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Rainfall Variability Analysis of Udham Singh Nagar District, Uttarakhand

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Abstract- In this study, the variation in rainfall pattern and its distribution at Udham Singh Nagar district of Uttarakhand was analyzed on the basis of long-term rainfall dataset of 53 years (1961-2013) recorded at the Govind Ballabh Pant University of Agriculture & Technology, Pantnagar. The analysis revealed high magnitude of rainfall dissimilarity as it varied in between 3.89-430.33 mm and 775.70-3218.60 mm on monthly and annual basis respectively. The analysis stressed out need to construct water harvesting bodies to utilize stored rainwater for growing crops during water stressed periods in the Udham Singh Nagar district of Uttarakhand.

Index Terms- Rainfall; departure; statistical.

1. INTRODUCTION

Water is becoming a scarce resource as a result of growing demand for its various uses e.g. hydropower, irrigation, water supply etc. It is the most limiting natural resource which can hinder economic development of any country and its availability at correct time in adequate quantity is one of the important factors which influence crop yields. The marginal and small farmers constituting 80% of agricultural income group still depend on rainfed farming. Throughout much of the world, irrigation is supplemental to rainfall which is the important factor to support life and produce food. Due to increasing population and developmental changes, over-exploitation of natural resources resulting in degraded land, reduced water availability and changed climatic conditions.

The non-availability of certain amount of rainfall, a continuous random variable at critical period can influence failure of various agricultural related issues. The determination of rainfall amount and its behaviour over time and space has many practical applications in engineering and agriculture. In designing and operation of irrigation systems, it is becoming increasingly important to account the contribution made by natural rainfall in crop production as it can contribute significantly to crop water requirements. The early or delay in onset monsoon and withdrawal of monsoon, breaks in monsoon period and unusual heavy rainfall may disturb normal crop growth and its development.

To utilize available rainfall effectively, crop planning and management practices must be followed based on amount and distribution of rainfall at a place. The production of agricultural crops can be significantly increased with proper management of rainwater and timely application of optimum irrigation water. In our country, rainfall distribution is very erratic in nature and varies from region to region and year to year though adequate rainfall is received through four different types of weather phenomenon namely, south-west monsoon (about 74%), north-east monsoon (about 3%), pre-monsoon (about 13%) and post-monsoon (about 10%) with an average annual rainfall as 119 cm. In Indian conditions, existing uncertainty in availability of water throughout the year can be effectively balanced by creating water storage reservoirs. A number of research workers have analyzed rainfall behaviour for various purposes. The fluctuation in rainfall at different timescales was analysed by [1]-[13], whereas, on statistical basis, it has been evaluated by [14]-[18] with different mathematical formulae presented in [19].

2. MATERIALS AND METHODS

The long-term daily rainfall data of Udham Singh Nagar district of Uttarakhand for a period of 53 years (1961-2013) collected from the Meteorological observatory situated at Crop Research Centre of G.B. Pant University of Agriculture & Technology, Pantnagar was analyzed by using mathematical and statistical techniques. The mathematical procedure involved determination of mean value of rainfall on monthly, seasonal and annual basis to evaluate its departure in order to understand its pattern. The values of mean, median, mode, dispersion, standard deviation and coefficients of Dispersion, Variation, Skewness and Kurtosis were computed as a part of statistical analysis.

3. RESULTS AND DISCUSSIONS

Mathematical analysis: The most commonly used mathematical method to understand rainfall variability is to calculate its arithmetic mean. Being mean of a particular distribution is mostly affected by extreme

events; therefore, values of median and mode of rainfall were also calculated. The maximum rainfall was observed as 108.60 mm (year 1961), 160.20 mm (year 1984), 89.60 (year 2007), 83.20 mm (year 2002), 325.80 mm (year 2000), 665.60 mm (year 1973), 840.00 mm (year 1988), 1154.60 mm (year 2000), 767.60 mm (year 1999), 354.20 mm (year 1985), 29.20 mm (year 1989) and 94.00 mm (year 1991) for January, February, March, April, May, June, July, August, September, October, November and December respectively. The average monthly and seasonal rainfall data of study area is presented in Table 1. The values of mean monthly rainfall is being exhibited in Fig. 1, whereas, its variation for all the 12 months (January-December), three seasons (monsoon, winter and summer) and different years is presented in Figs. 2a-l, 2m-o and 2p respectively.

The maximum rainfall during monsoon, winter and summer seasons was recorded as 2232.80 mm, 230.40 and 905.00 mm in years 1999, 1961 and 2000 respectively, whereas, their respective minimum values were recorded as 398.20 mm (year 1979), 5.02 mm (year 2008) and 32.40 mm (year 2012). The maximum annual rainfall during study period was observed as 3218.60 mm in year 2000, whereas, its minimum value (775.70 mm) was recorded in year 1978 with annual average as 1499.62 mm. The departure from mean rainfall of study area on monthly, seasonal (monsoon, winter, summer) and annual basis is shown in Figs. 3a-l, 3m-o, and 3p respectively.

The information regarding different years receiving more or less than mean rainfall on monthly basis (Table 2) shows that during months of July and August, maximum number of years (23) received rains more than mean monthly rainfall followed by May and September (20), whereas, maximum numbers of years receiving less than mean monthly rainfall were observed during October (42) followed by November (41). From Table 2, it can be inferred that out of 53 years, 34, 30, 30 and 33 years received less than mean monthly rainfall during the months of June, July, August and September respectively.

The average annual rainfall of Udham Singh Nagar district during study period (1961-2013) was obtained as 1499.62 mm. The graph (Fig. 2m) shows downside departure from average annual rainfall during years 1962, 1963, 1965, 1966, 1967, 1969, 1970, 1972, 1974, 1975, 1977, 1978, 1979, 1980, 1981, 1987, 1989, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 2004, 2006, 2009 and 2012 shows requirement of groundwater extraction for various uses. The trend of annual departure reveals that years showing annual departure more than long-term mean annual rainfall were 1961, 1964, 1968, 1971, 1973, 1976, 1982, 1983, 1984, 1985, 1986, 1988, 1990, 1998, 1999, 2000, 2001, 2002, 2003, 2005, 2007, 2008, 2010, 2011 and 2013. Hence, these years were found favourable for groundwater recharging.

Statistical analysis: The statistical method employed for analyzing rainfall data of study area includes determination of mean, median, mode, standard deviation, coefficients of Dispersion, Variation, Skewness and Kurtosis and pertinent results are presented in Table 3. The statistical analysis of annual rainfall data reveals that mean annual rainfall of area is 1454.72 mm, whereas, computed value of median (1442.86 mm) and mode (927.27 mm) indicates ideal rainfall. The calculated value of Standard Deviation reveals that deviation of rainfall is 426.60 mm over a period of 53 years. The coefficient of variation indicates that amount of rainfall varies up to 29.325 with coefficient of Skewness (1.2364) showing positive trend, whereas, coefficient of kurtosis (1.0236) confirms that annual distribution is relatively a peaked one.

4. CONCLUSIONS

The rainfall data analysis for a period of 53 years (1961-2013) reveals strong variation in amount and frequency of rainfall on both monthly and annual basis at Udham Singh Nagar district. The impact of rainfall variation on monthly, seasonal and annual basis in recharge phenomena of groundwater system in Udham Singh Nagar district of Uttarakhand is being presented in this paper.

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Table 1: Average observed monthly and seasonal rainfall (1961-2013).

Season(s)	Months	Mean monthly rainfall (mm)	Percent of mean annual rainfall (%)	Mean seasonal rainfall (mm)
Monsoon	July	430.33	28.70	288.79
	August	423.79	28.26	
	September	259.12	17.28	
	October	41.92	2.80	
Winter	November	3.89	0.26	20.00
	December	13.06	0.87	
	January	27.43	1.83	
	February	35.61	2.37	
Summer	March	17.18	1.15	66.11
	April	15.17	1.01	
	May	44.88	2.99	
	June	187.22	12.48	

Table 2: Years receiving excess and deficit rainfall in comparison to mean monthly rainfall (1961-2013).

