International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 4, Issue 4, April 2015

Studies on weekly water deficit during different crop growing seasons at Rahuri, India

Nayak. A.K

Lecturer, Department of Hydraulics and Water Resources Engineering, College of Engineering and Technology, Aksum University, Axum, Ethiopia,

ABSTRACT

The daily rainfall data of 34 years (1975-2009) at MPKV, Rahuri, District, Ahmednagar, M.S. have been analyzed. Daily rainfall data were converted into weekly rainfall, Weekly data of rainfall were found to be more useful for planning of crop management. Weekly ETr values for all the weeks were calculated for 34 years by using equation suggested by Hargreaves and Samani. The difference between weekly rainfall and weekly evapotranspiration computed as water deficit. The weekly data of rainfall, reference crop evapotranspiration and water deficit was arranged in descending order of magnitude to determine the percent chance of each time using Weibull formula. The weekly water deficit at 10%, 30%, 50%, 70% and 90% of probability level was computed for carrying out the analysis. The graphs of plotting position vs. water deficit at 10%, 30%, 50%, 70% and 90% of probability level were plotted and found that there is good possibility of water harvesting at 10% probability level for effective crop planning in *rabi* and summer season.

Index terms- **Evapotranspiration, weekly rainfall, water deficit, irrigation planning.**

1. INTRODUCTION

The rainfall management and irrigation planning is an essential component of water management in agriculture. In arid and semi-arid region rainfall is a major source of water supply to the crops grown. Hence rainfall is a major factor in planning agricultural programme of area. However, the rainfall distribution pattern in our country is most uneven and stochastic, hence Knowledge of average annual rainfall is not very useful for deciding the cropping pattern. But, Weekly rainfall analysis may be more helpful in better planning of cropping and estimating the time of sowing, cultural operation and irrigation and the crops to be grown in different seasons. Moreover, analysis of historical rainfall data on weekly basis has received considerable attention of meteorologists as well as agricultural scientists for better understanding of the distribution of rainfall. However, it is always desirable to interpret the rainfall distribution in relation to local agricultural practices, to bring out the implication of rainfall variability in agricultural planning and management. Analysis of historical rainfall data helps in the following aspects:

1. Critical period of crop growth sensitive to moisture stress can coincide with period of more assured rainfall.
2. High intensity rainstorms causing runoff are likely to occur at least twice or thrice during the season even in the region of low rainfall. Therefore, the potential of rain water harvesting and recycling can be assessed as accurately as possible.
3. Absence of rain for a week or more is a common feature even in the high rainfall region and such occasions are more in arid and semi-arid region leading to agricultural drought. Protective irrigation if possible, can be given to the crops during this period.

In addition evaporation plays an important role in the assessment and utilization of water resources for different purposes and an accurate determination of

ISSN: 2278 – 7798

the losses due to evaporation from free water surfaces is therefore, of utmost important in any scheme of utilization of water resources. Evapo-transpiration is the combined process by which water is transferred from the earth surface to the atmosphere and it includes evaporation of liquid from the soil as well as transpiration of liquid water through plant tissues. Thus, evaporation and evapotranspiration become the important factor in planning agricultural activities. In arid and semi-arid region soil water deficiency and high soil temperature are the probable major limitations to optimum growth and development of summer crops. Moreover, in this region, direct water evaporation from soil surfaces comprises a significant part of total evapotranspiration loss particularly during pre monsoon summer period and the difference between rainfall and evapotranspiration will give either the water deficit or surplus in the area for that period. However, evapotranspiration from the different crops will be different and hence maximum limit of evapotranspiration i.e. reference crop evapotranspiration can be considered as better estimate of demand of crop growing area. Rahuri, the headquarter of M.P.K.V. is in semi-arid region receiving 553 mm average annual rainfall and growing different crops viz. pearl millet, sorghum, wheat, green gram, black gram, red gram, Bengal gram, cotton, sugarcane and various fruits ranging from dry land to irrigated fruits. Hence the probability analysis can be used for prediction of occurrence of future events from available records and also, there are many theoretical distributions like Normal, Log normal, Gamma, Gumbel, etc. for analyzing the historical data. Although empirical distribution using Weibull formula for plotting position can also give better estimation. Hence considering the above problems the present study has been undertaken with an overall objective of to study weekly rainfall probabilities at Rahuri, to determine weekly reference crop evapotranspiration at different probability levels and to determine weekly water deficit or surplus at different probability levels.

