A water budget for irrigation scheduling

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There are many reasons why water is essential for turf growth: for the formation of sugar during photosynthesis, for the dissolution and absorption of plant nutrients from the soil, for the moderation of leaf temperature through transpiration or syringing, and others. Likewise there are many reasons why excessive water is detrimental to turf growth: lack of aeration resulting in reduced root growth and eventually reduced top growth, greater susceptibility to disease, increased compaction,and increased leaching of plant nutrients, to cite a few.

Water is supplied through rainfall or irrigation. Rainfall cannot be controlled, therefore it is essential that the turf manager has a system whereby irrigation can be scheduled to supplement rainfall. Modern automated irrigation systems greatly reduce the labour involved in irrigation, however, one or more of the disadvantages associated with excess water may easily result from "set the clock and forget it" automated systems. What is needed is a system whereby the turf manager may "set the clock" but at the same time change the settings to accommodate rainfall and changing weather conditions.

The installation of moisture sensing devices in the soil has been used to predict water requirements. The moisture block, which provides an electrical resistance reading, is most sensitive in relatively dry soils and is subject to significant salt effects. Another moisture sensing device is known as a tensiometer: a device which is sensitive at soil moisture level desirable for turf. Unfortunately the tensiometer has installation characteristics which interfere with other turf maintenance operations. It also requires considerable maintenance to give reliable data and must be removed every fall and reinstalled below the surface in the spring.

A water budget system offers a third alternative as a guide for when to irrigate. The budget is based on water gains by a turf area through rainfall and irrigation and water losses from a turf area through evapotranspiration (ET) and drainage.

The water gains as rainfall are measured by the placement of several plastic rain gauges in open areas around the golf course. To measure irrigation water gains it is necessary to obtain a calibration of the system used on each green. A calibration can be obtained by removing the tops from ten juice cans and randomly placing them on the green. Water is collected for a 30-minute irrigation period. Assuming a standard 1360 ml can having a surface area of 86.6 cm, the total collection of water in the ten cans, measured as grams or millilitres, is divided by 86.6 to give the mm of added water in 30 minutes. Division of the mm of added water by the number of minutes of irrigation provides an irrigation rate of mm of water per minute.

Water loss by ET is not easy to measure but may be estimated from meterological measurements and observations or by evaporation from a pan of water. The evaporation pan procedure is more accurate but requires some expenditure in equipment. The eva-poration pan is a circular pan constructed from 2.4 mm thick mild steel and measuring 122 cm in diameter and 25 cm deep (Fig. 1). Ten cm inside the outer ring a second ring ring is welded to the base to provide a water tight seal. An 8-cm diameter by 25 -cm deep stilling well stands near the edge of the inner com-

Fig. 1: A diagram of an evaporation pan for estimating evapotranspiration.

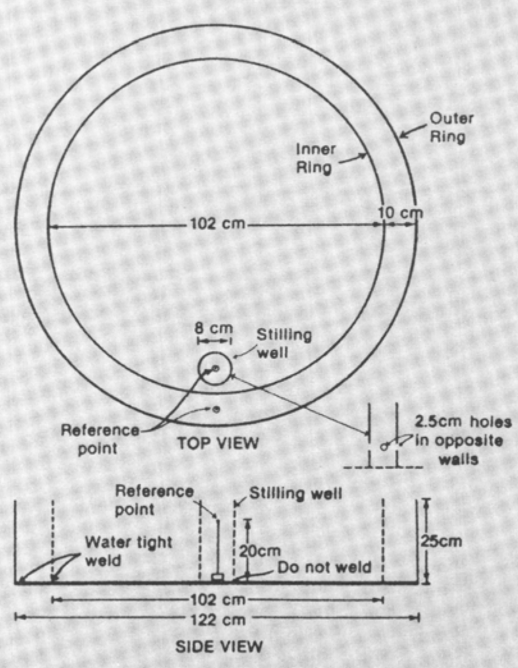


Table 1: How to calculate pan evaporation.

Weather Situation	**Formula for Pan** Evaporation in mm.
1. No rain. Added 'A' g or ml of water to pan to get correct level	$\frac{A}{817}$
2. Small rain of 'R' mm. Added 'A' g or ml of water to pan to get correct level	$R + \frac{A}{817}$
3. Big rain of 'R' mm. Took 'E' g or ml of water from pan to get correct level	$R - \frac{E}{817}$

partment. A sharp pointed brass rod, anchored in a lead base block and adjusted to a total length of 20 cm is placed in the centre of the stilling well. A similar pointed brass rod is placed between the inner and outer rings. The evaporation pan is placed on a slatted platform 10 cm above ground level in a non-shaded area, open to the free flow of the wind.

