RESEARCH REPORT

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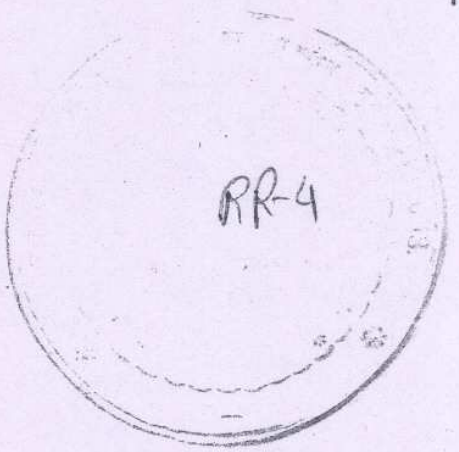

A STUDY OF POTENTIAL EVAPO-TRANSPIRATION OVER ANDHRA PRADESH

by

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Abstract

This paper discusses the potential evapo-transpiration values computed by Thornthwaite's and Leeper's formulae for a group of 16 representative stations in Andhra Pradesh. It is seen that the potential evapo-transpiration values by Leeper's method are less by 2 to 8 cms for hot weather period and by 10 to 13 cms in monsoon period than those computed by Thornthwaite's method. However, there is a fairly close agreement between the values for the winter and post monsoon seasons.

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Introduction

The combined loss of moisture by evaporation from the soil surface and transpiration from plants over a given area is termed as evapo-transpiration and is of importance in many scientific fields. It is one of the main components of the water budget, a knowledge of which is indispensable for many water management problems. The theoretical treatment of evapo-transpiration is excessively difficult since it is not easily tractable as a physical problem. It is rather complex since it is partly physical and partly physiological and complicated by the properties of soils and the physiology of plant cover.

Realising the difficulties involved in the determination of evapo-transpiration, Thornthwaite (1948) introduced another quantity called "Potential evapo-transpiration". It is defined as the maximum amount of water capable of being lost as water vapour in a given climate by a continuous stretch of vegetation covering the whole ground if there is sufficient water at all times in the root zone of the soil for the use of vegetation. This quantity according to Thornthwaite (1948) depends on climatic factors of the tract than on the kind of plant. Thus the computation of monthly and annual potential evapo-transpiration of various places in an area will give an estimate of water requirement in different months and the year as a whole.

Various empirical formulae have been developed for the determination of potential evapo-transpiration of a place if its mean

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monthly temperature, mean duration of sunshine, latitude etc. are known. In this note the potential evapo-transpiration values computed by the methods of Thornthwaite (1948) and Leeper (1950) for Andhra Pradesh (Fig. 1) are presented. The object of this note is, therefore to study and compare the estimates obtained by the above two methods.

2. Thornthwaite and Leeper methods for computing Potential evapo-transpiration

2.1 Thornthwaite method

Thornthwaite's (1948) basic formula for computing potential evapo-transpiration which is based on correlation between mean air temperature and transpiration rate is

$$PE = 16\, L \left(\frac{10\, T}{I} \right)^{a} \qquad (1)$$

where

PE = monthly potential evapo-transpiration (mms),

L = an adjustment for the number of hours of day light and days in the month and is related to latitude,

T = monthly mean air temperature (^{o}C),

I = a heat index which is constant for a given location and is the sum of 12 monthly values of the heat index i where $i \left\{ i = \left(\frac{T}{5} \right)^{1.514} \right\}$ is a function of the monthly normal temperature,

a = an empirically determined exponent which is function of I and whose value is given by

$$a = 6.75 \times 10^{-7}\, I^{3} - 7.71 \times 10^{-5}\, I^{2} + 1.79 \times 10^{-2}\, I + 0.49$$

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Information about temperature and the latitude of a place are sufficient to compute potential evapo-transpiration at any place. However, an arithmetic solution of the equation becomes an extremely laborious procedure primarily because of the complexity of the exponent a. Therefore, extensive use of this method for any location (over a long period of time) requires much time.

2.2 Leeper method

Leeper (1950) made a critical study of Thornthwaite's formula and formulated the following with a view to simplifying it. According to Leeper,

$$PE = 4.4 S + (T - M) \qquad (2)$$

where

PE = monthly potential evapo-transpiration (mms),

S = saturation vapour pressure (mm) at temperature T,

T = mean monthly air temperature (^{o}F) and

M = mean annual air temperature (^{o}F).