II. MATERIALS AND METHODS

a. Meteorological Data

The daily maximum and minimum temperature (ºC) data for 34 years (1975-2009) were collected from AICRP on Water Management, MPKV, Rahuri. The rainfall data for 34 years were collected from AICRP on Water Management MPKV, Rahuri. The daily data were summed up to get weekly data. The extraterrestrial radiation values (mm/day) for different latitude in Northern Hemisphere (Michael, 1978) were used to determine the Ra values for Rahuri having Latitude 19º 23’ and Longitude 74º 42’. Computed values of extraterrestrial radiation (mm/day) for different months are presented in Table I.

Table I. Extraterrestrial radiation values for Rahuri.

Sr. No.	Month	Extraterrestrial Radiation
1	Jan	11.32
2	Feb	12.79
3	Mar	14.31
4	April	15.9
5	May	16.24
6	June	16.31
7	July	16.24
8	Aug	15.87
9	Sep	14.83
10	Oct	13.39
11	Nov	11.72
12	Dec	10.82

b. Evapotranspiration

Evapotranspiration (ET) denotes the quantity of water transpired by plants during their growth or retained in the plant tissue, plus the moisture evaporated from the surface of soil and the vegetation (Michael 1978).

c. Potential Evapotranspiration

Potential Evapotranspiration can be defined as the ET that occurs when the ground is completely covered by actively growing vegetation and where there is no limitation in soil moisture. It may be considered to be the upper limit of evapotranspiration for a crop in a given climate (Michael, 1978).

d. Reference crop evapotranspiration

Doorenbos and Pruitt 1977 defined reference crop evapotranspiration (ETr) as the rate of

ISSN: 2278 – 7798

evapotranspiration from an extensive surface of 8 to 15 cm, green grass cover of uniform height, actively growing, completely shedding the ground did not short of water. ETr values for all the days were calculated for 34 years by using equation suggested by Hargreaves and Samani (1985b) as it gives fairly good estimates of ETr with comparatively less input meteorological data. Also there is not much difference in reference crop ET values calculated by modified Penman method and Hargreaves and Samani method (Chaudhari and Desai, 1988).

$$ETr = 0.0135\ (KT)\ (Ra)\ x\ (Td)^{1/2}\ (Tc + 17.8) \quad (1)$$

Where,

Td = Temperature difference, ºC

Td = *T*max. – *T* min.

Tc = Avg. Temp., ºC

$$Tc = \frac{T\max + T\min}{2}$$

KT = 0.19 for coastal region and KT = 0.162 for lnterior region

Ra = Extraterrestrial radiation, mm/day

The computed daily values of ETr were summed up to obtain the weekly ETr for standard meteorological weeks.

e. Weekly water deficit

Weekly water deficit can be defined as the negative difference between weekly rainfall and weekly evapotranspiration for a given location.

f. Weekly water surplus

Weekly water surplus can be defined as the positive difference between weekly rainfall and weekly evapotranspiration for a given location. Using the weekly data of rainfall and ETr the weekly water deficit or surplus was computed.

2.7 Probability analysis

Gumbel (1958) had given the following criteria for the acceptability of the plotting position formula (Haan, 1977).

1. The plotting position must be such that all observation can be plotted.
2. The plotting position should lie between the observed frequency of (m-1)/n and m/n where m is the rank of observation beginning with m = 1 for the largest (smallest) value and n is the number of years of record (if applicable) or the number of observations.
3. The return period of value to or larger than the largest observation and the return period of a value equal to or smaller than the smallest observation should converge toward n.
4. The observation should be equally spaced on the frequency scale.
5. The plotting position should have an intuitive meaning, be analytically simple, and be easy to use.

Weibull formula;

$$P = \frac{m}{n+1} \quad (2)$$

Where,

m = Rank, when data analyzed in descending or ascending order

n = Total number of observations,

p = Plotting position i.e. Percent chance.

It satisfies all the above criteria and hence it was used to carry out probability analysis.

The difference between weekly rainfall and weekly reference crop evapotranspiration computed as water deficit. It gives the net water available for the crop. The deficits at 10%, 30%, 50%, 70% and 90% probability levels are calculated. The values of weekly deficit or surplus are plotted against plotting positions. The plotting position should be plotted at abscissa and deficit or surplus as ordinate.

