USING AN ATMOMETER FOR IRRIGATION SCHEDULING IN EASTERN WASHINGTON

Introduction to Atmometers

Good irrigation water management improves grower profitability and also improves environmental water quality. Most irrigation scheduling techniques require an estimate of daily crop water use (evapotranspiration). Evapotranspiration (ET) is usually estimated by calculating the ET of a reference crop, which is usually grass or alfalfa, and then multiplying that by a crop coefficient that is specific to a particular crop and that crop's growth stage as indicated in the following equation.

$$ETc = Kc \times ETr$$

where ETc is the crop ET, Kc is the crop coefficient, and ETr is the reference crop evapotranspiration.

Although reference crop evapotranspiration can usually be calculated from weather data measured by automated agricultural weather stations such as those used by AgWeatherNet, these stations are expensive and may be located in areas that do not represent the local weather conditions of a particular field.

The atmometer (sometimes called an ET-gauge; Figure 1) is a relatively simple and inexpensive alternative to a full weather station and is used to estimate reference crop evapotranspiration for irrigation scheduling. An atmometer simply measures the evaporation rate of distilled water from a wet surface, which is related to crop water use or evapotranspiration.

An atmometer is a 16-inch tall, 2.5 inch diameter PVC tube that is capped with a porous ceramic surface and an evaporation regulating cover (Figures 1, 2, 3, and 4). The tube is filled with distilled water. As this water evaporates from the ceramic surface, water is drawn up a feeder hose inside, dropping the water level inside the tube. The water level is read on a clear sight/indicator tube mounted on the side. The amount of water that evaporates changes depending on the weather and can be used to approximate the changing water needs of a reference crop of short grass (ETo) or full-grown alfalfa (ETr), depending on the canvas wafer whose color and weave are calibrated to best represent a reference crop.

Figure 1. An atmometer fixed to a fence post. The sight tube indicates the water level in the reservoir. The water level in the reservoir drops as water evaporates from the top of the gauge. The wires on top of the atmometer discourage birds from perching on it. Photo: R.T. Peters.

