5.3 **ESTIMATING URBAN LANDSCAPE EVAPOTRANSPIRATION**

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1. INTRODUCTION

Irrigation controllers are now widely used to manage landscape irrigation; however, scientifically based information on when to apply water and how much to apply is limited. In California, the landscape industry is huge and there is increased competition among water users. Consequently, managing irrigations to optimize efficient water use is critically important to stretch existing water supplies. Therefore, the MS Excel program LIMP.XLS was written to help landscape professionals and homeowners to calculate ET_o rates, determine landscape coefficient (K_L) values, estimate landscape evapotranspiration (ET_L) and determine irrigation schedules. This program not only helps practitioners but it also clarifies what horticulturalists need to research to help to improve urban irrigation management.

Evapotranspiration from landscape vegetation is estimated by using a regional measure of evaporative demand (e.g., reference evapotranspiration or ET_o), a microclimate coefficient (K_m) to adjust the ET_o for the "local" microclimate, a vegetation coefficient (K_v) that accounts for the difference in ET between well watered vegetation and the local ET_o, a density coefficient (K_d) that adjusts the ET estimate for plant density, a stress coefficient (K_s) that adjusts for reductions in ET due to water stress and an evaporation coefficient (K_e) that defines a baseline coefficient value. Initially, the coefficient (K_w) to estimate ET of a well-watered vegetated cover is estimated as:

$$K_w = K_m \times K_v \times K_d \qquad (1)$$

Then K_w is multiplied by a stress coefficient (K_s) to adjust for reductions in ET below that of well-watered vegetation. However, the evaporation coefficient serves as a baseline, so the landscape coefficient is calculated as:

$$K_l = K_w \times K_s > K_e . \qquad (2)$$

Then the landscape evapotranspiration (ET_l) for the vegetation in that location is calculated as:

$$ET_l = ET_o \times K_l . \qquad (3)$$

2. MICROCLIMATE COEFFICIENT

In the "Weather" worksheet (Fig. 1), the upper table is used to estimate regional daily ET_o rates by month and to enter the coefficients used to calculate landscape ET (ET_l). The lower table (Fig. 1) is used to input weather data representing the microclimate of the irrigation site to develop monthly microclimate correction factors to estimate the "Local" ET_o rates. Either daily mean ET_o rates or weather data are input to estimate "Regional" ET_o rates in the upper table. Then the LIMP uses a smooth curve fitting technique to estimate daily ET_o rates during the year from the monthly data. Weather inputs can include the daily mean (1) solar radiation (MJ m^{-2} d^{-1}), air temperature (^oC), wind speed (m s^{-1}), and dew point temperature (^oC). The program calculates ET_o using the Penman-Monteith (PM) equation (Monteith, 1965) as presented in the United Nations FAO Irrigation and Drainage Paper (FAO 56) by Allen et al. (1998). If only temperature data are input, then the Hargreaves-Samani (1982) equation is used.

Weather, Pan Evaporation or ETo Data Entry

Year: 2004 | Station Name: Yuba City | Latitude: 38.9 | Elevation (m): 10.0 | Maximum ET_l/ET_o Vegetation Factor: 0.80

Mon	R_s MJ $m^{-2}d^{-1}$	T_x °C	T_n °C	U_2 m s^{-1}	T_d °C	Pcp mm	NRD #	MC ETo mm	Reg. ETo mm	Input ETo mm	PM ETo mm	HS ETo mm	100 Gnd. Cov. %	0<K_d<1 Density factor K_d	0<K_s<1 Stress factor K_s	0<K_m<1 Climate factor K_m
1	6.0	12.4	4.1	2.8	6.6	117.1	6.6	0.6	0.8		0.8	1.1		1.00	0.10	0.80
2	9.4	15	5.1	2.9	7.8	122.4	5	1.1	1.3		1.3	1.7		1.00	0.10	0.84
3	17.1	18.5	4.9	2.9	7.1	32.3	3	2.3	2.7		2.7	2.9		1.00	0.30	0.84
4	22.0	21.5	6.7	3.4	7.6	21.2	1	3.4	4.1		4.1	4.1		1.00	0.50	0.83
5	24.8	24.5	9.5	3.2	10.2	27.3	0	4.2	4.9		4.9	5.1		1.00	0.75	0.85
6	28.5	28.6	12.1	3.7	12.1	1.4	0	5.2	6.4		6.4	6.1		1.00	0.75	0.82
7	28.4	31.5	13.5	3.6	13.3	0	0	5.6	7.0		7.0	6.5		1.00	0.75	0.79
8	25.8	31.8	13.5	3.1	13.5	0.8	0	5.1	6.4		6.4	5.9		1.00	0.75	0.79
9	20.9	29.5	12.2	3.0	11.8	3.3	2	4.0	5.2		5.2	4.5		1.00	0.75	0.76
10	15.0	24.7	8.1	2.8	7.9	18.7	4	2.5	3.6		3.6	3.0		1.00	0.50	0.70
11	9.0	17.9	5.1	2.3	7.7	46.2	5	1.2	1.6		1.6	1.7		1.00	0.10	0.78
12	7.0	13.5	2.4	2.8	4.6	75.4	6	0.8	1.2		1.2	1.1		1.00	0.10	0.67