Water is added to the inner and outer compartments to bring the water up to the level where the point of the brass rod just breaks the water surface. A few crystals of copper sulphate (bluestone) are added to prevent algae growth. Each morning the weight of water (g) or volume of water (ml) required to bring the water level back to that point in the inner compartment is measured. If rain during the previous 24 hours has exceeded the amount of ET, the amount of water which must be removed to return the water to the point is recorded. To obtain the ET value it is necessary to subtract the amount of water which was removed from the amount of rainfall, both in mm. When the rainfall is less than ET, the amount of rainfall is added to the mm of water used to re-level the inner tank to give the total ET for the previous day. The amount of water removed or added in mm is obtained by dividing the weight (g), or volume (ml), of water removed or added by 817 which is 1/10 the surface area of the inner compartment (Table 1).

Table 2: Correction factors for adjusting pan evaporation to grass ET.

Month	Correction Factor*
May	0.55
June	0.65
July	0.75
August	0.75
September	0.55
October	0.45

* Pan Evaporation X Correction Factor = Grass ET.

Evaporation from a water surface in the pan is greater than from grass leaves, hence a correction factor must be applied to give grass ET. Measurements made at the microgreens at the Cambridge Research Station indicate the factor changes with time of season from 0.55 to 0.75 (Table 2).

An alternative, but less accurate, method for estimating grass ET is to record daytime weather conditions such as sunshine, temperature, wind velocity and humidity. Visual estimates of the variables except temperature, may be used in conjunction with Table 3 to estimate pan evaporation, to which the correction factors found in Table 2 are applied to provide rough estimates of grass ET.

Finally, to develop a water budget it is necessary to estimate the amount of plant available water retained in the rooting zone of the turf. The estimates may be known for sand rooting systems where the water characteristics of the sand were determined prior to construction. Alternatively the volume of plant available water may be computed from a knowledge of the bulk density and the percent silt and clay in samples from greens and fairways.

Table 3: Estimators for pan evaporation based on observed weather conditions.

	One p.m. Weather Observations			Estimated Pan
Sunshine	Temperature	Humidity*	Wind**	Evaporation (mm)
Full	Greater than 23 C	Low	High	8.0
Full	Greater than 23 C	Low	Low	7.5
Full	Greater then 23 C	High	High	7.0
Full	Greater than 23 C	High	Low	6.5
Full	Less than 23 C	Low	High	6.5
Full	Less than 23 C	Low	Low	6.0
Full	Less than 23 C	High	High	5.5
Full	Less than 23 C	High	Low	5.0
Cloudy	Greater than 23 C	Low	High	5.0
Cloudy	Greater than 23 C	Low	Low	4.5
Cloudy	Greater than 23 C	High	High	4.0
Cloudy	Greater than 23 C	High	Low	3.5
Cloudy	Less than 23 C	Low	High	3.5
Cloudy	Less than 23 C	Low	Low	3.0
Cloudy	Less than 23 C	High	High	2.5
Cloudy	Less than 23 C	High	Low	2.0

*Low = clear sky, unlimited visibility: High = smog, haze, fog.
** Low = leaves and small branches moving; High = tree tops moving.

It is generally accepted that irrigation should occur when 50% of the plant available water has been lost through ET. At that time sufficient water should be added to raise the water content of the rooting zone back to slightly above field capacity; any water in addition to this amount will be wasted through drainage loss.

Having established an estimate of the volume of plant available water in the rooting zone a water budget may be set up which is analogous to a daily interest savings account at a bank. A value equivalent to 50% of the plant available water serves as the water budget base line which must not be exceeded if water stress to the turf is to be avoided (minimum bank balance). Water removed from the rooting zone by grass ET (cheques written) is recorded daily and subtracted from the estimate of plant available water (Table 4). When rainfall occurs it is added to the plant available water balance (pay cheque deposited). When the balance approaches the water Budget base line sufficient irrigation must be applied to return the budget to the plant available water level (lottery winnings). When rainfall or rainfall plus irrigation occur which supply more water than necessary to raise the budget above the plant available water level the difference will be lost as drainage water (income tax paid) and the budget will remain at the plant available water level. An example of a water budget for a green having a storage capacity of 40 mm of water and a water budget base line of 20 mm is provided in Table 4. Personal computer buffs will find their water budget system for irrigation scheduling another use they can make of the computer.

