PRAKTIKUM RSDAL II
PERHITUNGAN EVAPOTRANSPIRASI POTENSIAL (ETo) DAN KEBUTUHAN AIR TANAMAN (ETCrop)

Peristiwa berubahnya air menjadi uap dan bergerak dari permukaan tanah dan permukaan air ke udara disebut Evaporasi. Peristiwa penguapan dari tanaman disebut transpirasi. Kedua-duanya secara bersama-sama disebut evapotranspirasi. Penguapan dari suatu permukaan dimana pada setiap kompleks perubahan Air menjadi uap dalam keadaan jenuh akan uap air (kelembaban mencapai 100%) disebut Evapotranspirasi potensial (ETo). Penguapan dari suatu tanaman dalam kondisi pertumbuhan optimal (cukup unsur hara dan air, terlindung dari hama dan penyakit dan cocok dengan iklim setempat disebut kebutuhan air tanaman (ETcrop). Sedangkan air yang hilang dari suatu tanaman dalam keadaan aktual dilapangan disebut evapotranspirasi Ril. Data tersebut sangat dibutuhkan dalam perencanaan irigasi.
Beberapa metode untuk memprediksi dan menghitung besarnya Evapotranspirasi Potensial (ETo) diantaranya metode Blaney-Criddle (1950), Thornthwaite (1955), pengukuran dengan Panci Evaporasi (Evaporation pan) dan metode Penman (1948).

1. Metode Blaney-Criddle

Evapotranspirasi Potensial (ETo) dapat dihitung secara empirik menggunakan data agroklimatologi. Kebutuhan air tanaman (ETcrop) dapat dihitung bila diketahui Kc (koefisien tanaman)nya.

No.	Rumus	Keterangan
1.	$T = \dfrac{(T\ \text{maksimum} + T\ \text{minimum}}{2}$	T = Rata-rata temperatur harian (^{o}C) P = Rata-rata persentase harian dari jam siang tahunan
2.	ETo = p (0.46 T + 8)	ETo = Evapotranspirasi Potensial (mm/hari)
3.	ETCrop = ETo X Kc	Kc = koefisien tanaman.
		Etcrop = Kebutuhan air tanaman (mm/hari)

Tabel 1. Rata-rata persentase harian (p) dari jam hari siang untuk berbagai lintang

Lintang	Utara	Jan	Feb	Maret	April	Mei	Jun	Jul	Agus	Sep	Okt	Nov	Des
	Selatan	Jul	Agus	Sep	Okt	Nov	Des	Jan	Feb	Maret	April	Mei	Jun
60		.15	.20	.25	.32	.38	.41	.40	.34	.28	.22	.17	.13
55		.17	.21	.26	.32	.36	.39	.38	.33	.28	.23	.18	.16
50		.19	.23	.26	.31	.34	.36	.35	.32	.28	.24	.20	.18
45		.20	.23	.27	.30	.34	.35	.34	.32	.28	.24	.21	.20
40		.22	.24	.27	.30	.32	.34	.33	.31	.28	.25	.22	.21
35		.23	.25	.27	.29	.31	.32	.32	.30	.28	.25	.23	.22
30		.24	.25	.27	.29	.31	.32	.31	.29	.28	.26	.24	.23
20		.24	.26	.27	.29	.30	.31	.31	.29	.28	.26	.25	.24
15		.25	.26	.27	.28	.29	.30	.30	.28	.28	.26	.26	.25
10		.26	.26	.27	.28	.29	.29	.29	.28	.28	.27	.26	.25

5		.26	.27	.27	.28	.28	.29	.29	.28	.28	.27	.26	.26
0		.27	.27	.27	.28	.28	.28	.28	.28	.28	.27	.27	.27

Tabel 2. Temperatur maksimum dan Minimum

Temperatur	Jan	Feb	Maret	April	Mei	Jun	Jul	Agus	Sep	Okt	Nov	Des
Maksimum	20	29	28	31	30	31	29	30	28	27	29	27
Minimum	26	26	24	23	22	21	21	22	24	23	21	21