Below, input the Microclimate Weather data or mean daily ETo for each month

Mon	R_s MJ $m^{-2}d^{-1}$	T_x °C	T_n °C	U_2 m s^{-1}	T_d °C	MC ETo mm	Reg. ETo mm	Input ETo mm	PM ETo mm	HS ETo mm	Calculation Column	Climate factor K_m
1	6.0	12.4	4.1	1.0	6.6	0.6	0.8		0.6	1.1		0.80
2	9.4	15	5.1	1.0	7.8	1.1	1.3		1.1	1.7		0.84
3	17.1	18.5	4.9	1.0	7.1	2.3	2.7		2.3	2.9		0.84
4	22.0	21.5	6.7	1.0	7.6	3.4	4.1		3.4	4.1		0.83
5	24.8	24.5	9.5	1.0	10.2	4.2	4.9		4.2	5.1		0.85
6	28.5	28.6	12.1	1.0	12.1	5.2	6.4		5.2	6.1		0.82
7	28.4	31.5	13.5	1.0	13.3	5.6	7.0		5.6	6.5		0.79
8	25.8	31.8	13.5	1.0	13.5	5.1	6.4		5.1	5.9		0.79
9	20.9	29.5	12.2	1.0	11.8	4.0	5.2		4.0	4.5		0.76
10	15.0	24.7	8.1	1.0	7.9	2.5	3.6		2.5	3.0		0.70
11	9.0	17.9	5.1	1.0	7.7	1.2	1.6		1.2	1.7		0.78
12	7.0	13.5	2.4	1.0	4.6	0.8	1.2		0.8	1.1		0.67

Figure 1. Climate data input worksheet for microclimate, vegetation, density, stress and evaporation coefficient factors.

Monthly climate data representing the "Local" site are input in the lower table of the Weather worksheet and ET_o is calculated using the PM or HS equations. The ratio of "local" over "regional" ET_o is computed and displayed in the right-hand column of the lower table. This ratio represents a monthly calibration for microclimate. While the microclimate (K_m) factors are shown in the lower table, they are only used by the program if they are copied to the right-hand column of the upper table using "Copy – Paste Special – Values". A smooth curve fitting procedure is used to estimate daily K_m values for the year. A sample plot of daily K_m using data from Figure 2 is shown in Figure 2. If no

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values are input into the right-hand column of the upper table, the default value of K_m = 1.0 is used.

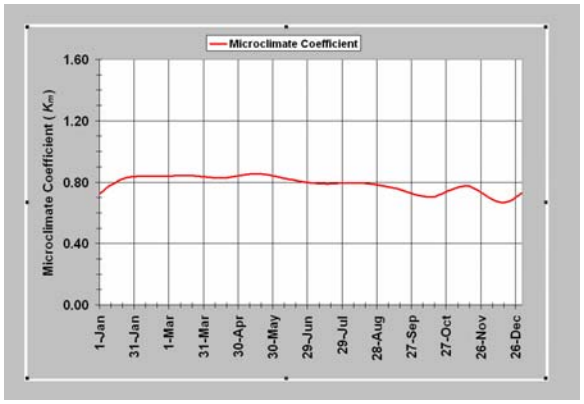

Figure 2. Plot of microclimate coefficient (K_m) versus date from data input into Figure 1.

3. VEGETATION COEFFICIENT

The vegetation coefficient (K_v) is input into the "Weather" worksheet to adjust *ET* for plant canopy differences from ET_o (i.e., the *ET* of 0.12 m tall, cool-season grass). The K_v coefficient represents well-watered vegetation with a full canopy. The K_v accounts for morphological and physiological differences between the vegetation and the reference surface (ET_o). For example, cool-season turfgrass is shorter than the 0.12 m tall, cool-season grass represented by ET_o, so turfgrass ET_l is commonly estimated using $K_v \approx 0.80$. The K_v accounts for differences in net radiation, turbulence due to surface roughness, and canopy resistance relative to ET_o. It is assumed that the plant physiology changes little during the year, so one value is used for K_v all year. The K_v value is input near the top right-hand side of the Weather worksheet (Fig. 1).

