Annals of Arid Zone 27 (3 & 4) : 253-261, 1988

COMPUTING POTENTIAL EVAPOTRANSPIRATION BY DIFFERENT METHODS*

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ABSTRACT

Potential evapotranspiration (PET) values at twenty two stations in semi-arid region of south India were evaluated by using the three methods (Diffusion, Thornthwaite, Penman). Comparison of monthly and annual values of PET by the three methods revealed PET values by diffusion method to be close to those by Penman method.

INTRODUCTION

An estimate of the water potential in different periods of the year is prerequisite for planned harnessing of water for irrigation purposes. One of the important parameters in water budgeting is the estimation of the PET to work out the actual losses of water vapour from soil to atmosphere. In the present study, an attempt was made to estimate the PET values for 22 stations covering the semi-arid region of south India (Fig 1) by using diffusion method (Murty, 1979). The calculated values were compared with the other methods viz. Thornthwaite (1948) and Penman (1948) modified formula (Rao et al., 1976).

MATERIAL AND METHODS

The principle of the diffusion method is based on the estimation of vertical water flux treating the problem as a boundary value problem. The details of solving the simultaneous equations were described by Murty (1979), Rao (1981) and Rao et al. (1983). This method provides for a more accurate estimation of the actual water vapour flux as a function of the dependent properties at two boundaries, that is, the soil surface and the incoming mass of air. For ease of calculation, a nomogram was prepared (Fig. 2). Utilizing this nomogram, the rate of evapotranspiration in mm/day could be estimated from the observed values of temperature, wind and atmospheric humidity. In PET value is read from the given value of actual vapour pressure in the horizontal axis by moving vertically up to the point of intersection with the observed temperature isotherm and then by moving horizontally up to the given value of wind.

* Part of the Ph D. work of first author.

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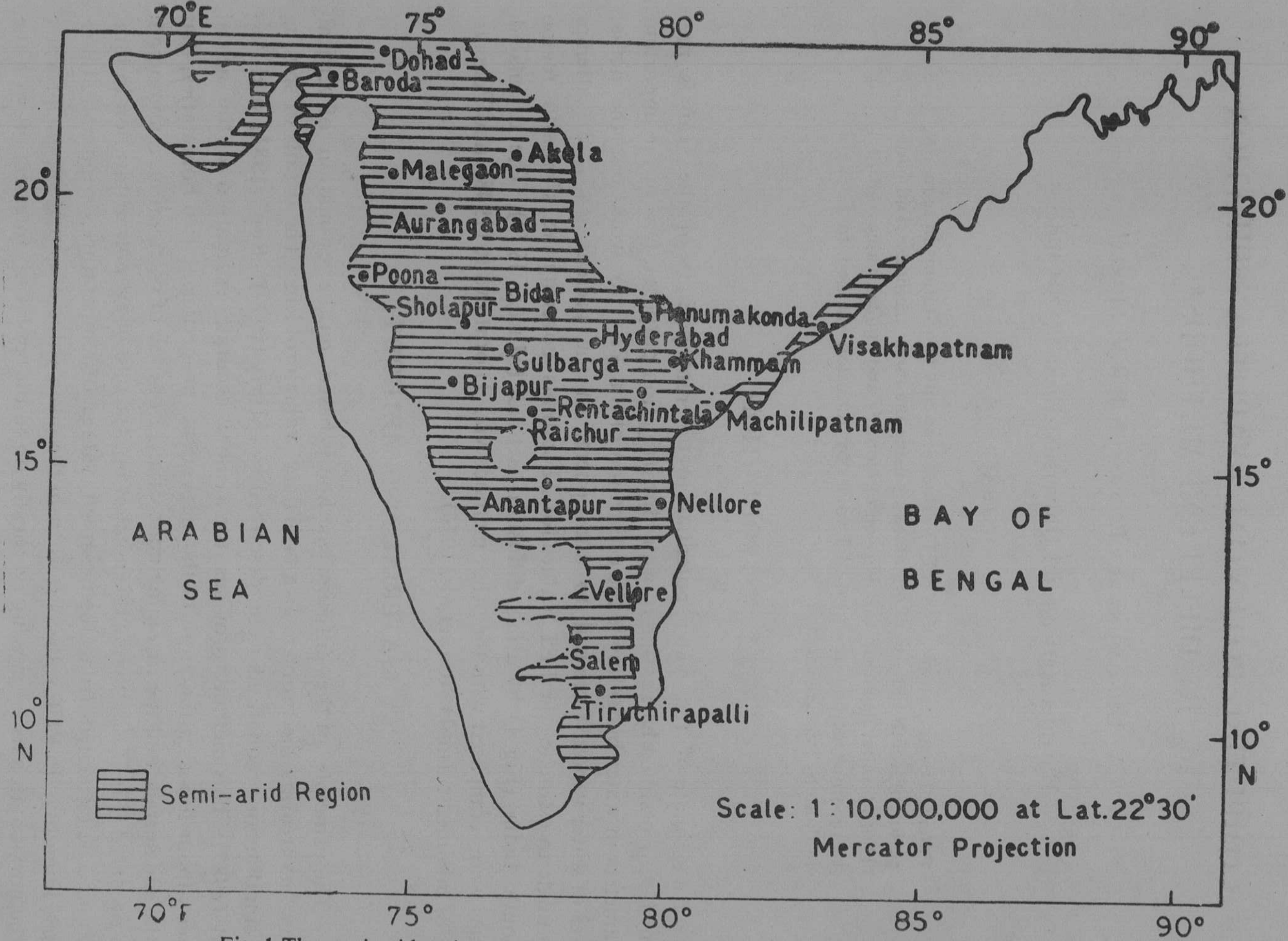