Months	Years receiving rainfall	
	More than mean monthly rainfall	Less than mean monthly rainfall
January	1961, 1962, 1968, 1970, 1971, 1975, 1979, 1981, 1982, 1983, 1989, 1994, 1995, 1996, 1999, 2002, 2003, 2005, 2013	1963, 1964, 1965, 1966, 1967, 1969, 1972, 1973, 1974, 1976, 1977, 1978, 1980, 1984, 1985, 1986, 1987, 1988, 1990, 1991, 1992, 1993, 1997, 1998, 2000, 2001, 2004, 2006, 2007, 2008, 2009, 2010, 2011, 2012
February	1961, 1965, 1971, 1972, 1976, 1978, 1979, 1984, 1986, 1990, 1991, 1994, 1996, 2000, 2002, 2003, 2005, 2007, 2013	1962, 1963, 1964, 1966, 1967, 1968, 1969, 1970, 1973, 1974, 1975, 1977, 1980, 1981, 1982, 1983, 1985, 1987, 1988, 1989, 1992, 1993, 1995, 1997, 1998, 1999, 2001, 2004, 2006, 2008, 2009, 2010, 2011, 2012
March	1962, 1968, 1971, 1975, 1978, 1979, 1980, 1981, 1982, 1983, 1988, 1990, 1991, 1993, 1998, 2000, 2003, 2005, 2007	1961, 1963, 1964, 1965, 1966, 1967, 1969, 1970, 1972, 1973, 1974, 1976, 1977, 1984, 1985, 1986, 1987, 1989, 1992, 1994, 1995, 1996, 1997, 1999, 2001, 2002, 2004, 2006, 2008, 2009, 2010, 2011, 2012, 2013
April	1965, 1969, 1971, 1977, 1982, 1983, 1986, 1988, 1994, 1997, 1998, 2002, 2003, 2004, 2007, 2008, 2009	1961, 1962, 1963, 1964, 1966, 1967, 1968, 1970, 1972, 1973, 1974, 1975, 1976, 1978, 1979, 1980, 1981, 1984, 1985, 1987, 1989, 1990, 1991, 1992, 1993, 1995, 1996, 1999, 2000, 2001, 2005, 2006, 2010, 2011, 2012, 2013
May	1970, 1971, 1973, 1976, 1977, 1981, 1982, 1985, 1986, 1987, 1990, 1998, 1999, 2000, 2001, 2003, 2004, 2006, 2010, 2011	1961, 1962, 1963, 1964, 1965, 1966, 1967, 1968, 1969, 1972, 1974, 1975, 1978, 1979, 1980, 1983, 1984, 1988, 1989, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 2002, 2005, 2007, 2008, 2009, 2012, 2013
June	1962, 1966, 1973, 1975, 1976, 1979, 1980, 1982, 1984, 1989, 1999, 2000, 2001, 2002, 2003, 2007, 2008, 2011, 2013	1961, 1963, 1964, 1965, 1967, 1968, 1969, 1970, 1971, 1972, 1974, 1977, 1978, 1981, 1983, 1985, 1986, 1987, 1988, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2004, 2005, 2006, 2009, 2010, 2012
July	1961, 1964, 1968, 1969, 1971, 1973, 1976, 1977, 1980, 1981, 1982, 1984, 1985, 1986, 1988, 1990, 1999, 2003, 2005, 2007, 2008, 2010, 2011	1962, 1963, 1965, 1966, 1967, 1970, 1972, 1974, 1975, 1978, 1979, 1983, 1987, 1989, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2000, 2001, 2002, 2004, 2006, 2009, 2012, 2013
August	1961, 1963, 1967, 1971, 1973, 1976, 1982, 1983, 1985, 1995, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2007, 2008, 2010, 2011, 2013	1962, 1964, 1965, 1966, 1968, 1969, 1970, 1972, 1974, 1975, 1977, 1978, 1979, 1980, 1981, 1984, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1996, 1997, 2006, 2009, 2012
September	1964, 1968, 1969, 1971, 1972, 1975, 1978, 1983, 1985, 1986, 1987, 1990, 1999, 2000, 2002, 2003, 2005, 2008, 2010, 2011	1961, 1962, 1963, 1965, 1966, 1967, 1970, 1973, 1974, 1976, 1977, 1979, 1980, 1981, 1982, 1984, 1988, 1989, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2001, 2004, 2006, 2007, 2009, 2012, 2013
October	1961, 1965, 1968, 1971, 1973, 1985, 1997, 1998, 1999, 2009, 2013	1962, 1963, 1964, 1966, 1967, 1969, 1970, 1972, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2010, 2011, 2012
November	1963, 1971, 1972, 1979, 1981, 1989, 1991, 1992, 1997, 1998, 2001, 2009	1961, 1962, 1964, 1965, 1966, 1967, 1968, 1969, 1970, 1973, 1974, 1975, 1976, 1977, 1978, 1980, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1990, 1993, 1994, 1995, 1996, 1999, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2010, 2011, 2012, 2013
December	1961, 1964, 1967, 1974, 1977, 1980, 1981, 1982, 1984, 1985, 1986, 1990, 1991, 1997, 1999, 2003, 2010	1962, 1963, 1965, 1966, 1968, 1969, 1970, 1971, 1972, 1973, 1975, 1976, 1978, 1979, 1983, 1987, 1988, 1989, 1992, 1993, 1994, 1995, 1996, 1998, 2000, 2001, 2002, 2004, 2005, 2006, 2007, 2008, 2009, 2011, 2012, 2013

Table 3: Statistical parameters of rainfall on seasonal and annual basis (1961-2013).

Statistical parameters	Mathematical formulae	Computed values for			
		Seasons			Annual
		Monsoon	Winter	Summer	
Mean ($\bar{x}$, mm)	$\frac{1}{N}\sum_{i=1}^{N} f_i x_i$	1160.38	82.55	266.04	1454.72
Median (mm)	$l + \frac{N - 2C}{2f} \times h$	1108.33	72.37	239.13	1442.86
Mode (mm)	$l + \frac{f_m - f_1}{2f_m - f_1 - f_2} \times h$	730.00	54.17	210.00	927.27
Standard Deviation (mm)	$\sqrt{\frac{\sum fd^2}{\sum f} - \left(\frac{\sum fd}{\sum f}\right)^2} \times h$	433.65	56.13	185.25	426.60
Coefficient of Dispersion	$\frac{Standard\ Deviation}{Mean}$	0.3737	0.6799	0.6963	0.2933
Coefficient of Variation	$Coefficient\ of\ Dispersion \times 100$	37.3715	67.9976	69.6337	29.3252
Coefficient of Skewness	$\frac{Mean - Mode}{Standard\ Deviation}$	0.9925	0.5056	0.3025	1.2364
Coefficient of Kurtosis	$\left\{\frac{n(n+1)}{(n-1)(n-2)(n-3)}\sum\left(\frac{x_i - \bar{x}}{\sigma}\right)^4\right\}$	-0.0233	0.0424	3.7667	1.0236

$\bar{x}$ = mean; N = total frequency; C = cumulative frequency of group preceding the median group; l = lower limit of modal class; f_m = maximum frequency; f_1, f_2 = frequencies of classes preceding and following modal class; h = width of uniform class.

