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Probable maximum precipitation over Tamil Nadu — A generalised approach

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सार-- इस शोध-पत्र में तमिलनाडु राज्य पर 1-दिन की अवधि के लिए 1000, 5000 और 10,000 वर्ग कि.मी. के लिए क्षेत्रीय सम्भाव्य अधिकतम वर्षण (पी.एम.पी.) के आकलन के लिए एक सामान्यकृत विधि का उपयोग किया गया है। इन तीनों क्षेत्रों के लिए क्षेत्रीय पी.एम.पी. के परिवर्तन को दृष्टिगोचर करने वाले तीन सामान्यकृत मानचित्र तैयार किए गए। प्रस्तुत अध्ययन के द्वारा 1-दिन की अवधि के लिए तमिलनाडु पर 1000, 5000 और 10,000 वर्ग कि.मी. के लिए क्षेत्रीय पी.एम.पी. के आकलन क्रमश: 48-32, 38-26 और 32-22 सेमी. के बीच पाए गए।

ABSTRACT. In this paper to estimate areal probable maximum precipitation (PMP) for 1000, 5000 and 10,000 km² for 1-day duration over Tamil Nadu, three generalised charts depicting variation of areal PMP for these three areas have been prepared. The study showed that the areal PMP estimates for 1000, 5000 and 10,000 km² over Tamil Nadu seems to vary between 48-32, 38-26 and 32-22 cm respectively for 1-day duration.

Key words — Probable maximum precipitation, Transposition, Moisture maximisation, Dew point, Rainstorm, Precipitable water.

1. Introduction

According to CWC (1972) spillways of dams and reservoirs with storage of more than 60 million cubic metre are to be designed for the Probable Maximum Flood (PMF) created by the Probable Maximum Precipitation (PMP) over the catchment.

The approach used in India to estimate PMP is based on the physical or synoptic method involving limited transposition and moisture maximisation of major recorded rainstorms in and around the catchment. The degree of accuracy depends on how many storms are available for analysis and how extreme the storms have been reached. As such, PMP estimates derived by physical method proved to be adequate but lacks confidence if only a short period of storm records were available and an extreme storm with near maximum efficiency has not been occurred near the region under consideration. This aspect has led to the development of a generalised method in which maximum recorded rainfall depths from a large area are used and various factors such as extreme moisture, distance of the storm from the coast, topography effects and intervening barrier between the rainfall area and the moisture source are made in applying the maximum recorded raindepths to a particular catchment.

A generalised method based largely on the technique used by USWB (1970) for the Mekong basin has been used in Australia by Kennedy (1982). A similar method with some modification for estimating PMP for the Indian region has been developed by Rakhecha and Kennedy (1985). The long term aim is to publish maps of PMP of various combination of area and duration for different regions of India based on generalised method.

In this paper, the generalised technique has been used to estimate areal PMP for 1000, 5000 and 10,000 km² areas at different locations in Tamil Nadu and accordingly generalised charts have been prepared. The spillway design floods for most of the dams in Tamil Nadu were computed using empirical formulae. The use of empirical formulae have been now abandoned for estimating spillway design flood for important dams, wherein loss of human life and large economic loss are expected if dams were to fail. The maps of PMP for different size areas will be very useful for estimating design storm of PMP magnitude of catchments falling in the range of 1000 to 10,000 km² size.

2. Generalised method

The essential steps for developing the generalised technique consists of :

(a) Determination of maximum average depth of rainfall for different size areas and durations from major rainstorms over Tamil Nadu and its neighbourhood.

(b) To moisture maximise the analysed rainfall values to an extreme moisture content which is determined by the dew point temperature.

(c) To normalise the maximised values to represent rainfall values to flat land close to the sea coast.

This is done by applying in reverse the adjustments for distance of the storm from the coast, topography and height of intervening mountain barrier.

(d) Plotting of the normalised values so as to obtain a smooth envelopment representing initial PMP values for a flat land close to the sea coast.