Fig. 1 The semi-arid region of south India and the locations of meteorological stations.

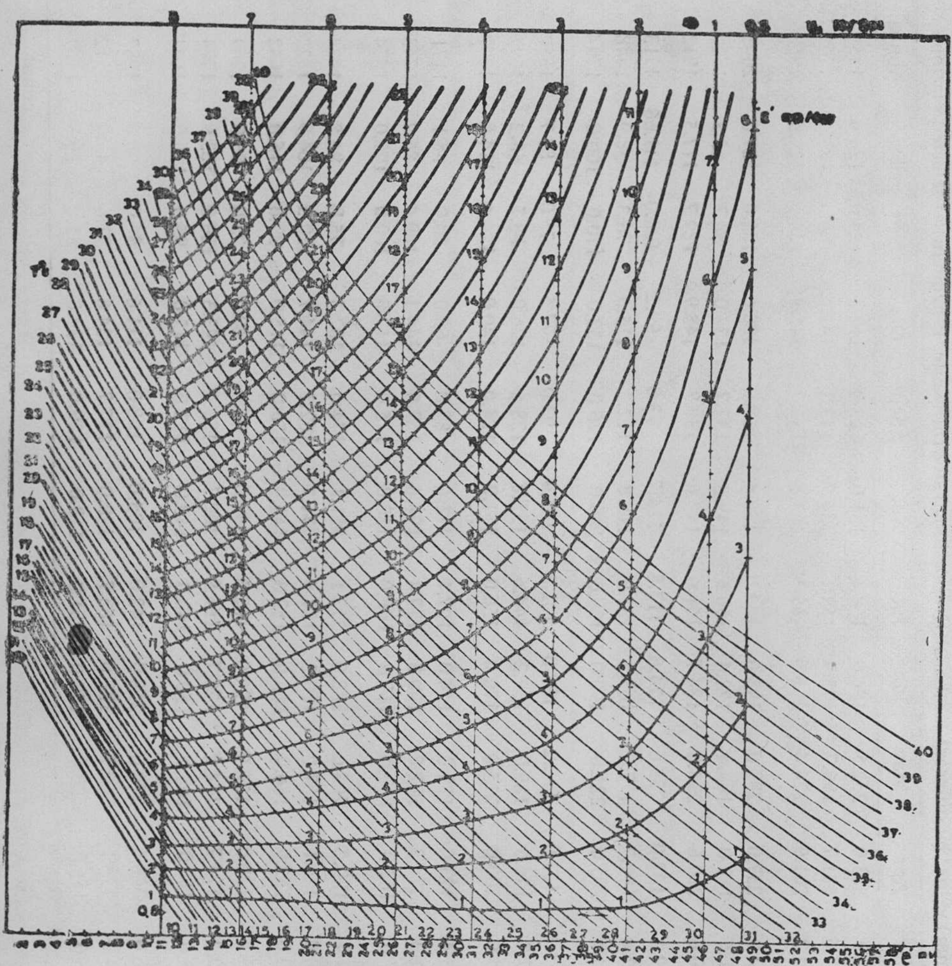

Fig. 2 Nomogram for the determination of evapotranspiration.

