



Research Article

Rainfall Characteristics Analysis for Rice Based Cropping System at Varanasi, Uttar Pradesh

M.K. YADAV*, R.S. SINGH AND CHANDRABHAN PATEL

Department of Geophysics, Banaras Hindu University, Varanasi - 221005, Uttar Pradesh

ABSTRACT

Knowledge about onset of monsoon, amount of rainfall and its distribution are prerequisite to adopt any cropping system model at a region especially for rainfed crops. In this study, seasonal analysis of rainfall at Varanasi was performed to quantify the water demand of different cropping systems. The probability analysis of the rainfall data revealed that the onset of monsoon is on 25th standard meteorological week (SMW) which is extended during June 18-24. Seasonal distribution of rainfall indicated that 71% of annual rainfall (719.6 mm) occurs in *kharif*. In *zaid* and *rabi* seasons, 243.9 and 55.4 mm of rainfall, respectively are received. The occurrence of rainy days (>2.5 mm rainfall per day) is 48 days per annum. There is a surplus rain of 304.1 mm during rice growing period (23-42 SMW). Based on the rainfall distribution, design of water harvesting structure has been suggested for rice cultivation. The dimension of a pond for 316 cu m water harvesting should be 26 m in length and 13 m in width (surface), 13 m of length and 6.5 m of width (bottom), and 1.5 m depth.

Key words: Rainfall, Cropping system, Water balance, Rice

Introduction

Rainfall and temperature of a region determine the sowing time and other agricultural activities, especially for rainfed farming systems. Rainfall also determines the potential of a region in terms of crops to be produced, farming systems to be adopted, nature and sequence of farming operations to be followed, and to achieve higher agricultural productivity (Singh and Dhillon, 1994). In rainfed agriculture, the total amount of rainfall and its distribution affects the plant growth (Sharma *et al.*, 1979; Sharda and Bhushan, 1985; Ram *et al.*, 1992).

Rice is one of the important food crops in eastern Uttar Pradesh. However, sowing time, length of growing period and transplanting of rice

are highly dependent on rainfall and temperature. Therefore, prediction of rainfall and temperature is necessary for timely agricultural operations. Probability analysis based on past rainfall records has been the most reliable method to predict occurrence of rainfall events (Kumar and Kumar, 1989). This helps in developing and modifying the crop management practices for sustainable production system, particularly in rice based cropping systems.

The amount of rainfall received by hot dry sub-humid region of eastern Uttar Pradesh is adequate for rainfed farming in *kharif* season. But, timely sowing in nursery and thereafter, its transplanting to the main field require precise prediction of onset of monsoon and construction of appropriate water harvesting structures. The harvested water may be useful as supplemental irrigation at critical crop growth stages. Under

*Corresponding author,
Email: manojagro@gmail.com

favourable soil moisture conditions, improved cultivars can attain their yield potential by responding to fertilizers and intensive management practices. Keeping these in view, the present study was undertaken to analyze the distribution of rainfall characteristics for better planning of rice based cropping systems at Varanasi, Uttar Pradesh.

Materials and Methods

Rainfall data were collected from the Meteorological Observatory of Department of Geophysics, Banaras Hindu University, Varanasi. The observatory is situated at 25°18' north latitude and 83°01' east longitude and 76 m above mean sea level. The yearly average rainfall in this region varies between 499.5 and 1368.9 mm, more than 2/3rd of which appears during the months of June to September. Mean annual maximum and minimum temperatures for the same period are 32.2 and 19.7°C, respectively. The month of May is the hottest with mean monthly maximum and minimum air temperatures of 41.4 and 26.7°C. Similarly, January is the coolest month (minimum - 9.3°C and maximum - 23.2°C) (Table 1). The climate is classified as sub-tropical and dry sub-humid.