3. Data used

Sixteen observatory stations of Andhra Pradesh have been chosen for this study (Fig. 1). Climatically all the stations considered in this study fall in semi-arid category, except Nellore and Kakinada of coastal strip, Nizamabad and Ramagundam in the northwest interior tract which fall in the dry sub-humid zone (Rakhecha, 1970). Normals of meteorological elements I.M.D. (1960) have been utilised for

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computing the potential evapo-transpiration by the above two methods (i.e. by using the equations 1 and 2).

4. Comparision of the results and interpretation

4.1 Potential evapo-transpiration by Thornthwaite method

Figures (1) and (2) show the isopleths of mean annual potential evapo-transpiration over Andhra Pradesh computed by Thornthwaite and Leeper methods respectively. For ensuring correct drawing of these isopleths, data of neighbouring stations have also been taken into account. The annual potential evapo-transpiration, which is an estimate of annual water need is the highest in the areas around Cuddapa and Nellore with the value exceeding 180 cms. Another area of higher annual potential evapo-transpiration (i.e. exceeding 175 cms) is also well marked around Khamam, Ongole, Rentichuntla and Gannavaram stations.

It is seen from Fig. (1) that the north-western portion of the state has comparatively low potential evapo-transpiration (i.e. the order of 160 cm) where as Hyderabad area in the west has the least annual potential evapo-transpiration of 146 cms. The monthly and seasonal values of the potential evapo-transpiration by Thornthwaite method are presented in table 1 and 2 respectively for various stations in Andhra Pradesh.

From a study of tables 1 and 2 the seasonal variation of potential evapo-transpiration over Andhra Pradesh by Thornthwaite method may be described as follows :-

During the winter season, the potential evapo-transpiration

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is the least, and is of the order of 15 to 22 cm. The increasing gradient is from northwest to southeast. With the commencement of the hot weather season potential evapo-transpiration increases appreciably and is of the order of 50 cms. It is interesting to note that during this season the semi-arid and dry sub-humid areas (vide Table 2) have more or less the same amount of potential evapo-transpiration. During the southwest monsoon season the region experiences the highest potential evapo-transpiration and is of the order of 70 cms excluding the areas west of Hyderabad where it is of the order of 57 cm or so. In this season dry sub-humid areas (vide Table 2) have potential evapo-transpiration varying from about 63 to 70 cms. During the post monsoon season the northwestern tract has the least amount of potential evapo-transpiration where as the coastal and southern portion of the state have more than 31 cms.

4.2 Potential evapo-transpiration by Leeper method

The distribution of the values computed by this method reveals similar feature except for the fact that for the year as a whole these values work out to be 6 to 10 percent less than those computed by Thornthwaite's method. It has been observed that the potential evapo-transpiration values computed by Thornthwaite formula are greater by 2 to 8 cms for hot weather period and 10 to 13 cms for the monsoon season. The large difference in the monsoon season suggests that this may be attributed to the humidity factor which has not been explicitly taken into account in Thornthwaite's formula, but has been accounted for in

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Leeper's formula trough saturation vapour pressure term. Further, it is interesting to note that during the hot weather period the differences in values obtained by these two methods decrease from coast to inland. In the case of monsoon season it is however seen that the differences in these values remain more or less constant. In winter and post monsoon seasons the potential evapo-transpiration values by both the methods are almost equal. The annual range of potential evapo-transpiration by Leeper's smethod is 134 to 163 cms for the whole state while it is of the order 146 to 182 cms by Thornthwaite's method.

5. Conclusions

From the above study the following broad conclusions can be drawn :-

(a) The potential evapo-transpiration values computed by Leeper's method for the year as a whole work out to be 6 to 10 percent less than those that obtained by Thornthwaite's method.

(b) Compared to Thornthwaite method the values obtained by Leeper's method are less by 2 to 8 cms for hot weather period and by 10 to 13 cms for the monsoon period. During the hot weather period the difference in values by these methods decreases as one proceeds from coast to inland, but in case of the monsoon season the difference in values remains more or less constant. However, during winter and post monsoon seasons potential evapo-transpiration values are nearly the same by both the methods.