Tabel 3. Nilai Koefisien Tanaman (Kc) dan lamanya tiap tahap pertumbuhan berbagai jenis tanaman

No.	Tanaman	Umur	Pertumbuhan Awal		Pertumbuhan lanjutan		Pembungaan		Pemasakan	
		hari	hari	Kc	hari	Kc	hari	Kc	hari	Kc
1.	Kedelai	135	20	0.35	30	0,75	60	1.10	25	0,60
2.	Jagung	125	20	0.40	35	0.80	40	1.15	30	0.70
3.	Melon	120	25	0.45	35	0.75	40	1.00	20	0.75
4.	Bawang	70	20	0.50	30	0.70	10	1.00	5	1.00
5.	Pepper	210	30	0.35	40	0.70	110	1.05	30	0.90
6.	Kentang	105	25	0.45	30	0.75	30	1.15	20	0.85

Untuk Contoh: posisi lintang 35 ^{o}LS, Jenis tanaman adalah pepper, dengan waktu tanam dimulai tanggal 1 April. Misal R untuk Maret 80 mm, April 76 mm, Mei 70 mm, Juni 55 mm, Juli 50 mm, Agustus 50 mm, September 60 mm, Oktober 60 mm. Serta jenis tanah liat.

PERHITUNGAN KEBUTUHAN AIR IRIGASI
MENURUT METODE BLANEY-CRIDDELE

Tanaman : Pepper Jenis Tanah : Liat
Waktu tanam : April Posisi Lintang : 35 ^{o}LS

No.	Bulan	Ket	April	Mei	Jun	Jul	Agus	Sep	Okt
1.	ETo (mm/hari)	ETo = p (0.46 T + 8)	=0,25{(0,46x$\frac{31-23}{2}$) + 8} = 2,92	2,27	2,27	2,26	2,46	2,41	2,58
2.	Tahap Tumbuh	Table 3	Pert. awal	Pert. Lanjutan	Pert.lanjutan | pembungaan	Pembungaan	Pembungaan	Pembungaan | pemasakan	pemasakan
3.	Kc/Tahap tumbuh	Tabel 3	0,35	0,70	0,70 | 1,05	1,05	1,05	1,05 | 0,9	0,90
4.	Kc/bulan	Tabel 3	0,35 /30 hari	0,70 / 31 hari	0,7/9 hari | 1,05/21 hari	1,05/31 hari	1,05/31 hari	1,05/27 hari | 0,90/ 3 hari	0,90/ 27 hari
5.	ETcrop (mm/hari)	ETCrop = ETo X Kc	= x 0,35 =1,022	1,59	1,59 | 2,38	2,37	2,58	2,53 | 2,17	2,322
6.	ETcrop (mm/bl)	ETcrop (mm/hari) x$\frac{jmlh\ hari\ perthp\ tmbh}{1\ bulan}$	= 1,022x $\frac{30}{1}$=30,66	49,29	14,31 | 49,98	73,47	79,98	68,31 | 6,51	62,69
67.	Pelumpuran (mm)	200 mm, bila padi	0	0	0	0	0	0	0
8.	Perembesan (mm/bl)	Perkolasi + Rembesan (sesuai Jenis Tanah)	=4 mm /hari x (30hari /1 bln)=120	124	120	124	124	120	120
9.	Genangan (mm)	50 mm, bila padi	0	0	0	0	0	0	0
10.	R (mm/bl)	Data	76	70	55	50	50	60	60
11.	Re (mm/bl)	Re = 0.8 R – 25 bila R > 75 mm/bulan; Re = 0.6 R – 10 bila R < 75 mm/bulan	= 0,8(76)-25= 35,8	32	23	20	20	26	26

12.	KAI (mm/bl)	KAI = ETcrop + Pelumpuran + Perembesan + Genangan - Re	=30,66 +0+120-35,8= 114,86	141,29	111,31 | 146,98	177,47	183,98	162,31 | 100,51	156,69
14.	KAI (mm/hari)	KAI (mm/bln) x $\frac{1\ bln}{jmlh\ hari\ dlm\ 1\ bln}$	=114,86 x $\frac{1}{30}$ = 3,83	4,56	3,71 | 4,899	5,72	5,93	5,41 | 3,35	5,05

