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Spatial Issues, Challenges and Approaches

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Observation and Analysis of Rainfall-Runoff Characteristics in a part of Semiarid Basaltic Catchment in Maharashtra

Dr. Namdev V. Telore[1]
[1*] Department of Geography, Raja Shripatrao Bhagawantrao Mahavidyalaya, Aundh, Dist. Satara

Dr. Maya G. Unde [2]
[2] Department of Geography, Ahmednagar College, Ahmednagar

Abstract

Hydrological studies deals with its relationship between water and its environment. As hydrology is mainly concerned with water close to the land surface, it focuses on those components of the hydrological cycle. Hydrological characteristics such as rainfall and runoff have high influence on watershed and environmental studies. The study area, northern part of the Yerla River basin, lies in the rain shadow zone of basaltic Deccan Traps region. The area receives -552.75 mm average annual rainfall and facing acute water scarcity. In the study area the early rains are scanty and the late rains are capricious, so drought occurs repetitively. In this article researchers are find out the relationship between rainfall and discharge of water in the study area. At the same time analysis of number of rainy days in the area also carried out.

Keywords: *Hydrological Characteristics, Rainfall - Runoff, Semiarid Region, Yerla River Basin, Deccan Traps*

Introduction

Hydrology, scientific discipline concerned with the waters of the Earth, including their occurrence, distribution and circulation via the hydrologic cycle and interactions with living things (Encyclopaedia Britannica, 2014). Hydrological studies deals with its relationship between water and its environment. As hydrology is mainly concerned with water close to the land surface, it focuses on those components of the hydrological cycle. Hydrological characteristics have high influence on watershed studies.

Subramanya (2000) and Mutreja (1995) have given details of Engineering and Applied Hydrology. Fu et al. (2012) were analysed Rainfall-Runoff Characteristics of Coastal Granite Catchment in Southern China. Sepaskhah and Moosavi-Fard (2010) determined rainfall-runoff relationship based on soil physical properties for use in micro catchment water harvesting system design. Gadgil (2002) studied rainfall characteristics of Maharashtra and stated that semi-arid part of the state faces repetitive drought condition. CGWB studied long-term rainfall data between 1901 and 1990 to compute rainfall statistics and demarcated drought-prone area of the Maharashtra State and found that the area experiences drought in every five years. Unde and Telore (2013) analysed critical drought prone Nidhal micro watershed of Khatav Tahsil and stated that watershed development programmes are essential for sustainable regional development. Shikalgar (2014) accessed and monitored droughts in the Yerla River basin and observed severe drought in the area in 2001, 2002 and 2012, using Modis Terra satellite data. Thigale (2013) stated that drought conditions occurred in this semi-arid zone after 4 years repetitively. GSDA (2009) observed that the northern part of the study area i.e. Khatav Tahsil is facing critical water scarcity problem and suggested a need of proper implementation of watershed management. Singh et al. (2003) and Simpson (2006) carried out rainfall analysis for understanding rainfall variations in different part of India. Economics and Political Weekly (EPW) (1988) observed that water scarcity in the Yerla River basin is occurred because of selling the massive scale sand from river bed without making any scientific study about the possible negative ecological effects. Pallavi and Deshmane (2013) critically analysed severe drought condition of Maharashtra in 2013 including Yerla River basin.

In the study area the early rains are scanty and the late rains are capricious, so drought occurs repetitively. Nature and distribution of rainfall and runoff is essential for watersheds management and allied studies. Therefore in this paper authors were find out the relationship between rainfall and discharge of water in the study area.

Study area

Administrative boundary of Satara and Sangli districts makes two parts of the Yerla River basin i.e. north and south. Northern part lies in Khatav Tahsil of Satara district (Fig. 1 and Table 1). Study area covers the the northern part of the Yerla River basin. The study area includes Vaduj and Khatav raingauge stations. This zone receives 552.75 mm average annual rainfall. On the basis of rainfall data it is found that the northern part of the semi arid basin receives less rainfall than the southern part. Rainfall increases towards the outlet of the Yerla River. The rainfall is shown in Fig. 2 and Table 2. Annual variability of rainfall of various raingauge stations are shown in Fig. 2 to 3 and monthly variability of these stations are given in Fig. 4 and 5. The Yerla River basin receives above

85 % orographic type of rainfall from south - west monsoon winds from June to mid October (rainy season). The study area lies in the 'rain shadow' zone of the Deccan Trap region. Temporal variations in rainfall are observed with wet and dry spells during the rainy season. Study area receives 552.72 mm average annual rainfall. September is the wettest month followed by June, October, July and August (Fig. 4 to 5). There are little or no rainfall occurred in the pre monsoon period from February to May and sporadic showers occurred during the post monsoon period from mid October to January.

