REFERENCE CROP EVAPOTRANSPIRATION AND OPEN WATER EVAPORATION IN INDIA

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ABSTRACT

Reference crop evapotranpiration (E_p) and open water evaporation (E_o) at sixty stations in India have been evaluated using the combination model. Monthly and annual values of the two parameters are reported. Radiant energy term's contribution to reference crop evapotraspiration is discussed.

KEY WORDS

Reference crop evapotranspiration, Open Water evaporation, Energy term.

INTRODUCTION

Evaporation from land and water surfaces is a matter of immense significance in many processes which influence the conditions of human life. The genesis of our climatic environment and the growth of crops are among the processes in which evaporation plays an important role. In an agricultural country like India water is a precious commodity and the accurate determination of water loss from crops and open water surfaces is a problem of considerable importance..

In the present study reference crop evapotranspiration (E_P) and open water evaporation (Eo) at sixty stations in India are evaluated using the Penman's approach. Monthly and annual values of reference crop evapotranspiration and open water evaporation are presented and the ratios between the two are reported.

MATERIALS AND METHODS

The Penman equation for reference crop evapotranspiration is

$$E_P = W \cdot R_N + (1 - W) \cdot E_a$$

Where $W = \dfrac{\Delta}{(\Delta + g)}$, $E_a = f(U) \cdot (e_S - e)$

$$R_N = R_S \cdot (1 - a) - L_N$$

With the usual notation for the symbols.

In the present study the following expression is used for the wind function :

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$$f(U) = 0.27 \cdot \left(1 + \frac{U}{100}\right)$$ (Doorenbos and Pruitt 1977)

Incident shortwave radiation is obtained from the Angstrom's equation and net radiation is computed using Penmans(1948) expression. The albedo of well watered vegetation is taken to be 0.25.

The expressions given above are also used to obtain open water evaporation with the following modifications:

For the wind function Penman's revised (1956) expression is used

$$f(U) = 0.26 \cdot \left(0.5 + \frac{U}{160}\right)$$

The reflection coefficient for open water for the latitudes involved is taken to be 0.06 (Budyko 1974).

From the climatological tables of observatories in India (India Meteorological Departament, 1967) climatological mean values of temperature, vapour pressure, cloud amount and wind speed were collected for the selected stations for all months of the year. The wind speeds at the anemometer level were reduced to two meters height using the logarithmic law. Extraterrestrial radiation values were taken from Messem's (1975) paper. Values of n/N were derived from the cloud amount data. The dependence of W on atmospheric pressure was taken into account by means of a table reported by Kisamo and Stigter (1977).

RESULTS AND DISCUSSION

In table I are given for the 60 stations, for the months of January, April, July and October: (1) reference crop evapotranspiration, (2) ratio of reference crop evapotranspiration over open water evaporation and (3) radiation terms contribution to reference crop evapotranspiration. Annual values of E_P and E_o are included in the table. Maximum, minimum and mean values of the parameters are given at the end of the table.1.

Annual values of E_P varied from 2734 mm at Rajkot to 956 mm at Shillong. Annual total of E_o ranged from 2427 mm at Rajkot to 1162 mm at Shillong.

Mean annual E_P for all stations is 96% of Eo. The difference between E_P and Eo is due to two factors. The magnitude of the wind term is higher in the case of E_P than in the case of Eo while the radiation term in Eo is greater then in E_P. The difference between E_P and Eo is thus depedent on the ratio of these two terms. Thus the highest value of the ratio of annual values of E_P and Eo, 1.13 is found at Rajkot where the ratio between the radiation term and the wind term has the lowest value of 0.52. The three lowest values of the ratio E_P/Eo, 0.82, 0.84 and 0.84 are found at Shillong, Gauhaiti and Tezpur. At these three stations the three highest values of the ratio between radiation term and wind term, 3.0, 3.3 and 3.5 are found to occurr.

The mean and extreme values of the ratio between Ep and Eo for the individual months and for the entire year suggest that open water evaporation cannot be used to calculate reference crop evapotranspiration on a monthly basis or vice versa applying an average ratio. This means that both reference crop evapotranspiration and open water evaporation should be calculated directly from observed or estimated meterological parameters making use of the appropriate expressions.

The ratio between the radiation term and E_P varied from 0.06 at Jodhpur in December to 0.98 at Mahabaleswer in July. The extremes for January, April, July and October are 0.79, 0.77, 0.98, 0.87 and 0.11, 0.29, 0.40, 0.34 respectively. On an annual basis the ratio ranged between 0.78 and 0.34 with a mean of 0.556. It can thus be seen that the statement that radiation term's contribution is of highest importance in crop evaporation in tropical regions is not entirely valid in the region under study.

CONCLUSIONS

Monthly values of reference crop evapotranspiration and open water evaporation at sixty stations in India are presented in this paper. It is found that reference crop evapotranspiration cannot be used to obtain open water evaporation using an average ratio and vice versa.Radiant energy term's contribution to reference crop evapotranspiration was much lower than is believed to be the case in tropical regions.

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Table.1 - Reference crop evapotranspiration and open water evaporation at selected stations in India .

