

## DAY TO NIGHT WIND SPEED RATIOS OVER INDIA

The value of data on evapotranspiration is well recognised by administrators and engineers in planning both large and small projects. Since the introduction of the concept of potential evapotranspiration (PET) by Thornthwaite (1948) and Penman (1948) several techniques have been proposed for the calculation of PET by means of (a) direct measurements, *viz.*, lysimeters, energy budget, mass transfer theories etc and (b) estimates from measured evaporation and empirical relationships with meteorological parameters. Among the methods using meteorological data, the semi-empirical technique developed by Penman is considered as the most useful. However, this method requires a number of meteorological parameters which are not generally recorded at most of the locations in India.

The Penman method consists of two parts :

(1) Net radiation term and

(2) Aerodynamic term which is a product of saturation vapour pressure deficit and wind speed in miles per day, recorded at height of 2 m.

A wide variety of empiric wind functions has been suggested because of the predominant effect of wind on evapotranspiration through the transport of moisture from a freely transpiring crop surface and heat from neighbouring area. This variety of wind functions may be attributed to (a) the dependence of the wind function on the surface over which the wind passes and (b) the variation of wind velocity with height of measurement and the difficulties of converting wind velocities at one height to wind velocities at another height. The effect of wind on evapotranspiration is more pronounced when radiation is high.