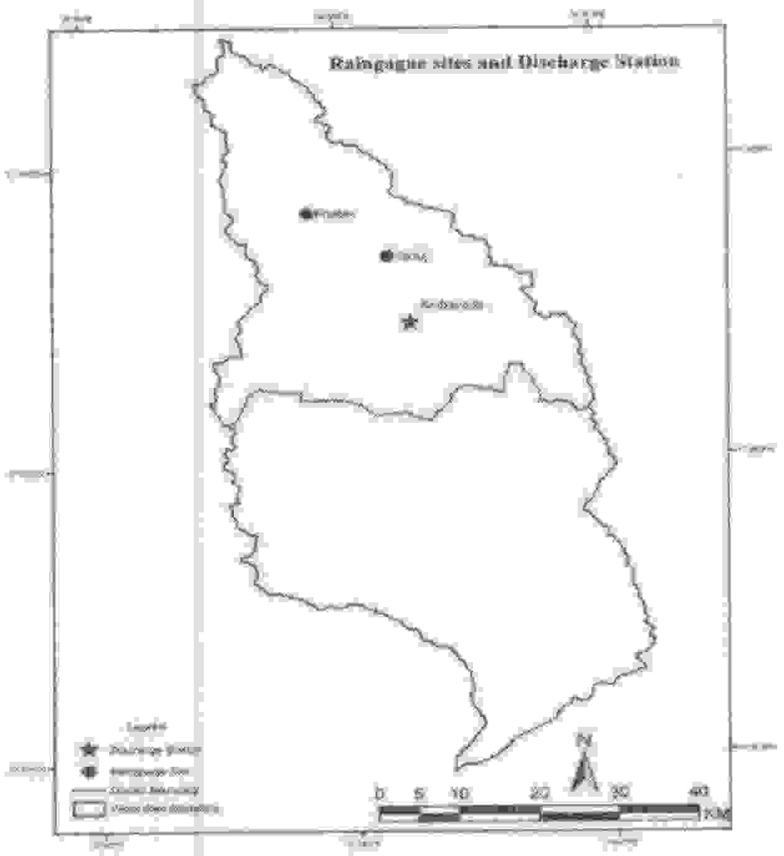


Fig. 1 Location of Raingauge Sites and Discharge Station

Rainfall Database

The monthly and annual rainfall and rainy days data during period 1980 to 2012 (33 years) obtained from India Meteorological Department, Pune were analysed on computer using MS Office Excel 2007 software. Two raingauge stations Vaduj and Khatav are located in northern part lies in study area. The description of raingauge stations and rainfall data used in study are shown in Table 1 and Fig. 1.

Table 1 Description of raingauge stations and rainfall data

Sr. No.	Station Name	Duration for which data is obtained
1	Vaduj	1980-1981, 1983-1985, 1987-1996, 1998, 2005-2012
2	Khatav	1997-2004

Rainfall Magnitude and Variability

Spatial Distribution

Spatial distribution of rainfall is observed in this rain shadow area from west to east and north to south. The Yerla River basin receives 592.48 mm average annual rainfall. The greatest fall was 1211.8 mm at Vita in 1981 and least 186.6 mm at Tasgaon in 2003 (Table 2). Average annual rainfall in the area ranges between 186.6 and 1211.80 mm. The maximum annual rainfall ranges from 951.5 mm at Khatav to 1211.8 mm at Vita and minimum annual rainfall ranges from 186.6 mm at Tasgaon to 306.9 mm at Vita. In the study area annual mean maximum and mean minimum rainfall is 1043.35 mm and 240.45 mm respectively. If individual stations are considered Vita records the highest average annual rainfall of 651.34 mm, followed by Tasgaon, 613.10 mm; Vaduj, 561.93 mm. Khatav receives lowest average annual rainfall of 543.51 mm (Table 2, Fig. 1).

Table 2 Rainfall statistics of the Yerla River basin (1980 - 2012)

Sr. No.	Station Name	Mean	Maxi-mum	Year	Mini-mum	Year	Standard Deviation	CV %	Skew-ness
1	Vaduj	561.93	1006.1	2009	275.4	2012	67.48	64.78	0.67
2	Khatav	543.51	951.5	2004	192.9	2003	53.55	60.49	0.13
	Average	552.72	978.8		234.15				

All Rainfall values in mm; CV % : Coefficient of Variation in %

Station Wise Rainfall Characteristics

1) Vaduj Station

Vaduj station receives 561.93 mm average annual rainfall for the period of 24 years from 1980 to 2012 (Fig. 2). Maximum annual rainfall of the station is 1006.1 mm in 2009 and minimum rainfall is 275.4 mm in 2012. During the record period of rainfall, 14 years rainfall is above average and 10 years it is below average. Distribution of rainfall at this station is multimodal. The gap between maximum peaks above average line is 3, 5, 2 and 4 years and minimum peak below average line is 2, 3, 1, 2, 6 and 3 years. Low rainfall peaks denote drought situations in the region. Table 2 and Fig. 2 shows that severe drought occurred in 2012. Rainfall data shows that repetitive drought situation occurred in this region.