The graphical representation of plotting position vs. rainfall and plotting position vs. ETr was done. The plotting position should be plotted as abscissa and rainfall or ETr as ordinate. The meteorological weeks selected for plotting of these figures of rainfall and reference crop evapotranspiration are 22^{nd}, 37^{th} and 40^{th} since 22^{nd} week is the starting of monsoon season and 40^{th} week if the end of monsoon season while 37^{th} week gives the maximum surplus. The graphs showing meteorological weeks vs. deficit are also plotted as meteorological weeks as abscissa and deficit as ordinate. These graphs show the net water deficit at particular weeks.

III. RESULTS AND DISCUSSION

a. Probability analysis of rainfall and ETr

ISSN: 2278 – 7798

Arranging the weekly rainfall data of 34 years in descending order for each week the plotting positions were determined using Weibull formula, which can be considered as probability of exceedence. The rainfall amount and its probability of exceedence were plotted for each week. Considering straight line relationship in adjacent points the rainfall amount for 10 per cent, 30 per cent, 50 per cent, 70 per cent and 90 per cent probability of exceedence were determined for each week. The plots of rainfall amount and probability of exceedence for three representative weeks for 22^{nd}, 37^{th} and 40^{th} MW are depicted in Fig.1.

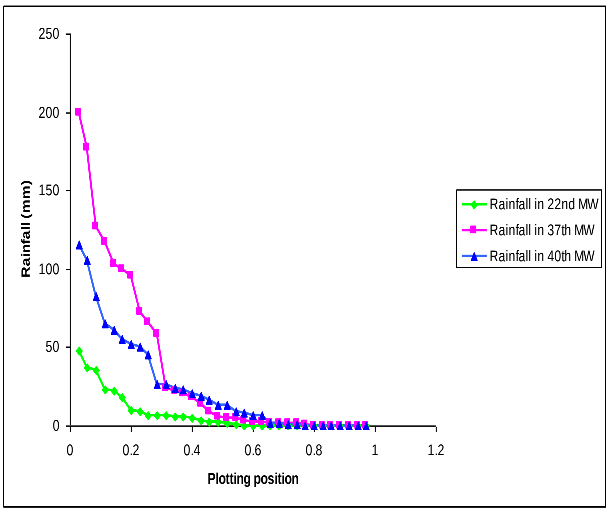

Figure1. Probability analysis of rainfall for 22^{nd}, 37^{th} and 40^{th} meteorological weeks

It can be revealed from this figure that maximum rainfall up to 30 percent probability of exceedence is received in 37^{th} MW whereas minimum amount of rainfall is received in 22^{nd} MW. From 70 per cent probability of exceedence onward all the three meteorological weeks showed same value of weekly rainfall.

The weekly reference crop evapotranspiration values computed as equation (1) were arranged in descending order for each week and the plotting position, i.e. probability of exceedence, were determined. The ETr values at 10 per cent, 30 per cent, 50 per cent, 70 per cent and 90 per cent probability of exceedence were determined for each week.

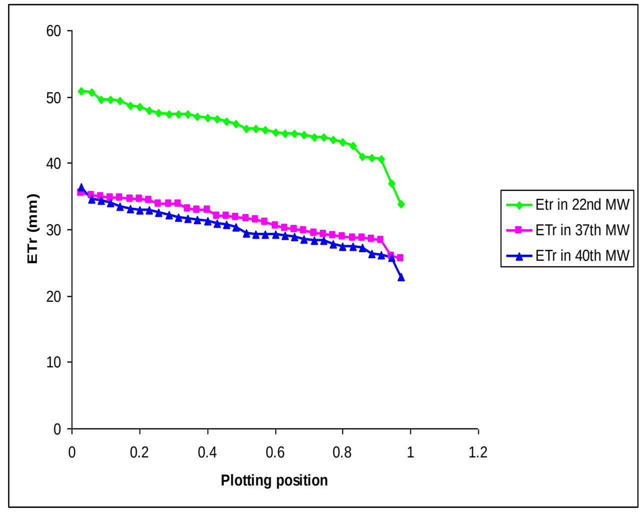

Figure 2. Probability analysis of reference crop evapotranspiration for 22^{nd}, 37^{th} and 40^{th} meteorological weeks

Fig.2 shows the graphical presentation of plotting position against weekly ETr values for 22^{nd}, 37^{th} and 40^{th} MW. The ETr values for 37^{th} and 40^{th} MW are almost matching for all the probability levels whereas ETr values for 22^{nd} MW are higher than those computed for 22^{nd} and 37^{th} MW for all probability levels.

b. Water deficit or surplus at different probability levels

Using the rainfall and ETr values at different probability levels the water deficit or surplus for all MWs were computed. The water deficit or surplus during different meteorological weeks at 10 per cent probability of exceedence, which signifies maximum water surplus, is shown in Fig.3.

