IRRIGATION SCHEDULING WITH ATMOMETERS

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INTRODUCTION

An atmometer is a device that measures the amount of water evaporated to the atmosphere from a wet, porous ceramic surface. Atmometers have been used since the late 1800's 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 (Altenhofen, 1985) 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). In other words, 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 cover has been achieved. Accuracy of daily ET data obtained by visually reading the plastic sight tube is somewhat 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 (Law and Israeli, 1988). 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 irrigaton scheduling purposes. It is recommended to periodically compare ET estimations by the atmometer to other methods to insure the atmometer reliability.

INSTALLATION AND OPERATION

The recommended procedure of installing an atmometer is to place the instrument in a vertical position with the top of the ceramic cup 3.3 feet above the soil surface. The instrument should be installed in a location with easy access within the irrigated field. The site should be representative of average field conditions. It should not be installed near wind shelters such as farm buildings, trees or tall crops. Detailed setting up instructions for the atmometer as well as maintenance instructions are provided by the manufacturer with the device. An important maintenance procedure is to keep the green canvas clean by washing it periodicially. It is also recommended to discourage birds from perching on the atmometer by installing a taller post next to the atmometer.

Operation of the modified atmometer is as simple as reading a rain gauge. The equivalent depth of water evaporated is determined by reading 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, distilled water should be added. Set-up instructions include an explanation of how to fill the atmometer with distilled water. An important procedure in the set-up and refille of the modified atmometer is to maintain continuity of water through the ceramic cup and suction tube. A lateral spout on the upper portion of the cylindrical reservoir is used for refilling 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 (Buchleiter et al., 1988; Lambert et al., 1988, Pleban and Israeli, 1989) as an estimation of the potential water loss from a reference crop. ET estimation is the difficult portion of the water balance method, and it is usually 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 in 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 the localized conditions at each farm.

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

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. (1987) for the following crops: alfalfa, corn, dry beans, pasture, potatoes, sorghum, soybeans, small grains, and sugar beets. These crop coefficients will show up in the data screen when the name of the crop will be entered. These crop coefficients were developed for use with alfalfa reference ET in the western U.S.

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 and MAD's are calculated and inserted in the WBT. The rest of the columns are to be filled out by the user during the growing season. Actual ET is found by multiplying the reference ET by the given crop coefficient and the soil and additional evaporation coefficients that are taken from the look up tables.

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

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

1. Enter reference ET in Column 1 (Table 1) and rain and/or irrigation depths in Column 7.

2. Find soil coefficient (K_s) value corresponding to the previous day's depletion from the look up table (Table 2). Enter the K_s value in Column 4. For example, let us assume that the soil water depletion on 14 May was 0.34 in. Looking up in Table 2 for 15 May, shows that the corresponding K_s value is 0.90.

3. Find the additional evaporation coefficient K_w value (Table 3) corresponding to the soil coefficient K_s value found in the previous step. Enter the K_w value in Column 5. Taking the K_s value found in Step 2 and looking up Table 3 or 15 May, shows that the corresponding K_w value is 3.85.

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. Find today's depletion by adding today's actual ET (Column 6) to the previous day's depletion and subtracting rain and/or irrigation (Column 7). The result is today's soil water depletion and is entered in Column 8. If the result is negtive, then enter zero in Column 8.

6. Irrigation is needed if today's soil water depletion (Colum 8) is equal to or exceeds the management allowable depletion in Column 9.

A short version of the WBT (Table 4) is also available which 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 needs only to enter reference ET and does not need the look up tables.

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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, Kcb, 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, ETa. Insert rain or irrigation applied in Column (7). Add the ETa 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 management allowable depletion, MAD, in Column (9). If today's depletion is greater than the MAD, then irrigation is

Field: SW-1
Crop: CORN

(1) Date	(2) Atmometer ET (in)		(3) Kcb		(4) Ks		(5) Kw		(6) ETa (in)		(7) Rain/ irrigation (in)		(8) Soil water depletion (in)	(9) 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

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 >	0.99	0.96	0.93	0.90	0.87	0.84	0.81	0.78	0.75	0.72	0.69	0.66
Date												
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 coefficient to adjust for recent irrigation or rain.