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(c) Since the estimates obtained by the above two methods do not differ largely, it is felt that fairly accurate estimates of potential evapotranspiration for a place may be obtained by taking the mean of the values obtained by the above two methods. However, where rough estimates are required for preliminary planning purposes, Leeper's method may be used as it gives fairly satisfactory estimates without undergoing elaborate time-consuming calculations.

6. Acknowledgement

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REFERENCES

Thornthwaite, C.W.	1948	An approach toward a Rational Classification of climate, Geographical Review, 38, pp.55-94
Leeper, G.W.	1950	Thornthwaite's Climate Formula, Jour.Aust.Inst.Agric.Sci.16, pp.2-6
Rakhecha, P.	1970	The study of droughts by water budget methods over Andhra Pradesh. Symposium on Incidence of Aridity and drought in Andhra-Pradesh, Waltair

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Table 1 : Monthly potential evapo-transpiration in cms by Thornthwaite and Leeper methods over Andhra Pradesh.

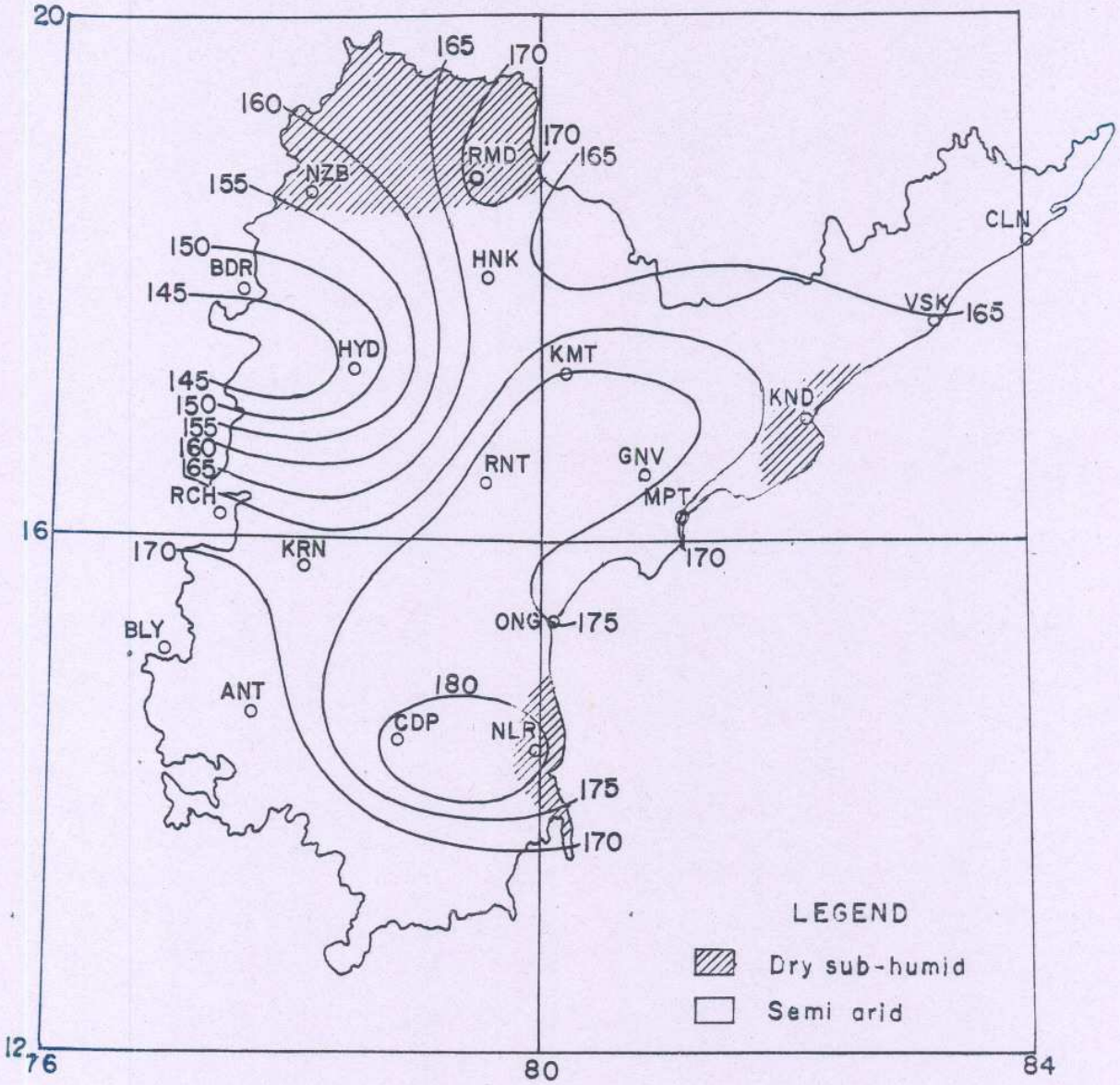
Sr. No.	Stations	Appre-vation		J	F	M	A	M	J	J	A	S	O	N	D
1	Nellore	NLR	T	8.8	12.3	15.9	17.7	19.9	19.2	18.8	18.1	16.7	15.4	10.4	8.1
			L	9.6	11.0	13.0	15.6	18.1	17.5	15.3	15.0	14.5	12.8	10.5	9.3
2	Masulipatnam	MPT	T	7.6	9.5	14.7	16.8	19.4	18.7	17.5	16.9	15.6	14.8	10.3	7.9
			L	8.9	10.1	12.0	14.3	16.8	16.3	13.5	13.4	13.1	12.4	10.4	9.0
3	Kakinada	KND	T	7.1	9.3	15.3	17.3	19.5	18.6	17.2	16.7	15.6	14.6	9.7	7.0
			L	8.6	10.1	12.6	14.9	16.8	16.0	13.1	13.2	13.2	12.3	10.1	8.5
4	Vishakha-patnam	VSK	T	6.6	8.4	14.3	16.5	18.7	18.1	17.5	17.0	15.5	14.6	10.2	7.1