ISSN: 2278 – 7798

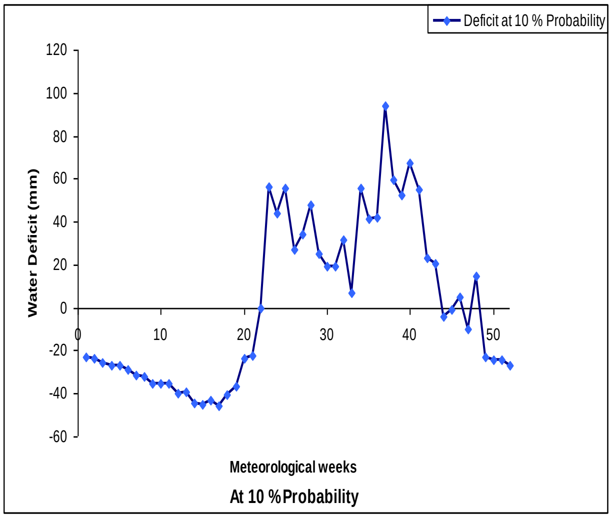

Figure 3. Meteorological weeks vs. deficit at 10% probability level

Fig.3 shows highest surplus of 94.01 mm in 37th meteorological week followed by 67.29 in 40th meteorological week. During entire meteorological weeks there was a total surplus of 897.88 mm and total deficit of (-) 797.13 mm. This indicates that there is a good possibility of water harvesting for effective crop planning in *Rabi* and summer season.
The water deficit or surplus during different MWs at 30 per cent probability, which roughly means a situation occurring during 3 years out of 10 years, is shown in Fig.4.

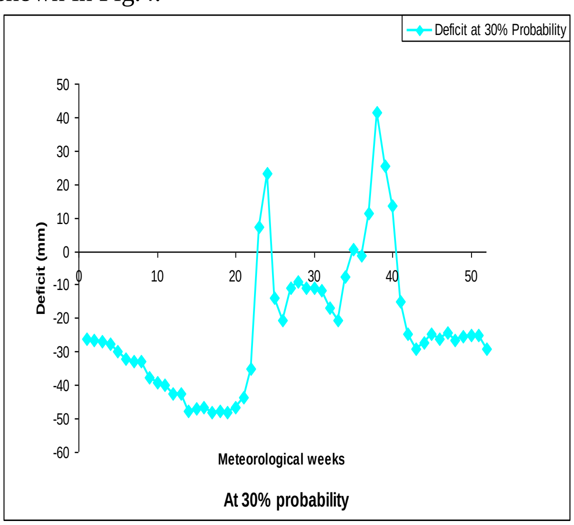

Figure 4. Meteorological weeks vs. deficit at 30% probability level

It is revealed from Fig.4 that there is highest surplus of 41.50 mm in 38th meteorological week. During entire meteorological weeks there was a total surplus of 122.84 mm and total deficit of (-) 1013.09 mm. Thus total surplus was not sufficient to harvest water for *Rabi* and summer season.

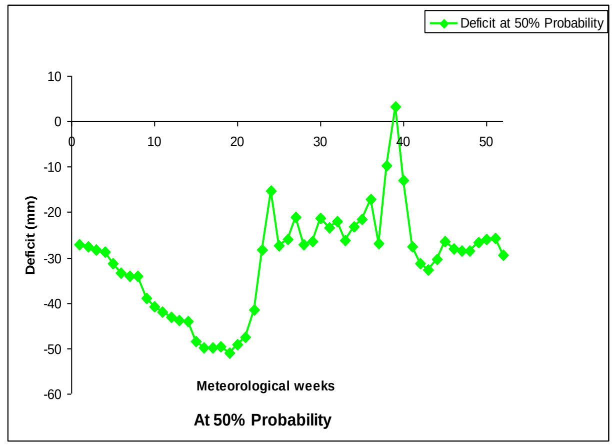

Figure 5. Meteorological weeks vs. deficit at 50% probability level

At 50% probability level the only surplus of 3.24 mm was observed in 39th week which is not sufficient to harvest water. There was the total deficit of (-) 1599.39 mm as depicted in Fig.5.