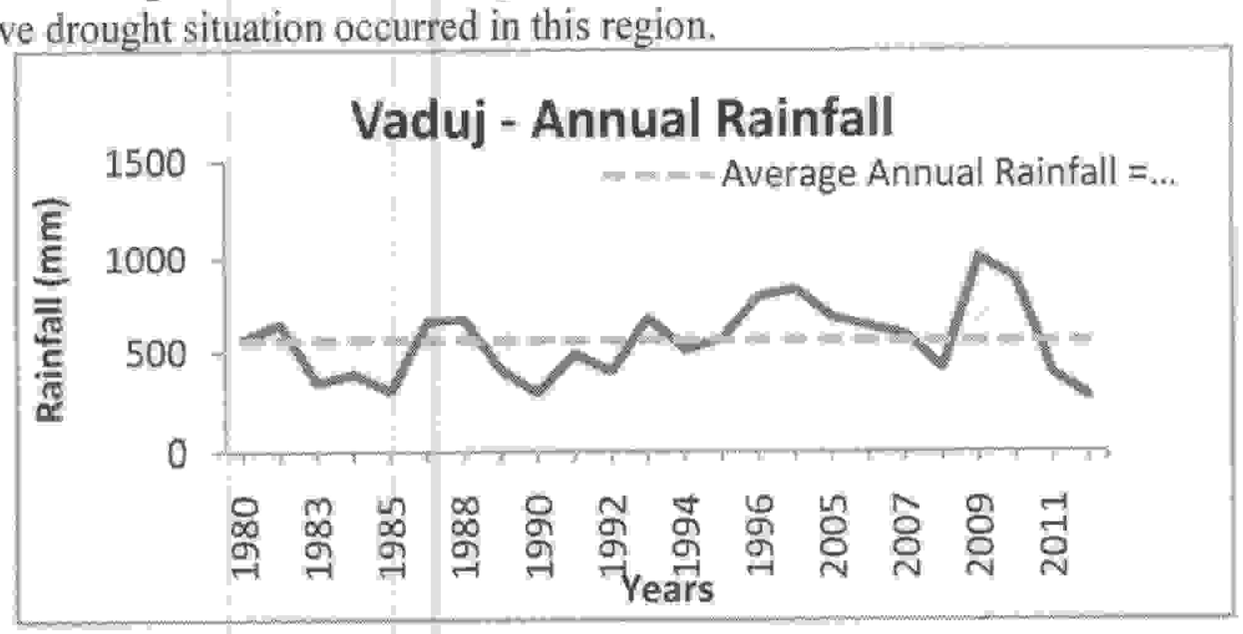


Fig. 2 Annual rainfall of Vaduj Station (1980-2012)

2) Khatav Station

The average annual rainfall of Khatav station is 543.51 mm for the period of 8 years from 1997 to 2004 (Fig. 3). Maximum annual rainfall of the station is 951.5 mm in 2004 and minimum rainfall is 192.9 mm in 2003. Out of 8 years, 3 years rainfall is above average and 5 years it is below average. Distribution of rainfall at this station is multimodal. The gap between maximum peaks is 2 and 2 years above average line and gap between minimum peaks is 2 and 3. Low rainfall causes to drought situation. In the year 2003 severe drought occurred in the Khatav station area (Fig. 3).

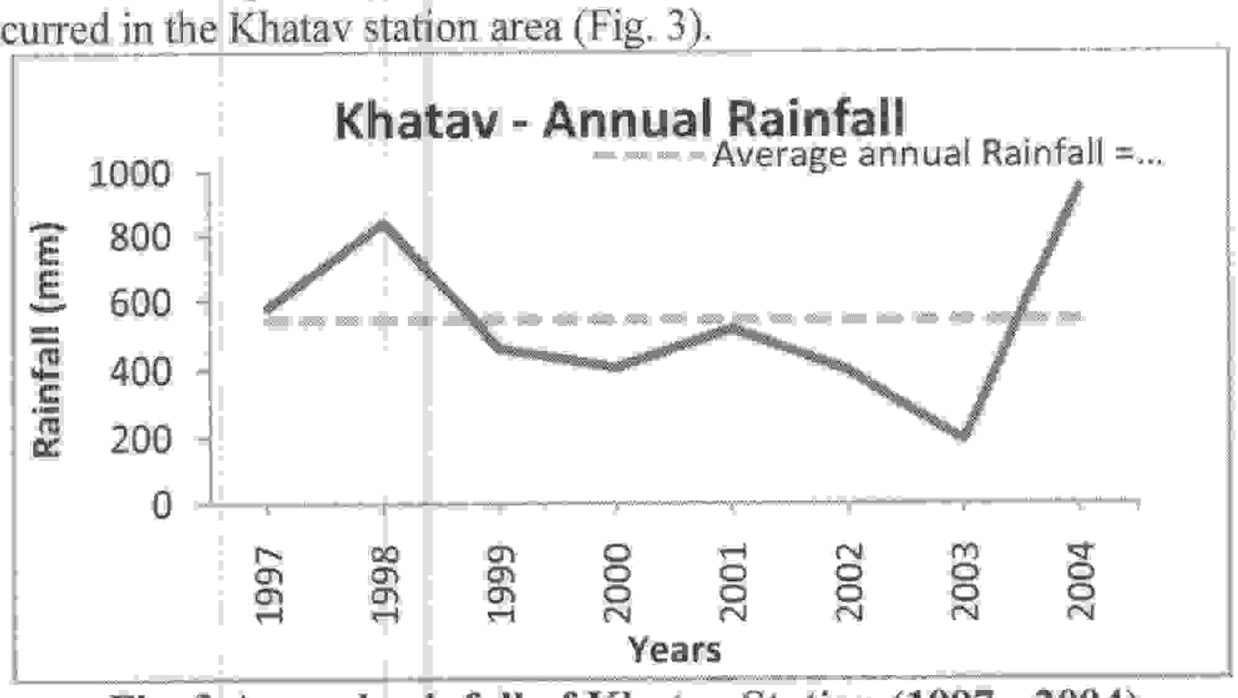


Fig. 3 Annual rainfall of Khatav Station (1997 - 2004)