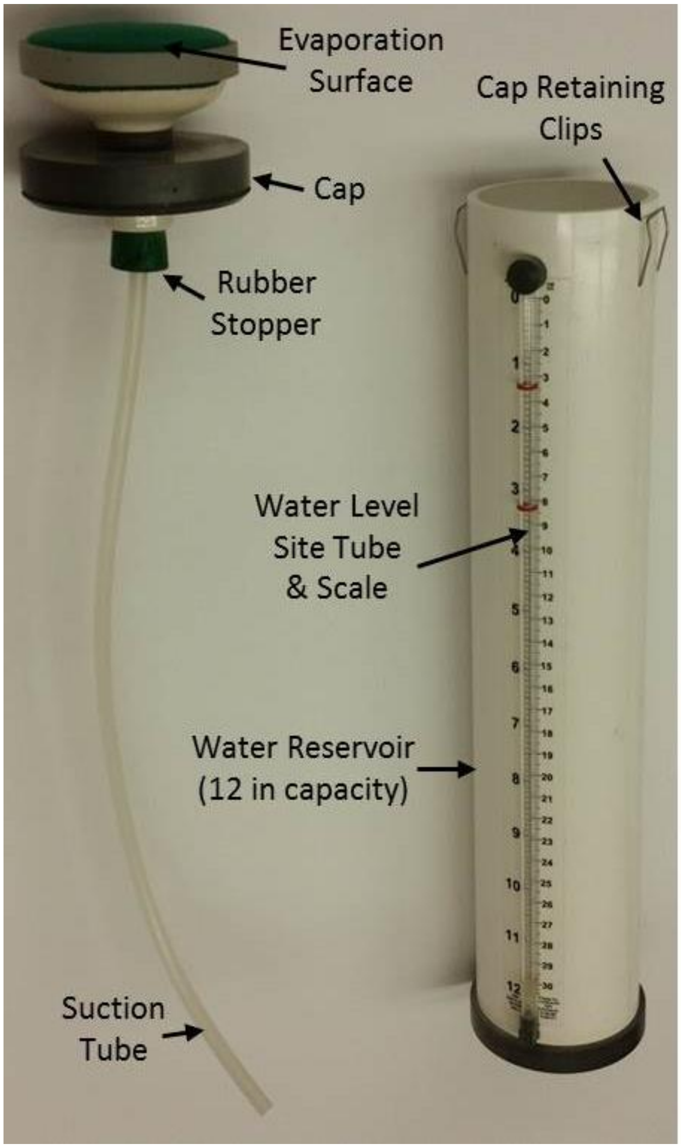

Figure 2. The components of an atmometer. The water reservoir is filled with distilled water, and as water evaporates from the ceramic cup at the top, the water level drops in the water reservoir. The water level differences can be read on the sight tube and are related to crop water use. Photo: R.T. Peters.

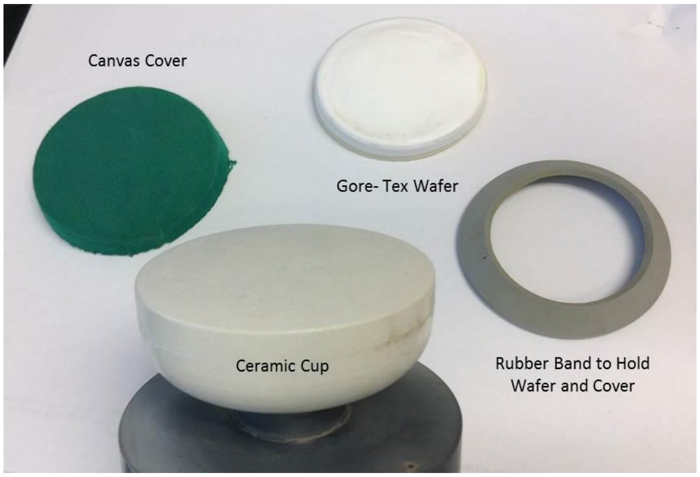

Figure 3. Atmometer head. The Gore-Tex wafer allows water to evaporate from the ceramic cup while excluding rainfall. Photo: R.T. Peters.

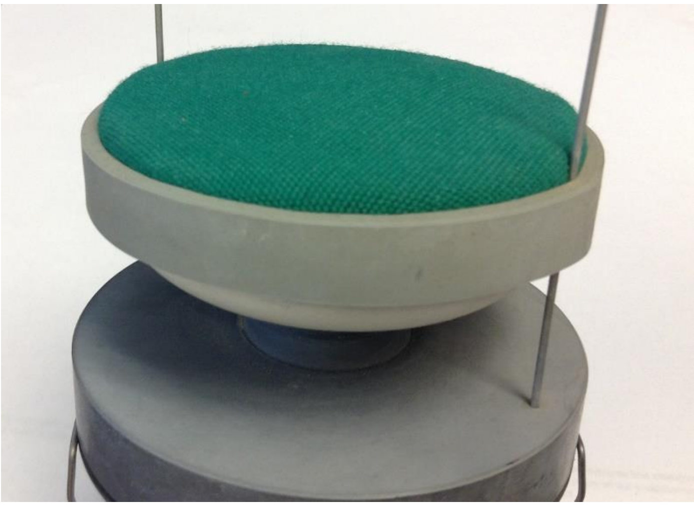

Figure 4. The assembled atmometer head including the bird wires. Photo: R.T. Peters.

Advantages and Disadvantages of Atmometers

Some advantages of using atmometers to estimate crop water use of a reference crop are:

- Atmometers are inexpensive (about $300) compared to a full weather station ($7,000) or most soil moisture monitoring methods (about $1,500, depending on the method used).
- They are site-specific. The results are closely related to the specific field growing conditions.
- They are simple to set up and read.
- They are intuitive.
- Unlike weather station-based ET estimates, atmometers help approximate the reduction in plant ET caused by dew.
- They are fairly robust (the atmometer handles adverse weather and wear fairly well).