The water deficit or surplus during different meteorological weeks at 70 per cent probability level, a situation most likely in scarcity region, is shown in Fig.6. The maximum deficit of (-) 52.39 mm was observed in 18th MW with total deficit of (-) 1808.70 mm indicating that irrigation facilities are essential for the sustainance of crop in the region.

ISSN: 2278 – 7798

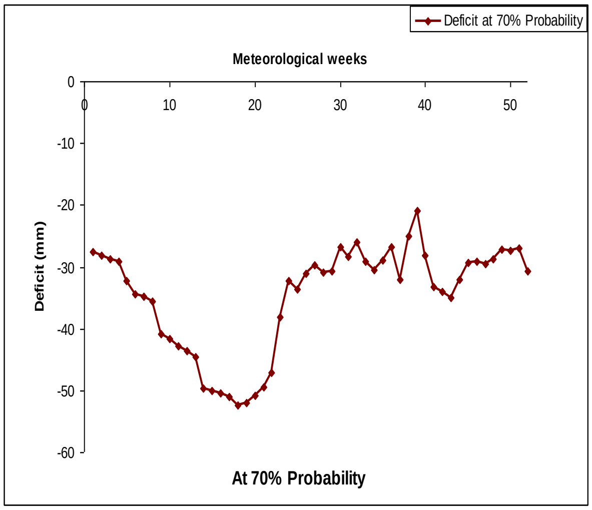

Figure .6 Meteorological weeks vs. deficit at 70% probability level

At 90 per cent probability of exceedence, a situation which is achieved almost during a years out of 10 years, there is always water deficit throughout the year. Fig.7 is always water deficit against different meteorological weeks. The total deficit during the year is (-) 1966.61 mm. The maximum weekly deficit was observed during 18th MW as (-) 54.39 mm.

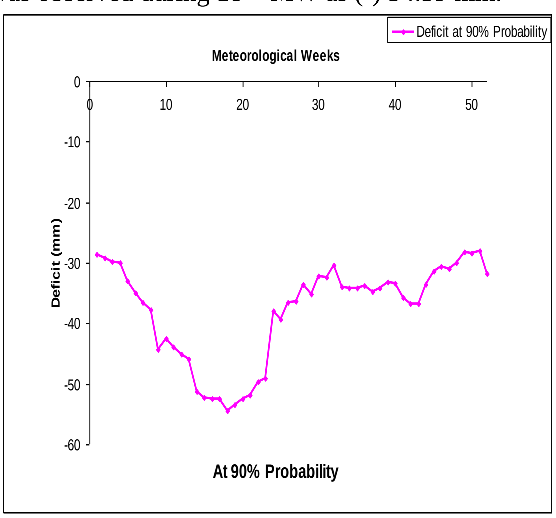

Figure 7. Meteorological weeks vs. deficit at 90% probability level

The graph of meteorological weeks vs. deficit or surplus at 10%, 30%, 50%, 70% and 90% probability levels is shown in Fig.8. From graph it is clear that at all the probability levels the deficit during 1st to 17th meteorological weeks was nearly equal. At 10% probability level deficit remarkably deviates from other probability levels from 18th meteorological week onwards till 49th meteorological week. Deficit followed similar trend for 70% and 90% probability level except for 38th to 40th meteorological week.