Rumus :
ETo = p (0.46 T + 8) mm/hari
Etcrop = ETo X Kc mm/hari
Re = 0.8 R – 25 bila R > 75 mm/bulan
Re = 0.6 R – 10 bila R < 75 mm/bulan
Perkolasi + Rembesan

1. Tanah Liat = 4.0 mm/hari
2. Tanah pasir = 8.0 mm/hari
3. Jenis lain = 6.0 mm/hari

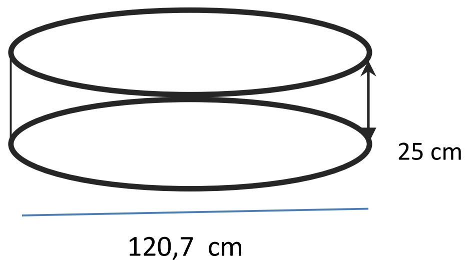
Pelumpuran = 200 mm
Genangan = 50 mm
Kebutuhan Air Irigasi (KAI) =

KAI = ETcrop + Pelumpuran + Perembesan + Genangan – Re

2. Penetapan Evapotranspirasi Potensial (ETo) menggunakan metode Panci Evaporasi.

Hari	Kedalaman Air (mm)	Hujan (mm)	E pan (mm)	Hari	Kedalaman Air (mm)	Hujan (mm)	E pan (mm)
1	155		=(155-148)= 7	17	151.9	19.0	3,3
2	148	2.5	=(148+2,5)-145,2= 5,3	18	167.6	25.4	3,5
3	145.2	4.3	8,6	19	189.5	33.1	3
4	140.9		8,4	20	219.6/156.1**	14.1	4,2
5	132.5		6,7	21	166		5,8
6	125.8		6,9	22	160.2		6,7
7	118.9		8,6	23	153.5		7,4
8	110.3		5	24	146.1		9,6
9	105.3		5,9	25	136.5		5
10	99.4/157*	3.5	6,4	26	131.5		8,4
11	154.1		6,1	27	123.1		8,1
12	148		9,5	28	115.0		6,8
13	138.5		7	29	108.2		8,3
14	131.5		9,1	30	99.9	12.0	6
15	122.4	14.1	3,6	31	105.9		2,9
16	132.9	23.8	4,8	1	103		
Jumlah E pan							197,9
Jumlah Hari							31 hari
E pan (mm/hari)							6,383
Kpan							0,7
ETo (mm/hari)							4,468

Clas A Evaporation pan



Keterangan :

- * = 57.6 mm air ditambahkan
- ** = 63.5 mm air dikeluarkan
- Jumlah E pan = ... mm/bulan
- Jumlah hari per bulan = ...
- Epan = $\frac{\text{Jumlah E pan}}{\text{Jumlah hari}}$ = ... mm/hari
- K pan = 0.70
- Eto = K pan X E pan = ... mm/hari

3. Metode Penman

Data

Data Klimatologi Rata-Rata Bulanan TH 2014

Stasiun : Cikatomas

Garis Lintang : 06º 55' LS

Garis Bujur : 107º 36' BT

Ketinggian Tempat : 791 m dpl

No.	Periode	Tempetur	Kelembaban Nisbi	Lama Penyinaran		Kecepatan Angin		
		(ºC)	(%)	(%)	(jam)	(Knot)	(m/dt)	km/hari
1	Januari	23,1	85,0	47,0	5,6	6,0	3,1	0,036
2	Februari	23,5	83,0	67,0	8,0	6,0	3,1	0,036
3	Maret	23,9	82,0	57,0	6,8	5,0	2,6	0,030
4	April	23,5	83,0	60,0	7,2	5,0	2,6	0,030
5	Mei	23,3	80,0	67,0	8,0	4,0	2,1	0,024
6	Juni	22,7	77,0	76,0	9,1	5,0	2,6	0,030
7	Juli	23,0	78,0	77,0	9,2	5,0	2,6	0,030
8	Agustus	22,6	76,0	89,0	10,7	5,0	2,6	0,030
9	Sptember	23,6	73,0	83,0	10,0	6,0	3,1	0,036
10	Oktober	24,4	72,0	77,0	9,2	6,0	3,1	0,036
11	November	24,8	78,0	65,0	7,8	4,0	2,1	0,024
12	Desember	23,2	88,0	42,0	5,0	2,0	1,0	0,012