Seasonal Variability

1) Vaduj

Analysis of monthly rainfall data shows that the mean rainfall of Vaduj station for the record period is 114.87 mm (Fig. 4). The seasonal mean rainfall of different years of record varies between 55.08 mm in 2012 and 148.20 mm in 1998 (Table 2). The coefficient of variation for the monsoon season for different years of record ranges between 110.68 % in 1993 and 11.6 % in 1980. The years having more than 100 % variation in rainfall are 1984, 1988 and 1993 indicating the operation of some extreme events in these years. Similarly, if we look at the direction of variation of rainfall in particular monsoon season on the study area the coefficient of skewness varies between - 0.94 in 1980 and +1.97 in 1988. Negative skewness means most of the rainfall received on later part of monsoon or rainy season and the positive skewness means much rainfall is received at earlier part of monsoon season. Analysis of rainfall data reveals that the skewness coefficient for the year 1980, 1989, 1992, 1996, 1998 and 2010 are negative suggesting much of rainfall was received in later stage of monsoon i.e. mid August to mid October. The skewness coefficient values for the year 1981, 1984, 1987, 1988,

1991, 1993 and 2005 are slightly greater than + 1.00 suggesting greater amount of rainfall received in early months of monsoon i.e. June to mid August. The remaining years have positive skewness closer to zero denotes normal distribution of rainfall (Table 4) During the period of record maximum mean rainfall received in September (144.54 mm) followed by June (105.34 mm), October (96.82 mm), July (87.06 mm) and August (73.39 mm) (Fig. 4).

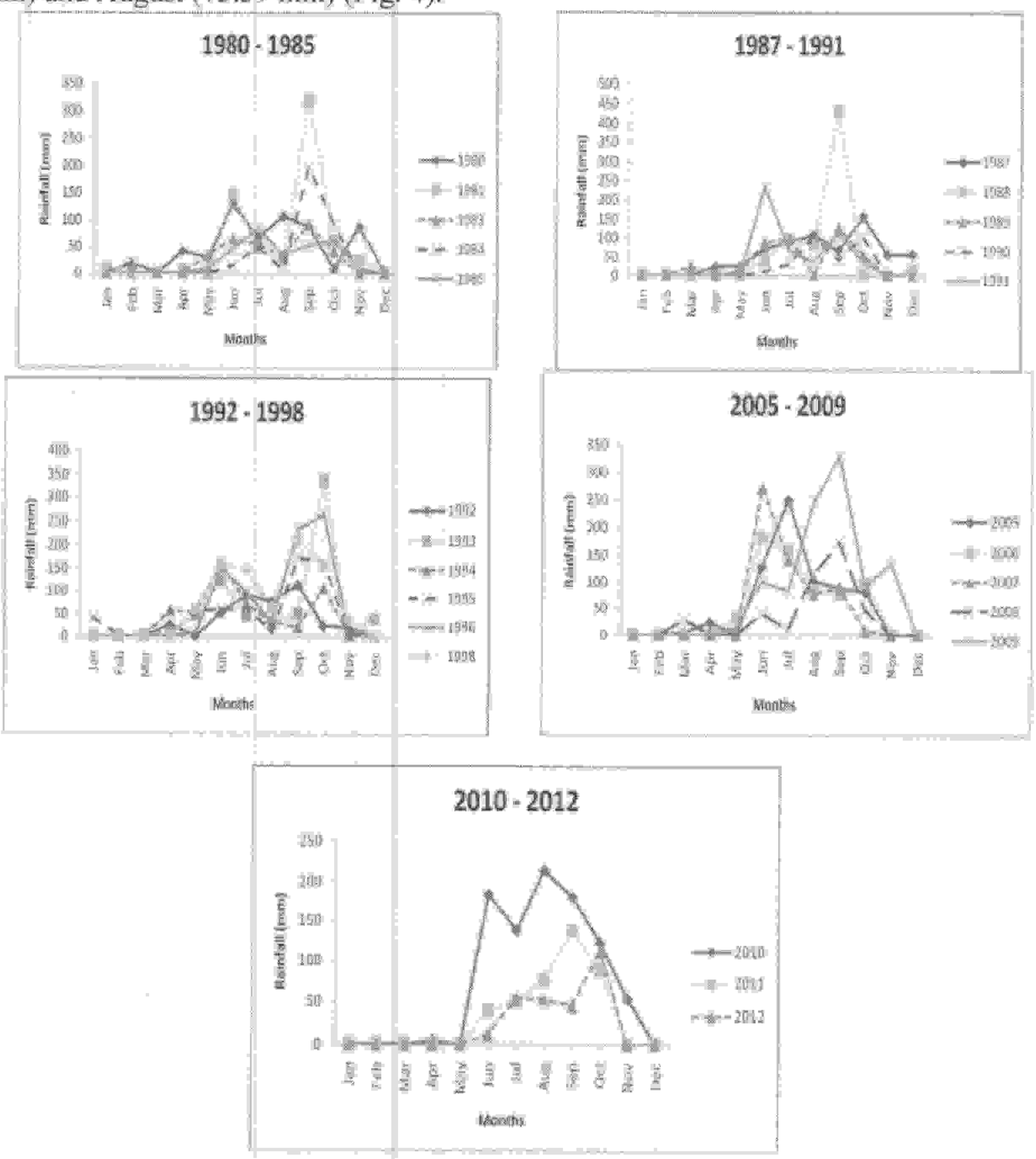


Fig. 4 Monthly rainfall of Vaduj Station (1980-2012)

2) Khatav

Analysis of monthly rainfall data of Khatav station shows that the mean rainfall for the record period is 96.44 mm (Fig. 5). The seasonal mean rainfall of different years of record varies from 36.08 mm in 2003 to 148.18 mm in 1998. The coefficient of variation for the monsoon season for different years of record ranges between 110.68 % in 1993 and 11.6 % in 1980. In the year 2003 more than 100 % variation in rainfall is observed, indicating the operation of extreme drought event (Table 2). The direction of variation of rainfall in monsoon season exhibits that the coefficient of skewness varies between - 0.85 in 1998 to + 1.72 in 2003. Analysis of monthly rainfall data reveals that the skewness coefficient for the year1998, 2002 and 2004 are negative suggesting much of the rainfall was received during mid August to mid October. The skewness coefficient values for the year 2003 is greater than + 1.00, suggesting more amount of rainfall is received in early monsoon months. The remaining years have positive skewness values closer to zero exhibits normal distribution of rainfall. During the period of record maximum mean rainfall is received in September i.e. 139.89 mm followed by June (119.56 mm), October (89.63 mm), August (70.46 mm) and July (62.68 mm) (Fig. 5).