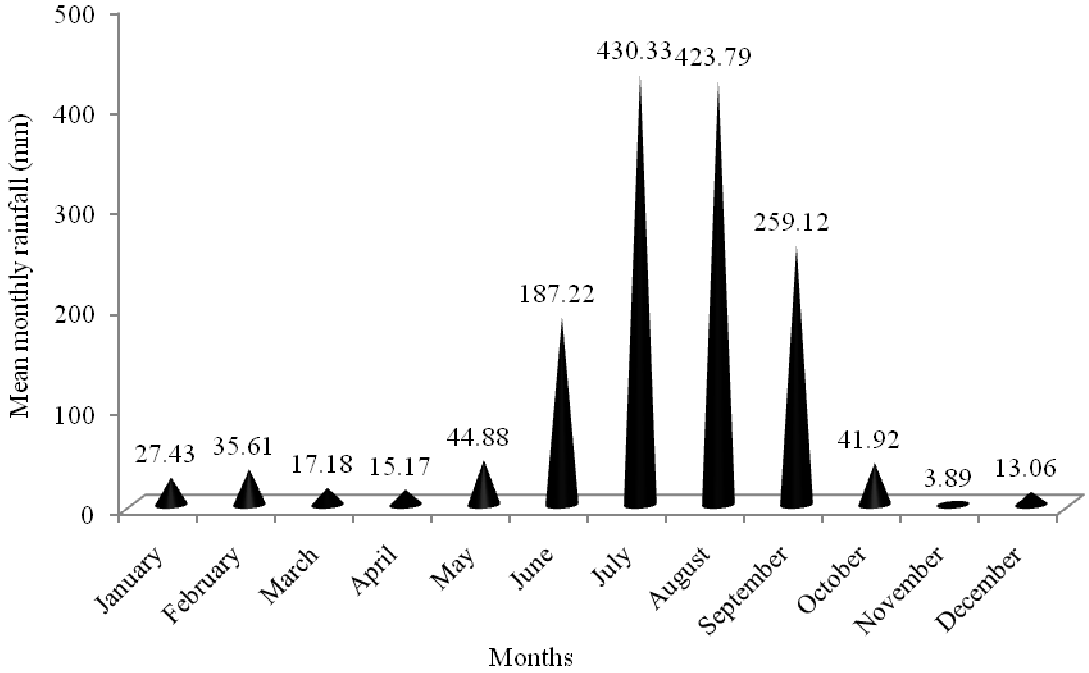

Fig. 1.Variation in mean monthly rainfall (1961-2013).

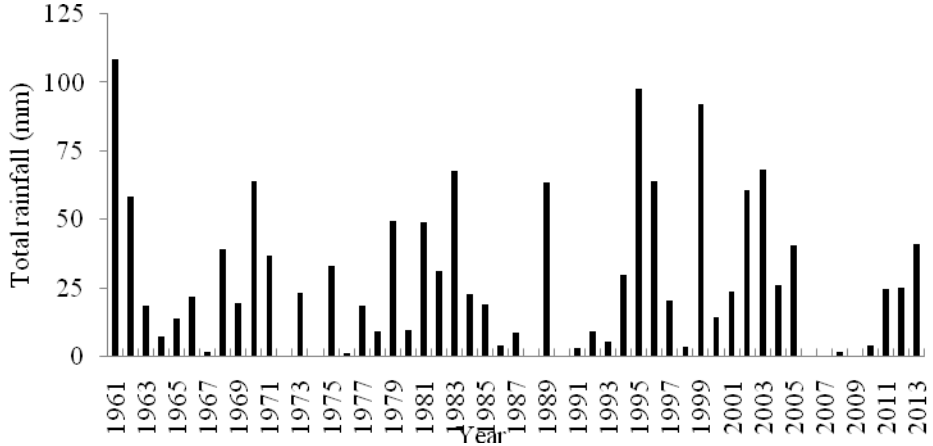

Fig. 2a.Rainfall variation during January (1961-2013).

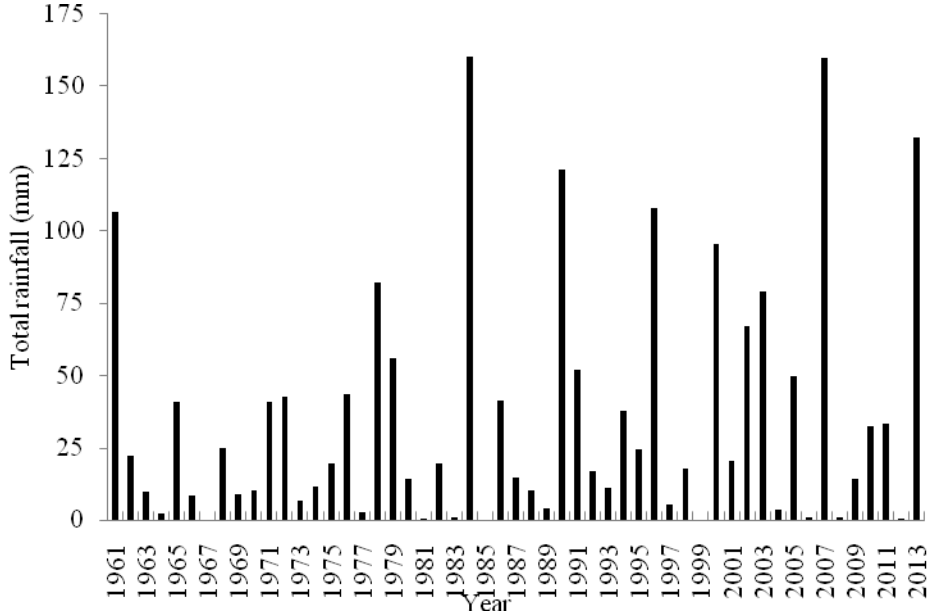

Fig. 2b.Rainfall variation during February (1961-2013).

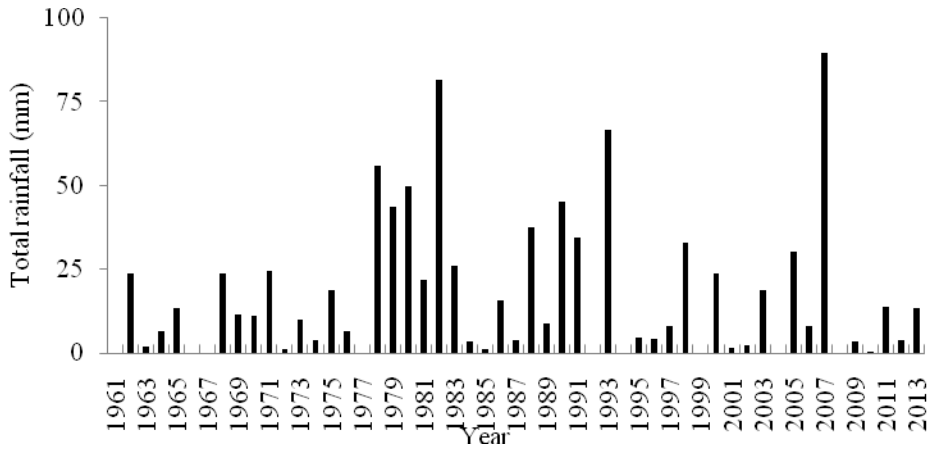

Fig. 2c.Rainfall variation during March (1961-2013).

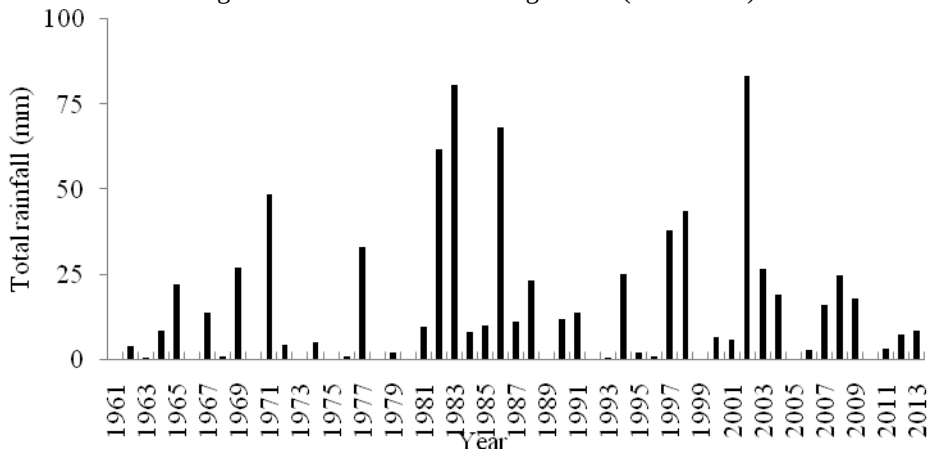

Fig. 2d.Rainfall variation during April (1961-2013).