Cara Perhitungan Penman

No	Deskripsi		Ket	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agst	Sept	Okt	Nov	Des
1	Temperatur (^oC)	t	data												
2	Faktor koreksi	c	Tabel												
3	Weighting factor	W	Tabel												
4	(1-W)		1-[3]												
5	Penyinaran matahari	n/N	Data												
6	Ekstra teresterial (mm/hari)	R_a	Tabel												
7	(1-a)(0.25+0.5n/N)		Tabel												
8	Gelombang pendek radiasi matahari yang masuk (%) = (1-a)R_s, a=0.25	R_{ns}	[6]*[7]												
9	Kelembaban relatif (%)	R_H	Data												
10	Tekanan uap jenuh (mmHg)	e_a	Tabel												
11	Tekanan uap aktual (mmHg) = e_a*R_H	e_d	[9]*[10]												
12	(e_a-e_d)		[10]-[11]												
13	Efek temperatur	f(T)	Tabel												
14	Efek tekanan uap	f(e_d)	Tabel												
15	Efek penyinaran matahari = 0.1+0.9*n/N	f(n/N)	0.1+0.9*[5]												
16	Radiasi neto = f(T).f(e_d).f(n/N)	R_{n1}	[13]*[14]*[15]												
17	Radiasi neto ekivalen (mm/hari) = R_{ns}-R_{n1} (mm/hari)	R_n	[8]-[16]												
18	W.R_n		[3]*[17]												
19	Kecepatan angin (km/hari)	U	data												
20	Fungsi kecepatan angin = 0.27(1+U/100)	f(u)	0.27*(1+[19]/100)												
21	**Evapotranspirasi (mm/hari) = c[W.Rn+(1-W).f(u).(ea-ed)]**	Et	[2]*{[18]+[4]*[20]*[12]}												

Lampiran Data table Penman.

Table 5 **Saturation Vapour Pressure (ea) in mbar as Function of Mean Air Temperature (T) in oC** 1/

Temper-ature °C	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
ea mbar	6.1	6.6	7.1	7.6	8.1	8.7	9.3	10.0	10.7	11.5	12.3	13.1	14.0	15.0	16.1	17.0	18.2	19.4	20.6•	22.0
Temper-ature °C	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
ea mbar	23.4	24.9	26.4	28.1	29.8	31.7	33.6	35.7	37.8•	40.1	42.4	44.9	47.6	50.3	53.2	56.2	59.4	62.8	66.3	69.9

1/ Also actual vapour pressure (ed) can be obtained from this table using available Tdewpoint data. (Example: Tdewpoint is 18°C; ed is 20.6 mbar)

Table 6a **Vapour Pressure (ed) in mbar from Dry and Wet Bulb Temperature Data in °C (Aspirated Psychrometer)**