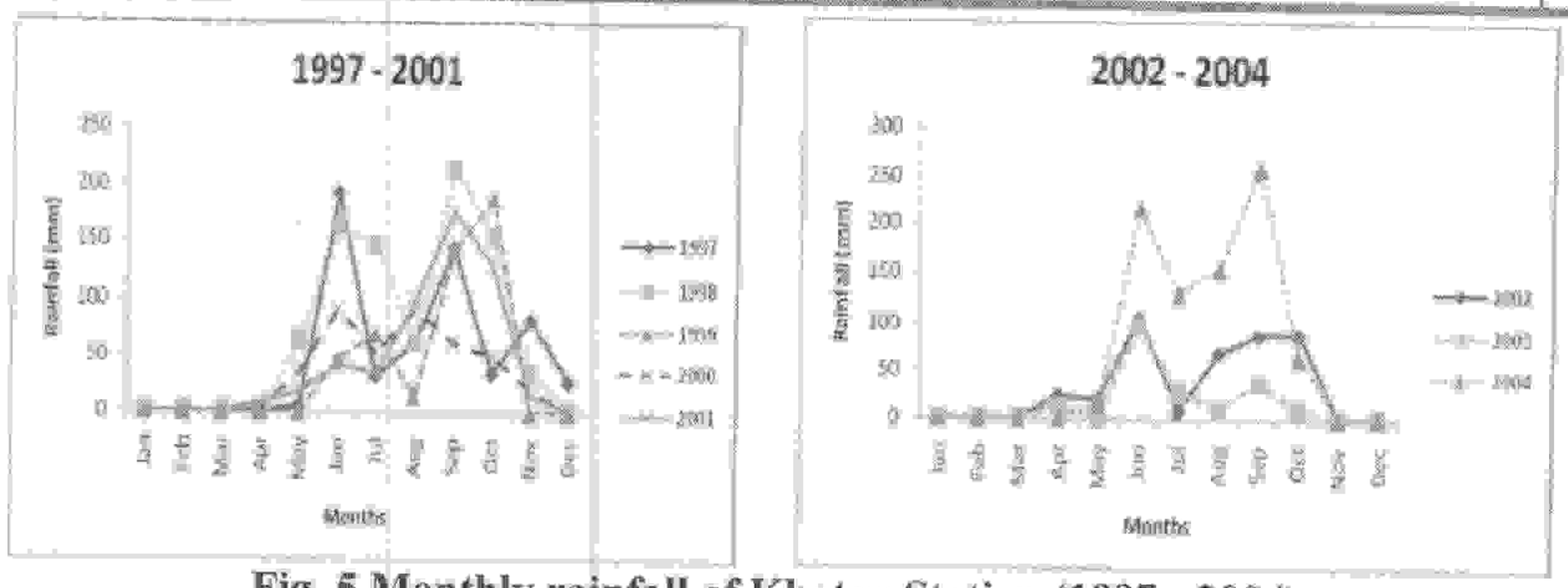


Fig. 5 Monthly rainfall of Khatav Station (1997 - 2004)

Correlation between Annual Rainfall and Number of Rainy Days

Correlation between average annual rainfall and average rainy days are calculated of each station. Average annual rainfall and number of rainy days in the study area are shown Table 2. Correlation values of Khatav, Vaduj are 0.8996, 0.8402 indicates strong positive correlation between these two parameters. In the study area high positive correlation was observed at Khatav in these parameters. In the Yerla River basin correlation between annual rainfall and rainy days is found strong positive to positive relationship between these two parameters indicates annual rainfall increases when rainy days increased.

Discharge characteristics

The discharge of a stream in the volume of water per unit time flowing past a cross-section of the stream, expressed usually in cubic meter per second (m^3/second) or cumecs. Hydrograph is a graphical representation of the instantaneous rate of discharge of a stream plotted with respect to time. Average annual discharge of the Yerla River basin at Ambavade station is 426.07 m^3/second (cumecs) for the tenure of 26 years from 1982 to 2007. On the basis of discharge data it is found that discharge is not released during the year 1992, 1997, 2002 and 2003 due to dry condition (Figure 6). First priority of dam storage water is for drinking purpose than agricultural purpose. Eight times in the year 1988, 1991, 1996, 1998, 1999, 2005, 2006 and 2007 average annual discharge are found above average and remaining eighteen years below average. Maximum discharge is 2133.11 cumecs in the year 1998 and minimum discharge 0.00 cumecs in the year 1992, 1997, 2002 and 2003 (Figure 6).