TABLE 1  
Day time wind speed and day to night wind speed ratios

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	<i>h</i>	<i>ha</i>	<i>N</i>
Minicoy	a	2.3	2.5	2.6	2.7	3.8	4.9	4.8	4.4	4.2	3.2	2.3	2.2	2	14	20
	b	1.7	1.9	1.8	1.6	1.2	1.2	1.1	1.1	1.2	1.2	1.5	1.7			
Trivandrum	a	2.0	2.1	2.9	3.1	3.7	3.8	4.0	4.4	4.1	3.1	3.0	1.9	64	12	20
	b	1.6	1.7	2.2	2.0	2.0	1.9	1.8	2.0	2.1	1.9	1.7	1.6			
Ernakulam	a	2.8	3.7	3.7	3.8	3.6	3.0	3.1	3.5	3.3	3.0	2.6	2.7	3	10	20
	b	1.5	1.9	1.7	1.7	1.5	1.4	1.4	1.6	1.7	1.9	1.7	1.6			
Madurai	a	3.0	2.7	2.1	1.8	2.3	3.5	3.2	2.6	2.4	1.7	2.3	2.8	131	3.5	20
	b	1.9	1.8	1.5	1.4	1.3	1.5	1.4	1.4	1.4	1.4	1.8	1.8			
Trichurapally	a	3.5	2.9	2.6	2.8	5.0	7.7	8.2	7.3	5.6	3.3	3.2	3.7	88	11	20
	b	1.5	1.4	1.1	1.0	1.2	1.2	1.3	1.3	1.3	1.5	1.5	1.5			
Nagapattinam	a	5.2	4.5	4.2	4.6	4.5	4.4	4.1	3.5	3.3	2.8	4.2	5.2	9	12	20
	b	1.0	1.0	1.0	1.3	1.5	1.4	1.5	1.4	1.4	1.3	1.1	1.0			
Coimbatore	a	3.1	3.0	2.9	2.9	4.7	7.5	6.9	7.0	6.0	3.5	2.9	3.1	409	13	20
	b	1.7	1.6	1.3	1.0	1.2	1.3	1.2	1.2	1.2	1.3	1.7	1.9			
Calicut	a	3.4	3.8	4.3	4.4	4.4	3.3	3.1	3.2	3.1	3.2	3.0	3.0	5	13	20
	b	1.4	1.3	1.4	1.4	1.3	1.2	1.2	1.3	1.4	1.4	1.5	1.4			
Salem	a	3.1	2.9	2.7	2.4	2.5	3.0	2.8	2.4	2.2	1.7	2.0	2.5	278	16	20
	b	1.0	0.8	0.8	1.0	1.1	1.3	1.3	1.2	1.3	1.3	1.1	1.0			
Cuddalore	a	3.6	3.2	3.4	4.1	4.0	3.5	3.7	3.0	2.8	2.4	3.2	3.9	12	18	20
	b	1.6	1.6	1.6	1.6	1.3	1.2	1.4	1.3	1.2	1.4	1.6	1.6			
Mangalore	a	3.1	3.2	3.1	3.3	3.4	2.9	2.9	2.7	2.5	2.5	2.4	2.9	22	17	20
	b	1.5	1.6	1.6	1.6	1.4	1.2	1.2	1.3	1.5	1.5	1.4	1.5			
Bangalore	a	3.3	3.2	3.1	2.7	3.7	5.5	5.7	5.2	4.2	2.7	2.8	8.3	897	15	20
	b	1.3	1.2	1.3	1.2	1.2	1.3	1.4	1.4	1.4	1.4	1.4	1.4			
Vellore	a	2.6	2.4	2.6	2.5	2.7	3.5	3.3	3.0	2.7	1.9	2.3	2.5	214	13	20