These normalised values can then be applied to any individual catchment with the appropriate adjustment factors, so as to derive reliable estimates of PMP.

3. Transposition

The generalised method considers the liberal transposition of storms and, therefore, the most important element in storm transposition is where any particular storm can be transposed. Setting transposition limits involves a detailed study of the storms to determine the meteorological reasons for the heavy rainfall. In view of this, the types of synoptic situations involved in rainfall in the Tamil Nadu are described.

During the course of a year, Tamil Nadu experiences two rainy seasons associated with southwest (June-September) and northeast (October-December) monsoons. Being located on the lee side of the Western Ghats, it does not experience southwest monsoon rains in abundance as other parts of the country. However, it receives about 47% of the mean annual rainfall during the period of northeast monsoon season (Dhar and Rakhecha 1983). Towards the end of southwest monsoon season, the low pressure belt over the north Indian plains moves to the central Bay of Bengal. Under its influence the general flow of winds is from northeast. These winds being of continental origin are therefore dry. During their passage over the Bay of Bengal these wind spick up moisture and cause the rains over Tamil Nadu and its neighbourhood. Apart from this, cyclonic storms also form occasionally in the south Bay of Bengal during pre-monsoon and post-monsoon seasons. These cyclonic storms move in a westerly direction and cause heavy rainfall in the Tamil Nadu and neighbourhood. The cyclonic storms during this period are important rain producing systems and the most extreme cyclonic storm producing rainfall that has been detected within this large area must be considered meteorologically transposable.

4. Major rainstorms of Tamil Nadu

The first step of the generalised method is the determination of major rainstorms on record that have occurred over the large area under study. A review of the available historical daily rainfall data up to 1986 showed that in past the following 6 severe rainstorms have occurred over Tamil Nadu and in its neighbourhood. The dates of occurrence of these rainstorms are 6-8 November 1898, 10-12 November 1903, 8-10 May 1930, 9-11 October 1943, 17-19 May 1943, and 7-9 December 1972.

All the above rainstorms have either occurred in the pre-monsoon month of May or in the northeast monsoon months of October-December. The quantitative analysis of the above six rainstorms when made by DAD method showed that 17-19 May 1943 rainstorm with its centre as Vanur contributed highest areal raindepths for one, two and three days duration. As such, the storm of May 1943 can be considered to be most severe rainstorm on record over Tamil Nadu. This rainstorm was caused by a depression which originated in the southwest Bay of Bengal and reached into a tropical storm intensity on the morning of 16 May. After crossing the Tamil Nadu coast, it moved over to Mysore plateau and Western Ghats and merged in the Arabian Sea off Honavar on the morning of 22 May. The rainstorm brought heavy rains for the period of 3 days over Tamil Nadu. The average maximum raindepths obtained from this rainstorm over different size areas ranging from 10 to 20,000 km² for 1 to 3 days duration are given in Table 1.

TABLE 1

Maximum areal raindepths (cm) for 1-day duration of May 1943 rainstorm

Rainstorm	Area (km²)					
	10	500	1000	5000	10000	20000
1-day (19 May)	42	39	37	29	25	21
2-day (18-19 May)	72	71	69	55	46	37
3-day (17-19 May)	95	93	91	70	61	49

The present study deals with the application of generalised method for 1-day duration for areas of 1000, 5000 and 10000 km². Table 1 shows that the maximum average raindepths for areas of 1000, 5000 and 10000 km² for 1-day duration have been found to be 37 29 and 25 cm respectively. These areal maximum values have been adjusted for the extreme moisture content, topography, distance from the moisture source and the height of the intervening barrier to obtain the initial PMP values for 1000, 5000 and 10000 km² areas near the coast.