4. DENSITY COEFFICIENT

Sparse canopies have lower *ET* than dense canopies of the same vegetation and a density coefficient (K_d) is needed for the adjustment. Since there is no known universal correction for landscape vegetation, the following correction for immature deciduous orchards (Fig. 3) is used to estimate K_d.

$$K_d = sin\left(\frac{C_G}{70}\frac{\pi}{2}\right) \quad (4)$$

where C_G is the percentage of ground covered by green growing vegetation. It is assumed that this relationship accounts for differences in light interception by canopies with cover less than 70 %. For canopies with more than 70 % cover, K_d = 1.0. The percentage ground cover is input by month in the upper table of the weather worksheet, the monthly K_d values are calculated and curve fitting is used to estimate the daily K_d values. If the ground cover cells are left blank, the default value K_d = 1.0 is used. The K_d value is multiplied by the vegetation coefficient (K_v) to estimate the landscape coefficient (K_l) that accounts for plant density and vegetation differences from the local (i.e., microclimate corrected) ET_o rate. For example, Figure 4 shows $K_v \times K_d$ for the data from Figure 1.

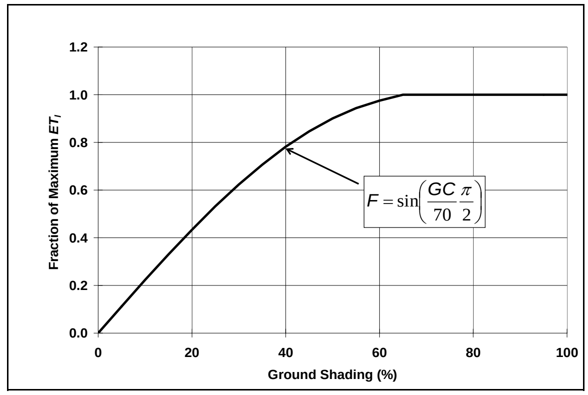

Figure 3. Plot of the density (K_d) correction or fraction of maximum ET_l versus ground cover (C_G) percentage.

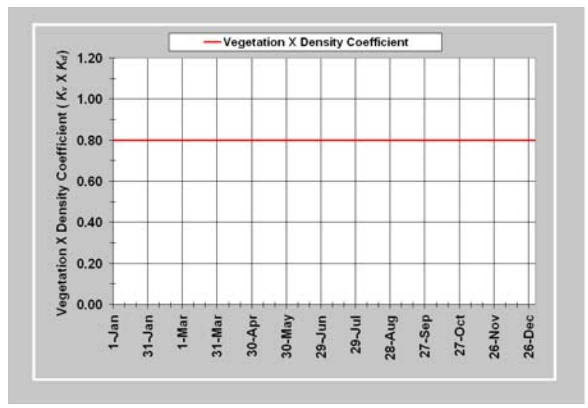

Figure 4. Plot of the product of the vegetation and density coefficient factors from data entered in Figure 1.

5. STRESS COEFFICIENT

Monthly stress coefficient (K_s) values are input into the upper table of the Weather worksheet (Fig. 1). A coefficient of K_s = 0 would force ET_l = 0 and a K_s = 1.0 implies no reduction in ET_l due to water stress. After entering the monthly data, daily K_s values are computed for the entire year using a curve fitting technique. In older literature, it was common to talk about water use differences between vegetation and a "species" coefficient was used to estimate the vegetation *ET* from ET_o. However, in LIMP, the vegetation coefficient (K_v) is used to estimate the *ET* of vegetation at the maximum *ET* rate and the K_s coefficient is used to estimate the *ET* when the vegetation is stressed. For example, warm-season turfgrass has ET rates at about 75% of cool-season turfgrass during the summer but the ET rate is near zero during the winter when the grass is dormant. Therefore, reasonable estimates of the stress coefficient (K_s) by month were input into the "Weather" worksheet (Fig. 1) and the daily values were estimated and plotted (Fig. 5). Then, the daily landscape coefficient values for a warm-season turfgrass would be calculated as $K_l = K_v \times K_d \times K_s$.

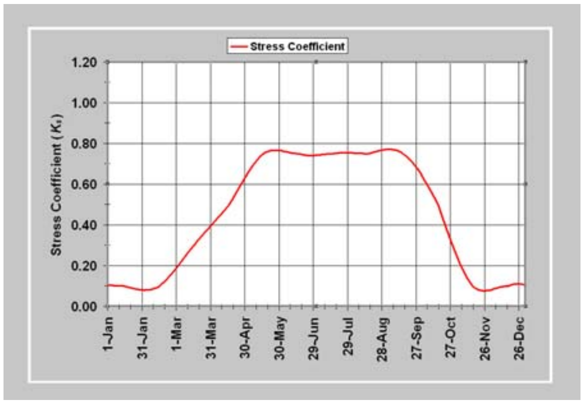

Figure 5. Plot of the daily stress coefficient based on data from Figure 1.

6. EVAPORATION COEFFICIENT

Bare soil evaporation is estimated for each day of the year using daily ET_o estimates and the number-of-rainy-days per month (NRD), which are input into the "Weather" worksheet (Fig. 1). The NRD is used to estimate the rainfall frequency for each month and the results are used with ET_o to estimate bare soil evaporation (E_s) using a 2-stage model. A plot of the evaporation coefficient estimates as a function of ET_o rate and rainfall frequency (days) is shown in Figure 6. The evaporation coefficient model is explained in Snyder et al. (2000). Then the estimated soil evaporation (E_s) is used to calculate a daily mean $K_e = E_s/ET_o$ value for bare soil for each month. Curve fitting is used to estimate daily K_e values over the year (Fig. 7). The K_l values are calculated using Eqs. 1 and 2, but the values must be greater than or equal to K_e (Fig. 7).