STATION	JANUARY			APRIL			JULY			OCTOBER			ANNUAL	
	Ep	Ep/Eo	A/A+B	Ep	Ep/Eo	A/A+B	Ep	Ep/Eo	A/A+B	Ep	Ep/Eo	A/A+B	Ep	Eo
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Jaipur	93.6	1,12	0.17	246.6	1.12	0.32	212.7	0.98	0.60	161.2	1.04	0.38	2180	2060
Bikaner	60.1	0.98	0.19	205.2	1.07	0.34	281.2	1.00	0.57	139.5	1.00	0.38	2092	2054
Ganganagar	46.8	0.90	0.26	189.6	1.00	0.45	290.5	1.01	0.55	127.4	0.97	0.43	1925	1954
Ajmer	58.9	0.93	0.28	208.2	0.97	0.37	200.0	0.98	0.59	123.1	0.95	0.45	1863	1875
Barmer	97.7	1.11	0.16	247.8	1,06	0.41	229.7	0.99	0.59	171.4	1.04	0.39	2240	2169
Jodhpur	103.5	1.17	0.11	236.4	1.11	0.32	244.3	1.04	0.51	154.4	1.04	0.34	2284	2114
Kota	64.2	0.90	0.35	189.6	1.03	0.38	169.3	0.96	0.64	130.8	0.93	0.52	1735	1779
Udaipur	61.1	0.86	0.39	176.1	0.96	0.49	138.9	0.92	0.71	118.7	0.88	0.60	1535	1664
Hissar	57.0	0.95	0.25	193.5	0.99	0.49	240.6	0.94	0.66	130.5	0.95	0.48	1883	1954
Delhi	70.4	1.04	0.21	228.6	1.10	0.33	209.9	0.95	0.64	135.2	0.98	0.43	2041	1970
Ambala	51.8	0.93	0.26	190.2	1.01	0.44	202.1	0.89	0.75	116.3	0.91	0.53	1739	1828
Agra	57.4	0.90	0.35	184.8	1.00	0.44	182.6	0.90	0.74	122.8	0.90	0.56	1681	1792
Roorkee	46.2	0.88	0.34	176.4	0.99	0.47	171.4	0.88	0.77	106.6	0.92	0.65	1553	1679
Lucknow	59.8	0.87	0.45	234.6	1.08	0.36	166.5	0.93	0.68	128.0	0.88	0.67	1827	1878
Kanpur	69.1	0.92	0.39	254.1	1.10	0.34	191.3	0.94	0.66	138.0	0.92	0.59	1996	2005
Gorakpur	56.7	0.83	0.50	203.7	1.00	0.48	162.8	0.88	0.79	123.7	0.86	0.71	1643	1816
Varanasi	68.8	0.88	0.48	261.9	1.12	0.33	163.1	0.94	0.69	139.2	0.90	0.65	1935	1958
Allahabad	67.6	0.89	0.44	223.5	1.08	0.35	150.0	0.95	0.67	134.2	0.90	0.63	1786	1825
Patna	70.1	0.90	0.44	223.2	1.04	0.43	175.8	0.89	0.76	135.2	0.88	0.68	1768	1873
Purnea	57.0	0.79	0.58	190.2	0.95	0.56	140.4	0.86	0.82	122.8	0.83	0.80	1511	1723
Hazaribagh	79.1	0.95	0.37	212.7	1.06	0.38	113.2	0.91	0.74	119.4	0.86	0.69	1579	1635
Ranchi	70.1	0.88	0.45	185.4	0.97	0.50	104.5	0.88	0.79	111.9	0.83	0.75	1447	1589
Daltongan	64.8	0.84	0.52	190.8	0.99	0.47	134.5	0.92	0.72	123.1	0.86	0.71	1572	1692
Kalimpong	52.1	0.83	0.48	139.5	0.86	0.70	121.2	0.80	0.90	97.3	0.81	0.75	1217	1473
Calcutta	80.0	0.86	0.55	219.9	0.97	0.60	129.6	0.96	0.67	131.1	0.86	0.76	1644	1783
Burdwan	75.0	0.86	0.54	202.2	0.95	0.61	159.0	0.86	0.82	133.0	0.85	0.78	1685	1904
Tejpur	56.1	0.78	0.63	158.7	0.89	0.69	141.4	0.84	0.87	110.4	0.81	0.84	1357	1621
Shillong	39.1	0.72	0.67	124.5	0.85	0.70	82.5	0.87	0.81	73.5	0.76	0.87	956	1162
Gauhati	57.0	0.79	0.65	154.8	0.88	0.72	129.9	0.86	0.83	113.2	0.83	0.81	1349	1599
Rajkot	154.7	1.22	0.15	319.2	1.15	0.33	222.9	1.10	0.45	203.4	1.06	0.40	2734	2427
Ahmedabad	102.9	1.06	0.23	229.8	1.04	0.43	163.5	0.99	0.60	154.4	0.96	0.53	1940	1946
Akola	107.3	1.01	0.33	227.4	1.06	0.38	167.4	0.97	0.62	145.7	0.93	0.58	2055	2044
Malegoan	102.6	1.01	0.31	225.9	1.06	0.39	151.9	1.03	0.55	145.7	0.94	0.55	1933	1913