5. Adjustment for maximum moisture content

For moisture adjustement, the recorded areal rainfall values are adjusted for maximum recorded moisture content using the ratio of the moisture indices for the extreme and the storm dew points. The moisture in an airmass from which large precipitation occurs can be estimated from the surface dew points decreasing with height at the saturated pseudo-adiabatic lapse rate. A table of precipitable water values used as the moisture index for a range of dew point temperatures is given in WMO (1986). Based on 20 representative stations of Tamil Nadu, maps of 24-hour extreme dew point temperatures for the months of May, October, November and December have been prepared. The highest dew point temperature of 26°C reduced to 1000 hPa has been found for Tamil Nadu region. The areal raindepths given in Table 1 are adjusted using a moisture index (the precipitable water) corresponding to the extreme persisting dew point temperature of 26°C and then were normalised by applying in reverse the adjustment factors of distance from the coast, topography and intervening barrier.

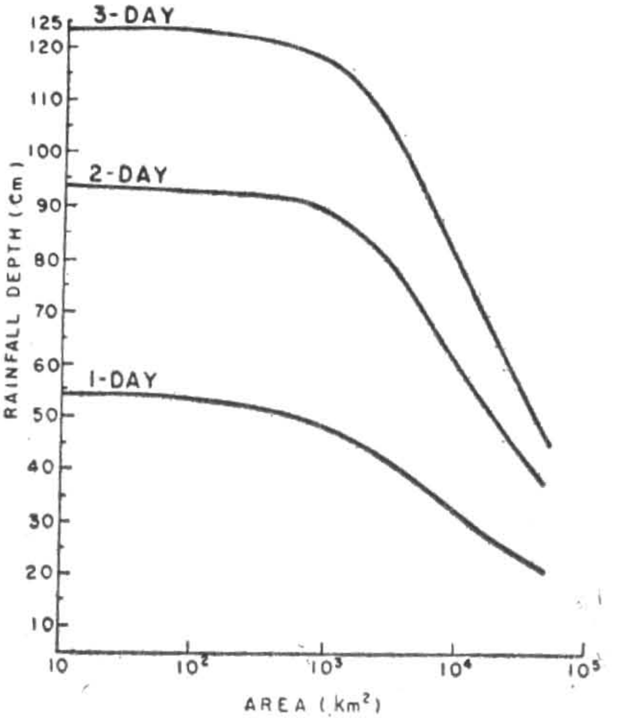


Fig. 1. Normalised maximum rainfall depth-duration-area curves for Tamil Nadu

6. Distance from the coast adjustment

Tropical storms oridinarily release their intense rainfall fairly near the coast. Thus, there is a factor to allow for the depletion of moisture due to the distance travelled by the air over land. The relationship showing the variation in storm rainfall with distance inland has been derived by Rakhecha *et al.* (1990) by using rainfall data recorded in major storms in Peninsular India. The values of the reduction factor to allow for the depletion of moisture for distance are given in Table 2.

TABLE 2

Moisture reduction factor

Distance (km)	Reduction factor
100	0.94
200	0.88
300	0.82
400	0.75

7. Topography adjustment

The method of adjusting for the effect of topography is that given by WMO (1986), namely :

(*i*) No variation in rainfall for elevation of less than 300 m,

(*ii*) An increase of rainfall by 10% per 300 m of ascent above 300 m for the first upslope, and

(*iii*) A decrease of 5% per 300 m of any subsequent descent.

8. Barrier correction

An adjustment factor is required when there is a barrier or mountain range in the path of moist air being fed into the storm area as the mountain range blocks off a certain fraction of the moist inflow into the storm area. The usual method (WMO 1969) of allowing for the effect of a barrier is to reduce the PMP (P) values by the ratio of the precipitable water in a column of air above the height of the barrier to precipitable water extending to ground level in the windward side of the barrier, *i.e.*,

where, $P_1 = P \times W_2 / W_1$

P — Rainfall value not behind a barrier,

P_1 — Adjusted rainfall behind a barrier,

W_1 — Precipitable water in a saturated pseudo-adiabatic atmosphere from ground to some great height corresponding to maximum surface dew point at location of storm,