Historical rainfall data for the period (1991-2011) were arranged into weekly, monthly and seasonal rainfall by simple mathematical means. Three agricultural seasons: *zaid* (summer; April 1–July 15), *kharif* (rainy; July 16–November 16) and *rabi* (winter; November 16–March 31) were identified according to the existing rice-based cropping rotation in this region. The total rainfall of the periods of the respective seasons was summed up for its probability analysis. Daily rainfall of the respective year was accumulated to obtain yearly rainfall and the average of the period was calculated. Rainy day was considered when rainfall in a particular day exceeded 2.5 mm. The date of onset of monsoon was defined as the date of commencement of a 7-day spell following the criteria as given by Verma and Sharma, 1989; Sharma *et al.*, 1979; Sahoo, 1993).

The mean date and standard deviation of onset of monsoon was calculated as follows:

$$D_m = \Sigma (X_i/n); \text{ and } \sigma = \sqrt{[\{X_i - (\Sigma (X_i/n))\}^2 / n]}$$

Where, D_m is mean date; X_i is date of onset of monsoon in i^{th} year ($i=1, 2 \dots n$); n is number of years for which rainfall data were analyzed; σ is standard deviation of date of onset from mean date.

The probability analysis was carried out using Weibull's method (Chow, 1964), which is

$$P = [m/(n+1)] * 100$$

Where, P is the plotting position in percent chance; m is the rank number when the data are arranged in descending order and n is total number of years.

Results and Discussion

Annual and seasonal rainfall

Average annual rainfall during 21 years (1991-2011) was 1018.9 mm; the maximum and minimum rainfall occurred in 1999 (1368.9 mm) and 2009 (499.5 mm). Out of this, 70.6% occurred during *kharif*, 23.9% in *zaid* and 5.4% in *rabi* season (Table 2). Coefficient of variation (CV) in seasonal rainfall was 29.9, 43.7 and 71.9% for *kharif*, *zaid* and *rabi*. Therefore, cultivation in *rabi* and *zaid* seasons requires assured irrigation. However in *kharif* season, crops can be rainfed depending upon the water requirement of the crops. The amount of rainfall 719.6 mm during *kharif* is sufficient for rice cultivation including raising nursery and land preparation if adequate water harvesting technology is adopted.

Annual and seasonal rainy day

Number of rainy days varied from 26 to 63 in a year with a mean of 48 (Table 2) and CVs of 17%. The occurrence of rainy days in the *kharif* was 64.3%, followed by 26.4% in *zaid* and 9.3% in *rabi* season. The lowest CV was recorded in *kharif* (18.6%), which indicated consistent rainfall. The CVs of rainy days in *zaid* was 34.2%, and in *rabi*, 69.4%. Higher CVs implied that *rabi* season cultivation depends largely on residual soil moisture or assured irrigation due to uncertain rainfall events.

Table 1. Annual and monthly potential evapotranspiration, rainfall and temperature at Varanasi

Month	Potential evapotranspiration (mm)	Rainfall	Temperature		
			Mean	Mean max.	Mean min.
			(°C)		
January	63	14	16.3	23.2	9.3
February	89	24	19.1	26.4	11.8
March	150	9	25.4	33.4	17.3
April	188	6	30.7	38.6	22.7
May	229	17	34.1	41.4	26.7
June	186	119	33.6	39.0	28.2
July	127	236	29.9	33.6	26.2
August	114	293	29.1	32.4	25.8
September	119	256	28.9	32.7	25.0
October	121	33	26.6	32.5	20.7
November	81	8	21.0	28.6	13.3
December	60	4	17.0	24.3	9.6
Annual	1525	1018.9	26	32.2	19.7

Monthly rainfall and rainy day

Monthly rainfall distribution followed the bell shaped curve (Fig. 1). Rainfall was more during the period (June to September), 88.8% of annual rainfall. However, maximum rainfall of 293.3 mm was recorded in August and the minimum of 4.0 mm in December (Table 1). High rainfall in *kharif* season is favourable for high water requiring crops like paddy in this region. It also necessitates in harvesting excess water during this period and to recycle during off-season cultivation for better water management.