The monthly PET values were estimated using the three methods (Diffusion, Thornthwaite, Penman's modified formula) for 22 stations in the semi-arid region of south India from the climatological normals for the period 1931-60 published by India Meteorological Department.

RESULTS AND DISCUSSION

The annual variations of the monthly PET values obtained in the three methods for different stations are peresented in Table 1.

The annual march is generally similar at all the stations showing higher value in the month of May and a secondary peak value in the month of October. The

Table 1. Potential evapotranspiration (mm) values by different methods (D-diffusion, T-thornthwaite, P-penman) at selected s tations

Station	Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Raichur	D	133.3	140.0	182.9	183.0	232.5	186 0	158 1	155 0	123 0	117.8	123.0	124.0	1858
	T	95.0	126.1	167.6	181.7	196.7	173.9	159.1	154.7	143.1	141.7	106.4	83.5	1730
	P	131.6	144.8	193.2	201.9	224.4	188.9	169.5	163.8	132.7	141.9	126.1	121.3	1950
Gulbarg	D	142.6	159.6	217.0	237.0	297.0	198.0	145.0	136.4	138.0	130.0	135.0	127.0	2045
	T	72.0	111.9	161.5	181.0	199.4	172.4	156.6	149.8	137.7	133.0	82.72	63.3	1620
	P	124.8	114.1	190.6	209.6	234.8	184.7	151.6	147.6	130.9	145.9	129.7	117.5	1912
Bidar	D	133.3	154.0	189.1	183.0	235.6	174.0	117.8	114.7	93.0	99.2	108.0	111.66	1713
	T	73.9	99.0	152.4	169.7	177.8	163.5	131.9	118.8	112.2	115.0	76.3	58.9	1448
	P	119.0	132.0	180 0	205.0	221.0	190.0	139.0	140.0	126.0	132.0	110.0	100.0	1794
Bijapur	D	96.9	103.6	133.3	153.0	192.2	135.0	102.3	105.4	93 0	77.5	75.0	83.7	1350
	T	19.7	109.2	157.7	176.0	189.0	159.2	144.6	135.2	128.5	126.0	83.7	68.2	1497
	P	110.0	130.0	175.0	200.0	215.0	170.0	156.0	151.0	124.0	140.0	124.0	114.0	1809
Vellore	D	68.2	81.2	105.4	123.0	133.3	144.0	127.1	111.6	87.0	65.0	60.0	65.1	1171
	T	88.2	110.1	151 3	174 3	192 8	180.3	177.4	171.6	157.6	144.1	109.4	86.2	1743
	P	115.0	128.0	167.0	162.0	180.0	167.0	148.0	150.0	115.0	117.0	100.0	105.0	1654
Tiruchi-rapalli	D	96.1	89.6	114 7	129.0	204.6	288.0	313.1	251.1	174.0	102.3	75.0	86.8	1924
	T	110.9	126.9	160.0	174.1	187.2	180.2	181.4	174.7	162.1	144.7	120.3	104.9	1827
	P	125.0	131.0	160.0	152.0	166.0	160.0	152.0	146.0	120.0	115.0	99.0	116.0	1642
Salem	D	114.7	128.8	148.8	120.0	120.9	120 0	102.3	93.0	81.0	68.2	75.0	96.0	1269
	T	108.9	126.1	162.2	174.7	184.2	170.7	166.9	160.7	152.4	143.3	120.0	103.9	1774
	P	121.0	130.0	165.0	157.0	168.0	150.0	140.0	140.0	113.0	115.0	95.0	110.0	1604
Dohad	D	93.0	134.4	226.0	300.0	320.0	258.0	142.0	105.0	108.0	111.6	96.0	96.0	1987
	T	39.1	65.9	144.5	179.1	200.7	188.0	163.7	140.0	137.7	134.6	73.6	46.0	1512
	P	66.0	89.0	146.0	186.0	220.0	200 0	131.0	118.0	129.0	130.0	85.0	69.8	1569

contd.

(Table 1 contd.)