	b	1.6	1.4	1.2	1.0	1.3	1.4	1.3	1.5	1.7	1.6	1.6	1.6			
Madras	a	4.5	3.9	4.2	4.8	5.2	5.6	5.1	4.6	4.3	3.7	4.7	4.7	16	15	20
	b	1.7	1.6	1.6	1.6	1.3	1.4	1.4	1.4	1.5	1.5	1.7	1.7			
Port Blair	a	2.2	2.3	1.9	2.0	5.1	6.7	5.8	6.8	5.2	2.7	2.3	2.2	79	—	4
	b	1.6	1.7	1.9	1.7	1.6	1.6	1.6	1.5	1.7	1.6	1.2	1.1			
Nellore	a	2.3	2.7	3.3	3.7	3.4	3.5	3.4	3.3	2.6	2.0	2.2	2.3	20	14	20
	b	2.4	2.2	1.8	1.5	1.3	1.5	1.6	1.7	1.8	2.0	2.1	1.9			
Ananthapur	a	2.7	2.9	2.7	2.7	3.7	5.9	5.8	5.2	3.7	2.7	2.8	3.1	350	15	6
	b	1.2	1.1	1.2	1.1	1.1	1.4	1.5	1.3	1.4	1.6	1.4	1.4			
Belgaum	a	3.3	2.2	2.2	2.3	2.6	3.4	3.5	3.1	2.5	2.0	2.4	2.3	733	11	20
	b	2.1	1.9	1.6	1.5	1.3	1.4	1.3	1.3	1.4	1.6	1.9	1.8			
Gadag	a	2.8	2.5	2.5	2.6	3.5	5.9	6.4	5.7	3.9	2.5	2.8	3.0	650	10	20
	b	1.6	1.5	1.2	0.9	0.9	1.3	1.3	1.3	1.1	1.4	1.9	1.9			
Vengurla	a	2.7	3.0	3.5	3.8	4.1	2.7	3.0	3.3	2.8	2.6	2.5	2.5	9	4	10
	b	2.9	3.5	3.6	3.1	2.6	1.7	1.3	1.6	2.9	3.3	3.0	2.9			
Kolhapur	a	3.2	3.1	3.2	3.5	4.7	6.2	6.4	5.8	4.4	3.2	3.8	3.7	570	11	22
	b	1.8	1.5	1.2	1.4	1.1	1.5	1.4	1.5	1.6	1.8	2.5	2.4			
Gannavaram	a	3.7	3.7	4.2	4.4	4.7	6.2	5.7	5.5	4.2	3.2	3.8	3.5	24	9	20
	b	1.9	1.9	1.8	1.5	1.3	1.5	1.7	1.7	1.8	1.7	1.7	1.7			
Hyderabad	a	3.1	3.1	3.2	3.3	4.2	6.5	7.0	5.9	4.6	3.1	2.8	2.7	545	5	20
	b	1.8	1.6	1.6	1.3	1.3	1.2	1.2	1.3	1.5	2.0	2.0	2.1			
Solapur	a	2.8	2.8	2.8	3.1	3.7	3.9	4.4	3.8	3.2	3.0	3.1	2.8	479	9	23
	b	1.5	1.4	1.4	1.3	1.2	1.3	1.5	1.5	1.5	1.6	1.5	1.4			
Devgad	a	4.3	4.8	5.3	5.6	5.7	5.9	7.7	7.0	4.7	3.6	3.4	3.5	36	7	21
	b	1.4	1.4	1.6	1.4	1.2	1.1	1.0	1.2	1.1	1.4	1.4	1.3			
Miraj	a	3.1	2.7	2.9	3.1	4.5	6.0	6.6	6.0	4.6	2.9	3.4	3.5	554	10	13
	b	1.6	1.4	1.2	1.0	1.1	1.6	1.8	1.8	1.7	1.6	1.9	1.9			