			L	8.2	9.5	11.6	13.8	15.3	15.0	13.4	13.6	13.1	12.3	10.3	8.5
5	Kalinga-patnam	CLN	T	6.6	9.0	14.6	16.5	18.7	18.0	17.4	17.0	15.7	14.5	9.0	6.2
			L	8.2	9.8	12.1	13.9	15.2	14.8	13.3	13.5	13.4	12.3	9.7	8.0
6	Ongole	ONG	T	8.1	9.9	15.1	17.1	19.7	19.1	18.4	17.7	16.3	15.1	10.6	8.2
			L	9.2	10.4	12.2	14.5	17.5	17.5	14.6	14.4	14.0	12.6	10.5	9.3
7	Gannavaram	GNV	T	8.7	12.2	15.9	17.9	20.0	19.1	17.4	16.6	15.7	14.8	10.7	8.3
			L	9.5	11.1	13.1	16.0	18.2	16.8	13.2	12.9	13.1	12.3	10.7	9.3
8	Rentichuntla	RNT	T	7.9	12.7	16.9	18.4	20.4	19.2	18.0	17.5	15.9	15.0	9.2	6.4
			L	9.2	11.4	14.5	17.2	19.8	17.1	13.9	13.9	13.3	12.4	9.9	8.5
9	Nizamabad	NZB	T	6.8	9.6	15.8	18.1	20.5	18.4	15.7	14.9	13.9	12.4	6.9	5.3
			L	8.3	10.2	13.3	16.6	19.5	15.3	11.7	11.3	11.5	11.0	8.5	7.3
10	Hyderabad	HYD	T	6.2	8.4	14.7	17.1	19.6	17.1	14.4	13.4	12.3	11.1	6.8	5.3
			L	7.7	9.5	12.3	15.0	17.3	13.9	11.2	10.8	10.9	10.4	8.2	7.1
11	Hanamkonda	HNK	T	7.5	10.4	16.1	18.0	20.4	18.8	16.5	15.8	14.7	13.9	8.1	6.2
			L	8.8	10.6	13.5	16.3	19.3	16.1	12.3	12.1	12.1	13.8	9.3	8.0
12	Khamam	KMT	T	8.1	12.5	16.6	18.3	20.4	19.1	17.3	16.6	15.5	14.6	8.9	6.8
			L	9.3	11.3	14.2	16.9	19.4	16.8	13.0	12.8	12.8	12.1	9.7	8.6
13	Ramagundam	RMD	T	7.0	12.2	16.8	18.5	20.8	19.7	17.0	16.2	15.2	14.6	7.6	5.7
			L	8.8	11.1	14.5	18.1	21.3	17.9	12.7	12.3	12.6	12.1	9.1	8.0
14	Cuddapa	CDP	T	9.1	13.2	17.2	18.6	20.1	18.6	18.2	17.3	15.9	15.1	10.4	7.8
			L	9.8	12.0	15.0	17.9	19.0	16.1	14.2	14.0	13.3	12.4	10.4	9.1
15	Kurnool	KRN	T	8.2	12.5	16.7	18.3	19.9	17.7	16.6	15.8	14.7	14.4	9.6	7.4
			L	9.2	11.4	14.3	17.2	18.2	14.6	12.5	12.3	12.1	11.9	10.0	8.7
16	Anantpur	ANT	T	8.2	10.9	16.1	18.0	19.1	17.3	16.6	15.9	14.9	14.0	9.2	7.1
			L	9.1	10.8	13.7	16.6	16.4	14.2	12.6	12.5	12.4	11.6	9.7	8.5