Discharge Database

In the present study daily computed discharge data of the study area is taken from Hydrology Project, Nashik for the period of 26 years from 1982 to 2007. Monthly and annual discharge values were analysed using Microsoft Excel software. In the Yerla River basin discharge data is available for a single station - Ambavade, located 5 km downstream of Yeralwadi Medium Irrigation Project in Khatav taluka of Satara district. The location of discharge station is shown in Figure 1. Discharge data of the year is taken for south west monsoonal months i.e. June to October.

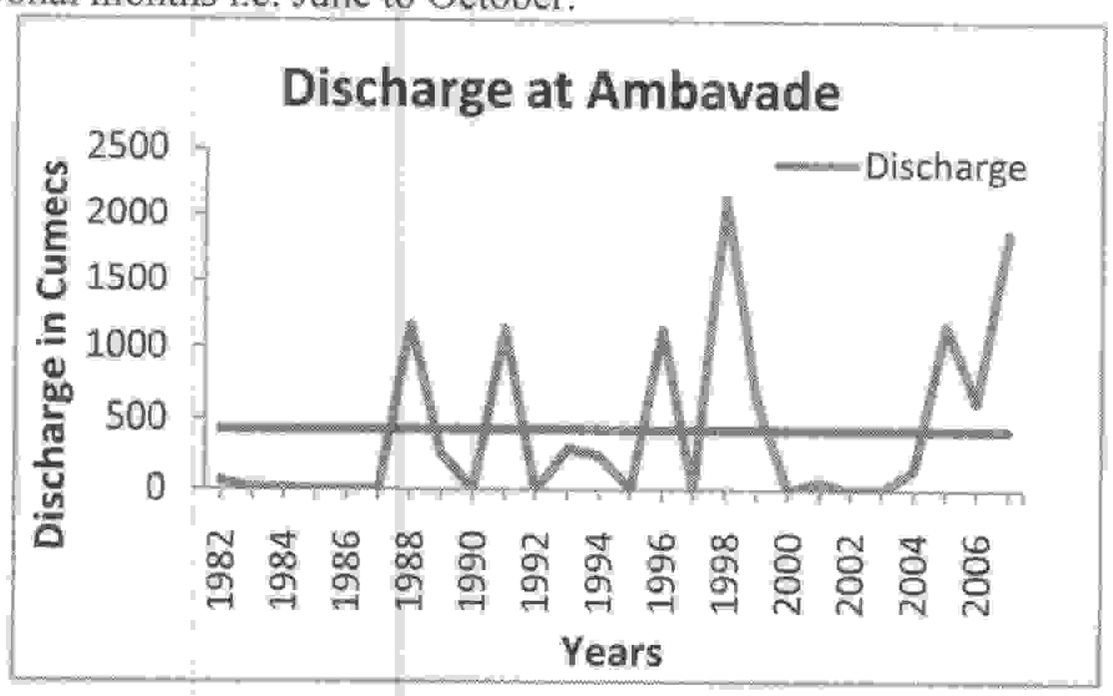


Fig. 6 Annual average discharge of Ambavade Station

Discharge Curve

Annual hydrographs are constructed for each year from 1982 to 2007. Close observation of hydrographs for 1982 - 1986 shows that peak discharge for 1982 and 1983 had occurred in the month of October and for 1983 if occurred in the month of September. Maximum discharge in this five year is found in October 1982 (0.64 cumecs) and minimum discharge is 00 cumecs found in the month of June in 1984, 1985 and 1986, all these values are below the average annual discharge of Ambavade station (Figure 6).

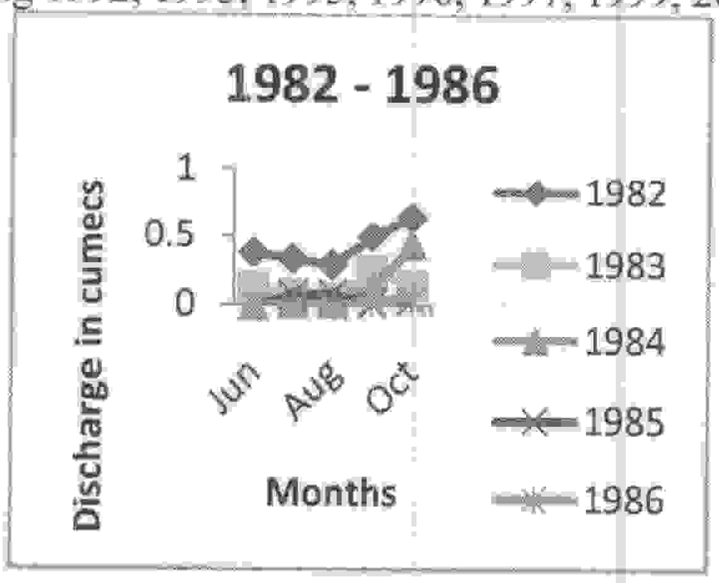
Hydrographs for the next five year (1987 - 1991) shows maximum discharge is 24.423 cumecs in September 1987, which is less than the average discharge of study area. Minimum discharge is 00 cumecs found in June of 1987 and 1990. Above average discharge is found in the 1991 from last ten years from 1982 to 1991 (Figure 7).

