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Probability studies of agricultural water management in Haryana State

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ABSTRACT. The probability of water surplus and deficiencies have been utilised in viewing the problems of agricultural water management. For maximization of the yield, the supply system must be based on the amount of water deficits and their durations. At Ambala, maximum water storage capacity is attained only once in 11 years for 150 days duration from July. The Kharif crop of 90 days duration can successfully be taken once in 2 years, the crops of 120 days duration can succeed in 2 out of 5 years, whereas the crops of still longer duration, *i.e.*, 150 days can grow well only once in 3 years without moisture stress. An adequate amount of water is required even during the rainy season at Hissar. During the monsoon months, the drainage capacity of 7 mm/day is desired once in 2 years. The climatic conditions are suitable during 12 July to 14 September and 15 December to 17 February at Ambala once in 2 years for storing the water in anticipation of the demand.

1. Introduction

The meteorological data has sufficient importance in solving the problems of water management. The precipitation data has been widely used in frequency distributions to indicate the climatic variations, but climate can be described more elaborately in water balance studies with the help of precipitation and evapotranspiration data. Such studies were carried in Netherland by Stol (1958) and in Yugoslavia by Baars (1966).

The present study was conducted to investigate the climatological situations for agricultural water management using the water budgeting method. The agricultural water management policy will involve the amount of water necessary, the time at which supply is needed, the rate at which supply is desired and the duration of the supply. The estimation of these variables will require the probable course of future weather conditions, which is essentially unkown but which, with the past data, can be forecasted.

2. Material and methods

The precipitation, maximum-minimum temperature data for 30 years (1941-70) was available for the two stations, Hissar and Ambala. The data on the actual evapotranspiration is not available, therefore, the potential evapotranspiration values have been computed with the use of Thornthwaite's formula :

$$P_{ET} = 16\, C\, (10t/I)^a$$

where,

P_{ET} = potential evapotranspiration in mm,

t = mean monthly air temperature in °C,

I = annual heat index obtained by summing the twelve monthly heat indices, each of which is defined by $i = (t/5)^{1.514}$,

$$a = \frac{675\, I^3}{10^9} - \frac{771\, I^2}{10^7} + \frac{1792\, I}{10^5} + 0.49239$$ and

C = correction factor for the length of day time hours according to the latitude of the locality and the month under consideration.

Padmanabhamurty *et al.* (1970) indicated that Thornthwaite method over-estimates the potential evapotranspiration during the summer months. However, the lysimetric results are better values of the potential evapotranspiration than these empirical methods.

The above data is computed so as to give the following variables :

(*i*) The differences between precipitation (P) and potential evapotranspiration (P_{ET}).

(*ii*) The various durations comprising of 30, 60, 90 and so on, consecutive days.

(*iii*) The month of the year, each month serving as a starting point for the series of durations.

(*iv*) The frequencies of excess of the differences between P and P_{ET} expressed as water surplus (W_S) and water deficit (W_D).

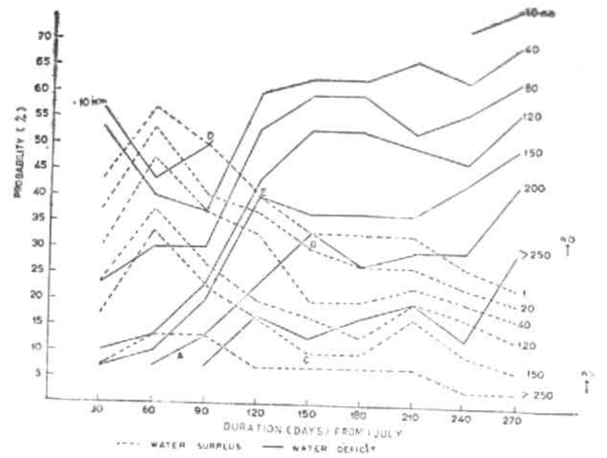

Fig. 1. Curves for equal P-P_{ET} quantities from 1 July onwards at Ambala

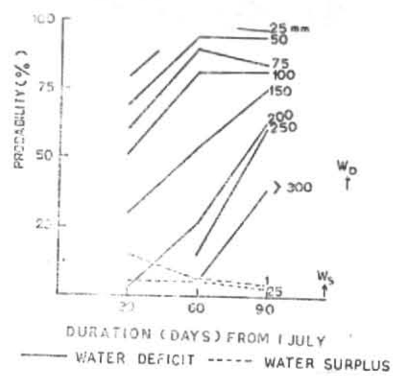

Fig. 2. Curves for equal P-P_{ET} quantities from 1 July onwards at Hissar

These four factors will give rise to a number of diagrams each one illuminating a definite facet of their inter-relation, but here only five figures have been presented to draw very useful conclusions regarding the problems of the water supply system, the drainage system and the general description of the climatic conditions.