T = PE by Thornthwaite's method L = PE by Leeper's method

Table 2 : Seasonal variation of potential evapo-transpiration in cms over Andhra Pradesh.

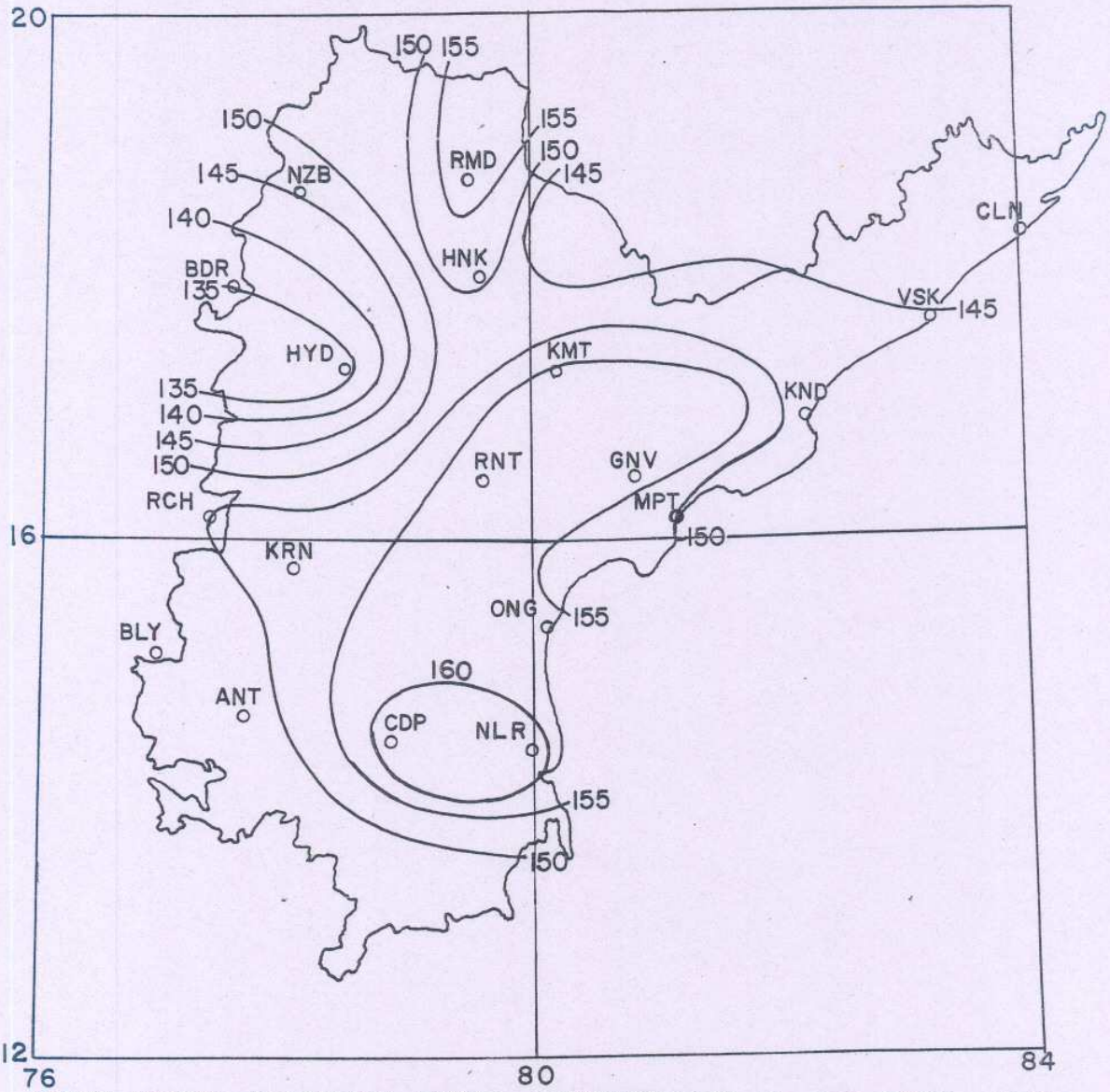
Sr. No.	Stations	Abbre-viations		Winter Jan-Feb.	Hot Weather Mar. - May	Monsoon Jun.-Sep.	Post Monsoon Oct.-Dec.	Annual
1	Nellore	NLR	T	21.1	53.5	72.8	33.9	181.3
			L	20.6	47.6	62.3	32.6	162.2
2	Masulipatnam	MPT	T	17.1	50.9	68.7	33.0	169.7
			L	19.0	43.1	56.3	31.8	150.2
3	Kakinada	KND	T	16.4	52.1	68.1	31.3	167.9
			L	18.7	44.3	55.3	30.9	149.4
4	Vishakhapatnam	VSK	T	15.0	49.5	68.1	31.9	164.5
			L	17.7	40.7	55.1	31.1	144.6
5	Kalingapatnam	CLN	T	15.6	49.8	68.1	29.7	163.2
			L	18.0	41.2	55.0	30.0	144.2
6	Ongole	ONG	T	18.0	51.9	71.5	33.9	175.3
			L	19.6	44.2	60.5	32.4	156.7
7	Gannavaram	GNV	T	20.9	53.8	68.8	33.8	177.3
			L	20.6	47.3	56.0	32.3	156.2
8	Rentichuntla	RNT	T	20.6	55.7	70.6	30.6	177.5