TABLE 1 (contd)

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	<i>h</i>	<i>ha</i>	<i>N</i>
Ratnagiri	a	3.0	3.1	3.5	4.3	4.4	4.8	6.3	5.8	3.4	2.7	3.1	2.8	35	12	5
	b	2.0	2.2	2.8	2.6	2.2	1.4	1.0	1.1	1.6	2.3	2.3	2.1			
Harnai	a	4.1	4.6	5.3	5.6	5.4	4.6	6.1	5.7	4.3	3.6	3.5	3.6	220	10	22
	b	1.3	1.3	1.4	1.3	1.3	1.1	1.0	1.0	1.3	1.4	1.3	1.2			
Mahabaleswar	a	2.2	2.3	2.6	2.8	3.2	4.2	5.5	4.9	3.4	2.8	2.6	2.4	1382	9	22
	b	1.0	1.0	0.9	0.9	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9			
Dahanu	a	4.6	4.8	5.4	5.7	5.9	6.2	7.7	7.2	5.4	4.1	3.8	4.1	5	11	23
	b	1.8	1.9	2.0	1.8	1.5	1.3	1.2	1.2	1.4	1.8	1.8	1.8			
Bombay (Colaba)	a	2.8	3.1	3.6	3.8	3.5	3.8	4.5	4.0	3.2	2.7	2.3	2.5	11	16	20
	b	1.2	1.4	1.6	1.7	1.5	1.1	1.1	1.1	1.3	1.4	1.3	1.3			
Pune	a	1.3	1.4	1.6	1.8	2.5	3.0	3.0	2.7	2.2	1.4	1.4	1.3	559	7	23
	b	3.4	2.4	2.0	1.6	1.5	1.7	1.6	1.8	2.0	2.7	4.5	5.1			
Jeur	a	2.6	2.8	2.8	2.8	4.0	5.6	6.4	5.7	4.2	2.8	2.6	2.4	521	9	16
	b	2.6	2.3	1.6	1.2	0.9	1.3	1.7	1.7	1.5	2.0	2.6	3.0			
Visakhapatnam	a	3.4	3.8	4.5	5.8	5.7	5.2	5.4	4.6	3.4	2.9	3.5	3.6	3	9	20
	b	3.1	3.6	3.0	2.2	1.8	1.7	1.6	1.8	2.0	2.2	2.3	2.9			
Jagadalpur	a	1.3	1.6	1.9	2.3	2.4	2.6	2.0	1.7	1.3	1.5	1.8	1.1	553	9	5
	b	3.7	2.8	2.2	2.0	1.8	2.0	2.4	2.5	3.4	4.1	3.4	4.3			
Sironcha	a	1.5	1.9	2.1	2.3	2.5	2.5	2.3	2.2	1.9	1.7	1.5	1.3	123	11	12
	b	2.3	2.3	1.9	1.5	1.5	1.6	1.8	2.0	2.2	2.2	3.3	2.9			
Parbhani	a	2.0	2.4	2.6	2.9	3.9	4.8	4.8	4.2	3.5	2.9	2.4	2.0	423	10	15
	b	1.8	1.8	1.5	1.5	1.2	1.2	1.5	1.6	1.7	2.3	2.4	2.1			
Ahmednagar	a	2.3	2.5	2.7	3.1	3.4	3.7	3.9	3.7	3.0	2.6	2.4	2.2	657	11	22
	b	1.9	1.8	1.6	1.5	1.4	1.5	1.7	1.8	1.9	2.0	2.1	2.1			
Aurangabad	a	2.5	2.7	3.1	3.5	4.7	5.7	6.1	5.5	4.2	2.7	2.2	2.0	581	11	22
	b	1.2	1.3	1.2	1.0	1.0	1.1	1.4	1.4	1.4	1.5	1.4	1.4			
Buldhana	a	2.7	2.9	2.8	3.0	4.2	4.3	4.2	3.6	3.4	2.3	2.1	2.2	650	11	18
	b	1.5	1.5	1.2	1.1	1.1	1.1	1.2	1.3	1.3	1.6	1.5	1.4			
Chandrapur	a	1.6	1.9	1.9	2.4	3.2	4.0	3.8	3.5	2.9	1.8	1.6	1.5	193	9	21
	b	2.3	2.1	1.9	2.0	2.1	1.8	2.0	2.0	2.4	3.0	3.5	3.1			
Hirakud	a	1.1	1.3	1.4	1.3	1.7	2.2	2.0	1.6	1.7	1.3	1.4	1.1	159	9	5
	b	2.4	2.4	2.1	1.7	1.5	1.4	1.6	1.4	1.7	1.6	1.9	2.8			
Yeotmal	a	2.9	3.3	3.6	3.8	4.7	6.0	6.0	5.4	4.2	2.8	2.7	2.5	451	10	17
	b	1.3	1.4	1.4	1.3	1.1	1.2	1.4	1.4	1.5	1.7	1.5	1.3			
Akola	a	2.0	2.2	2.5	2.8	4.8	4.9	4.8	4.4	3.5	2.0	1.8	1.5	282	13	21
	b	1.5	1.6	1.6	1.4	1.1	1.3	1.6	1.6	1.6	1.9	1.7	1.4			
Jalgoan	a	2.8	3.1	3.5	4.2	6.4	6.7	5.8	4.8	4.1	2.7	2.7	2.7	201	11	21
	b	1.4	1.4	1.4	1.2	1.1	1.2	1.6	1.7	1.6	1.7	1.6	1.4			
Amraoti	a	2.6	3.0	3.3	3.5	4.4	5.4	5.5	4.9	3.8	2.8	2.6	2.3	370	10	21
	b	1.1	1.2	1.4	1.5	1.5	1.4	1.5	1.5	1.7	1.6	1.3	1.1			
Nagpur	a	2.1	2.6	2.8	3.2	4.2	4.7	4.5	4.2	3.7	2.7	2.4	2.1	310	12	21
	b	1.5	1.6	1.5	1.4	1.3	1.4	1.7	1.9	1.8	1.8	1.7	1.6			
Gondia	a	1.3	1.6	1.8	2.1	2.3	2.4	2.5	2.0	1.8	1.4	1.3	1.1	313	9	22
	b	2.5	2.4	2.5	2.1	2.0	1.6	1.7	1.7	2.0	2.8	4.3	3.5			
Betul	a	1.5	1.7	1.8	1.8	2.2	2.4	2.2	2.3	1.8	1.4	1.4	1.3	653	10	5
	b	3.3	3.5	3.5	3.4	2.6	1.7	1.7	1.7	2.7	3.4	4.1	3.1			
Indore	a	2.4	2.8	3.3	4.0	5.4	5.7	5.5	5.5	4.1	2.4	2.3	2.0	567	11	5
	b	1.6	1.6	1.4	1.1	1.1	1.1	1.3	1.4	1.4	1.8	2.2	1.9			
Rajkot	a	3.4	4.0	4.2	4.4	7.4	8.7	7.4	7.1	5.1	3.6	3.3	3.2	138	13	5
	b	1.5	1.4	1.3	1.2	1.2	1.2	1.4	1.5	1.5	1.5	1.6	1.7			
Pendra Road	a	1.7	2.1	2.3	2.5	3.0	2.8	1.7	2.0	2.0	1.5	1.4	1.5	924	10	5
	b	2.2	2.4	2.2	2.3	2.0	1.8	1.4	1.5	1.7	3.1	2.4	2.4			