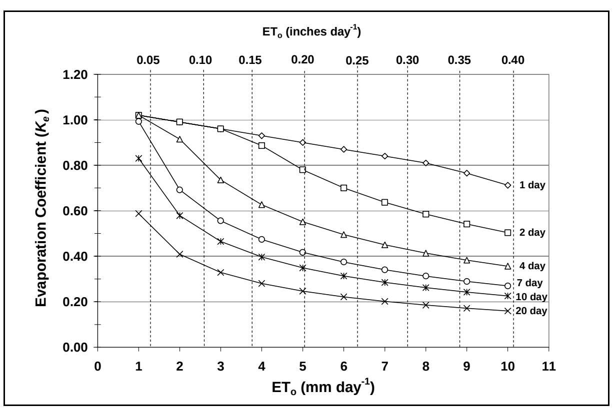

Figure 6. Evaporation (K_e) coefficient as a function of ET_o rate and wetting frequency.

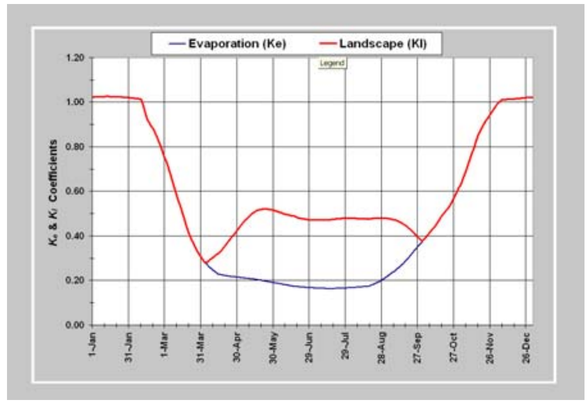

Figure 7. Plot of the landscape coefficient (K_l) and evaporation (bare soil) coefficient (K_e) based on data from Figure 1.

7. OUTPUT & SCHEDULING

Daily values from each of the coefficients are plotted in the charts Km_plot, Kd_plot, Ks_plot and Kl_plot and are listed in worksheets Km, Kd, KvKd, Ks, Ke and Kl. The landscape (K_l) and baseline K_e coefficients are plotted in Figure 7. The daily landscape coefficient is calculated using Eqs. 1 and 2 and ET_l is calculated using Eq. 3. The ET_o and ET_l rates are plotted in the chart ET (Fig. 8) and the cumulative ET_o and ET_l are plotted in the chart CET (Fig. 9).

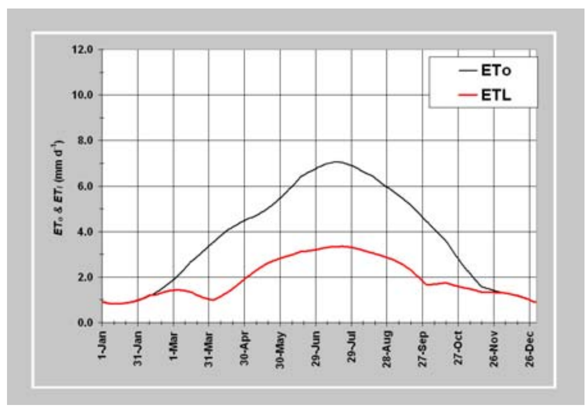

Figure 8. Plot of daily ET_o and ET_l using the data from Figure 1.

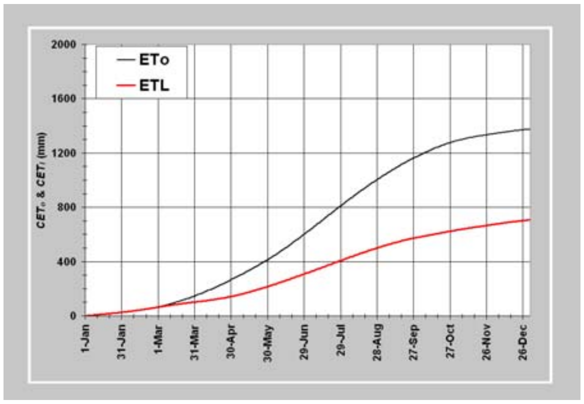

Figure 9. Plot of cumulative ET_o and ET_l using the data from Figure 1.

The OUTPUT worksheet (Fig. 10) contains a row of all coefficient and *ET* calculations for each day of the year. The LIMP program also supplies information for irrigation scheduling in the worksheet RT (Fig. 11). Daily sprinkler runtimes needed to replace the ET_l losses and account for application efficiency are displayed. The application rate and efficiency are input at the top of the worksheet and the runtime minutes to efficiently irrigate are displayed in the table. When the application area is input, the total runtime hours and application amount for the year are displayed at the top of the table.