			L	20.6	51.5	58.2	30.8	161.1
9	Nizamabad	NZB	T	16.4	54.4	62.9	24.6	158.3
			L	18.5	49.4	49.8	26.8	144.5
10	Hyderabad	HYD	T	14.6	51.4	57.2	23.2	146.4
			L	17.2	44.6	46.8	25.7	134.3
11	Hanamkonda	HNK	T	17.9	54.5	65.8	28.2	166.4
			L	19.4	49.1	52.6	31.1	158.2
12	Khamam	KMT	T	20.6	55.3	68.5	30.3	174.7
			L	20.6	50.5	55.4	30.4	156.9
13	Ramagunadam	RMD	T	19.2	56.1	68.1	27.9	171.3
			L	19.9	53.9	55.5	29.2	158.5
14	Cuddapa	CDP	T	22.3	55.9	70.0	33.3	181.5
			L	21.8	51.9	57.6	31.9	163.2
15	Kurnool	KRN	T	20.7	54.9	64.8	31.4	171.8
			L	20.6	49.7	51.5	30.6	152.4
16	Anantpur	ANT	T	19.1	53.2	64.7	30.3	167.3
			L	19.9	46.7	51.7	29.8	148.1

T = PE by Thornthwaite's method L = PE by Leeper's method



MEAN ANNUAL POTENTIAL EVAPO-TRANSPIRATION IN Cms OVER ANDHRA PRADESH BY THORNTHWAITE'S METHOD.

FIG. 1



MEAN ANNUAL POTENTIAL EVAPO-TRANSPIRATION IN Cms OVER ANDHRA PRADESH BY LEEPER'S METHOD.

FIG. 2