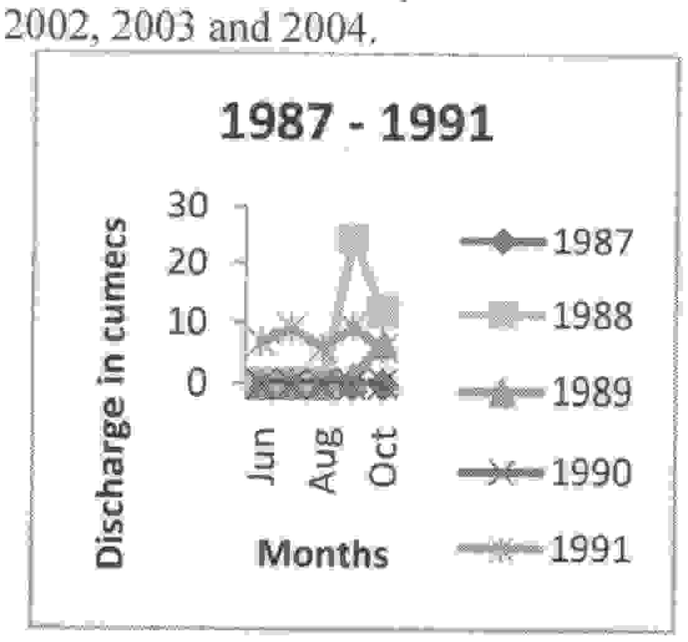
During the next five year from 1992 to 1996, most of the value indicates minimum discharge due to less rainfall. In the year 1994 due to good rainfall discharge is found throughout rainy season. Maximum discharge is 36.94 cumecs in October 1996. During this five year the station receives low discharge, with below average annual value (Figure 7).

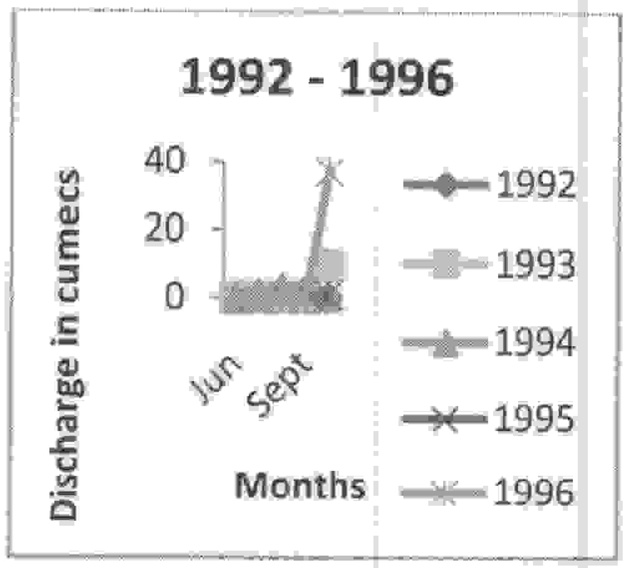
In the next five year from 1997 to 2001 maximum discharge is found in September 1998 (29.11 cumecs) and in 1997 and 2000 due to low rainfall no discharge found. During this five year no discharge occurred in June to September, excluding October 1998 (Figure 7).

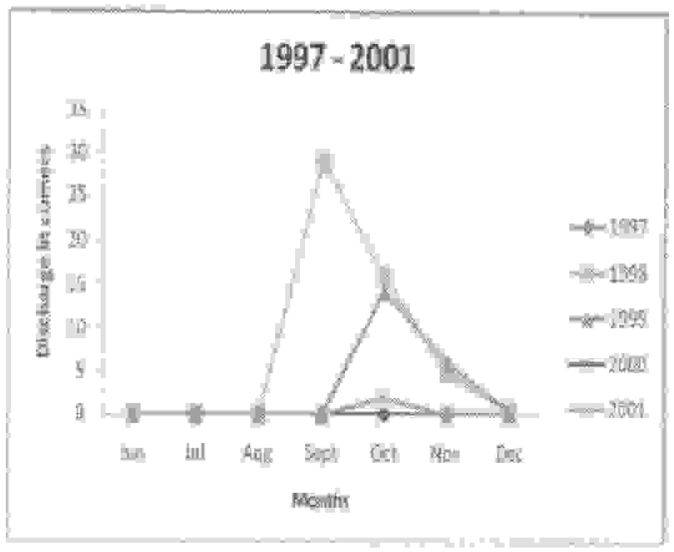
The hydrograph of remaining six year from 2002 to 2007 exhibits peak discharge in the month of July and December of 2007. In the year 2002 and 2003 no discharge is released from the station. During 2000 to 2004 throughout the rainy season no discharge is released excluding October and November months of 2001 and 2004.

In the Yerla River basin at Ambavade station for the period of 26 years from 1982 to 2007, the highest peak was formed in October 1996 (36.94 cumecs) and the lowest peak (00 to less than 0.38 cusecs) occurred in the month of June of every years excluding 1991 and 2007. During this span of maximum discharge is occurred in the year 2007 (2872.46 cumecs). Maximum discharge is commonly found in the month of September or October and minimum discharge is commonly found in the month of June. In the Yerla River basin no discharge is found in early four months i.e. June to September in eleven year including 1992, 1993, 1995, 1996, 1997, 1999, 2000, 2001, 2002, 2003 and 2004.