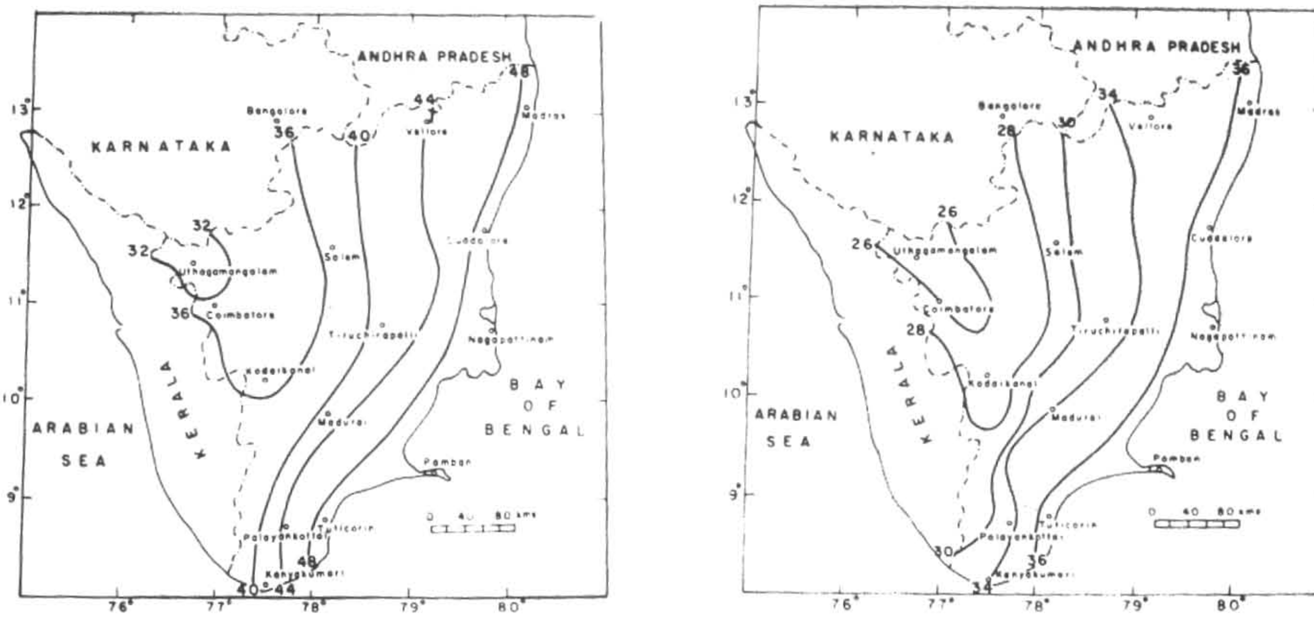
W_2 — Precipitable water in a saturated pseudo-adiabatic atmosphere from the top of barrier to same great height.

The maximum areal raindepths for different areas for 1, 2 and 3-day duration are adjusted to a moisture index of 26°C (the highest of Tamil Nadu coast) and then were normalised for factors such as distance from the coast, topographic effects and intervening barrier. The normalised depth-duration-area curves are shown in Fig. 1 which provides the initial PMP values for a flat land close to the sea coast and with no barrier between it and its moisture source. The normalised values of PMP for 1-day duration for 1000, 5000 and 10000 km² areas have been found to be about 48, 38 and 33 cm respectively (Fig. 1).

9. Preparation of generalised maps for 1000, 5000 and 10000 km²

The PMP estimates for individual areas of 1000, 5000 and 10000 km² size at different locations in Tamil Nadu region have been computed using procedure given WMO (1986).