Kw VALUES FOR THE FIRST DAY AFTER RAIN OR IRRIGATION

Field: SW-1
Crop: CORN

Ks >	0.99	0.96	0.93	0.90	0.87	0.84	0.81	0.78	0.75	0.72	0.69	0.66
Date												
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, Kcb, in Column (3), and write the result in Column (4) which is today's actual water use, Eta. Insert rain or irrigation applied in Column (5). Add the Eta 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 management allowable depletion, 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) Kcb		(4) Eta 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

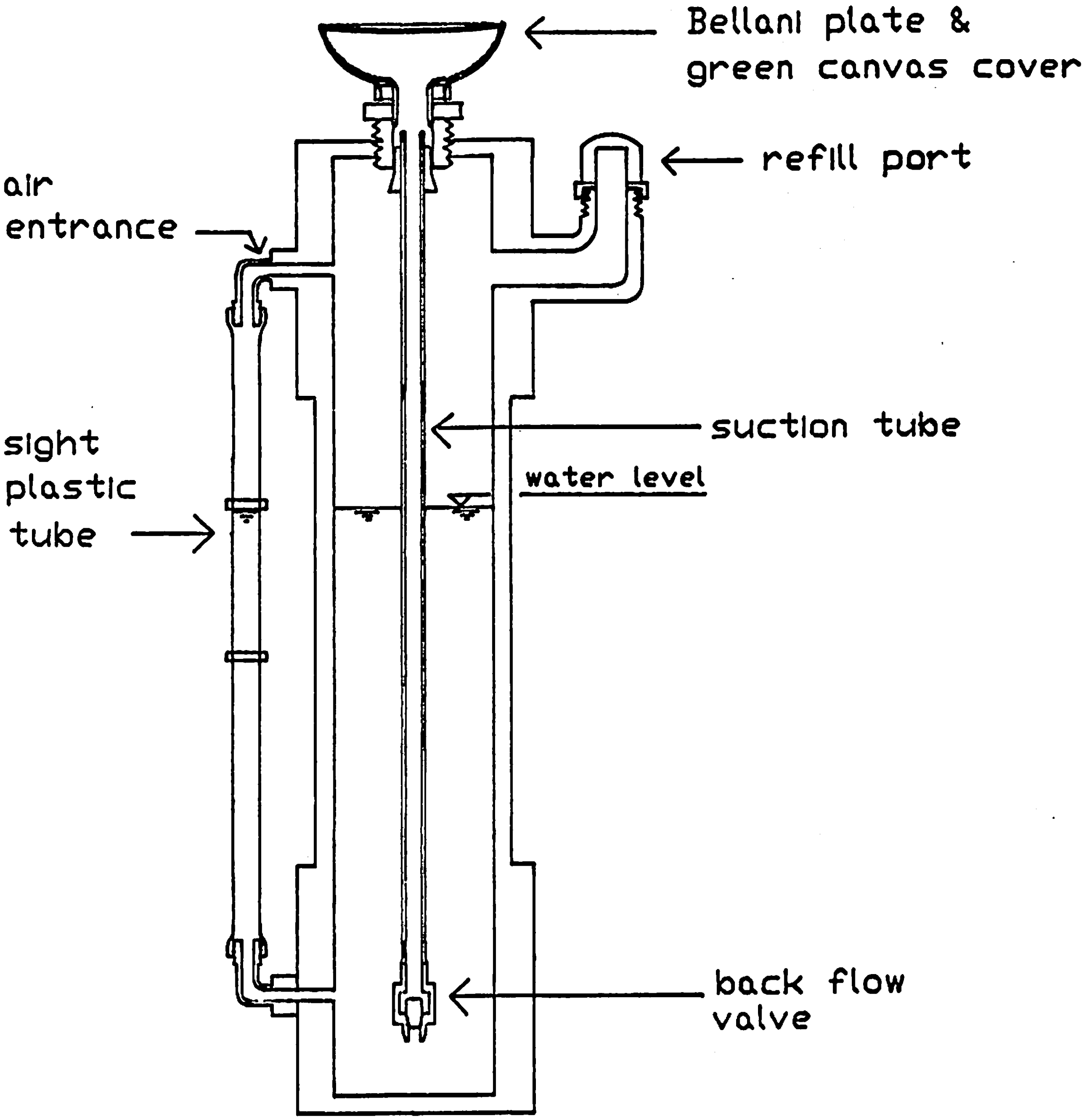

FIGURE 1. Schematic description of the modified atmometer.