Year 2004 | Vegetation Factor: 0.80 | Mean NRD/mon: 2.7

						Coefficients							
			Historical	Current	climate	density		stress	evaporation	landscape	Current	Current	Current
Day	Date	DOY	ET_o	ET_o	K_m	K_d	$K_v \times K_d$	K_s	Ke	K_l	ET_l	CET_l	CET_o
Thu	1-Jan-04	1	0.90	0.90	0.73	1.00	0.80	0.11	1.02	1.02	0.92	0.9	0.9
Fri	2-Jan-04	2	0.89	0.89	0.73	1.00	0.80	0.11	1.02	1.02	0.91	1.8	1.8
Sat	3-Jan-04	3	0.87	0.87	0.74	1.00	0.80	0.11	1.02	1.02	0.89	2.7	2.7
Sun	4-Jan-04	4	0.86	0.86	0.74	1.00	0.80	0.11	1.02	1.02	0.88	3.6	3.5
Mon	5-Jan-04	5	0.84	0.84	0.75	1.00	0.80	0.11	1.02	1.02	0.86	4.5	4.4
Tue	6-Jan-04	6	0.83	0.83	0.76	1.00	0.80	0.10	1.03	1.03	0.85	5.3	5.2
Wed	7-Jan-04	7	0.82	0.82	0.76	1.00	0.80	0.10	1.03	1.03	0.84	6.2	6.0
Thu	8-Jan-04	8	0.82	0.82	0.77	1.00	0.80	0.10	1.03	1.03	0.84	7.0	6.8
Fri	9-Jan-04	9	0.81	0.81	0.77	1.00	0.80	0.10	1.03	1.03	0.83	7.8	7.6
Sat	10-Jan-04	10	0.81	0.81	0.78	1.00	0.80	0.10	1.03	1.03	0.83	8.7	8.4
Sun	11-Jan-04	11	0.81	0.81	0.78	1.00	0.80	0.10	1.03	1.03	0.83	9.5	9.3
Mon	12-Jan-04	12	0.81	0.81	0.79	1.00	0.80	0.10	1.03	1.03	0.83	10.3	10.1
Tue	13-Jan-04	13	0.81	0.81	0.79	1.00	0.80	0.10	1.03	1.03	0.83	11.1	10.9
Wed	14-Jan-04	14	0.81	0.81	0.80	1.00	0.80	0.10	1.03	1.03	0.83	12.0	11.7
Thu	15-Jan-04	15	0.81	0.81	0.80	1.00	0.80	0.10	1.03	1.03	0.83	12.8	12.5
Fri	16-Jan-04	16	0.81	0.81	0.80	1.00	0.80	0.10	1.03	1.03	0.83	13.6	13.3
Sat	17-Jan-04	17	0.82	0.82	0.81	1.00	0.80	0.10	1.03	1.03	0.84	14.5	14.1
Sun	18-Jan-04	18	0.82	0.82	0.81	1.00	0.80	0.10	1.03	1.03	0.84	15.3	14.9
Mon	19-Jan-04	19	0.83	0.83	0.82	1.00	0.80	0.09	1.03	1.03	0.85	16.1	15.8
Tue	20-Jan-04	20	0.84	0.84	0.82	1.00	0.80	0.09	1.02	1.02	0.86	17.0	16.6
Wed	21-Jan-04	21	0.84	0.84	0.82	1.00	0.80	0.09	1.02	1.02	0.86	17.9	17.4
Thu	22-Jan-04	22	0.85	0.85	0.82	1.00	0.80	0.09	1.02	1.02	0.87	18.7	18.3
Fri	23-Jan-04	23	0.86	0.86	0.83	1.00	0.80	0.09	1.02	1.02	0.88	19.6	19.1
Sat	24-Jan-04	24	0.87	0.87	0.83	1.00	0.80	0.09	1.02	1.02	0.89	20.5	20.0
Sun	25-Jan-04	25	0.88	0.88	0.83	1.00	0.80	0.09	1.02	1.02	0.91	21.4	20.9
Mon	26-Jan-04	26	0.90	0.90	0.83	1.00	0.80	0.08	1.02	1.02	0.92	22.3	21.8
Tue	27-Jan-04	27	0.91	0.91	0.83	1.00	0.80	0.08	1.02	1.02	0.93	23.3	22.7

Figure 10. Sample of the first 27 days of the Output worksheet using data from Figure 1.