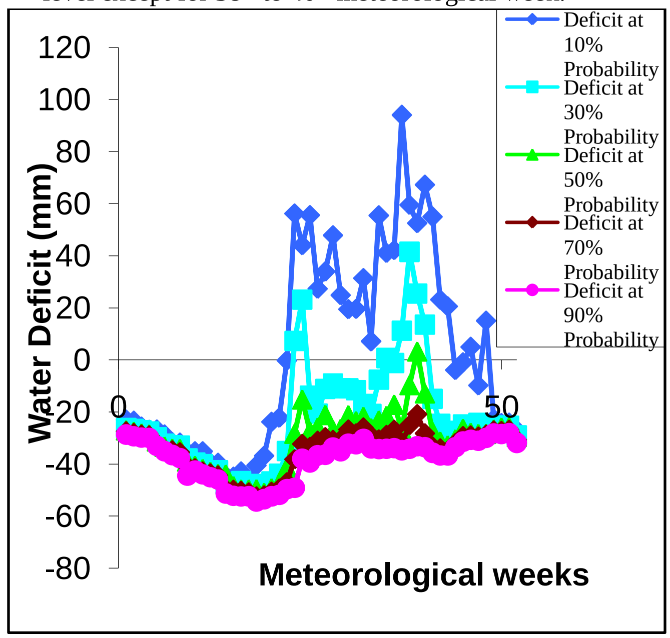

Figure 8. Weekly water deficit at 10%, 30%, 50%, 70% and 90% probability levels for different meteorological weeks

3.3 Water deficit or surplus during different crop growing seasons

In India three crop growing seasons are considered *kharif*, extending from 23rd to 41st MW; *rabi* from 42nd to 8th MW and summer from 9th to 22nd MW. The water deficit or surplus at 10, 30, 50, 70 and 90 per cent probability of exceedence, during these crop growing seasons were computed. Table II. shows the water deficit or surplus during *kharif*, *rabi* and summer seasons for 10, 30, 50, 70 and 90 per cent probability.

Table II. Water deficit or surplus at different probability levels during three crop growing seasons.

ISSN: 2278 – 7798

Seasons	Probability levels				
	10 %	30%	50%	70%	90%
Kharif	834.20	(-) 26.47	(-) 399.76	(-) 562.12	(-) 670.38
Rabi	(-) 267.09	(-) 522.90	(-) 557.59	(-) 580.33	(-) 606.53
Summer	(-) 486.25	(-) 612.88	(-) 638.79	(-) 666.20	(-) 691.71

The surplus was observed during *kharif* at 10 per cent level only. For all the probabilities there was deficit during *kharif*. During the *rabi* season and summer season there was always water deficit at all the five levels of probability. Thus, it implies that the evapotranspiration demand of the region is too high.
It can also be revealed from the table that difference in water deficit or surplus at 10 per cent and 90 per cent probability of exceedence was maximum 1504.58mm during *kharif,* which was reduced to 339.44 mm during *rabi* and 205.46 mm during summer season. This analysis of data may be more useful in better planning of cropping and for water harvesting during monsoon season for effective irrigation during *rabi* and summer season.

IV. SUMMARY AND CONCLUSION

Irrigation is of prime importance for assured crop production. But Maharashtra state has limited water resources due to which the effective use of water is essential. Therefore water harvesting for effective crop planning is an essential component. The study was undertaken to carry out the probability analysis of rainfall data, computed ETr data and the water deficit or surplus for Rahuri. It was decided to compute reference crop evapotranspiration from historical data by Hargreaves and Samani methods as it gives fairly good estimates of ETr with comparatively less input meteorological data to the equation.

The rainfall data and maximum, minimum temperature data for 34 years were collected from All India Co-ordinated Research Project on Water Management Scheme, MPKV, Rahuri. It was decided to do the probability analysis of weekly deficit or surplus. Weekly ETr values were computed for 34 years and difference of weekly rainfall and ETr values computed as deficit or surplus.
Plotting positions were determined by Weibull formula. The weekly deficit or surplus values were computed for 10%, 30%, 50%, 70% and 90% probability levels. The graphs of plotting position vs. deficit or surplus at different probability levels were plotted. Also the graphs of plotting position vs. rainfall and plotting position vs. ETr were plotted.
It was found that at 10% probability level there was a surplus of 897.88 mm during all meteorological weeks. At 30% and 50% probability level there was not sufficient water to harvest for *Rabi* and summer season and at 70% and 90% probability levels the deficit followed similar trend i.e. no surplus present.
Following conclusions were drawn from the results of the study

1. There is good possibility of water harvesting at 10% probability level for effective crop planning in *rabi* and summer season with a total surplus of 897.88 mm
2. At 70% and 90% probability level it is difficult to have *rabi* crops due to more deficits.

V. REFERENCE

[1] Agnihotri, Y., Madhukar, R.M. and Singh Prahlad, (1986). Weekly rainfall analysis and agricultural draughts at Chandigarh. Vayumandandal, 16 (3 & 4): 54-56.

