crop coefficient, KC, in column (3), and write the result in column (4), which is today's actual water use, AET. Insert rain or irrigation applied in column (5). Add the AET in column (4) with the previous day's depletion in column (6) then subtract column (5) to get today's soil water depletion. Today's soil water depletion can be negative if rain and/or irrigation exceed the soil water depletion. In this case, enter a zero in column (6). Write today's soil water depletion in column (6) to record today's depletion. Now, compare the soil water depletion to the MAD, in column (7). If today's depletion is greater than the MAD, then irrigation is needed.

Field: SW-1
Crop: CORN

(1) Date	(2) Atmometer ET (in)		(3) KC		(4) AET (in)		(5) Rain and irrigation (in)		(6) Soil water depletion (in)	(7) MAD (in)
10-May		*	0.20	=		—		→		0.30
11-May		*	0.20	=		—		→		0.33
12-May		*	0.20	=		—		→		0.36
13-May		*	0.21	=		—		→		0.40
14-May		*	0.21	=		—		→		0.43
15-May		*	0.22	=		—		→		0.46
16-May		*	0.23	=		—		→		0.49
17-May		*	0.23	=		—		→		0.52
18-May		*	0.24	=		—		→		0.55
19-May		*	0.25	=		—		→		0.59
20-May		*	0.26	=		—		→		0.62