Yuba City 2004 | Run Time (minutes/day) | Total Runtime: 3629 minutes | Applied Water: 78.6 cu. m | Appl. Rate: 13 mm hr^{-1} | DU: 90 % | Application Area: 100 sq. m

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	5	5	7	5	10	15	17	17	14	9	8	7
2	5	5	7	5	10	15	17	17	14	9	8	7
3	5	5	7	5	10	15	17	17	14	9	8	7
4	4	5	7	5	11	15	17	17	14	9	8	7
5	4	6	7	5	11	15	17	16	14	9	8	7
6	4	6	7	5	11	15	17	16	14	9	8	7
7	4	6	7	6	11	15	17	16	13	9	7	7
8	4	6	7	6	11	15	17	16	13	9	7	7
9	4	6	7	6	12	15	17	16	13	9	7	6
10	4	6	7	6	12	15	17	16	13	9	7	6
11	4	6	7	6	12	16	17	16	13	9	7	6
12	4	6	7	6	12	16	17	16	13	9	7	6
13	4	6	7	6	12	16	17	16	13	9	7	6
14	4	6	7	7	13	16	17	16	12	9	7	6
15	4	6	7	7	13	16	17	16	12	9	7	6
16	4	6	7	7	13	16	17	16	12	9	7	6
17	4	6	7	7	13	16	17	16	12	9	7	6
18	4	7	7	7	13	16	17	15	12	9	7	6
19	4	7	6	8	13	16	17	15	11	9	7	6
20	4	7	6	8	13	16	17	15	11	9	7	6
21	4	7	6	8	14	16	17	15	11	9	7	6
22	4	7	6	8	14	16	17	15	11	8	7	6
23	5	7	6	8	14	16	17	15	10	8	7	5
24	5	7	6	9	14	16	17	15	10	8	7	5
25	5	7	6	9	14	16	17	15	10	8	7	5
26	5	7	6	9	14	16	17	15	10	8	7	5
27	5	7	6	9	14	16	17	15	9	8	7	5
28	5	7	5	9	14	16	17	15	9	8	7	5
29	5	7	5	10	14	16	17	15	9	8	7	5
30	5		5	10	15	17	17	14	9	8	7	5
31	5		5		15		17	14		8		5

Figure 11. Sample the RT worksheet using data from Figure 1.

The CRT worksheet (Fig. 11) shows the cumulative runtime minutes to replace ET_l losses during the year. If any character is input in the small cell immediately left of a cumulative value, the cumulative runtime is reset to zero on that date and the runtime will accumulate until the end of the year. If one knows the maximum runtime possible to avoid runoff, entering characters on dates with that runtime or less will provide a schedule during the year.

Yuba City | Cumulative Run Time (minutes) | 2004

Enter a character to the left of a runtime to irrigate

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	5	144	331	532	749	1146	1621	2147	2629	2977	3241	3453
2	9	150	338	537	759	1161	1637	2164	2643	2985	3249	3460
3	14	155	345	542	769	1176	1654	2181	2657	2994	3256	3467
4	18	160	353	547	780	1191	1671	2197	2671	3003	3264	3473
5	23	166	360	553	791	1206	1688	2214	2684	3011	3272	3480
6	27	172	368	558	802	1221	1704	2230	2698	3020	3279	3487
7	32	177	375	563	813	1236	1721	2246	2712	3029	3287	3493
8	36	183	382	569	825	1251	1738	2263	2725	3037	3294	3500
9	40	189	389	575	836	1267	1755	2279	2738	3046	3301	3506
10	44	196	397	581	848	1282	1772	2295	2751	3055	3309	3513
11	49	202	404	587	860	1297	1789	2311	2764	3064	3316	3519
12	53	208	411	593	872	1313	1806	2327	2777	3072	3323	3525
13	57	214	418	600	885	1329	1823	2343	2789	3081	3330	3531
14	61	221	425	606	897	1345	1840	2359	2802	3090	3337	3538
15	66	227	432	613	910	1361	1858	2374	2814	3099	3344	3544
16	70	233	438	620	923	1377	1875	2390	2826	3108	3351	3550
17	74	240	445	627	936	1393	1892	2405	2838	3117	3358	3556
18	78	246	452	635	949	1409	1909	2421	2849	3126	3365	3562
19	83	253	458	642	963	1425	1926	2436	2860	3134	3371	3567
20	87	260	464	650	976	1441	1943	2452	2871	3143	3378	3573
21	92	267	471	658	990	1457	1960	2467	2882	3152	3385	3579
22	96	273	477	666	1003	1473	1978	2482	2893	3160	3392	3584
23	101	280	482	674	1017	1490	1995	2497	2903	3168	3399	3590
24	105	287	488	683	1031	1506	2012	2512	2913	3177	3406	3595
25	110	295	494	691	1045	1522	2029	2527	2923	3185	3413	3600
26	115	302	500	700	1059	1538	2046	2542	2933	3193	3419	3605
27	119	309	505	710	1074	1555	2063	2557	2942	3201	3426	3610
28	124	316	511	719	1088	1571	2080	2571	2951	3209	3433	3615
29	129	323	516	729	1102	1588	2097	2586	2960	3217	3440	3620
30	134		521	738	1117	1604	2114	2600	2968	3225	3447	3625
31	139		527		1131		2131	2614		3233		3629

Figure 11. Sample of the CRT worksheet using data from Figure 1.