On a large base map of Tamil Nadu, a suitable grid system conforming with the latitude-longitude grid has been constructed. The points found by the inter-section of the grid lines indicate the locations to which the normalised raindepths are applied with proper adjustments. For moisture adjustment, the extreme persisting dew point temperature for each grid point has been determined from the map of persisting dew point temperatures so that the normalised values could be reduced appropriately. Applying the various adjustment factors with regard to moisture, topography and distance from the coast of each grid, the PMP estimates for each grid point have been determined, for 1000, 5000 and 10000 km² areas. The PMP values over areas 1000, 5000 and 10000 km² were then plotted on each grid point and smooth isolines were drawn so as to show the regional variation of areal PMP. Figs. 2 (a-c) show respectively the generalised patterns of 1-day PMP for 1000, 5000 and 10000 km² areas.



Figs. 2(a-b). Generalised chart of 1-day probable maximum precipitation (cm) for : (a) 1000 km², and (b) 5000 km² over Tamil Nadu

10. Discussion of results

The PMP estimates for 1-day duration that can possibly occur over areas of 1000, 5000 and 10000 km² over Tamil Nadu have been found to range from 48-32, 36-26 and 32-22 cm respectively. The highest values of PMP occur close to the coast of Tamil Nadu. The magnitudes of PMP progressively decreasing inland from east to west. The highest PMP values near coast are 48, 36 and 32 cm respectively. The lower value occurred near northwestern part of Tamil Nadu. The lowest values of PMP are 32, 26 and 22 cm respectively.

The spillway design floods for most of the dams in Tamil Nadu were computed by using empirical formulae. The use of empirical formulae have now been abandoned for estimating spillway design flood for more important dams wherein loss of human life and large economic loss are expected if dams were to fail. These maps of PMP for different size areas will be very useful for estimating design storm of PMP magnitude for catchment having the areas in the range of 1000 and 10000 km².

11. Application of generalised technique to the *Ponnaiyar* river catchment

The *Ponnaiyar* river catchment (Fig. 3) is located in Tamil Nadu and adjoining southeast part of Karnataka between Long. 77° 30′ E to 78° 50′ E and Lat. 11° 50′ N to 13° 30′ N. The river rises on the hills of Channarayanbetta to the northeast of Nandidurg in the Kolar district of Karnataka state. The catchment area up to Sathanur dam site is about 10820 km². The generalised technique developed in this paper can be applied to the sub-area of the *Ponnaiyar* river catchment.

In applying the technique to Ponnaiyar catchment, the adjustement factors need to be applied to the initial PMP value to allow for any difference in extreme persisting dew point, the topography of the subject catchment, its distance from the coast and effect of any significant barriers. The initial PMP value obtained from the enveloping curve (Fig. 1) for 1-day duration for about 10820 km² has been found to be 32 cm.

Adjustments to this value determined by the characteristics of the catchment are as follows :

11.1. *Adjustment for moisture*

The extreme persisting dew point for the catchment derived from maps is 25°C. The initial PMP value is adjusted using the ratio of precipitable water corresponding to the extreme dew point (25°C) to that for the highest dew point (26°C). The moisture adjustment factor is found to be 0.92.

11.2. *Adjustment for distance from the coast*

The distance from the coast of the dam site is approximately 200 km. The adjustment factor for distance from the coast worked out to be 0.88 (Table 2).