Station	Method	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual
Rajkot	D	167.4	173.6	248.0	288.0	340.0	276.6	173.0	145.7	132.0	164.3	168.0	158.1	2434
	T	33.4	44.5	125.6	172.4	200.3	195.6	177.0	164.0	160.0	147.0	96.0	53.0	1568
	P	120.7	138.4	205.7	249.4	302.4	239.9	269.8	150.6	154.4	168.6	131.1	113.6	2144
Baroda	D	105.4	112.0	148.8	174.0	232.5	171.0	161.4	83.7	75.0	99.2	108.0	99.2	1570
	T	47.0	73.0	148.0	179.7	205.0	195.0	178.5	166.5	154.7	147.1	92.0	55.2	1640
	P	82.0	97.6	144.9	180.8	226.7	185.0	120.1	114.1	124.1	129.9	92.9	76.2	1574
Khandwa	D	96.1	142.8	170.5	246.0	316.2	201.0	111.6	93.0	84.0	89.9	84.0	80.6	1715
	T	49.8	74.7	145.3	183.5	208.2	193.0	163.2	150.0	141.4	122.8	66.2	42.8	1540
	P	120.0	128.0	176.0	201.0	215.0	170.0	151.0	151.0	120.0	140.0	120.0	111.0	1803
Malegaoa	D	93.0	112.0	158.1	207.0	241.8	159.0	108.5	99.2	81.0	93.0	87.0	86.0	1525
	T	54.5	72.9	140.9	174.0	198.0	180.6	160.4	149.85	127.5	122.0	74.5	57.66	1513
	P	100.0	126.0	148.0	204.0	243.0	170.0	123.0	119.0	132.0	131.0	103.0	92.0	1681
Aurangabad	D	117.8	145.6	272.8	267.0	303.8	174.0	114.7	136.4	96.0	133.3	102.0	99.2	1962
	T	62.7	80.1	149.5	183.1	197.4	172.5	135.7	124.3	116.3	119.0	76.26	62.0	1407
	P	108.1	128.8	183.2	213.0	250.2	178.7	124.1	122.8	122.1	135.2	110.3	96.8	1773
Akola	D	96.1	109.2	161.2	216.0	306.9	192.0	108.5	96.1	37.0	89.9	84.0	83.7	1630
	T	58.3	81.9	153.9	191.0	207.0	191.1	166.0	155.7	144.7	136.8	69.9	50.8	1607
	P	97.1	113.5	161.0	193.5	250.4	199.9	137.9	133.2	128.7	130.1	98.3	85.6	1729
Sholapur	D	173.6	140.0	195.2	216.0	241.8	147.0	111.6	114.7	93.0	111.6	123.0	127.1	1794
	T	77.7	108,9	160.8	181.3	180.4	172.5	155.6	149.5	137.7	133.0	90.29	68.4	1616
	P	120.4	135.1	179.4	200.6	220.8	165.0	139.3	136.4	127.2	139.5	123.9	113.7	1801
Poona	D	89.9	81.2	114.7	129.0	136.4	102.0	68.2	68.2	60.0	65.1	69.0	68.2	1052
	T	60.8	76.5	133.9	164.6	182.3	157.0	119.7	111.1	139.14	114.0	77.2	57.0	1363
	P	92.2	108.0	149.6	172.0	191.0	140.7	107.7	104.9	107.9	117.5	95.3	85.5	1473
Hanuman-	D	96.1	117.6	167.4	192.0	229.4	168.0	165.4	68.2	78.0	77.5	66.0	77.0	1443
Kanda	T	76.8	107,0	160.8	181.0	185.3	188.3	165.1	158.0	146.6	139.5	80.84	62.7	1652
	P	113.0	134.6	184.0	204.8	233.5	185.7	136.7	134.9	123.6	131.8	06.5	97.6	1785

contd.

(Table 1 contd.)