Depression wet bulb T°C altitude 0-1 000 m												drybulb	Depression wet bulb T°C altitude 1 000-2 000 m											
0	2	4	6	8	10	12	14	16	18	20	22	T°C	0	2	4	6	8	10	12	14	16	18	20	22
73.8	64.9	56.8	49.2	42.2	35.8	29.8	24.3	19.2	14.4	10.1	6.0	40	73.8	65.2	57.1	49.8	43.0	41.8	31.0	25.6	20.7	16.2	12.0	8.1
66.3	58.1	50.5	43.6	37.1	31.1	25.6	20.5	15.8	11.4	7.3		38	66.3	58.2	50.9	44.1	37.9	36.7	26.8	21.8	17.3	13.2	9.2	5.7
59.4	51.9	44.9	38.4	32.5	26.9	21.8	17.1	12.7	8.6	4.9		36	59.4	52.1	45.2	39.0	33.3	32.1	23.0	18.4	14.3	10.4	6.8	3.5
53.2	46.2	39.8	33.8	28.3	23.2	18.4	14.0	10.0	6.2			34	53.2	46.4	40.1	34.4	29.1	24.1	19.6	15.4	11.5	8.0	4.6	1.5
47.5	41.1	35.1	29.6	24.5	19.8	15.4	11.3	7.5	4.0			32	47.5	41.3	35.5	30.2	25.3	20.7	16.6	12.6	9.1	5.8	2.6	
42.4	36.5	30.9	25.8	21.1	16.7	12.6	8.8	5.3				30	42.4	36.7	31.3	26.4	21.9	17.7	13.8	10.2	6.9	3.8	0.9	
37.8	32.3	27.2	22.4	18.0	14.0	10.2	6.7	3.4				28	37.8	32.5	27.5	23.0	18.9	14.9	11.4	8.0	4.9	2.1		
33.6	28.5	23.8	19.4	15.3	11.5	8.0	4.7	1.6				26	33.6	28.7	24.1	20.0	16.1	12.5	9.2	6.0	3.2	0.5		
29.8	25.1	20.7•	16.6	12.8	9.3	6.0	2.9					24	29.8	25.3	21.1	17.2	13.9	10.3	7.2	4.3	1.6			
26.4	22.0	18.0	14.2	10.6	7.4	4.3	1.4					22	26.4	22.3	18.3	14.3	11.5	8.3	5.5	2.7	0.2			
23.4	19.3	15.5	12.0	8.7	5.6	2.7						20	23.4	19.5	15.9	12.6	9.5	6.6	3.9	1.3				
20.6	16.8	13.3	10.0	6.9	4.1	1.4						18	20.6	17.1	13.7	10.6	7.8	5.0	2.5	0.1				
18.2	14.6	11.4	8.3	5.4	2.7							16	18.2	14.9	11.7	8.9	6.2	3.6	1.3					
16.0	12.7	9.6	6.7	4.0	1.5							14	16.0	12.9	10.0	7.3	4.8	2.4	0.3					
14.0	10.9	8.1	5.3	2.8								12	14.0	11.2	8.4	5.9	3.6	1.4						
12.3	9.4	6.7	4.1	1.7								10	12.3	9.6	7.0	4.7	2.6	0.4						
10.7	8.0	5.5	3.1	0.8								8	10.7	8.2	5.8	3.7	1.6							
9.3	6.8	4.4	2.1									6	9.3	7.0	4.8	2.7	0.7							
8.1	5.7	3.4										4	8.1	6.0	3.8	1.8								
7.1	4.8	2.6										2	7.1	5.0	2.9	1.0								
6.1	4.0	2.0										0	6.1	4.1	2.1									

Values of Weighting Factor (1-W) for the Effect of Wind and Humidity on ETo at Different Temperatures and Altitudes

Temperature °C	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
(1-W) at altitude m																				
0	0.57	.54	.51	.48	.45	.42	.39	.36	.34	.32	.29	.27	.25	.23*	.22	.20	.19	.17	.16	.15
500	.56	.52	.49	.46	.43	.40	.38	.35	.33	.30	.28	.26	.24	.22	.21	.19	.18	.16	.15	.14
1 000	.54	.51	.48	.45	.42	.39	.36	.34	.31	.29	.27	.25	.23	.21	.20	.18	.17	.15	.14	.13
2 000	.51	.48	.45	.42	.39	.36	.34	.31	.29	.27	.25	.23	.21	.19	.18	.16	.15	.14	.13	.12
3 000	.48	.45	.42	.39	.36	.34	.31	.29	.27	.25	.23	.21	.19	.18	.16	.15	.14	.13	.12	.11
4 000	.46	.42	.39	.36	.34	.31	.29	.27	.25	.23	.21	.19	.18	.16	.15	.14	.13	.12	.11	.10

Table 9 Values of Weighting Factor (W) for the Effect of Radiation on ETo at Different Temperatures and Altitudes