The worksheet Kl_Mult (Fig. 12) is used to input the K_l values for up to 20 watering zones.

Year 2004 | Copy and Paste Landscape Coefficient (K_l) to the Correct Zone

			mm	Zone Number																
Day	Date	DOY	ETo	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Thu	1-Jan-04	1	0.90	1.10	1.10															
Fri	2-Jan-04	2	0.89	1.10	1.10															
Sat	3-Jan-04	3	0.87	1.10	1.10															
Sun	4-Jan-04	4	0.86	1.10	1.10															
Mon	5-Jan-04	5	0.84	1.10	1.10															
Tue	6-Jan-04	6	0.83	1.10	1.10															
Wed	7-Jan-04	7	0.82	1.10	1.10															
Thu	8-Jan-04	8	0.82	1.10	1.10															
Fri	9-Jan-04	9	0.81	1.10	1.10															
Sat	10-Jan-04	10	0.81	1.10	1.10															
Sun	11-Jan-04	11	0.81	1.10	1.10															
Mon	12-Jan-04	12	0.81	1.10	1.10															
Tue	13-Jan-04	13	0.81	1.10	1.10															
Wed	14-Jan-04	14	0.81	1.10	1.10															
Thu	15-Jan-04	15	0.81	1.10	1.10															
Fri	16-Jan-04	16	0.81	1.10	1.10															
Sat	17-Jan-04	17	0.82	1.10	1.10															
Sun	18-Jan-04	18	0.82	1.09	1.09															
Mon	19-Jan-04	19	0.83	1.09	1.09															
Tue	20-Jan-04	20	0.84	1.09	1.09															
Wed	21-Jan-04	21	0.84	1.09	1.09															
Thu	22-Jan-04	22	0.85	1.09	1.09															
Fri	23-Jan-04	23	0.86	1.09	1.09															
Sat	24-Jan-04	24	0.87	1.09	1.09															
Sun	25-Jan-04	25	0.88	1.09	1.09															
Mon	26-Jan-04	26	0.90	1.09	1.09															
Tue	27-Jan-04	27	0.91	1.09	1.09															
Wed	28-Jan-04	28	0.92	1.09	1.09															

Figure 12. Sample of the Kl_Mult worksheet with landscape coefficients entered for the first two zones.

To input the K_l values, create the K_l values for the vegetation of interest using the Weather worksheet and then copy the daily K_l column from the OUTPUT worksheet to the appropriate column in K1_Mult. When a column of K_l values is copied to the worksheet, a column of runtime values is created in the RT_Mult worksheet (Fig. 13). Then the application rate and application efficiency are input at the tops of the columns in the RT_Mult worksheet. Assuming little or no runoff, the distribution uniformity can be used to estimate the application efficiency. The runtime needed to replace daily water losses on each day of the year by zone is displayed under the application efficiency.

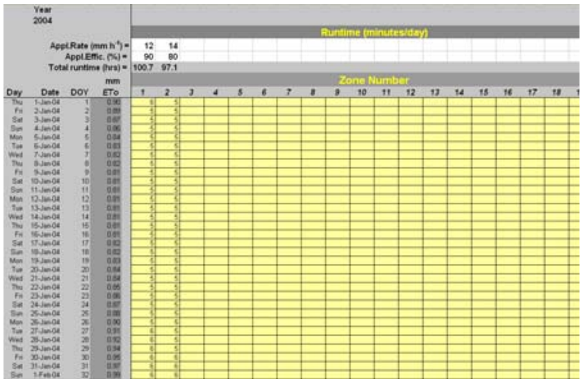

Figure 13. Sample RT_Mult worksheet using the K_l values from the Kl_Mult worksheet (Fig. 12). Values in the table are daily minutes of runtime required to apply a mean depth to the low quarter equal to the soil water depletion estimated using evapotranspiration.

The CRT_Mult worksheet (Fig. 14) provides the corresponding cumulative runtime requirements for each day of the year for each of the 20 zones. Entering any character in the blue column to the left of the table will zero the accumulation on the corresponding date and the runtimes will begin to accumulate again on the following day.

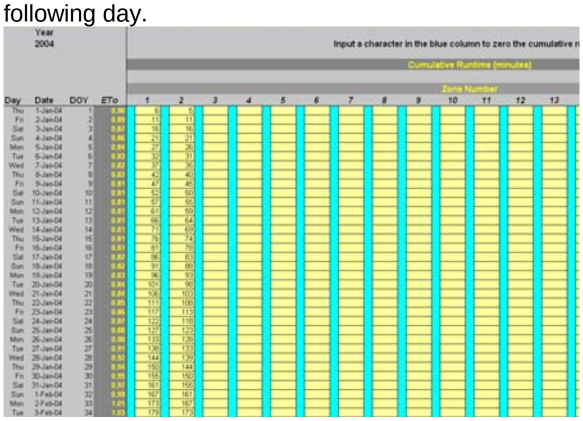

Figure 14. Sample CRT_Mult worksheet using data from the RT_Mult worksheet (Fig. 13). Values in the table are cumulative minutes of runtime required to apply a mean depth to the low quarter equal to the soil water depletion estimated using evapotranspiration.