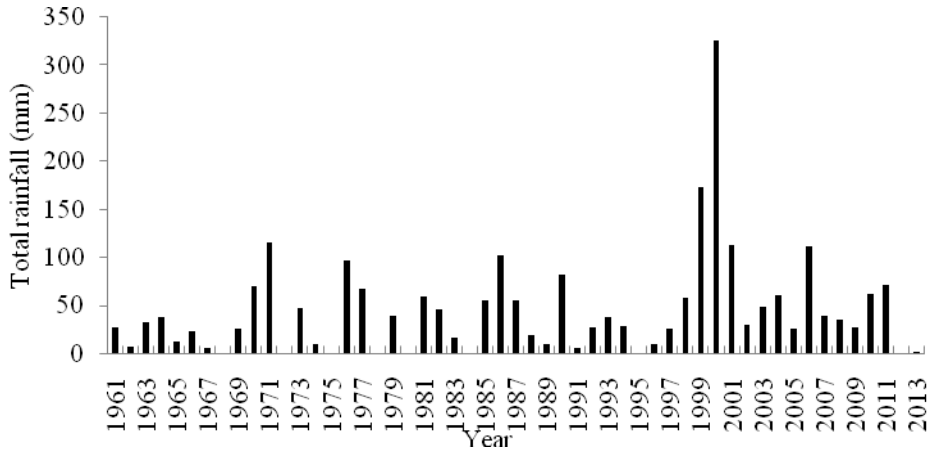

Fig. 2e.Rainfall variation during May (1961-2013).

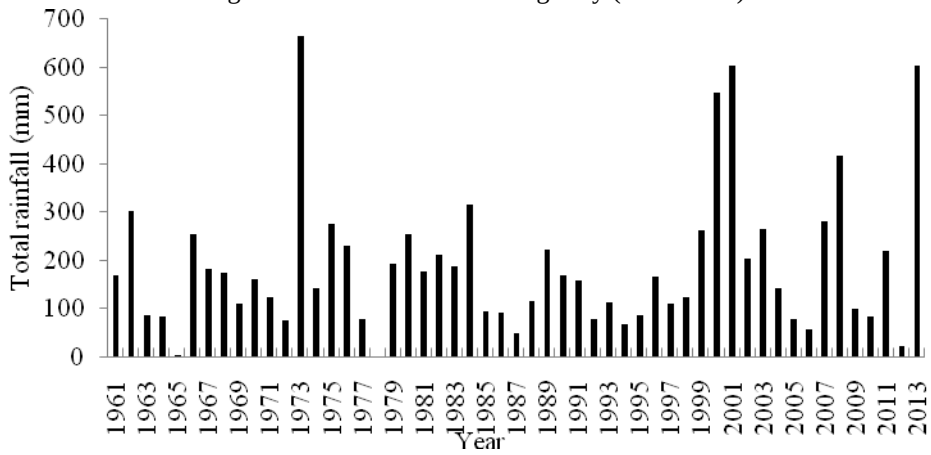

Fig. 2f.Rainfall variation during June (1961-2013).

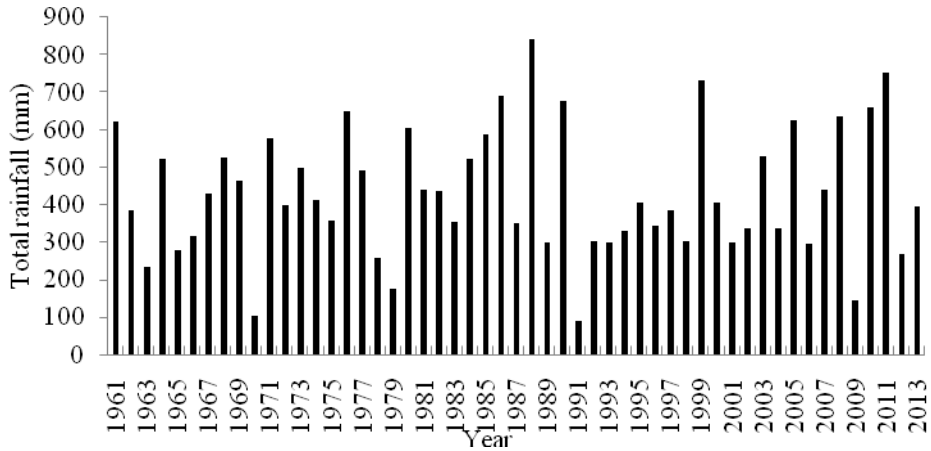

Fig. 2g.Rainfall variation during July (1961-2013).

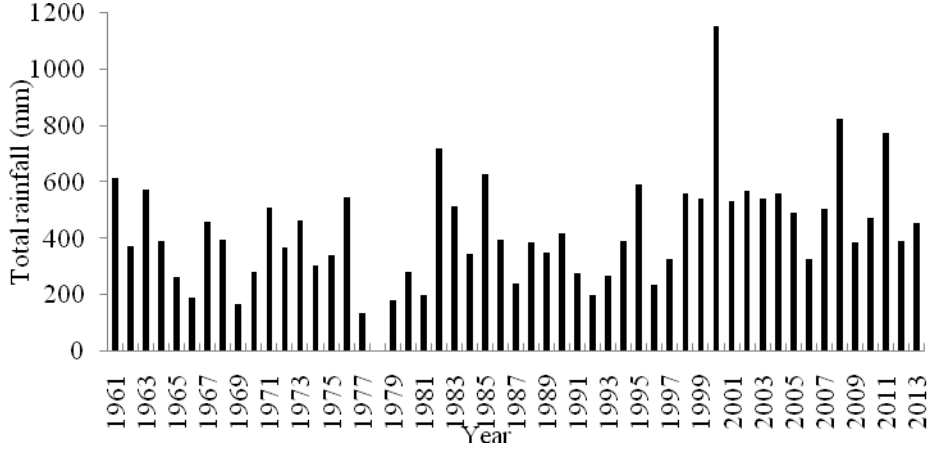

Fig. 2h.Rainfall variation during August (1961-2013).

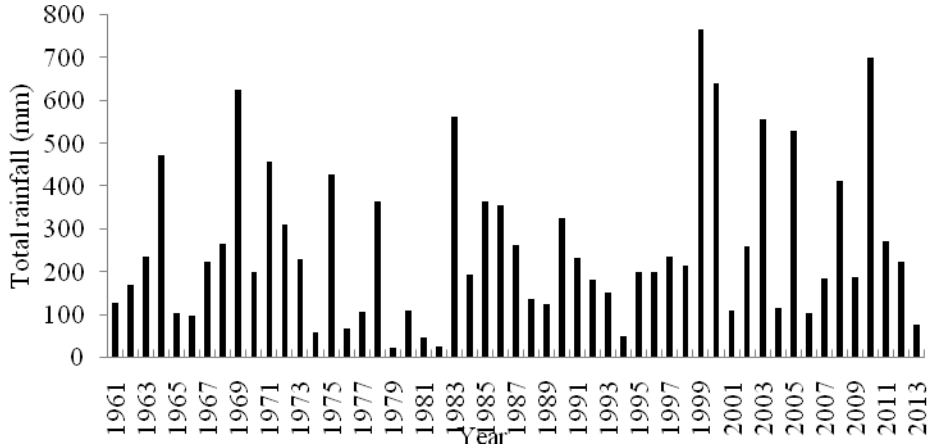

Fig. 2i.Rainfall variation during September (1961-2013).

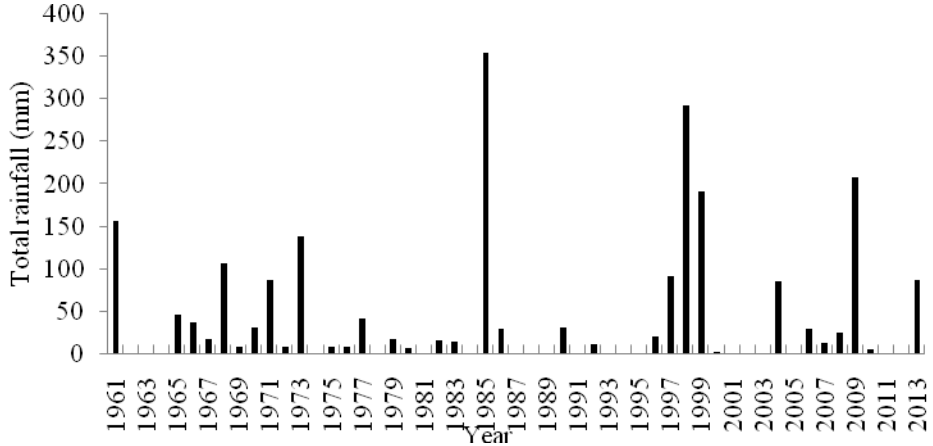

Fig. 2j.Rainfall variation during October (1961-2013).