Temperature °C	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
W at altitude m																				
0	0.43	.46	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77*	.78	.80	.82	.83	.84	.85
500	.44	.48	.51	.54	.57	.60	.62	.65	.67	.70	.72	.74	.76	.78	.79	.81	.82	.84	.85	.86
1 000	.46	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.80	.82	.83	.85	.86	.87
2 000	.49	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.87	.88
3 000	.52	.55	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.87	.88	.89
4 000	.54	.58	.61	.64	.66	.69	.71	.73	.75	.77	.79	.81	.82	.84	.85	.86	.87	.89	.90	.90

Table 10 Extra Terrestrial Radiation (Ra) expressed in equivalent evaporation in mm/day

Northern Hemisphere													Southern Hemisphere											
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Lat	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
3.8	6.1	9.4	12.7	15.8	17.1	16.4	14.1	10.9	7.4	4.5	3.2	50°	17.5	14.7	10.9	7.0	4.2	3.1	3.5	5.5	8.9	12.9	16.5	18.2
4.3	6.6	9.8	13.0	15.9	17.2	16.5	14.3	11.2	7.8	5.0	3.7	48	17.6	14.9	11.2	7.5	4.7	3.5	4.0	6.0	9.3	13.2	16.6	18.2
4.9	7.1	10.2	13.3	16.0	17.2	16.6	14.5	11.5	8.3	5.5	4.3	46	17.7	15.1	11.5	7.9	5.2	4.0	4.4	6.5	9.7	13.4	16.7	18.3
5.3	7.6	10.6	13.7	16.1	17.2	16.6	14.7	11.9	8.7	6.0	4.7	44	17.8	15.3	11.9	8.4	5.7	4.4	4.9	6.9	10.2	13.7	16.7	18.3
5.9	8.1	11.0	14.0	16.2	17.3	16.7	15.0	12.2	9.1	6.5	5.2	42	17.8	15.5	12.2	8.8	6.1	4.9	5.4	7.4	10.6	14.0	16.8	18.3
6.4	8.6	11.4	14.3	16.4	17.3	16.7	15.2	12.5	9.6	7.0	5.7	40	17.9	15.7	12.5	9.2	6.6	5.3	5.9	7.9	11.0	14.2	16.9	18.3
6.9	9.0	11.8	14.5	16.4	17.2	16.7	15.3	12.8	10.0	7.5	6.1	38	17.9	15.8	12.8	9.6	7.1	5.8	6.3	8.3	11.4	14.4	17.0	18.3
7.4	9.4	12.1	14.7	16.4	17.2	16.7	15.4	13.1	10.6	8.0	6.6	36	17.9	16.0	13.2	10.1	7.5	6.3	6.8	8.8	11.7	14.6	17.0	18.2
7.9	9.8	12.4	14.8	16.5	17.1	16.8	15.5	13.4	10.8	8.5	7.2	34	17.8	16.1	13.5	10.5	8.0	6.8	7.2	9.2	12.0	14.9	17.1	18.2
8.3	10.2	12.8	15.0	16.5	17.0	16.8	15.6	13.6	11.2	9.0	7.8	32	17.8	16.2	13.8	10.9	8.5	7.3	7.7	9.6	12.4	15.1	17.2	18.1