Station	Method	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
Nellore	D	65.1	64.4	93.0	120.0	151.9	159.0	127.1	117.8	90.0	65.1	54.0	55.8	1163
	T	97.02	123.0	158.0	176.8	197.6	192.0	187.0	180.4	167.2	154.0	18.08	87.3	1839
	P	110.0	126.4	172.5	184.3	197.0	169.5	152.2	152.9	142.1	122.0	99.2	98.8	1728
Renta	D	80.6	103.6	148.8	171.0	189.1	204.0	142.6	136.4	93.0	71.3	66.0	65.1	1471
Chintala	T	82.6	127·0	168.2	185.3	204.8	192.4	181.0	174.6	159.2	147.8	01.5	68.1	1633
	P	110.9	131.9	184.5	195.8	214.0	187.5	151.9	150.8	127.1	120.5	01.8	98.0	1775
Ananta-pur	D	114.7	128.8	189.1	195.0	192.1	189.0	167.4	130.2	132.0	86.8	93.0	102.3	1720
	T	79.5	111.9	161.5	180.4	191.7	172.9	165.54	158.6	149.0	139.9	95.95	85.3	1692
	P	131.0	142.6	190.4	196.7	199.0	178.5	160.9	158.1	142.7	124.2	17.8	114.5	1856
Khammam	D	71.3	98.0	130.2	141.0	176.7	150.0	96.1	74.4	63.0	58.9	63.0	65.1	1187
	T	82.5	125.3	166.1	183.4	204.0	190.4	173.0	164.5	154.7	145.3	99.6	788.8	1764
	P	111.8	131.4	179.7	191.0	211.0	168.7	129.0	122.9	115.1	115.6	102 0	97.9	1676
Hyderabad	D	96.1	106.4	161.2	180.0	226.3	216.0	133.3	114.7	75.0	83.7	81.0	83.7	1557
	T	61.4	91.0	146.9	170.8	195.6	170.1	142.4	135.2	126.9	116.0	68.6	51.8	1474
	P	109.8	129.5	181.5	197.8	219.9	196.4	140.4	135.5	119.3	123.6	104.1	98.6	1756
Machili patnam	D	65.1	64.4	80.6	96.0	142.6	159.0	99.2	93.0	69.0	65.1	66.0	74 4	1074
	T	84.1	105.5	146.9	166.9	189.5	133.1	170.1	166.2	156.2	149.3	212.3	87.1	1725
	P	117.7	120.8	161.9	177.0	205.0	181.4	144.0	140.3	124.6	121.3	109.2	106.5	1703
Visakha patnam	D	49.6	44.8	65.1	87.0	105.4	96.0	80.6	58.9	60.0	65.1	69.0	62.0	8435
	T	67.2	84.6	142.7	165.3	170.9	181.7	173.8	162.5	155.4	145.3	105.3	73.1	1628
	P	96.2	109.3	154.7	162.8	166.2	128.3	118.4	120.0	110.0	116.3	105.7	94.4	1481

increase in PET from winter to summer is fairly rapid while the PET latter decreases slowly in almost all the cases. However, there are certain conspicuous differences among the stations with regard to the secondary maximum and minimum. Even though the three methods for each station broadly show similar trends, sharp differences in some cases are noticeable.

At the stations Dohad, Akola, Aurangabad, Gulbarga and Tiruchirapalli the annual variation of PET is found to be very large and this is particularly reflected in the diffusion method which is showing relatively higher range of variation, from minimum to maximum at all these stations except Gulbarga. This is mainly due to the high wind speeds associated with the water vapour transport which are taken into account only by the diffusion method. It is interesting to note that the PET values of Visakhapatnam, Machilipatnam, Nellore, Khammam and Vellore (all stations nearer to the east coast) are strikingly similar. PET by diffusion method is consistently estimated lower than by the other two methods. This is probably due to lower magnitudes of water transports under sea breeze effects. However, Tiruchirapalli, though nearer to the coast, presents a quite different type of variation probably due to the very high winds. At other stations the three methods are giving values which are comparable. At these stations the wind effects and the associated water vapour transport correspond to average conditions and this may be one of the reasons for the low values computed by the diffusion method agreeing fairly well with those by the other methods. For all the stations, values from the Penman method are in agreement with the diffusion method better than those from Thornthwaite method. The diffusion method, considering more number of input parameters, offers a realistic explanation of the basic physical processes involved and gives a detailed picture of the PET variations.