The relationship between rainfall and rainy days was similar for weekly, monthly and seasonal data. The correlation between monthly rainfall and rainy day is expressed by linear regression ($y = 23.78x - 11.07$, where 'y' is monthly rainfall and 'x' is number of rainy days) which can explain more than 95% of the variability ($R^2 = 0.984$). Similar findings were reported by Barman *et al.* (2011), Barman *et al.* (2012), Singh (2012), Chakraborty and Mandal (2008), and Dabral (1996).

Weekly rainfall

Weekly rainfall, evaporation and mean temperature are depicted in Fig. 2, to identify

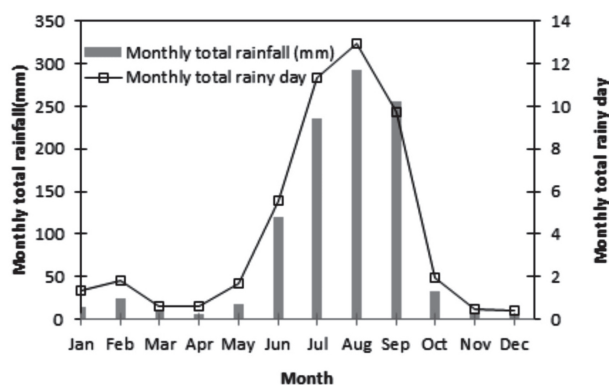


Fig. 1. Monthly distribution of rainfall and rainy days at Varanasi

water balance for selected crops and their water management practices. Average weekly rainfall was maximum (80.7 mm) in 29th week followed by 78.0 mm (35th week) and then 76.0 (33rd week). From Fig. 2, it was clear that SMW numbers 23rd to 42rd correspond to monsoon weeks. During this period, total rainfall was 932.3 mm, which was higher than the evaporative demand of 628.2 mm. Therefore, a surplus rain water of 304.1 mm was available and could be managed within the soil profile or harvesting on the surface for its utilization during the rain-deficit period. Except monsoon period, rest of the time in a year water deficit was to the magnitude of 790.2 mm.

Table 2. Annual and seasonal variability of rainfall (mm) and rainy days (number) at Varanasi

Year	<i>Zaid</i>		<i>Kharif</i>		<i>Rabi</i>		Annual	
	Rainfall	Rainy day	Rainfall	Rainy day	Rainfall	Rainy day	Rainfall	Rainy day
1991	93.9	7	819.6	29	61.0	7	974.5	43
1992	50.1	7	770.5	32	27.6	2	848.2	41
1993	352.7	12	592.8	30	29.3	3	974.8	45
1994	170.8	14	793.2	32	81.9	7	1045.9	53
1995	44.5	7	1138.8	35	89.6	12	1272.9	54
1996	318.0	15	789.0	33	104.9	5	1211.9	53
1997	307.6	18	822.2	38	72.3	5	1202.1	61
1998	329.6	12	851.3	38	61.9	6	1242.8	56
1999	382.3	16	959.7	45	26.9	2	1368.9	63
2000	285.3	16	786.0	33	3.8	1	1075.1	50
2001	321.8	18	1029.7	33	6.7	1	1358.2	52
2002	249.1	14	650.8	29	78.8	8	978.7	51
2003	229.8	11	803.3	37	108.8	8	1141.9	56
2004	227.6	17	321.9	26	63.5	4	613.0	47
2005	260.4	9	502.3	25	115.7	7	878.4	41
2006	269.7	14	564.2	27	12.5	1	846.4	42
2007	242.6	11	534.7	23	132.5	8	909.8	42
2008	432.8	21	588.3	27	29.5	2	1050.6	50
2009	153.8	6	321.1	19	24.6	1	499.5	26
2010	106.9	7	541.2	31	23.2	4	671.3	42
2011	292.1	16	931.0	32	8.5	1	1231.6	49
Mean	243.9	12.8	719.6	31.1	55.4	4.5	1018.9	48.4
SD	106.6	4.4	215.5	5.8	39.8	3.1	238.7	8.3
CV(%)	43.7	34.2	29.9	18.6	71.9	69.4	23.4	17.0