8.8	10.7	13.1	15.2	16.5	17.0	16.8	15.7	13.9	11.6	9.5	8.3	30	17.8	16.4	14.0	11.3	8.9	7.8	8.1	10.1	12.7	15.3	17.3	18.1
9.3	11.1	13.4	15.3	16.5	16.8	16.7	15.7	14.1	12.0	9.9	8.8	28	17.7	16.4	14.3	11.6	9.3	8.2	8.6	10.4	13.0	15.4	17.2	17.9
9.8	11.5	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.3	10.3	9.3	26	17.6	16.4	14.4	12.0	9.7	8.7	9.1	10.9	13.2	15.5	17.2	17.8
10.2	11.9	13.9	15.4	16.4	16.6	16.5	15.8	14.5	12.6	10.7	9.7	24	17.5	16.5	14.6	12.3	10.2	9.1	9.5	11.2	13.4	15.6	17.1	17.7
10.7	12.3	14.2	15.5	16.3	16.4	16.4	15.8	14.6	13.0	11.1	10.2	22	17.4	16.5	14.8	12.6	10.6	9.6	10.0	11.6	13.7	15.7	17.0	17.5
11.2	12.7	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.3	11.6	10.7	20	17.3	16.5	15.0	13.0	11.0	10.0	10.4	12.0	13.9	15.8	17.0	17.4
11.6	13.0	14.6	15.6	16.1	16.1	16.1	15.8	14.9	13.6	12.0	11.1	18	17.1	16.5	15.1	13.2	11.4	10.4	10.8	12.3	14.1	15.8	16.8	17.1
12.0	13.3	14.7	15.6	16.0	15.9	15.9	15.7	15.0	13.9	12.4	11.6	16	16.9	16.4	15.2	13.5	11.7	10.8	11.2	12.6	14.3	15.8	16.7	16.8
12.4	13.6	14.9	15.7	15.8	15.7	15.7	15.7	15.1	14.1	12.8	12.0	14	16.7	16.4	15.3	13.7	12.1	11.2	11.6	12.9	14.5	15.8	16.5	16.6
12.8	13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5	12	16.6	16.3	15.4	14.0	12.5	11.6	12.0	13.2	14.7	15.8	16.4	16.5
13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9	10	16.4	16.3	15.5	14.2	12.8	12.0	12.4	13.5	14.8	15.9	16.2	16.2
13.6	14.5	15.3	15.6	15.3	15.0	15.1	15.4	15.3	14.8	13.9	13.3	8	16.1	16.1	15.5	14.4	13.1	12.4	12.7	13.7	14.9	15.8	16.0	16.0
13.9	14.8	15.4	15.4	15.1	14.7	14.9	15.2	15.3	15.0	14.2	13.7	6	15.8	16.0	15.6	14.7	13.4	12.8	13.1	14.0	15.0	15.7	15.8	15.7
14.3	15.0	15.5	15.5	14.9	14.4	14.6	15.1	15.3	15.1	14.5	14.1	4	15.5	15.8	15.6	14.9	13.8	13.2	13.4	14.3	15.1	15.6	15.5	15.4
14.7	15.3	15.6	15.3	14.6	14.2	14.3	14.9	15.3	15.3	14.8	14.4	2	15.3	15.7	15.7	15.1	14.1	13.5	13.7	14.5	15.2	15.5	15.3	15.1
15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8	0	15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8