Some disadvantages of atmometers include:

- Like all ET estimation techniques, atmometers are not sensitive to differences in crop water use at different crop development stages. Therefore, water use estimates must be multiplied by crop stage-specific factors (crop coefficients).
- A small amount of maintenance is required (i.e., refilling reservoir two to three times per season with distilled water).
- Requires direct observations and record keeping.

Previous Research Supports the Use of Atmometers

Many studies have shown that atmometers provide reliable measurements of grass water use (Magliulo et al. 2003; Broner and Law 1991; Hess 1996; Alam and Trooien 2001; Irmak et al. 2005). Daily errors were not uncommon, but cumulative weekly and seasonal totals had average errors of 2 to 5% compared to more sophisticated ET estimation methods (Magliulo et al. 2003; Broner and Law 1991; Gavilan and Castillo-Llanque 2009). Schlegel (2009) and Gavilan and Castillo-Llanque (2009) showed that on cooler, windy days the atmometer overestimated water use, and on hot and calm days water use was underestimated. Atmometers matched actual conditions best if used under non-windy and moderate temperature conditions, or under hot and windy conditions. Another study also indicated that the atmometer underestimated crop water use under rainy conditions (Irmak et al. 2005). Despite these minor drawbacks, most irrigation experts support the use of atmometers for estimating crop water use for irrigation management (Bauder 1999; Alam and Elliot 2003; Parchomchuk et al. 1996).

Figure 5. The atmometer study site located next to the WSUHQ AgWeatherNet station for ET comparison. Photo: R.T. Peters.

Eastern Washington Atmometer Test

At the Washington State University Irrigated Agriculture Research and Extension Center in Prosser, Washington, the reference crop water use estimates from atmometers were compared to crop water use calculated using the ASCE Standardized Penman-Monteith equation (ETo) from carefully calibrated weather data from an AgWeatherNet station immediately adjacent to the atmometers (Figure 5). Three atmometers were set up on wooden stands about three-feet high with the tops covered with a grass reference canvas wafer. The daily water loss was recorded and tracked over two summer seasons. Monthly cumulative water use estimates from the atmometer were all within ±5% of the computed grass reference ETo from the WSU AgWeatherNet HQ (WSUHQ) site. Comparisons of the cumulative *seasonal* evapotranspiration of the atmometers with the computed values of grass reference evapotranspiration are shown in Figures 6 and 7. In 2008 the atmometer overestimated the cumulative ETo by about 8%, while in 2009 the gauges underestimated ETo by about 3% for most of the season. Based on these comparisons, the atmometer was shown to be a reasonable estimator of daily grass reference ET throughout the season.

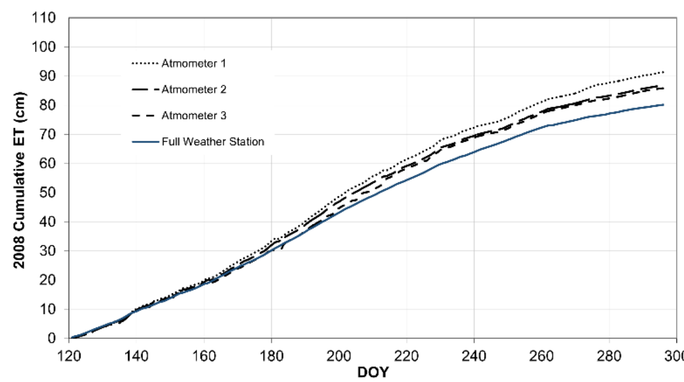

Figure 6. Plot of the cumulative seasonal (2008) evapotranspiration from the different atmometers and the computed cumulative grass (ETo) reference evapotranspiration. DOY along the x-axis is the day of the year or Julian day.