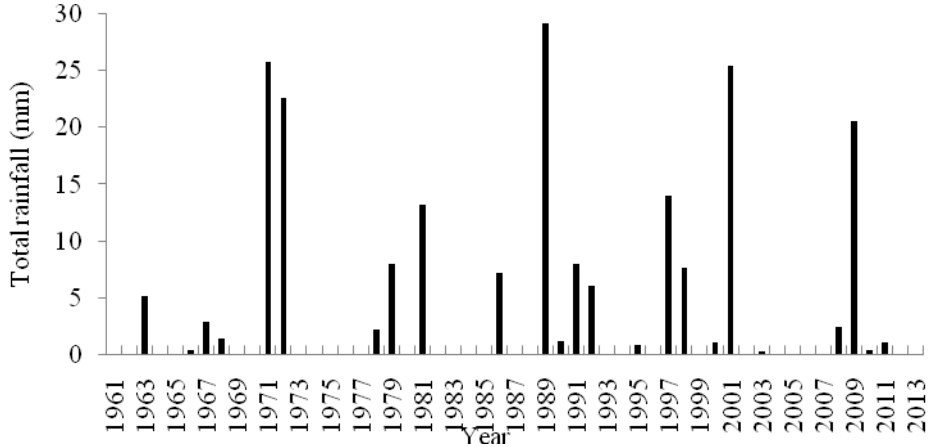

Fig. 2k.Rainfall variation during November (1961-2013).

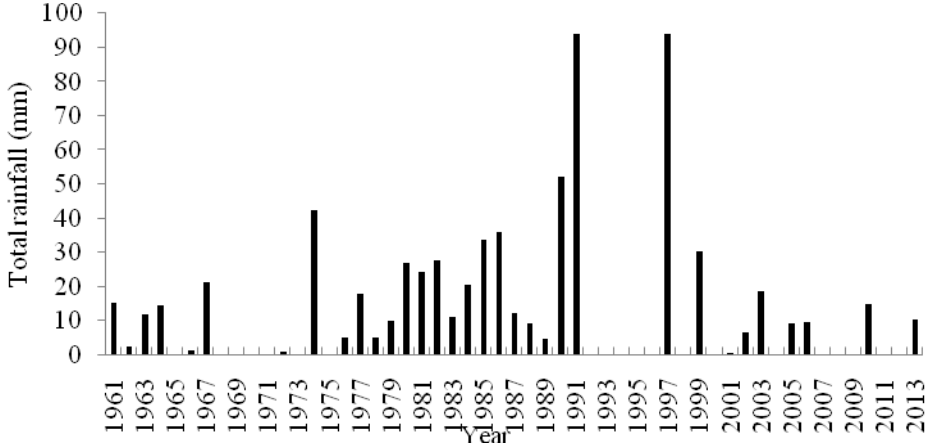

Fig. 2l.Rainfall variation during December (1961-2013).

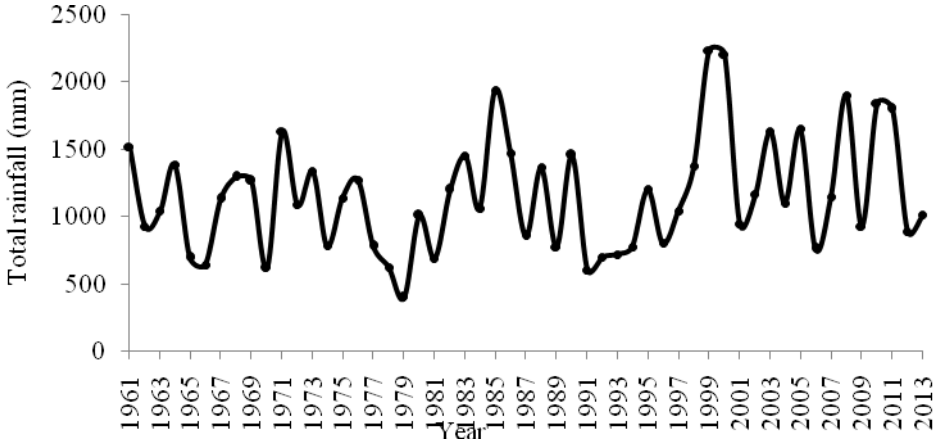

Fig. 2m.Rainfall variation during monsoon season (1961-2013).

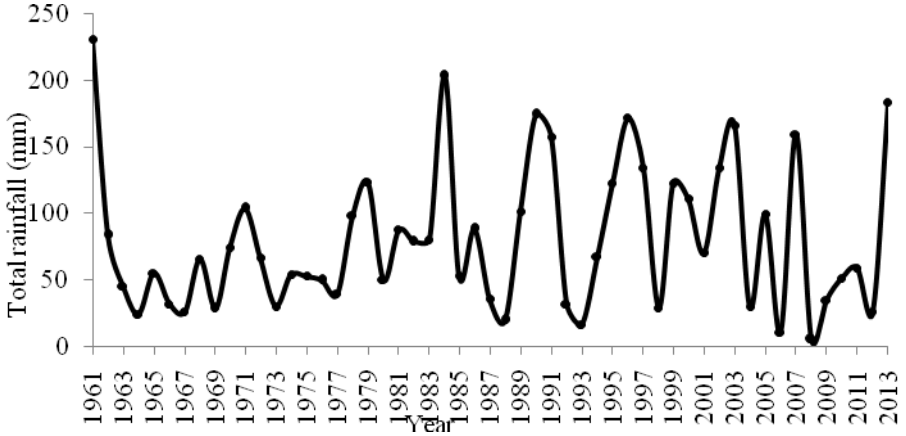

Fig. 2n.Rainfall variation during winter season (1961-2013).

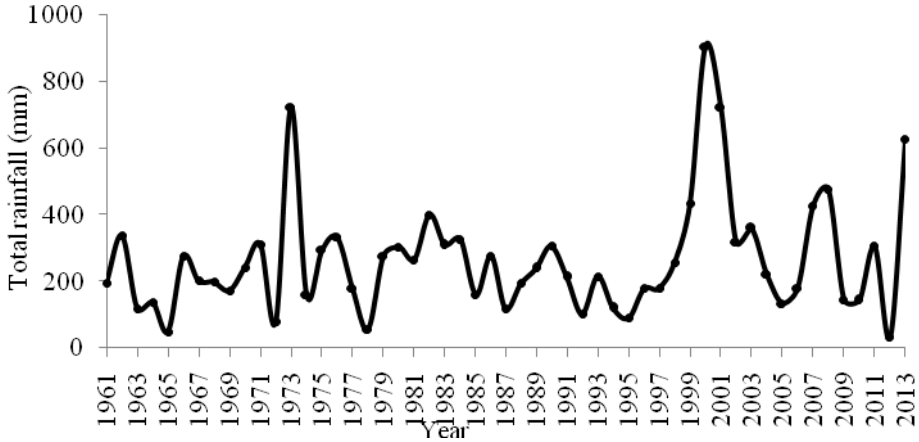

Fig. 2o.Rainfall variation during summer season (1961-2013).