Table 12 — Conversion Factor for Extra-Terrestrial Radiation (Ra) to Net Solar Radiation (Rns) for a Given Reflection α of 0.25 and Different Ratios of Actual to Maximum Sunshine Hours $(1-\alpha)(0.25 + 0.50\ n/N)$

n/N	0.0	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0
$(1-\alpha)(0.25 + 0.50\ n/N)$	0.19	.21	.22	.24	.26	.28	.30	.32	.34	.36	.37	.39	.41	.43	.45	.47	.49*	.51	.52	.54	.56

Table 13 — Effect of Temperature f(T) on Longwave Radiation (Rnl)

T°C	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
$f(T) = \sigma Tk^4$	11.0	11.4	11.7	12.0	12.4	12.7	13.1	13.5	13.8	14.2	14.6	15.0	15.4	15.9	16.3*	16.7	17.2	17.7	18.1

Table 14 — Effect of Vapour Pressure f(ed) on Longwave Radiation (Rnl)

ed mbar	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
$f(ed) = 0.34 - 0.044\sqrt{ed}$	0.23	.22	.20	.19	.18	.16	.15	.14	.13*	.12	.12	.11	.10	.09	.08	.08	.07	.06

Table 15 — Effect of the Ratio Actual and Maximum Bright Sunshine Hours f(n/N) on Longwave Radiation (Rnl)

n/N	0	.05	.1	.15	.2	.25	.3	.35	.4	.45	.5	.55	.6	.65	.7	.75	.8	.85	.9	.95	1.0
$f(n/N) = 0.1 + 0.9\ n/N$	0.10	.15	.19	.24	.28	.33	.37	.42	.46	.51	.55	.60	.64	.69	.73	.78	.82*	.87	.91	.96	1.0

Adjustment Factor (c) in Presented Penman Equation

mm/day / m/sec	RHmax - 30%				RHmax - 60%				RHmax - 90%			
	3	6	9	12	3	6	9	12	3	6	9	12
Uday/Unight - 4.0												
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.79	.84	.92	.97	.92	1.00	1.11	1.19	.99	1.10	1.27	1.32
6	.68	.77	.87	.93	.85	.96	1.11	1.19	.94	1.10	1.26	1.33
9	.55	.65	.78	.90	.76	.88	1.02	1.14	.88	1.01	1.16	1.27
Uday/Unight - 3.0												
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.76	.81	.88	.94	.87	.96	1.06	1.12	.94	1.04	1.18	1.28
6	.61	.68	.81	.88	.77	.88	1.02	1.10	.86	1.01	1.15	1.22
9	.46	.56	.72	.82	.67	.79	.88	1.05	.78	.92	1.06	1.18
Uday/Unight - 2.0												
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.69	.76	.85	.92	.83	.91	.99*	1.05*	.89	.98	1.10*	1.14*
6	.53	.61	.74	.84	.70	.80	.94	1.02	.79	.92	1.05	1.12
9	.37	.48	.65	.76	.59	.70	.84	.95	.71	.81	.96	1.06
Uday/Unight - 1.0												
0	.86	.90	1.00	1.00	.96	.98	1.05	1.05	1.02	1.06	1.10	1.10
3	.64	.71	.82	.89	.78	.86	.94*	.99*	.85	.92	1.01*	1.05*
6	.43	.53	.68	.79	.62	.70	.84	.93	.72	.82	.95	1.00
9	.27	.41	.59	.70	.50	.60	.75	.87	.62	.72	.87	.96

R_H = relative humidity

R_S = incoming short-wave radition

U day/U night = ratio of day to night wind travel

EXAMPLE OF CALCULATION OF PENMAN METHOD

Penman reference crop ETo = c [W.Rn + (1-W) f(u) (ea-ed)]

Country: UAR
Period: July
Place: Cairo
Latitude: 30°N
Longitude: 30°
Altitude: 95 m

DATA			
Tmean 28.5 °C	ea mbar	(5) 1/	33.9
RHmean 55 %	RH/100	data	0.55
	ed mbar	calc	21.4
or T wetbulb depression or T dewpoint		(5) or (6)	
	(ea-ed) mbar	calc	17.5
U2 232 km/day	f(u)	(7)'	0.90
Tmean 28.5 °C altitude 95 m	(1-W)	(8)	0.23
	(1-W) f(u) (ea-ed) mm/day	calc	3.6
month July latitude 30°N	Ra mm/day	(10)	16.8
	n hr/day	data	11.5
month July latitude 30°N	N hr/day	(11)	13.9
	n/N	calc	0.83
	(0.25+0.50 n/N)	calc (12)	0.67
	Rs mm/day	calc	11.2
(α = 0.25)	Rns mm/day (1 - α) Rs	calc	8.4 2/
Tmean 28.5 °C	f(T)	(13)	16.4
ed 21.4 mbar	f(ed)	(14)	0.13
n/N 0.83	f(n/N)	(15)	0.85
	Rnl = f(T) f(ed) f(n/N) mm/day	calc	1.8
	Rn = Rns - Rnl	calc	6.6
Tmean 28.5 °C altitude 95 m	W	(9)	0.77
	W.Rn	calc	5.1
			8.7
Uday/Unight 1.5 RHmax, Rs 80% 11.2	c	(16)	1.01
	ETo = c [W.Rn + (1-W) f(u) (ea-ed)]	mm/day	

1/ Numbers in brackets indicate Table of reference.

2/ When Rs data are available Rns = 0.75 Rs.