Table.1-continued

STATION	JANUARY			APRIL			JULY			OCTOBER			ANNUAL	
	Ep	Ep/Eo	A/A+B	Ep	Ep/Eo	A/A+B	Ep	Ep/Eo	A/A+B	Ep	Ep/Eo	A/A+B	Ep	Eo
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Puna	97.0	0.91	0.46	197.1	0.97	0.53	115.6	0.96	0.66	132.7	0.88	0.68	1645	1767
Mahabaleswar	133.6	1.04	0.30	192.0	0.97	0.52	62.0	0.78	0.98	123.1	0.88	0.66	1446	1546
Aurangabad	124.3	1.06	0.29	263.1	1.12	0.33	143.2	1.05	0.52	157.8	0.97	0.52	2042	2017
Satna	68.2	0.89	0.43	198.9	1.01	0.44	140.1	0.92	0.72	123.1	0.87	0.67	1666	1758
Bhopal	90.2	1.00	0.30	218.7	1.07	0.35	134.2	0.98	0.62	132.4	0.92	0.57	1829	1808
Indore	111.9	1.07	0.26	282.6	1.16	0.29	160.3	1.07	0.49	155.3	0.98	0.49	2271	2077
Nimuch	85.6	1.04	0.22	221.4	1.07	0.36	158.1	0.99	0.59	138.0	0.97	0.46	1908	1856
Kanker	81.5	0.85	0.58	202.5	0.99	0.52	136.1	0.90	0.73	124.0	0.84	0.76	1644	1772
Gwallar	64.2	0.95	0.31	201.6	1.07	0.32	170.5	0.96	0.65	124.0	0.90	0.59	1745	1769
Sambalpur	83.7	0.87	0.54	201.0	0.97	0.54	110.7	0.93	0.72	129.3	0.86	0.75	1620	1752
Balasore	87.7	0.88	0.55	217.8	0.97	0.61	113.2	0.97	0.66	123.7	0.86	0.78	1597	1714
Puri	125.2	0.96	0.50	200.8	0.93	0.68	166.8	0.98	0.62	163.4	0.94	0.64	2009	2105
Bijapur	117.5	0.97	0.42	209.4	1.00	0.49	165.2	1.01	0.55	141.1	0.92	0.62	1912	1938
Hyderabad	123.7	0.97	0.47	240.6	1.04	0.46	166.8	1.08	0.47	146.3	0.92	0.63	2117	2062
Waltair	101.1	0.80	0.79	194.1	0.90	0.74	131.8	0.96	0.66	139.5	0.87	0.77	1713	1934
Kurnool	128.3	0.97	0.47	231.0	1.03	0.46	196.9	1.15	0.40	146.6	0.93	0.64	2136	2068
Masulipatam	121.2	0.87	0.68	205.5	0.92	0.70	175.2	0.96	0.64	143.8	0.88	0.76	2003	2171
Khammam	122.5	0.93	0.55	227.1	0.99	0.55	146.6	0.99	0.60	135.5	0.87	0.74	1955	2033
Nellore	120.9	0.87	0.70	216.0	0.95	0.64	177.9	1.07	0.49	143.8	0.89	0.73	2024	2122
Ongole	115.3	0.83	0.75	195.3	0.88	0.77	167.7	0.96	0.65	136.4	0.97	0.77	1927	2132
Cuddapah	149.1	0.96	0.53	246.3	1.01	0.53	173.9	1.06	0.51	144.5	0.89	0.71	2153	2194
Kakinada	122.8	0.89	0.64	204.6	0.92	0.69	165.9	0.94	0.67	150.4	0.90	0.71	1986	2153
Hanamkonda	126.5	0.97	0.46	244.2	1.04	0.47	162.6	0.99	0.59	150.0	0.90	0.67	2109	2126
Madras	129.6	0.99	0.67	201.9	0.93	0.68	192.2	1.13	0.43	147.9	0.91	0.70	2089	2144
Salem	160.0	0.99	0.49	205.7	0.97	0.58	154.8	1.01	0.56	141.2	0.92	0.68	2015	2076
Calicut	157.2	0.92	0.63	187.2	0.92	0.69	91.5	0.88	0.79	133.0	0.88	0.76	1723	1908
Mangalore	151.1	0.93	0.59	181.8	0.91	0.71	88.0	0.89	0.78	126.8	0.86	0.78	1633	1815
Mean	90.9	0.93	0.43	210.8	1.00	0.49	161.7	0.96	0.66	134.6	0.90	0.64	1827	1893
Maximun	160.0	1.22	0.79	319.2	1.16	0.77	290.5	1.15	0.98	203.4	1.06	0.87	2734	2427
Minimum	39.1	0.78	0.11	124.5	0.85	0.29	62.0	0.78	0.40	73.5	0.76	0.34	996	1162

Ep = Reference crop evapotranspiration
Eo = Open water evaporation
A/A+B = Radiant energy term's contribution to reference crop evapotranspiration