TABLE 1 (contd)

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	<i>h</i>	<i>ha</i>	<i>N</i>
Ranchi	a	2.3	2.7	2.6	3.1	3.5	3.3	3.4	3.6	3.8	2.8	2.4	2.6	652	9	2
	b	1.6	1.5	1.5	1.6	1.8	1.4	1.6	1.5	1.3	2.0	2.0	1.5			
Ambikapur	a	1.7	2.1	2.5	2.9	3.0	2.6	2.5	2.4	1.6	1.6	1.5	1.4	611	17	3
	b	1.5	1.7	1.6	2.1	1.8	1.4	1.4	1.2	1.3	1.7	1.5	1.3			
Bhuj	a	2.7	3.0	3.4	4.1	5.9	6.3	5.4	5.2	4.0	2.7	2.5	2.7	80	10	5
	b	1.9	1.8	1.6	1.4	1.3	1.2	1.3	1.3	1.6	1.8	1.9	2.1			
Deesa	a	2.3	2.8	2.9	3.3	4.1	4.4	3.0	2.5	2.6	2.7	1.7	2.1	136	13	3
	b	1.4	1.5	1.8	1.8	1.5	1.1	1.2	1.1	1.3	1.7	1.5	1.3			
Barmer	a	1.6	1.6	2.3	2.6	3.3	3.2	2.4	2.2	2.3	2.4	1.4	1.5	194	8	3
	b	1.8	1.8	1.1	0.9	1.0	1.0	1.2	1.0	1.1	1.7	1.7	2.0			
Kota	a	1.8	2.2	2.2	2.4	3.6	3.8	3.6	3.1	2.7	1.7	1.7	1.4	257	10	4
	b	1.7	1.8	1.6	1.5	1.3	1.1	1.3	1.4	1.6	1.7	1.9	1.7			
Satna	a	1.6	2.0	2.4	2.8	3.3	3.3	2.7	2.6	2.4	1.8	1.3	1.5	317	10	5
	b	2.6	2.9	2.7	2.9	2.4	1.5	1.7	1.6	2.1	3.3	3.3	2.6			
Guna	a	2.3	2.7	3.3	3.9	3.9	4.7	4.0	3.7	3.6	2.5	2.1	2.0	478	10	5
	b	2.6	2.4	2.5	2.6	1.9	1.5	1.5	1.7	2.0	4.0	3.6	3.4			
Babatpur	a	2.0	2.0	2.7	3.4	4.3	4.1	4.2	3.8	3.8	2.3	2.1	1.8	85	16	3
	b	1.4	1.4	1.8	1.9	1.3	1.4	1.4	1.5	1.5	1.7	1.7	1.4			
Bikaner	a	1.2	1.5	1.7	2.0	2.7	2.7	2.3	2.3	2.1	1.5	1.2	1.0	224	10	--
	b	3.0	2.4	2.1	1.7	1.3	1.3	1.4	1.4	1.7	2.5	3.2	4.9			
Churu	a	1.5	1.7	2.1	2.4	2.8	3.1	2.4	2.3	2.3	1.6	1.3	1.2	—	—	3
	b	3.1	2.2	2.0	2.0	1.7	1.5	1.5	1.3	1.9	4.9	4.7	4.7			
Bareilly	a	1.5	1.7	2.0	2.2	2.3	1.8	1.6	1.6	1.6	1.0	1.0	1.1	173	10	3
	b	1.8	1.7	1.8	1.9	1.9	1.7	1.8	2.0	2.3	2.9	2.6	2.2			
Cooch-behar	a	0.8	1.4	1.8	2.1	2.0	1.5	0.9	1.4	1.4	1.4	1.4	1.3	43	3	4
	b	10.6	4.4	4.7	2.1	1.8	2.3	1.6	2.1	2.2	3.0	3.0	11.1			
Pasighat	a	1.9	2.0	2.6	1.5	1.3	0.5	0.5	0.5	0.5	1.1	1.3	2.2	157	2.5	2
	b	0.5	0.6	0.7	0.6	0.6	0.7	0.7	0.6	0.4	0.5	0.5	0.5			
Raxaul	a	1.5	2.1	2.8	3.8	4.4	4.1	3.7	3.6	3.0	1.6	1.3	1.0	79	4.5	5
	b	2.6	2.6	2.7	1.7	1.3	1.3	1.4	1.5	1.7	2.0	2.7	2.9			
Amritsar	a	1.1	1.6	1.8	2.1	2.1	2.2	1.4	0.7	1.2	1.3	1.5	1.1	234	6.9	11
	b	2.1	2.5	2.1	2.1	2.0	1.6	2.1	1.6	3.1	4.4	3.1	4.0			