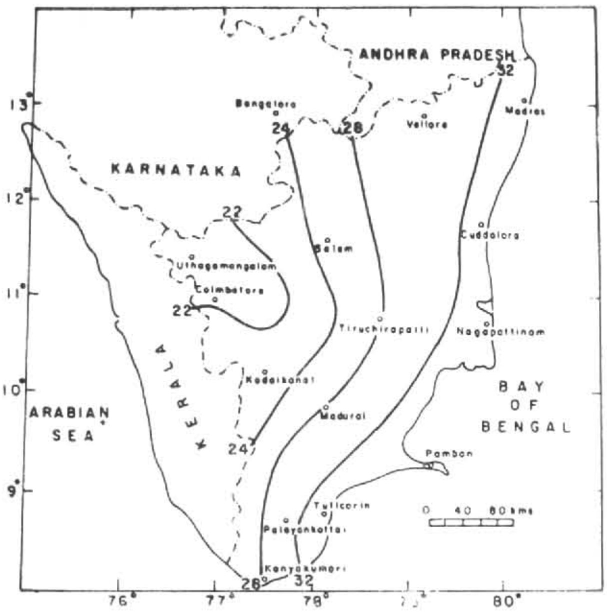
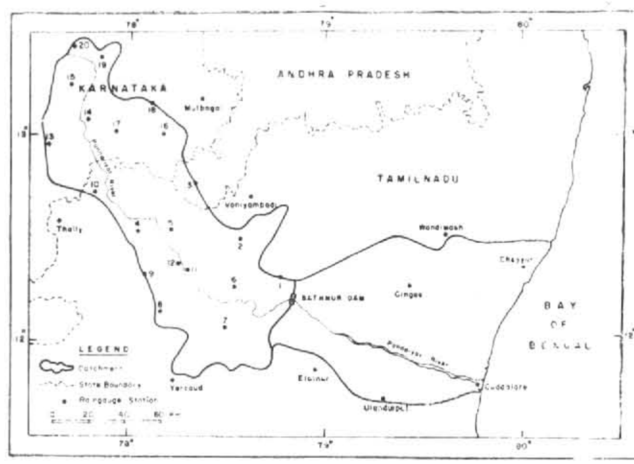


Fig. 2(c)-Generalised chart of 1-day probable maximum precipitation (cm) for 10000 km² over Tamil Nadu



1. Chengam 2. Tiruppattur 3. Kuppam
4. Rayakota 5. Krishnagiri 6. Uttangara
7. Harur 8. Dharampuri 9. Palacode
10. Hosur 11. Barur 12. Nedungal
13. Bangalore 14. Hoskote 15. Devanhalli
16. Bangarpet 17. Malur 18. Kolar
19. Sidlaghatta 20. Chikballpur

Fig. 3. Location map of Ponnaiyar catchment

11.3. *Adjustment for intervening barrier height*

The most critical direction of low level inflow which would give the heaviest rains from consideration of both synoptic influences and height of intervening barrier over the catchment was considered to be northeasterly and for this direction no effective barrier heights for the catchment is determined. The adjustment factor for intervening barrier height is determined as 1.0.

11.4. *Adjustment for topography*

A detailed examination of the topography of the catchment and appliation of the recommended procedure gave an adjustment as 1.0 for topography. This adjustment has been applied to the 1-day initial PMP values to derive 1-day PMP for *Ponnaiyar* river catchment are summarised below :

1-day initial PMP value	= 32 cm
Adjustment factor for moisture	= 0.92
Adjustment factor for distance from coast	= 0.88
Adjustment factor for intervening barrier	= 1.0
Adjustment factor for topography	= 1.0

Combined adjustment factor $= 0.92 \times 0.88 \times 1.0 \times 1.0$
$= 0.81$

1-day PMP estimates $= 32 \times 0.81 \approx 26$ cm

Fig. 2(c) shows that the 1-day PMP for an area of about 10000 km² for *Ponnaiyar* catchment located between Long. 77°30′ to 78°50′E and Lat. 11°50′N to 13°30′ N is about 26 cm.

Rakhecha *et al.* (1990) in their study on the design storm estimation of *Ponnaiyar* river catchment up to Sathanur dam site in Tamil Nadu having an area of about 10820 km² have estimated PMP for 1, 2 and 3-day duration by physical method. The estimate of PMP for the basin for 1-day duration was reported to be 24 cm. This may be compared with the PMP estimate of 26 cm obtained by the generalised method. It can, therefore, be inferred that the areal PMP estimates obtained by generalised method though slightly to the higher side, nevertheless well comparable with the values that obtained by physical method. The PMP generalised charts, therefore, can be used to estimate PMP for any catchment located in Tamil Nadu. The main advantage of this method is that it gives more satisfactory and consistent results than estimates made on projectwise basis.

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