Rainy day: >2.5 mm d⁻¹

Onset of effective monsoon

The knowledge of mean date of arrival of monsoon is very useful for planning timely *kharif* operations to take maximum advantage of

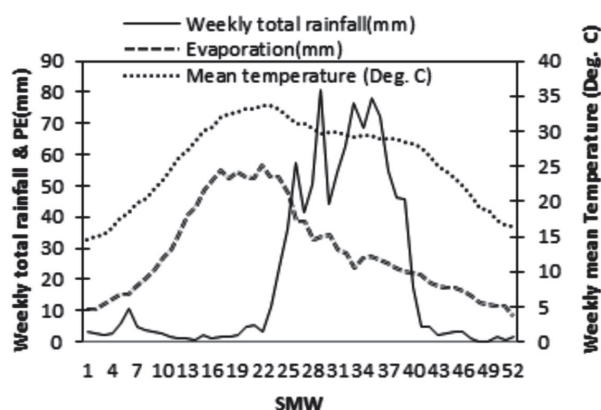


Fig. 2. Weekly distribution of rainfall, evaporation and mean temperature at Varanasi

monsoon rain. The probability analysis showed that the onset of monsoon on 25th SMW which is extended between 18th to 24th June at >95% probability level. During the year, India Meteorological Department, Pune predicted June 20 as the probable date of onset of monsoon at Varanasi, which is well-matched with our analysis.

Probability of rainfall and rainy days

The probability of annual and seasonal (*kharif*, *zaid* and *rabi*) rainfall occurrence could aid in optimizing the choice of crops, sowing date and irrigation scheduling. The probability of occurrence of rainfall at 82% confidence level was 846.4 mm per annum, 534.7 mm in *kharif*, 106.9 mm in *zaid* and 12.5 mm in *rabi* (Fig. 3). In *zaid*, rainfall also occurred during April and

May due to low pressure caused by local convectional heating and thunderstorm. The probability of occurrence of rainy days at 82% confidence level was 42 (yearly), 26 (*kharif*), 7 (*zaid*) and 1 (*rabi*) days (Fig. 4).

Water budget for rice

Lowland rice requires nearly 1000 mm water for its growth and development during its life cycle. In addition, 40 mm water is required for nursery raising for good seed germination and early seedling growth and 200 mm for land preparation (puddling) (Kung, 1971). However, during nursery and land preparation (22nd, 23th and 24th SMW), rainfall in this area was erratic and inconsistent during the study period (Fig. 5).

We calculated the average rainfall during 22nd to 27th week (May 28–July 8) at 173 mm in 21 years (Fig. 2). Therefore, the deficit of water during nursery and land preparation was 67 mm. This would increase through evaporation from the soil surface and deep percolation loss in soil profile depending upon numerous factors. Hence, it is always necessary for assured irrigation to rice nursery to supplement rain water for better germination and early seedling growth.

Rice cultivation and water management

Land preparation (puddling) of one hectare rice field requires nearly 200 mm of water (Kung, 1971). This water demand can be fulfilled by rainwater because rice land preparation and