(a) Day time wind speed (m/sec), (b) Day to night wind speed ratios, (*h*) Altitude of the station (m), (*ha*) Height of anemometer above ground (m), (*N*) Number of years of data.

An examination of all wind function shows that an increase in the wind speed results in an increase in evapotranspiration. However, this increase is partly counteracted by a net decrease in saturation vapour pressure at the evaporating surface temperature. An error of 25% in wind speed lead to an error of 6% in PET (anonymous). Lysimetric measurements revealed that 80-90% of daily evapotranspiration occurs during day time (Venkataraman *et al.* 1980). Thus average wind speed obtained by combining day time wind speed which is generally higher and night time wind speed, will reduce its effect on evapotranspiration estimates. Hence, due consideration has to be given to day time and night time wind conditions.

F.A.O (1977) suggested an adjustment factor to compensate for the effect of day and night weather conditions. To calculate the adjustment factor,

day time wind speed, day to night wind speed ratio, radiation and relative humidity are required. Radiation can be obtained from tables. Relative humidity can be obtained from published data. But day time wind speed and day to night wind speed ratios are not readily available. Hence problems arise in India, in using Penman method suggested by F.A.O. In the present study, an attempt is made to present day time wind speeds and day to night wind speed ratios.

2. Anemometer readings are recorded at 0830 and 1730 IST at a number of stations in India. For the present study data recorded at stations under Regional Meteorological Centres, Madras, Bombay and Nagpur and from evaporation network under 4th Five Year Plan Scheme, are selected.

Differences between the anemometer readings from 0830 to 1730 IST and from 1730 to 0830 IST of the following day were used to calculate the day (0830-1730 IST) and night (1730-0830 IST) time wind speeds. These values were used to calculate the day to night wind speed ratios which are presented in Table 1. The day time wind speeds are not reduced to 2 m height above the ground. Since wind speed varies with altitude, the altitude of the station ( $h$ ) and height of the anemometer above ground ( $h_a$ ) along with the number of years of data ( $N$ ) are also presented in Table 1.

3. Day time wind speeds are highest over Gujarat and in and around Cauvery basin and lowest in and around Dandakaranya throughout the year. On an average, the ratios lie between 1 and 2 for the year as a whole.

*Cauvery basin* — The day to night wind speed ratios increase from summer to winter. The ratios are comparatively high along the east and west coast. The ratios increase from north to south throughout the year. There is a slight increase in the ratios from east to west in the basin proper.

*Krishna basin* — The ratios are low in the basin proper and increase again in all directions.

*Godavari basin* — The ratios increase from summer to post monsoon and again decrease in winter. The ratios decrease from north to south. Highest ratios occur along the Eastern and Western Ghats.

*Narmada and Tapti basin* — The ratios increase from summer to post monsoon and decrease

slightly during winter. The ratios are the highest in and around Dandakaranya.

*Ganga basin* — Due to insufficient data, no definite pattern could be obtained. However, the ratios and day time wind speeds are generally higher in the southern parts of the basin.

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