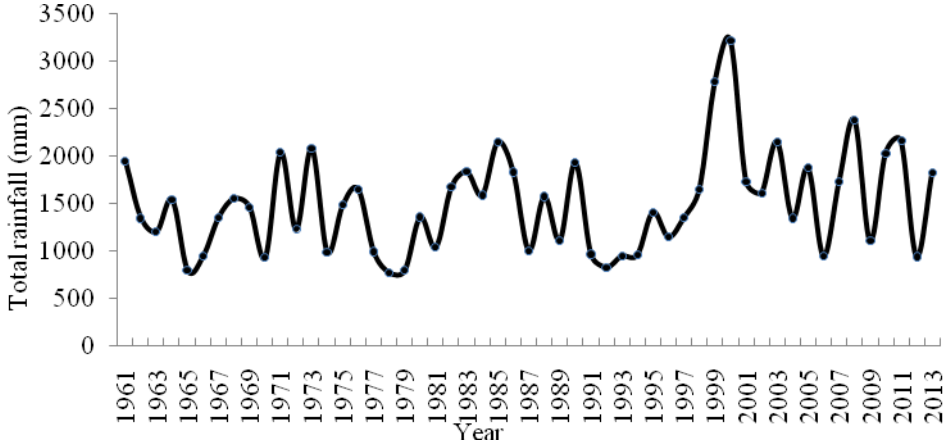

Fig. 2p.Variation in annual rainfall (1961-2013).

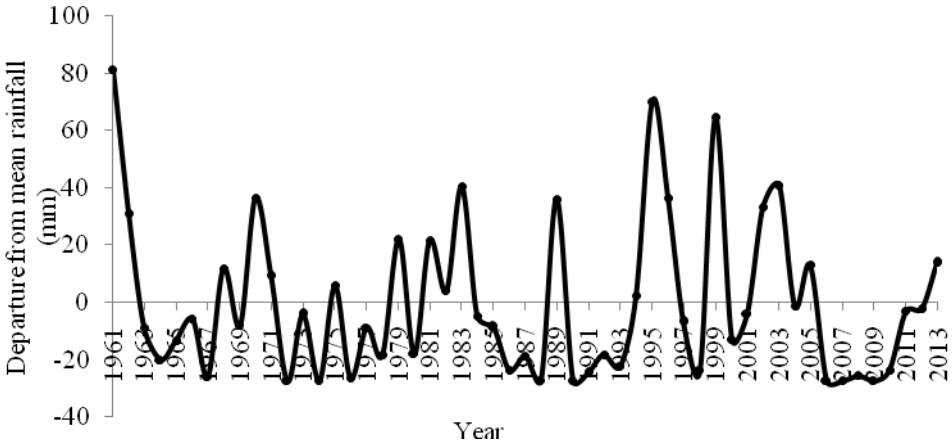

Fig. 3a.Departure from mean rainfall in January (1961-2013).

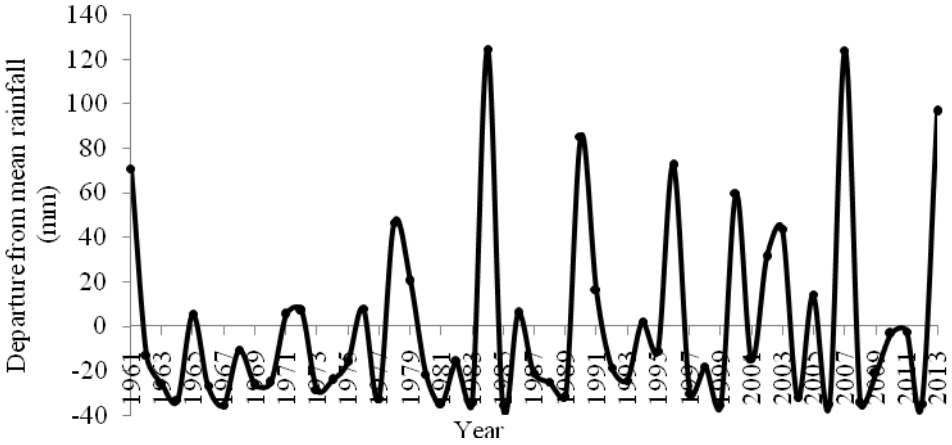

Fig. 3b.Departure from mean rainfall in February (1961-2013).

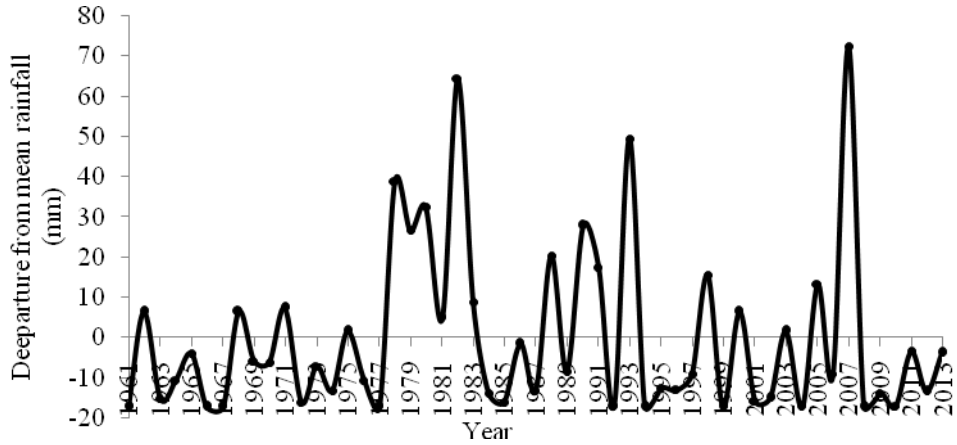

Fig. 3c.Departure from mean rainfall in March (1961-2013).

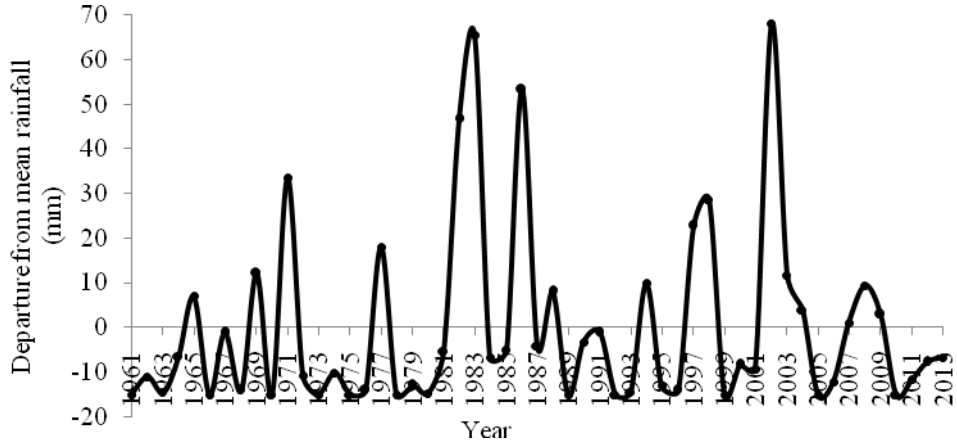

Fig. 3d.Departure from mean rainfall in April (1961-2013).

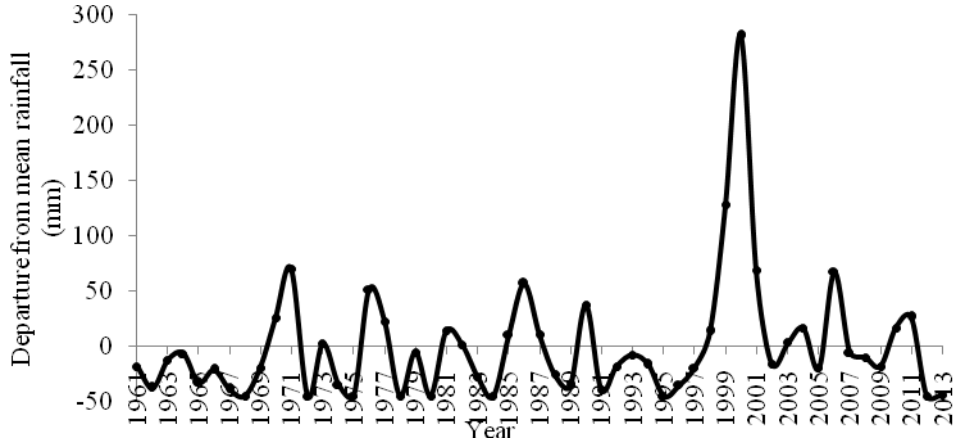

Fig. 3e.Departure from mean rainfall in May (1961-2013).