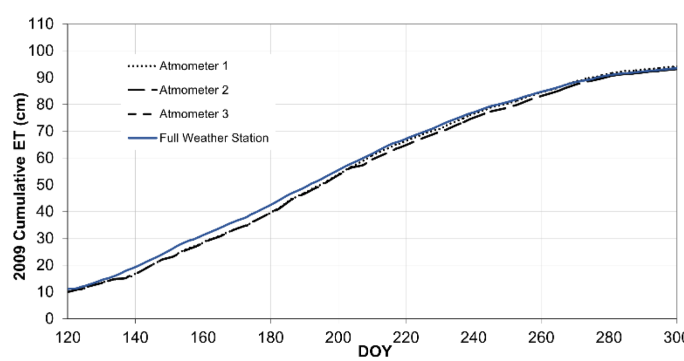

Figure 7. Plot of the cumulative seasonal (2009) evapotranspiration from the different atmometers and the computed cumulative grass (ETo) reference evapotranspiration. DOY along the x-axis is the day of the year or Julian day.

Crop Coefficients

Atmometers estimate the crop water use of a reference crop of short grass and are a measurement of the weather and climate effects on crop water use. They do not take into account how crops use different amounts of water during their various growth stages. For example, a recently emerged corn plant does not use as much water as a fully grown corn plant. To be used accurately, the atmometer water evaporation values must be multiplied by crop coefficients that are specific to the crop and that crop's stage of growth. Rough estimates of crop coefficients for use with the alfalfa reference canvas that are applicable to eastern Washington are given in Table 1. Grass reference crop coefficients can be approximated from alfalfa reference crop coefficients by multiplying by 1.2. More sophisticated crop coefficients for use with the alfalfa reference ET can be found at the AgriMet website.

Practical Use of Atmometers to Schedule Irrigations

The total depth of evaporated water from the atmometer multiplied by the corresponding crop coefficient approximates crop water use. This total crop water must be replaced by irrigation or precipitation or the crop will become water stressed. Be careful not to apply more water than the soil can retain in the crop's root zone through irrigation.

Table 1. Rough estimates of monthly average crop coefficients for use with alfalfa reference ET (ETr). Multiply by 1.2 for use with grass reference ET.

	Month							
Crop	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**
Alfalfa	0.01	0.59	1.07	1.05	1.02	0.99	0.97	0.12
Apples		0.31	0.83	1.05	1.05	1.05	0.84	0.30
Apricots		0.31	0.87	1.10	1.10	1.00	0.69	0.07
Asparagus		0.02	0.42	0.65	0.88	1.00	0.97	0.11
Beans (dry)			0.06	0.48	0.92	0.56		
Beans (green)			0.06	0.66	0.86			
Beets (table)		0.07	0.44	0.66	0.86	0.88	0.83	0.05
Blackberries	0.02	0.44	0.91	1.05	1.02	0.90	0.78	0.14
Blueberries	0.06	0.79	1.03	1.03	1.01	0.36		
Bluegrass Seed	0.19	0.65	0.95	0.71	0.11			
Broccoli	0.02	0.50	0.66	0.86	0.87	0.81		
Brussel Sprouts	0.02	0.58	0.71	0.87	0.88	0.81		
Cabbage	0.01	0.41	0.75	0.99	0.83	0.42		
Canola	0.13	0.71	1.05	0.82	0.01			
Cantaloupe			0.23	0.52	0.69	0.64		
Carrots	0.02	0.70	0.77	0.85	0.85	0.78		
Cauliflower	0.02	0.58	0.71	0.86	0.87	0.81		
Celery			0.55	0.74	0.80	0.80	0.24	
Cheatgrass	0.59	0.69	0.10					
Cherries		0.19	0.97	1.12	1.12	1.02	0.70	0.07
Clover	0.01	0.63	0.92	0.92	0.92	0.92	0.84	0.10
Corn (grain)			0.12	0.39	0.98	1.06	0.27	
Corn (sweet)			0.19	0.48	0.90	0.85		
Cranberries		0.30	0.75	0.75	0.75	0.75	0.75	0.09
Cucumbers			0.29	0.65	0.70	0.70	0.70	0.09
Garlic	0.02	0.58	0.69	0.82	0.83	0.69		