[2] Ahire V.D. and Sapkale H.A. 2004. Probability analysis of reference crop evapotranspiration. An unpublished B. Tech Project Report. Submitted to MPKV, Rahuri. 1-51.

[3] Ashwinikumar and Guha, Sandip Kumar. (1987). Rain pack: A basic package for analysis of rainfall data. Journal of Agricultural Engineering. Vol.24 (2).

ISSN: 2278 – 7798

[4] Bhatia, K.G, R.N. Singh and R, S. Singh. 1975. Analysis of rainfall data for soil conservation and crop planning. Indian Forester, 101 (4): 238-248.

[5] Chaudhari D.A. and P.T.Desai 1988. Evaluation of crop coefficient for various crops. An unpublished B.Tech. Project Report. Submitted to MPKV, Rahuri: 15-30.

[6] Chow V.T. 1964. Handbook of Applied Hydrology, McGraw Hill Book Co. Inc. Chapter 8, Section 1: 8.1-8.91

[7] Gupta, S.K., Rambabu and K.G. Tejwani. 1975. Weekly Rainfall of India for planning Cropping Programme. Soil Conservation Digest. 3(1): 31-36.

[8] Haan, C.T. (1977). Stastical methods in Hydrology. The IOWA state university press, Ames. IOWA, USA.

[9] Hazari A.K., Atre A.A. and Bangal G.B. (1992) analysis of rainfall at Rahuri in scarcity region of Maharashtra for farm operations planning. Journal of Indian Water Resources Society. Vol. 12: No.3 & 4.

[10] Jajoo, S.B, Benke S.D. and Atal, G.R. 1991. Probability analysis of daily and weekly rainfall for Akola. *P.K.V. Res. J*. 16(2): 223-237.

[11] Michael A. M. (1978). Handbook of Irrigation Theory and Practices.

[12] Nagarajan, M. and K. Ramaswamy. (2006). Probability analysis for prediction of rainfall for Tamilnadu Agricultural University, Coimbatore. Journal of Soil and Water Conservation, India. Vol.5 (2): 69-76

[13] Panigraphi, B. and S.N. Panda. (2001). Analysis of weekly rainfall for crop planning in Rainfed region. Journal of Agricultural Engineering. Vol.38 (4): 47-48.

[14] Ray, C.R., P.C. Senapati and R. Lal., 1980. Rainfall analysis for crop planning at Gopalpur (Orissa). Agril. Engg. 17(3 & 4): 1-8.

[15] Senapati, P.C., Sharma S.D., and Lal, R. 1979. Probability analysis of annual rainfall data at Bhubaneshwar (Orissa). Journal of Agricultural Engineering. 16(4): 131-140.

[16] Sharma, H.C., H.S. Chauhan and Sewa Ram (1979). Probability analysis of rainfall for crop planning. Journal of Agricultural Engineering.Vol.16 (3): 87-94.

[17] Sharma, H.C., R.N. Shrivas and R.K.S. Tomar. 1987. Agricultural Planning on the basis of Rainfall. J. IWRS. 7(2): 17-27.

[18] Shinde A.N., Patil S.A.and Borate S.N. 2008. Probability analysis of annual maximum weekly rainfall at Niphad, Pune and Kasbe Digras in plain zone of Maharashtra. An unpublished B. Tech

ISSN: 2278 – 7798

Project Report. Submitted to MPKV, Rahuri. 1-56.

[19] Sidhpuria. M. S., H.C. Sharma, R.K. Goel and H.S. Chauhan. 1989. Water Conservation and Crop Planning on the Basis of Rainfall at Shahjanhanpur. Proc. of 4th National Convention of Agril. Engineers and Seminar on Agril Engg. for Hill Regions, held at Srinagar from May 27-29, 1989.

[20] Tiwari A.K., Sharma A.K. and Srivastava (1992). Probability analysis of rainfall data of Datia District, Bundelkhand for crop planning. Indian J. Soil Conservation Vol. 20 No.3. pp. 82-88.

[21] Varshney, K.G. (1989). Frequency analysis of weekly rainfall using analytical technique proceedings of XXV Annual convention of ISAE held at Udaipur. January 5-7, 1989. Paper No. WRM, 85-20: 140-147.

[22] Verma, H.N. and Sharma. P.B.S. (1988) Analysis of short duration rainfall for planning rainfed crops. Journal of Agricultural Engineering. 125 (3): 15-19

ISSN: 2278 – 7798