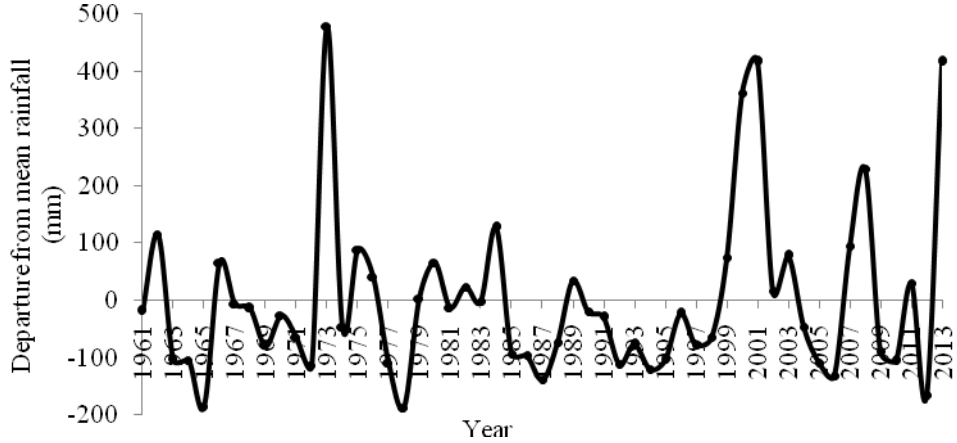

Fig. 3f.Departure from mean rainfall in June (1961-2013).

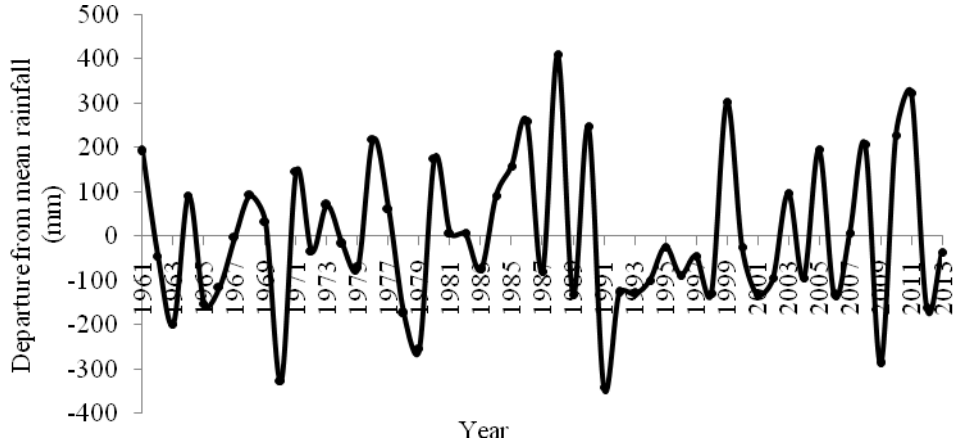

Fig. 3g.Departure from mean rainfall in July (1961-2013).

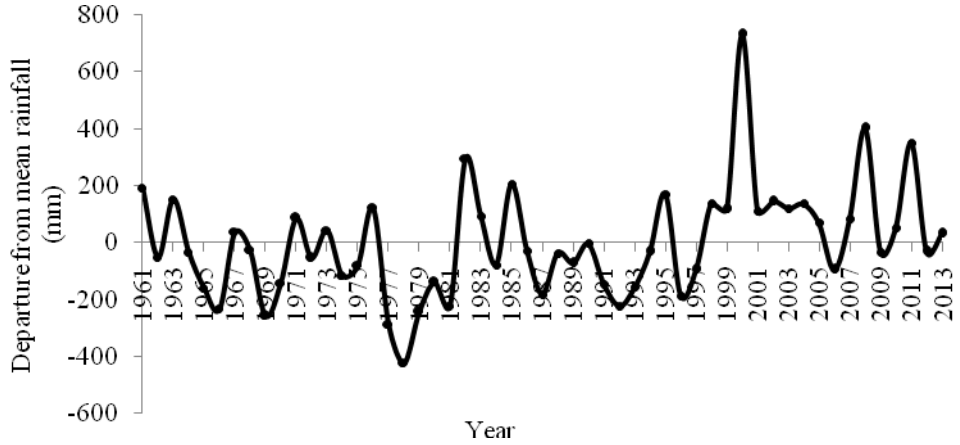

Fig. 3h.Departure from mean rainfall in August (1961-2013).

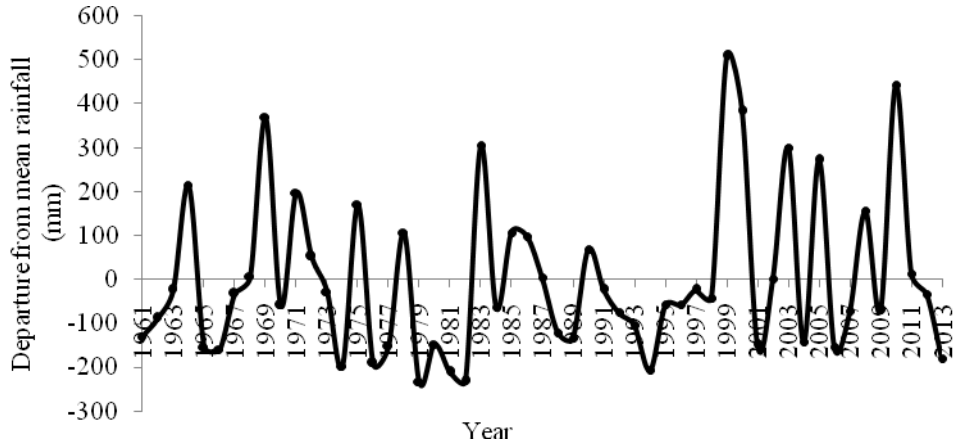

Fig. 3i.Departure from mean rainfall in September (1961-2013).

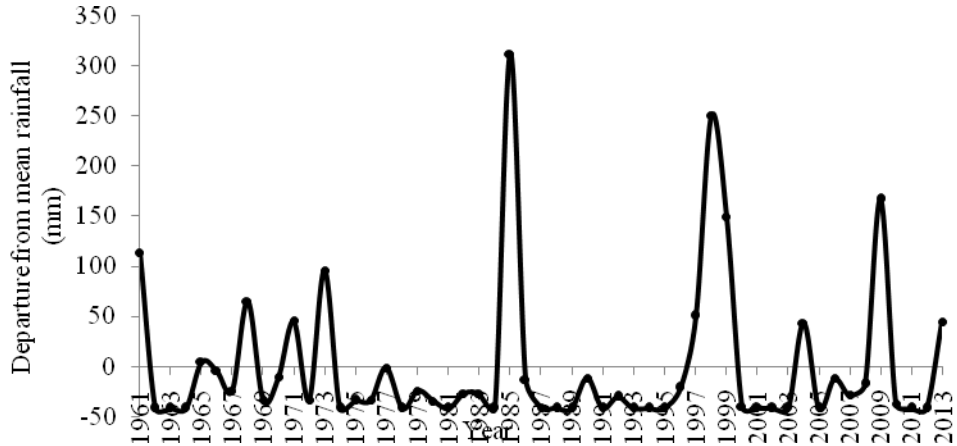

Fig. 3j.Departure from mean rainfall in October (1961-2013).