	Month							
Crop	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**
Grain (spring)		0.35	0.74	1.04	0.94			
Grain (winter)	0.22	0.65	1.04	1.05	0.44			
Grapes (juice)		0.11	0.48	0.78	0.90	0.90	0.90	0.11
Grapes (wine)		0.06	0.19	0.39	0.61	0.70	0.70	0.09
Grass (hay)	0.19	0.72	0.90	0.90	0.90	0.85	0.77	0.09
Grass (pasture)	0.10	0.50	0.65	0.65	0.65	0.65	0.58	0.07
Grass (tall pasture)	0.10	0.56	0.75	0.75	0.75	0.75	0.64	0.07
Grass (turf)	0.39	0.64	0.65	0.65	0.65	0.65	0.65	0.08
Hops		0.10	0.25	0.36	0.69	1.00	0.70	
Lentils		0.16	0.67	1.02	0.67	0.02		
Lettuce		0.68	0.11					
Melons			0.18	0.68	0.80	0.80	0.70	0.08
Mustard	0.15	0.61	0.85	0.69	0.01			
Onions (dry)	0.03	0.50	0.67	0.93	0.95	0.62		
Onions (green)	0.29	0.64	0.73					
Peaches		0.19	0.92	1.12	1.12	1.02	0.70	0.07
Peaches	0.39	0.42	0.92	1.12	1.12	1.02	0.70	0.50
Pears		0.19	0.90	1.15	1.15	1.08	0.73	0.07
Plums		0.19	0.90	1.15	1.15	1.15	0.85	0.07
Peas	0.02	0.41	0.72	0.96	0.34			
Peppermint	0.05	0.41	0.76	0.98	0.98	0.98	0.97	0.11
Peppers			0.27	0.62	0.83	0.80		
Plums		0.11	0.77	1.05	1.05	1.04	0.76	0.07
Potatoes			0.36	0.67	0.85	0.78	0.19	
Pumpkin			0.23	0.48	0.72	0.83	0.77	0.09
Radishes		0.59	0.09					
Raspberries	0.01	0.41	0.93	1.08	1.08	1.04	0.84	0.09
Safflower	0.01	0.38	0.93	1.08	0.87	0.08		
Sorghum			0.19	0.57	0.90	0.89	0.46	
Soybeans		0.01	0.40	0.82	0.96	0.92	0.27	
Spearmint		0.10	0.50	0.98	1.03	0.88		
Spinach	0.07	0.55	0.64	0.78	0.79	0.05		
Squash			0.22	0.46	0.69	0.80	0.73	0.08
Strawberries	0.13	0.40	0.56	0.69	0.70	0.65	0.59	0.07
Sugar Beets		0.04	0.32	0.68	1.02	1.05	0.86	0.05
Sunflower		0.23	0.54	0.96	0.99	0.36		
Sunflowers		0.14	0.41	0.87	0.91	0.37		
Tomato			0.27	0.62	0.83	0.79		
Tomatoes			0.27	0.66	0.92	0.86		
Tubers	0.16	0.52	0.73	0.90	0.92	0.88	0.82	0.10
Watermelon		0.19	0.45	0.81	0.85	0.58		

Conclusion

Atmometers give a reasonable approximation of reference evapotranspiration. In our tests, atmometers provided a close correlation (R^2>0.95) with reference ET estimates from well-calibrated agricultural weather stations. Using reference ET estimates from atmometers with a crop coefficient approximates crop water use and can be used to achieve better yields with less water.

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