8. UPDATING WITH CURRENT ET_o RATES

The LIMP program can determine runtimes needed for irrigation of urban landscape vegetation using daily ET_o calculated from monthly climate data. However, one can also input the current ET_o data into the ETo worksheet (Fig. 15), which is located to the right of the Weather worksheet. To change ET_o values, click on the cell to the left of where data are to be changed and then enter the current ET_o value.

Yuba City — Reference ET (ETo) in mm d^{-1} — 2004

Click on the cell to the left to update an ETo rate

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.90	0.99	1.90	3.43	4.51	5.59	6.83	6.81	5.79	4.39	2.43	1.33
2	0.89	1.01	1.95	3.48	4.54	5.64	6.86	6.79	5.75	4.33	2.36	1.32
3	0.87	1.03	2.00	3.53	4.56	5.69	6.88	6.76	5.72	4.28	2.30	1.31
4	0.86	1.05	2.05	3.57	4.59	5.74	6.90	6.73	5.68	4.22	2.24	1.30
5	0.84	1.07	2.10	3.62	4.61	5.80	6.93	6.71	5.64	4.17	2.17	1.29
6	0.83	1.09	2.15	3.67	4.63	5.85	6.95	6.68	5.60	4.11	2.11	1.28
7	0.82	1.11	2.20	3.71	4.66	5.90	6.96	6.65	5.56	4.06	2.05	1.26
8	0.82	1.14	2.25	3.76	4.68	5.96	6.98	6.62	5.53	4.01	1.99	1.25
9	0.81	1.16	2.30	3.80	4.71	6.01	7.00	6.60	5.49	3.96	1.93	1.24
10	0.81	1.19	2.36	3.84	4.73	6.07	7.01	6.57	5.45	3.90	1.87	1.23
11	0.81	1.21	2.41	3.89	4.76	6.13	7.02	6.54	5.41	3.85	1.82	1.22
12	0.81	1.24	2.47	3.93	4.79	6.18	7.03	6.51	5.36	3.80	1.76	1.21
13	0.81	1.27	2.53	3.97	4.81	6.24	7.04	6.49	5.32	3.76	1.70	1.20
14	0.81	1.30	2.59	4.01	4.84	6.30	7.04	6.46	5.28	3.71	1.65	1.19
15	0.81	1.33	2.64	4.05	4.87	6.36	7.05	6.43	5.24	3.66	1.59	1.17
16	0.81	1.36	2.71	4.08	4.90	6.42	7.05	6.41	5.19	3.61	1.57	1.16
17	0.82	1.39	2.75	4.12	4.94	6.45	7.05	6.37	5.14	3.53	1.55	1.14
18	0.82	1.43	2.79	4.15	4.97	6.47	7.05	6.32	5.09	3.45	1.53	1.13
19	0.83	1.46	2.83	4.18	5.01	6.50	7.04	6.28	5.03	3.37	1.51	1.11
20	0.84	1.50	2.87	4.22	5.05	6.53	7.03	6.24	4.98	3.29	1.50	1.09
21	0.84	1.53	2.92	4.25	5.09	6.56	7.02	6.20	4.93	3.22	1.48	1.08
22	0.85	1.57	2.96	4.28	5.13	6.59	7.01	6.16	4.88	3.14	1.46	1.06
23	0.86	1.61	3.01	4.30	5.18	6.62	7.00	6.13	4.82	3.06	1.45	1.04
24	0.87	1.65	3.06	4.33	5.22	6.64	6.98	6.09	4.77	2.99	1.43	1.02
25	0.88	1.69	3.10	4.36	5.26	6.67	6.97	6.05	4.71	2.92	1.42	1.00
26	0.90	1.73	3.15	4.39	5.31	6.70	6.95	6.01	4.66	2.84	1.40	0.98
27	0.91	1.77	3.20	4.41	5.35	6.73	6.93	5.97	4.60	2.77	1.39	0.95
28	0.92	1.81	3.24	4.44	5.40	6.76	6.91	5.94	4.55	2.70	1.37	0.93
29	0.94	1.86	3.29	4.46	5.45	6.78	6.88	5.90	4.50	2.63	1.36	0.90
30	0.95		3.34	4.49	5.49	6.81	6.86	5.86	4.44	2.56	1.35	0.90
31	0.97		3.39		5.54		6.84	5.83		2.50		0.90

Figure 15. Sample of the ETo worksheet that displays the ET_o values used in the ET_l calculations. This worksheet is used to update ET_o based on climate data with current ET_o rates.

8. REFERENCES

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