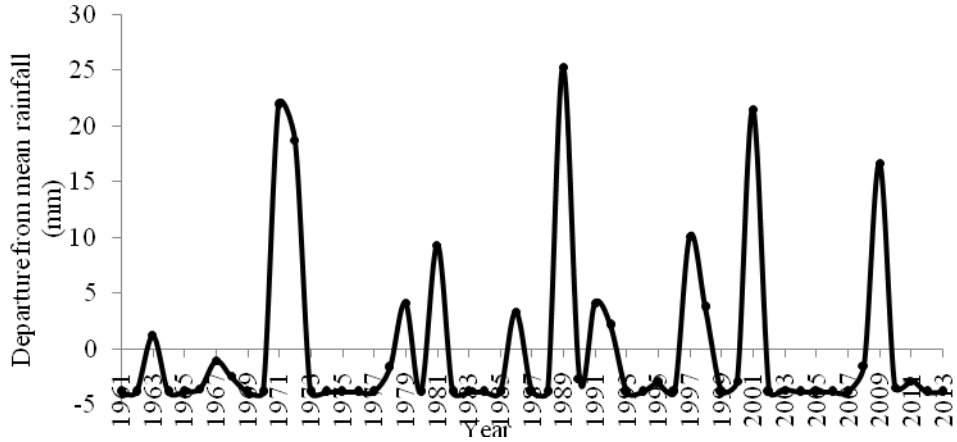

Fig. 3k.Departure from mean rainfall in November (1961-2013).

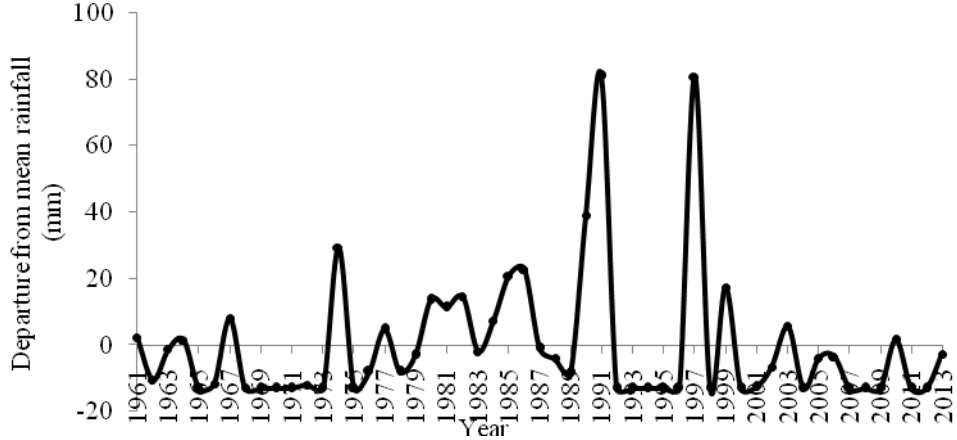

Fig. 3l.Departure from mean rainfall in December (1961-2013).

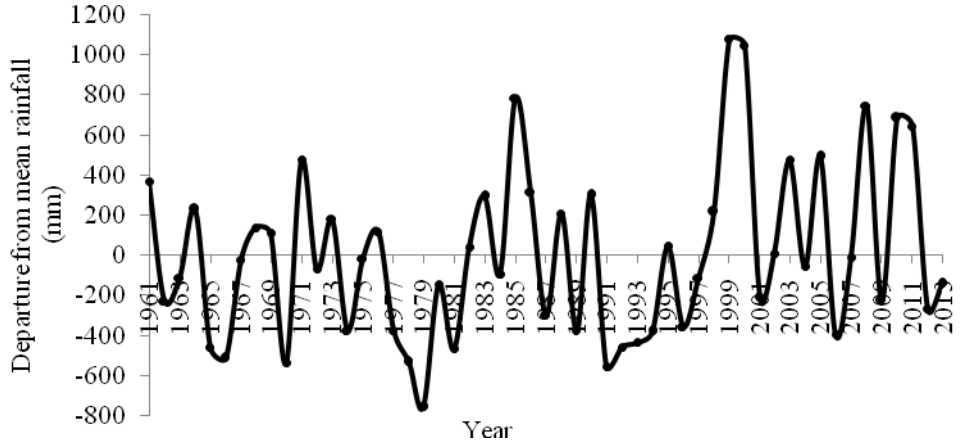

Fig. 3m.Departure from mean monsoon rainfall (1961-2013).

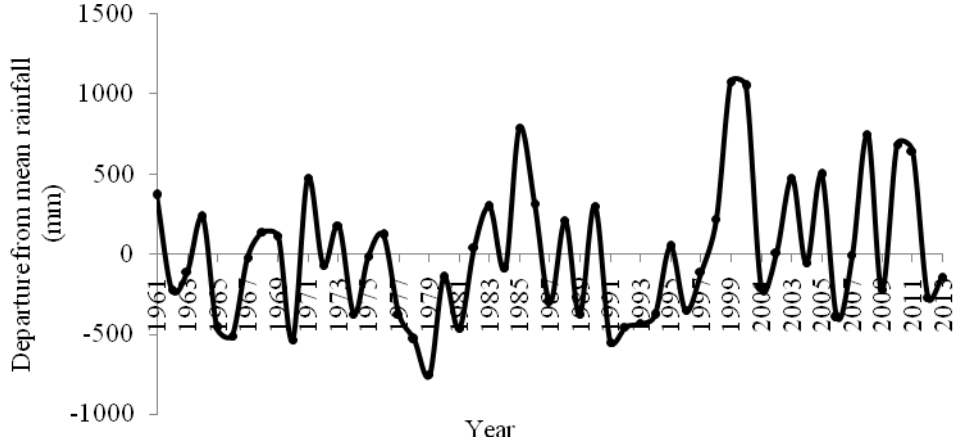

Fig. 3n.Departure from mean winter rainfall (1961-2013).

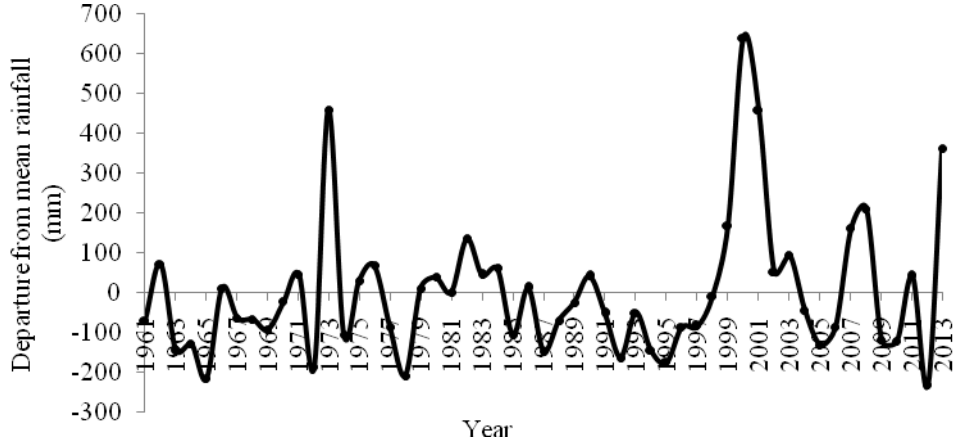

Fig. 3o.Departure from mean summer rainfall (1961-2013).

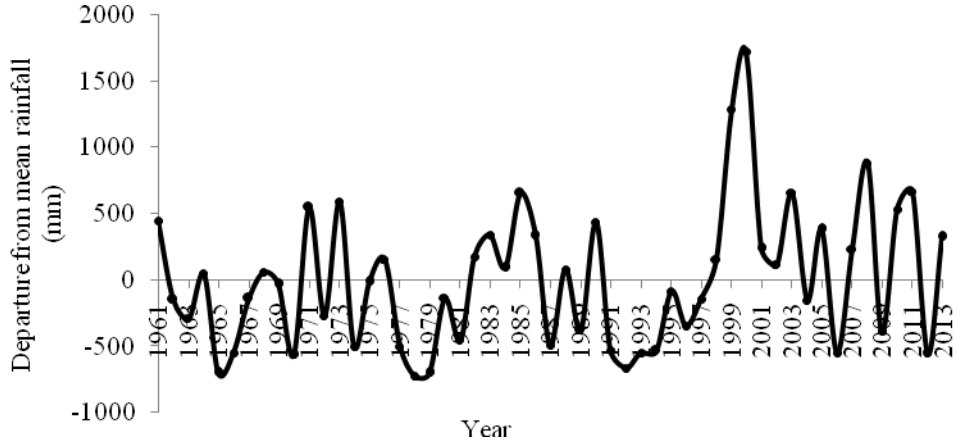

Fig. 3p.Departure from mean annual rainfall (1961-2013).