3. Results and Discussions

It is worth to note that the normal water deficiency exists from September at Ambala, but the percentage number of chances of water surplus are 33 per cent in September, 10 per cent in October, 3 per cent in November and 30 per cent in December. The normal water deficiency at Hissar exists throughout the year except in January, but the percentage of chances of water surplus are 15 in July, 18 in August, 21 in September, 3 each in October and November and 15 per cent in December respectively (Table 1). Thus it is worth to study the water budgeting on the basis of probability pattern rather than on normal basis.

3.1. *The water supply system* — The soil moisture capacity is an important parameter and has to be kept in view while studying these diagrams. Figs. 1 and 2 show the probabilities of water surplus, water deficiency and the course of evaporation from 1 July onwards at Ambala and Hissar, respectively. Soil moisture capacity of Ambala is 200 mm. Assuming that initially on 1 July this amount is available for plant use, from 200 mm of water deficiency curve in Fig. 1, it will be observed that water deficit is expected 75 days later (point A) once in 10 years. The probability of deficiency increases progressively till a maximum of 33 per cent is reached at 150 days (point B). It means that in 3 out of the 10 years period, the soil profile is incapable of supplying the desired amount of moisture to sustain the plant growth. From the water surplus curve of 200 mm, it is evident that the soil moisture capacity is attained only once in 11 years for 150 days duration (point C). The Kharif crops of 90 days duration can successfully be taken only once in 2 years (point D), the crops of longer duration, *i.e.*, 120 days can succeed in 2 out of the 5 years (point E), whereas the crops of still longer duration, 150 days, can grow well only once in 3 years without moisture stress. This figure also indicates that at 25 per cent probability level, the water deficiency of 93 mm is expected in 60 days, a deficiency of atleast 107 mm in 90 days, and a deficiency of 218 mm in 150 days. Thus if the water can be supplied at the rate of 1.4 mm/day, it will be sufficient to meet the evaporation demand without depleting the stored moisture.

Visualizing the situation at Hissar during the rainy season, water surplus of 1 mm exists only once in 20 years for 90 days duration. It is worth to note from Fig. 2 that an adequate amount of water is required even during the rainy season.

Fig. 3 reveals the situation during the six-month period (October to March) at Ambala. The curves of water surplus indicate the effect of higher rainfall intensities during this period, although the rain spells are few in number. Assuming that an accumulated conserved moisture of 150 mm is stored during the southwest monsoon

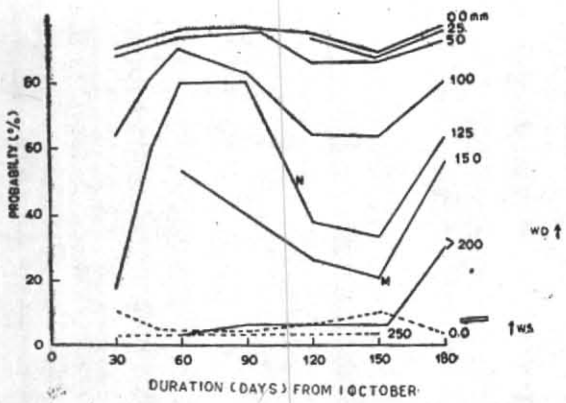

Fig. 3. Curves for equal $P\text{-}P_{ET}$ quantities from 1 October onwards at Ambala