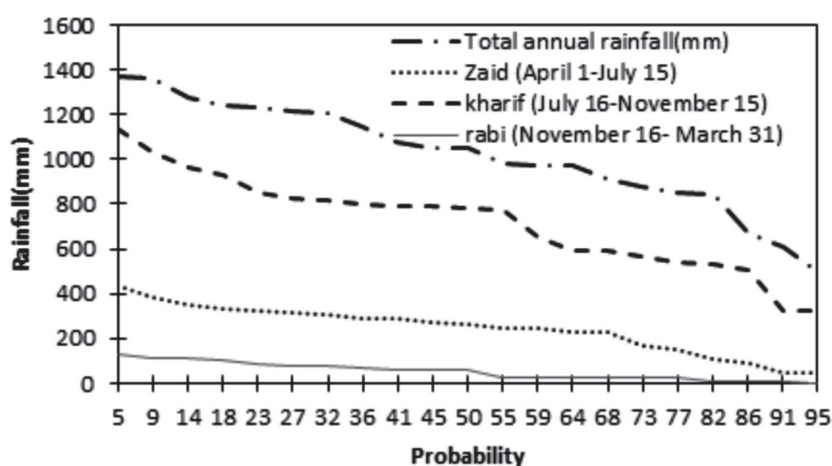


Fig. 3. Probability of occurrence of annual and seasonal rainfall at Varanasi

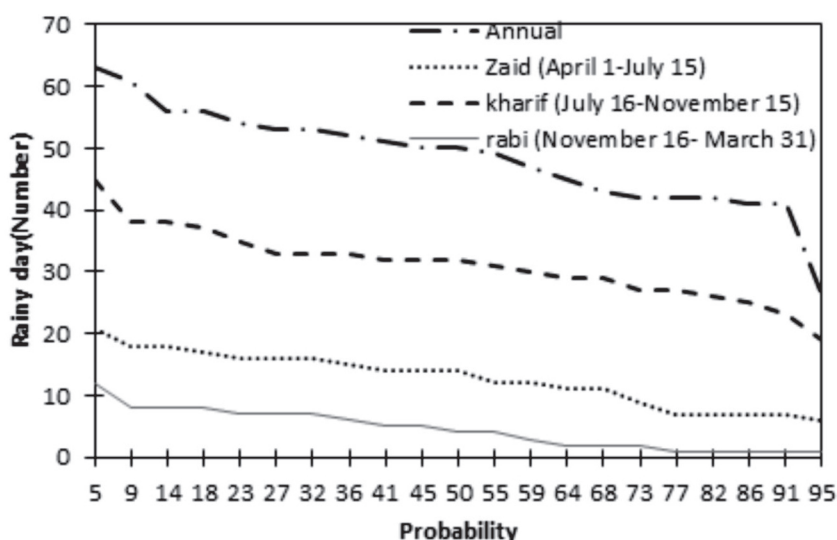


Fig. 4. Probability of occurrence of annual and seasonal rainy days at Varanasi

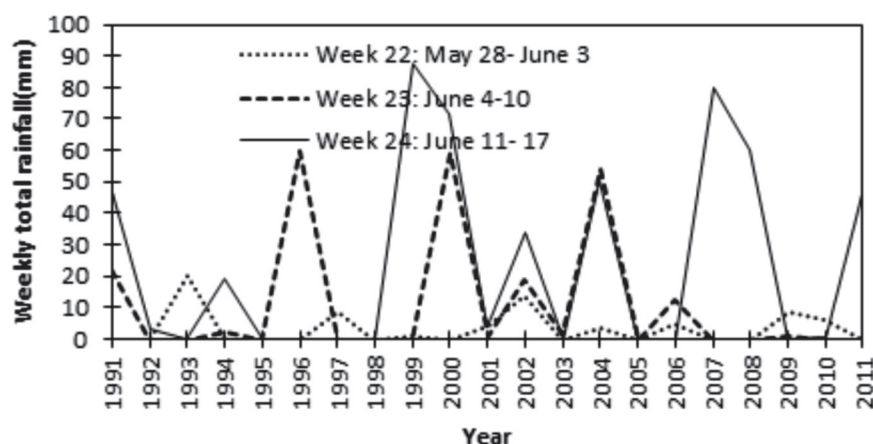


Fig. 5. Weekly rainfall distribution at sowing of rice in nursery during 1991 - 2011 at Varanasi

transplanting time is well coincided with the early period of monsoon in the Varanasi region. *In-situ* rain water harvesting for puddling and transplanting of rice may be started on 23rd week and extended till 29th week during which possibility of rainwater harvesting could be 301 mm, without considering the evaporation and percolation loss (Fig. 2). Therefore, for one hectare land, 3010 cu m of water can be harvested. If loss of rainwater through potential evaporation of 2970 cu m from one hectare land is considered in addition to the percolation loss in sandy loam soil in this region, sufficient amount of water can still be required for puddling and transplanting of rice through assured irrigation. Water harvesting is possibly the best choice. A pond with the capacity of 316 cu m water harvesting should have 26 m length, 13 m width (at surface) and 13 m length and 6.5 m width (at bottom), and 1.5 m depth.

