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IRRIGATION REQUIREMENTS FOR TURF

by

George H. Hargreaves[1]

INTRODUCTION

There is much overirrigation of turf. Some is unavoidable but significant savings of water can be had from a better understanding of the principles of scheduling irrigation. Irrigation scheduling is greatly facilitated by uniformity of soil depth and moisture storage capacity.

This paper describes the basic principles of irrigation and provides a simple and reliable method for calculating the rate at which grass is using water. For arid climates the only weather measurement required is mean air temperature. For mean relative humidities above 64 percent, a correction for relative humidity is desirable.

The methodology is presented in a form that will permit manual calculation, machine calculation, or computer scheduling. However, ease of computation makes use of a computer unnecessary.

SOIL CHARACTERISTICS

The Ames Irrigation Handbook gives the following values for soil moisture storage capacities for various soils:

Table 1. Approximate readily available soil moisture storage capacity per foot of depth.

Texture	Inches/foot	Texture	Inches/foot
Coarse sands	0.50	Silt loam	1.75-2.00
Fine sands	0.75	Silty clay loam	2.00
Loamy sands	1.00	Clay loam	2.00-2.25
Fine sandy loam	1.25-1.50	Heavy clays	1.75

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If the turf to be irrigated contains areas of shallow or very sandy soils then the readily available moisture storage capacity for those areas is quite low. It then becomes desirable to irrigate when these critical areas are showing moisture stress. Irrigation is usually scheduled when approximately half of the readily available moisture in the crop root zone is depleted.

ESTIMATING WATER USE BY GRASS

The California State Department of Water Resources (1)[2] measured Class A pan evaporation from irrigated grass areas and the water use by grass (evapotranspiration) in various locations. Grass evapotranspiration averaged about 0.80 times pan evaportation. This relationship is probably satisfactory for pans located in moderate to large irrigated areas and for locations having fairly low sensible heat transfer as in the case for high humidities with low wind velocities.

Various authors have related water use to day length and climatic factors. A methodology proposed by Christiansen (2) and used and modified by various graduate students, engineers and technicians, makes use of extraterrestreal radiation expressed as units of evaporation and coefficients for several weather elements.

A modification proposed by Hargreaves (3) can be written

$$ETP = 0.35 \times RT \times C \qquad (1)$$

in which

ETP is potential evapotranspiration

RT is the extraterrestrial radiation expressed as equivalent evaporation by dividing the radiation (cal/cm^2/day) by the heat of vaporization at the mean temperature, TM, and converting to appropriate units, usually inches or mm per day or per month (Table 2.)

$$C = CT \times CH \times CW \times CE \qquad (1a)$$

$$CT = 0.40 + 0.024 \times TM \qquad (1b)$$

(TM is mean temperature in °C)

$$CT = 0.013 \times TMF \qquad (1c)$$

(TMF is mean temperature in °F)

$$CH = 0.05 + 1.58 \times (1.00 - HM)^{1/2} \qquad (1d)$$

with a maximum value of 1.00 for values of HM less than .64 (HM is mean relative humidity expressed decimally using integrated values over a 24-hour period)

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[2] Numberals in parentheses refer to corresponding items in the Appendix - References.