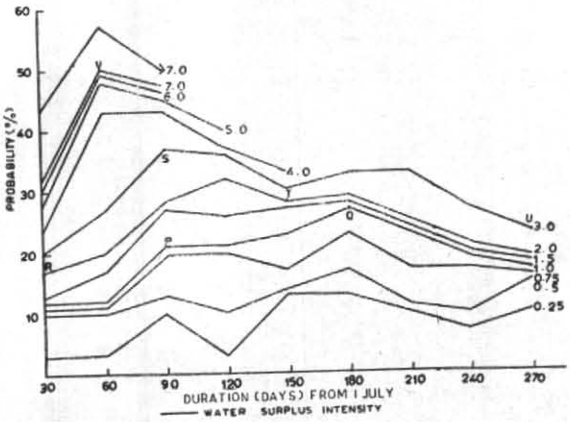

Fig. 4. Curves for equal intensities of precipitation surpluses at Ambala

TABLE 1

Normal monthly water (mm) budget (1941-72)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
						AMBALA							
Precipitation	41·2	34·0	25·5	5·3	16·3	53·6	211·8	221·7	138·9	19·3	7·0	13·1	787·7
Potential evapotranspiration	14·7	26·1	70·9	154·3	204·5	210·0	199·8	182·2	160·6	116·0	45·8	18·1	1403·0
Water deficit	0·0	0·0	45·4	149·0	188·2	156·4	0·0	0·0	21·7	96·7	38·8	5·0	701·2
Water surplus	26·5	7·9	0·0	0·0	0·0	0·0	12·0	39·5	0·0	0·0	0·0	0·0	85·9
No. of chances for water surplus (%)	70	47	10	—	—	—	43	67	33	10	3	30	3
						HISSAR							
Precipitation	16·8	13·4	10·3	7·3	13·2	33·8	111·2	123·3	77·1	13·8	5·3	4·9	430·4
Potential evapotranspiration	12·9	25·1	79·8	158·2	205·6	211·4	206·6	187·7	162·1	120·8	44·3	16·8	1431·3
Water deficit	0·0	11·7	69·5	150·9	192·4	177·6	95·4	64·4	85·0	107·0	39·0	11·9	1004·8
Water surplus	3·9	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	3·9
No. of chances for water surplus (%)	36	18	—	—	—	—	15	18	21	3	3	15	—

season, then it will be enough for the Rabi crop of 150 days duration which is available only once in 5 years (point M). The conserved moisture of 125 mm can last for 120 days only in 2 out of the 5 years (point N). Thus during the winter season evapotranspiration demanded is of the order of 1 mm/day.

Therefore, with these existing situations, our supply system must be based according to the amount of water deficiency and their durations at a probability level depending on the economic considerations.

3.2. *The drainage system* — The drainage problems will arise from the precipitation surplus occurring during the monsoon months. The water surplus amounts have been converted into water surplus intensities [$(P—P_{ET})$ duration mm/day]. The probabilities of water surplus have been plotted against their duration from 1 July onwards for the different values of water surplus intensities shown in Fig. 4. The probability of water surplus intensity averaging more than 1 mm/day is 79 per cent after 90 days (point P) and 73 per cent after 180 days (point Q). The probability of water surplus intensity averaging more than 3 mm/day is 80 per cent after 30 days (point R), 63 per cent after 90 days (point S), 70 per cent after 150 days (point T) and 77 per cent after 270 days (point U). The probability level varies during the different durations because the summation involves the months of increasing and decreasing evapotranspiration. Thus with the help of such diagrams, the amount of water that must be discharged by drainage in lower areas can be determined and can be stored in basins, in canals and the soil itself in anticipation of the demand. It is worth to note that during first 60 days from July, the water surplus occurring once in 2 years, the drainage capacity would need to be 7 mm/day (point

V). In practice, the drainage capacity should be higher to reduce the element of risk and higher intensities of rainfall, which are likely to occur over the short periods during the monsoon months.

3.3. *Description of climatic conditions* — The complete series of graphs beginning on the first day of each month of the year will make it possible to give the description of the climate suitable for use in agricultural water management. Curves of probability-duration relationships for $P_{ET} \geqslant P$ beginning with each month as a starting point are given in Fig. 5. Each curve represents the boundary between the water surplus and the deficiencies. Water surplus occurs above the curves and water deficit below them. It will be seen from these curves that water surplus is likely to be experienced during 12 July to 14 September, and 15 December to 17 February, at least once in 2 years (at 50 per cent probability) at Ambala. For the remaining duration, sufficient amount of deficiency exists which has to be met with irrigation facilities.

4. Conclusions

The normal water deficiency exists from September at Ambala, whereas at Hissar it exists throughout the year except in the month of January. It was concluded that the supply system should be based on the amount of water deficiency and their durations. The water surplus intensity averaging more than 3 mm/day is 80 per cent after 30 days, 63 per cent after 90 days, 70 per cent after 150 days and 77 per cent after 270 days at Ambala. During the first 60 days from July at Ambala, the water surplus intensity is 7 mm/day

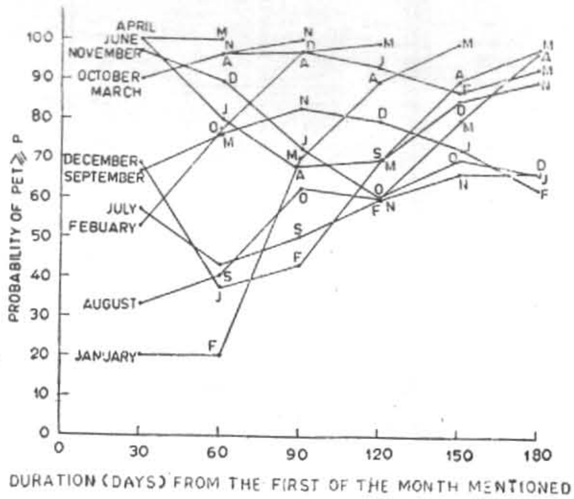

Fig. 5. Probability-duration relationship for $P_{ET} \geqslant P$ at Ambala

(50 per cent probability level). The water surplus is experienced during 12 July to 14 September and 15 December to 17 February, at least once in 2 years at Ambala. The amount of water surplus collected during these periods in anticipation of the demand can be utilised during water deficiency periods.

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