Conclusions

The knowledge of probable time of arrival of monsoon, which is 25th week (June 18-24) for Varanasi region, will be helpful for planning *kharif* crops to take maximum advantage of monsoon rain. Probability of 534.7 mm rainfall (at 82% confidence level) in *kharif* indicated cultivation of high water demanding crops like paddy in this season. In *kharif*, rainfall is adequate for rice cultivation; however, irrigation is required for *rabi* and *zaid* crops, particularly for land preparation and sowing of the crop. Similarly,

the probability of 106.9 mm rainfall during *zaid* season at 82% confidence level depicted the requirement of suitable water harvesting structure for growing short duration pulse crops like green and black gram, and coarse cereal like maize. This prediction helps to optimize choice of crops and irrigation scheduling for different crops cultivated in this region.

Acknowledgements

The authors wish to acknowledge technical assistance rendered by Ms. Anila Harshit Bhengra in compilation of data.

References

- Barman, D., Jakhar, P., Gowda, H.C. and Naik, B.S. 2011. Probability analysis of rainfall characteristics of Semiliguda in Koraput, Orissa. *Indian J. Soil Conserv.* **39**: 9-13.
- Barman, D., Saha, A.R., Kundu, D.K. and Mahapatra, B.S. 2012. Rainfall characteristics analysis for Jute based cropping system at Barrackpore, West Bengal, India. *J. Agril. Phys.* **12**: 23-28.
- Chakraborty, P.B. and Mandal, A.P.N. 2008. Rainfall characteristics of Sagar island in Sunderban, West Bengal. *Indian J. Soil Conserv.* **36**: 125-128.
- Chow, V.T. 1964. *Handbook of Applied Hydrology*, McGraw Hill Book Co., New York.
- Dabral, P.P. 1996. Meteorological drought analysis based on rainfall. *Indian J. Soil Conserv.* **24**: 37-40.

- Kumar, D. and Kumar, S. 1989. Rainfall distribution pattern using frequency analysis. *J. Agril. Eng.* **26**: 33-38.
- Kung 1971. *Irrigation Agronomy in Monsoon Asia*. FAO, Rome, Italy.
- Ram S., Kumar, D., Prashad, R. and Rai, R.K. 1992. A note on analysis of rainfall for crop planning at Pusa, Bihar. *Indian J. Soil Conserv.* **20**: 23-27.
- Sahoo, M.K. 1993. Analysis of drought phenomenon of pre-divided Kalahandi district of Orissa. *M. Tech. Thesis*, Dept. of Soil and Water Conserv. Engg., Orissa Univ. of Agri. and Tech., Bhubaneswar.
- Sharda, V.N. and Bhushan, L.S. 1985. Probability analysis of annual maximum daily rainfall for Agra. *Indian J. Soil Cons.* **13**: 16-20.
- Sharma, H.C., Chauhan, H.S. and Sewa Ram 1979. Probability analysis of rainfall for crop planning. *J. Agric. Eng.* **XVI**: 87-94.
- Singh, J. and Dhillon, S.S. 1994. Physical determinants of agricultural patterns: In: *Agricultural Geography* (2nd edn.). Tata McGraw Hill Publication Co. New Delhi, pp. 60-72.
- Singh, R.S. 2012. Rainfall record and climatic water balance over BHU, Varanasi in the Eastern Uttar Pradesh region. AMFU, BHU, Varanasi pp. 55.
- Verma, H.N. and Sharma, P.B.S. 1989. Critical dry spells and supplemental irrigation to rainfed crops. *J. Indian Soc. Water Resour.* **9**:12-16.

Received: 25 October 2013; Accepted: 17 December 2013