TABLE 2. EXTRATERRESTRIAL RADIATION IN MM PER MONTH AT 25. DEGREES CENTIGRADE

NORTH	MONTH											
LAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
60.	44.	94.	214.	342.	471.	514.	506.	406.	261.	143.	58.	30.
58.	58.	109.	229.	352.	477.	515.	509.	415.	275.	158.	72.	43.
56.	72.	123.	244.	363.	482.	517.	512.	423.	288.	174.	86.	56.
54.	87.	137.	259.	373.	487.	519.	516.	431.	301.	190.	101.	70.
52.	102.	151.	273.	383.	492.	520.	519.	439.	313.	205.	116.	85.
50.	117.	166.	287.	392.	496.	522.	521.	447.	325.	221.	131.	100.
48.	133.	180.	301.	401.	500.	523.	524.	454.	337.	236.	147.	115.
46.	149.	194.	314.	409.	504.	524.	526.	460.	348.	251.	162.	131.
44.	165.	208.	327.	417.	507.	524.	527.	466.	359.	266.	177.	147.
42.	181.	222.	340.	425.	510.	524.	529.	472.	370.	280.	193.	163.
40.	197.	235.	352.	432.	512.	524.	530.	477.	380.	294.	209.	179.
38.	213.	248.	364.	438.	514.	523.	530.	482.	389.	308.	223.	195.
36.	229.	262.	375.	444.	516.	522.	530.	486.	398.	322.	238.	211.
34.	244.	274.	385.	450.	517.	521.	530.	490.	407.	335.	253.	227.
32.	260.	287.	396.	455.	517.	519.	529.	493.	415.	348.	269.	243.
30.	275.	299.	406.	459.	517.	516.	527.	495.	422.	360.	282.	259.
28.	291.	311.	415.	463.	516.	513.	525.	497.	429.	372.	296.	275.
26.	306.	323.	424.	467.	515.	510.	522.	494.	435.	383.	310.	290.
24.	320.	334.	432.	470.	513.	506.	519.	499.	442.	394.	324.	305.
22.	335.	345.	441.	472.	511.	502.	516.	500.	447.	405.	338.	320.
20.	349.	355.	449.	474.	508.	447.	512.	499.	452.	415.	351.	335.
18.	363.	366.	454.	475.	505.	491.	507.	499.	457.	425.	363.	350.
16.	376.	379.	460.	475.	501.	485.	502.	497.	460.	434.	376.	364.
14.	389.	385.	466.	475.	497.	479.	496.	495.	464.	442.	388.	378.
12.	402.	393.	471.	474.	492.	472.	490.	493.	466.	451.	349.	391.
10.	414.	402.	476.	474.	486.	465.	483.	490.	466.	459.	410.	404.
8.	426.	410.	480.	472.	480.	457.	476.	486.	470.	465.	421.	417.
6.	438.	417.	483.	470.	474.	449.	468.	482.	471.	472.	431.	430.
4.	449.	424.	486.	467.	466.	440.	460.	477.	471.	478.	441.	441.
2.	459.	431.	489.	464.	459.	431.	451.	472.	471.	483.	450.	453.
0.	469.	437.	489.	460.	451.	421.	442.	466.	470.	498.	459.	464.

$$CE = 1.00 + 0.04\ EL/1000 \qquad (1e)$$

(EL is elevation in meters)

CW = a coefficient for wind speed

Based upon data from lysimeters planted to grass in several different states and/or countries, an equation was developed that combines the concepts of day length and extraterrestrial radiation. The equation can be written

$$ETP = ETF \times CT \times CH \qquad (2)$$

in which

$$ETF = 0.35 \times RT \times DL/12.0$$

(DL is mean day length in Hrs. for the period)

CT and CH are defined in Equation 1.

If the location is at a fairly high elevation, Equ. 1e should also be used indicating an increase in water use of about 1.2 percent per thousand feet above sea level.

The constant in the coefficient for temperature in °F can be combined with ETF in order to obtain a new coefficient to be used to calculate the evapotranspiration by a short grass. The resulting equation becomes

$$ETG = T°F \times ETFG \qquad (3)$$

in which

ETG is grass evapotranspiration
T°F is mean temperature in Farenheit, and
ETFG is the potential evapotranspiration factor for grass (Table 3).

If the elevation is such as to require a correction coefficient and if mean 24 hour humidities average above 64 percent, then additional corrections are required. The equation becomes

$$ETG = T°F \times ETFG \times CH \times CE \qquad (4)$$

in which

ETG, T°F, ETFG, CH and CE are as defined in Eqs. 1, 2, and 3. Coefficients to correct for relative humidity are given in Table 4.

This methodology has been evaluated using measured grass evapotranspiration from a mixture of rye grass and Bermuda grass at Abde and Tyr in Lebanon; rye grass at Davis, California; and deep rooted grasses cut for hay at Coshocton, Ohio. During cold weather there is some loss of

Table 3. Potential ET or ETP factor in inches per month for grass, ETFG
(Factor to be multiplied times mean temp. °F to calculate ET for grass.)

NORTH LAT	MONTH JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
50.	.015	.024	.050	.079	.112	.125	.122	.095	.060	.034	.017	.012
49.	.016	.025	.051	.079	.112	.124	.121	.095	.061	.036	.018	.013
48.	.017	.027	.052	.080	.111	.123	.120	.095	.062	.037	.020	.014
47.	.018	.028	.053	.081	.111	.122	.120	.095	.063	.039	.021	.015
46.	.020	.029	.055	.081	.111	.121	.119	.096	.064	.040	.022	.017
45.	.021	.030	.056	.082	.110	.120	.118	.096	.065	.041	.024	.018
44.	.022	.032	.057	.082	.110	.119	.117	.096	.066	.043	.025	.019
43.	.024	.033	.058	.083	.110	.118	.117	.096	.067	.044	.026	.021
42.	.025	.034	.059	.083	.109	.117	.116	.096	.068	.045	.028	.022
41.	.027	.035	.060	.084	.109	.116	.115	.096	.069	.047	.029	.023
40.	.028	.037	.061	.084	.108	.116	.115	.096	.069	.048	.030	.025
39.	.029	.038	.063	.084	.108	.115	.114	.097	.070	.049	.032	.026
38.	.031	.039	.064	.085	.108	.114	.113	.097	.071	.051	.033	.027
37.	.032	.040	.065	.085	.107	.113	.113	.097	.072	.052	.034	.029
36.	.034	.042	.066	.086	.107	.112	.112	.097	.073	.053	.036	.030
35.	.035	.043	.067	.086	.106	.111	.111	.097	.073	.054	.037	.032
34.	.036	.044	.068	.086	.106	.110	.111	.097	.074	.056	.039	.033
33.	.038	.045	.069	.086	.106	.110	.110	.097	.075	.057	.040	.035
32.	.039	.046	.070	.087	.105	.109	.109	.097	.075	.058	.041	.036
31.	.041	.048	.071	.087	.105	.108	.109	.097	.076	.059	.043	.038
30.	.042	.049	.071	.087	.104	.107	.108	.096	.077	.060	.044	.039
29.	.044	.050	.072	.087	.104	.106	.107	.096	.077	.062	.046	.041
28.	.045	.051	.073	.088	.103	.105	.106	.096	.078	.063	.047	.042
27.	.047	.052	.074	.088	.102	.104	.106	.096	.078	.064	.048	.044
26.	.049	.053	.075	.089	.102	.103	.105	.096	.079	.065	.050	.045
25.	.050	.055	.076	.088	.101	.102	.104	.096	.079	.066	.051	.047
24.	.051	.056	.076	.089	.101	.102	.103	.096	.080	.067	.052	.048