The annual totals of PET as obtained from the three methods at the 22 stations were used to prepare the annual PET charts for the semi-arid region of south India (Fig. 3 a to c). In all the three methods, the eastern parts of Karnataka are showing relatively higher PET. However there are some differences in the three charts with regard to the gradients and latitudinal and longitudinal orientations of the isolines. In the diffusion method (Fig. 3 a), the PET isolines are generally longitudinally oriented and there is a narrow belt of high PET from Anantapur towards north-north-west. The PET values generally decrease towards south-east towards the coast. There are large variations of PET and the isolines are very close to one another indicating high latitudinal gradients of PET. There is another pocket of high PET toward the south near Tiruchirapalli. In the Penman method the high PET values are mainly concentrated in the eastern Karnataka region (Fig. 3 b). PET values decrease towards north, south and east. The longitudinal nature of the isolines as observed in the diffusion method is present only towards north. Except in this region, the latitudinal gradients are relatively small when compared to diffusion method.

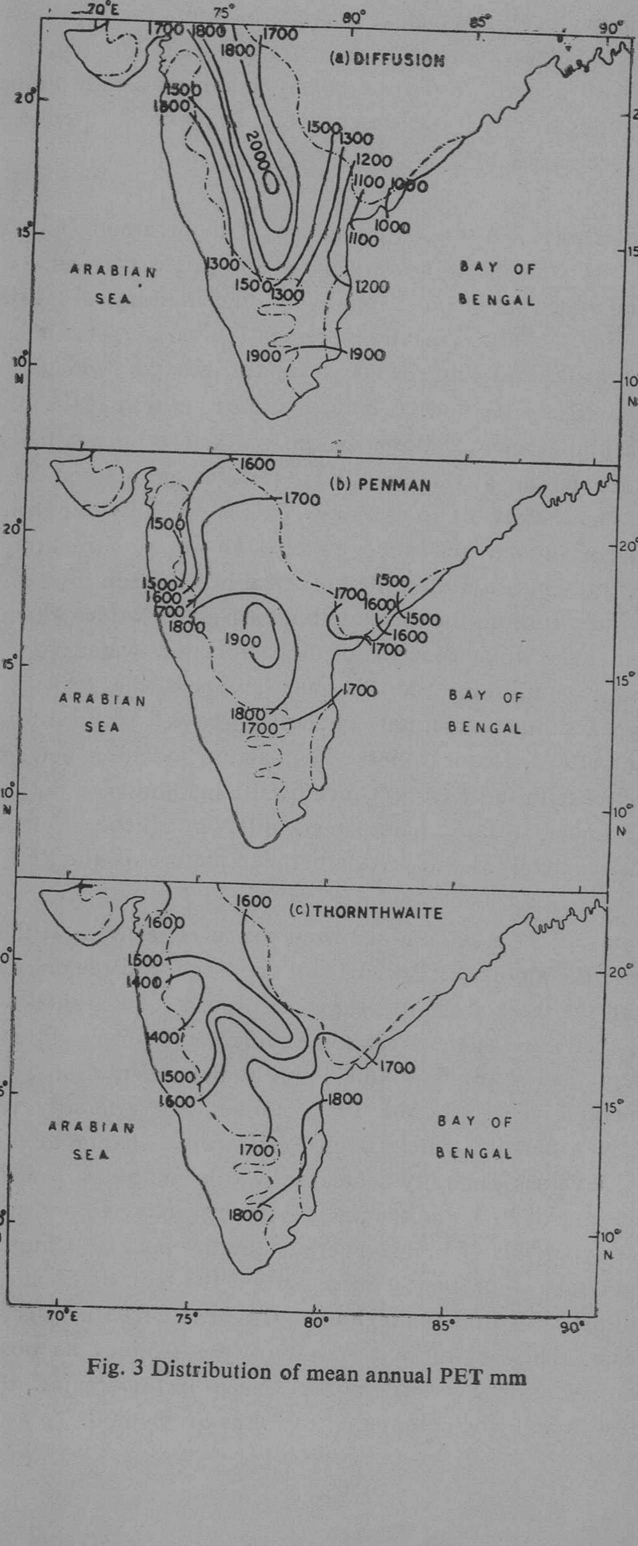

Fig. 3 Distribution of mean annual PET mm

The Thornthwaite method shows somewhat different characteristics of PET variation (Fig. 3c). The PET increases from north-east to south-east and a tongue-like structure of high PET values extends into eastern Karnataka region from the south. Further the isolines are more latitudinally oriented and the gradients are directed more longitudinally. However a region of low PET values is conspicuous in the region around Poona in all the three methods. In all the three charts an increasing tendency is observed from Salem to Tiruchirapalli.

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