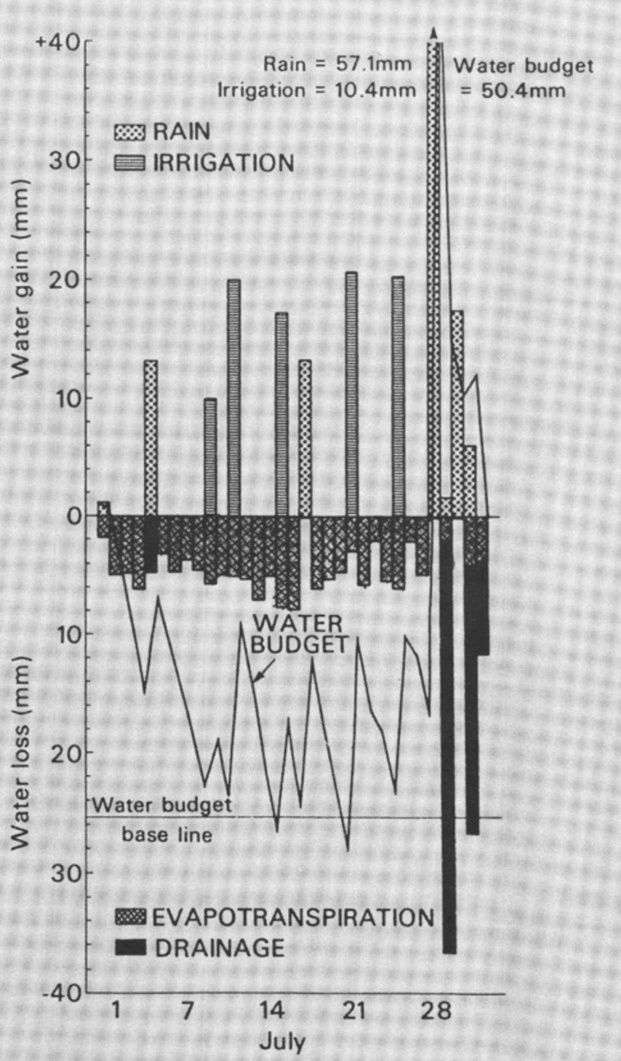
The microgreen installation at the Cambridge Research Station offered an opportunity to evaluate the water budget system. During 1983, a particularly warm and dry season, daily

Table 4: A hypothetical water budget record sheet for sand rooting zone having a water storage of 40 mm of plant available water in the rooting zone at the time records start.

	Water Input*			Water Output*	
Date	Rainfall	Irrigation	Evaporation	Drainage	Balance
			(mm)		
Aug. 7	-	-	-6.0	-	34.0
Aug. 8	+3.0	-	-2.6	-	34.4
Aug. 9	-	-	-6.O	-	28.4
Aug. 10	-	-	-5.25	-	23.15
Aug. 11	-	+15.0	-4.2	-	33.95
Aug. 12	+18.0	-	-3.0	8.95	40.00
Aug. 13	-	-	-4.0	-	36.0
Aug. 14	-	-	-2.8	-	33.2

*All measurements made at 9:00 a.m.

Fig. 2: The water input through rain and irrigation and loss through evapotranspiration and drainage during July,1983, on the micro greens at the Cambridge Research Station.



records of pan evaporation, rainfall, irrigation and drainage loss were used to schedule irrigation. A plot of the data for the period of June 30 to Aug. 1 is shown in Figure 2. The sand in the microgreens had an estimated storage capacity of 50 mm of plant available water in a 30 cm depth, hence at 50% use of plant available water irrigation should occur when 25 mm of water has been consumed by plant growth. On June 30 the budget indicated a positive value of +0.7 mm, a value which fell to -23 mm by July 8 when it approached the water budget base line which signalled the need for irrigation.

During the period June 30 to Aug. 1 irrigation was used six times and rain occurred six times, primarily as a heavy 57.4 mm rain on July 28 and lesser amounts on the three subsequent days. Note that irrigation was not required every day, even on a sand rooting zone. The maximum ET was about 8 mm, thus a storage of 25 mm of water would provide sufficient water for a three days without irrigation.

The July 28 rain was preceded by 10.4 mm of irrigation which had been called for by the water budget. As a result a drainage loss of 69 mm occurred over the following days as the rainfall continued. Such occurrences can not always be avoided as it's impossible to predict the intensity and duration of summer storms.

GRASS CLIPPINGS

- Researchers at Texas A&M University have quantified the cooling effect of turfgrass, noting that on a sunny day the turf will reduce surface temperatures by 30-40 degrees-F in comparison to bare soil.
- Through the extensive and intertwined system of leaves and roots, the turfgrass acreage in the U.S. is estimated to trap some 12 million tons of dust and dirt annually.
- One acre of grass will absorb hundreds of pounds of fossil fuel-created sulphur dioxide in a single year.