Table 4. Relative humidity coefficients, CH

Rel. Hum.	CH	Rel. Hum.	CH	Rel. Hum.	CH
64	1.00	73	0.87	82	0.72
65	0.98	74	0.86	83	0.70
66	0.97	75	0.84	84	0.68
67	0.96	76	0.82	85	0.66
68	0.94	77	0.81	86	0.64
69	0.93	78	0.79	87	0.62
70	0.92	79	0.77	88	0.60
71	0.90	80	0.76	89	0.57
72	0.89	81	0.74	90	0.55

precision due to variability in growth. For those months of mean temperatures of 48°F and above the mean absolute difference between measured and calculated monthly grass evapotranspiration varied for the locations between 6 and 10 percent. On an annual basis differences are almost negligible. Based upon this evaluation it would seem that the proposed methodology estimates the evapotranspiration uses by grass with a high degree of accuracy.

AN EXAMPLE OF CALCULATIONS

If it is assumed that a golf course manager wishes to estimate the water use during a 3-day period in June at latitude 38°N., elevation 1000 ft above sea level, mean temperature of 70°F and a mean 24 hour relative humidity of 72 percent, the computations can be made as follows:

ETFG for grass, (Table 3, line 13 under June)
factor = 0.114

CH for 72% (Table 4) = 0.89

CE for 1000 ft elevation = 1.01

Evapotranspiration use for three days equals

3/30 x 0.114 x 70 x 0.89 x 1.01 = 0.72" or 0.24" per day.

The correction for elevation for altitudes under 1000 ft can be disregarded. The humidity correction can be disregarded for relative humidites less than 65 percent.

If it is assumed that the soil is medium textured with a capacity to hold 1.50 inches per foot of depth and if the effective root depth is

12.0 inches then using a 50 percent depletion of the readily available soil moisture, irrigation will be required every three days. For fine sands or for a 6.0 inch soil depth irrigation will be required about every day. With increased effective root depth irrigation will be required less frequently.

If we can assume an efficiency of 75 percent, then an application of 0.96 inches of water every three days should be adequate for a medium textured soil with an effective root depth of 12 inches.

CLIMATIC DATA

For many locations maximum and minimum temperatures are published in the local papers. There is some difference between 24 hour mean temperatures and the mean of two readings. However, errors introduced by using the mean of two readings will not be great.

Mean 24 hour relative humidity data are less readily available. Various recorders are available that measure both temperature and humidity. Advice on the proper installation of equipment and callibration with standardized data can probably best be obtained from the local Weather Bureau Office.

CONCLUSION

Methodology is presented for calculating the water use of grass from a minimum of climatic data. For low elevations (under 1000 ft) and low humidities (24 hour means under 65 percent) the only weather measurement required is temperature. Based upon available grass evapotranspiration data the average accuracy and provision of this procedure appears most satisfactory.

APPENDIX REFERENCES

1. California State Department of Water Resources, " Vegetative Water Use," Bulletin No. 113-2, 1967, 82 pages.

2. Christiansen, J. E., " Water Requirements for Waterfowl Areas Near the Great Salt Lake," unpublished report to Utah State Fish and Game Department and the Utah Cooperative Wildlife Research Unit, 1960, 58 pages.

3. Hargreaves, George H., "The Evaluation of Water Deficiences," Age of Changing Priorities for Land and Water, Irrigation and Drainage Specialty Conference, American Society of Civil Engineers, Spokane, Washington, September 1972, 18 pages.