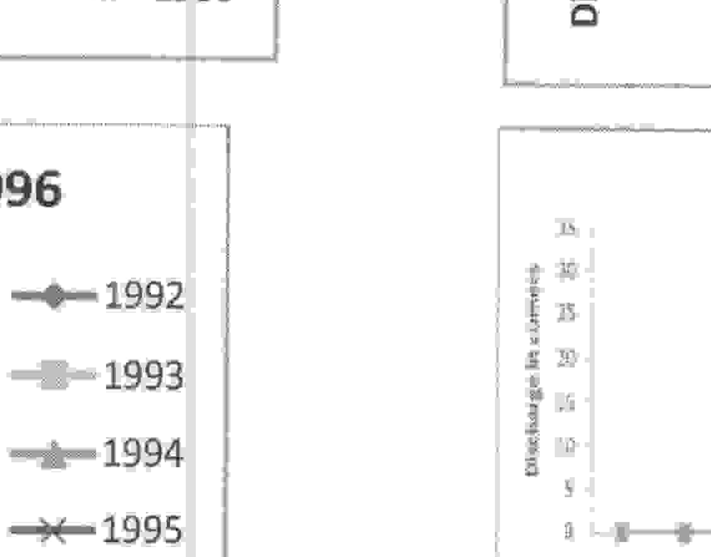


Fig. 7 Annual hydrographs of Ambavade station

Rainfall Discharge Relationship

The total runoff generated the mainstream of the watershed is the function of total precipitation received on the watershed. However, all the precipitation received is not converted into discharge due to hydrological losses. Interception by vegetation cover, temporary storages in ponds and lakes, infiltration and evapo - transpiration are principal losses. Therefore to study the relationship between rainfall and discharge are essential for watershed management studies for suggesting watershed management structures. Rainfall and discharge relationship is established for the Yerla River basin at Ambavade station using discharge data of Ambavade Station and rainfall data of Vaduj station. Vaduj station is located 11 km upstream of the Ambavade station. The correlation coefficient is calculated as 0.7868, which shows strong positive correlation between average rainfall and mean discharge of the Yerla River basin (Figure 8).

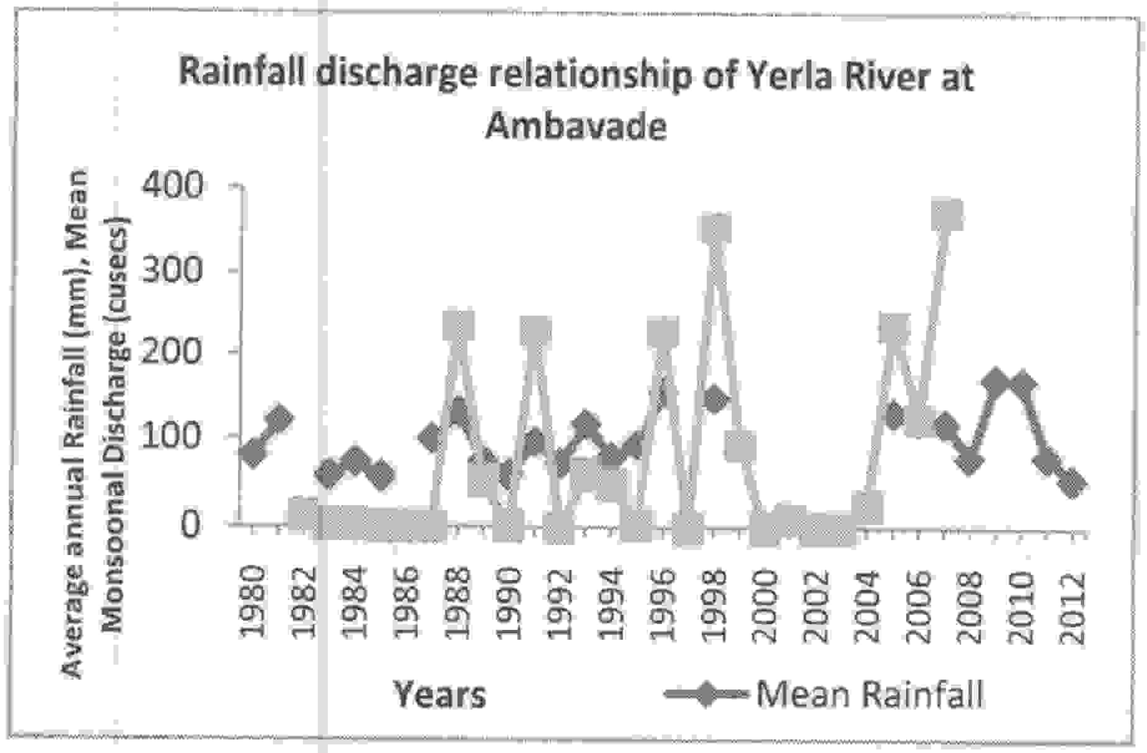


Fig. 8 Rainfall Discharge relationship of River Yerla at Ambavade with mean monsoonal discharge at Ambavade station and annual average rainfall of Vaduj station

Table 2 Average annual rainfall and average discharge of the study area

Year	Average Rainfall in mm	Mean Discharge in cusecs	Year	Average Rainfall in mm	Mean Discharge in cusecs
1980	80.62		1997		0
1981	121.14		1998	148.2	355.5183
1982		13.212	1999		92.97486
1983	57.8	3.6166	2000		0.1825
1984	72.2	3.744	2001		10.365
1985	56.62	1.242	2002		0
1986		0.514	2003		0
1987	99.78	0.38	2004		25.34667
1988	131.48	234.4702	2005	131.2	235.4658
1989	74.68	51.812	2006	121.1	124.326
1990	58.8	2.057	2007	118.7	374.494
1991	96.8	229.0636	2008	78.08	
1992	71.3	0	2009	170.9	
1993	116.9	59.386	2010	167.9	
1994	78.4	49.276	2011	78.78	
1995	92.8	3.528	2012	55.08	
1996	155.2	229.08			

Peak Discharge

In the semi arid Yerla watershed peak discharge is occurred due to various reasons. Year wise peak discharge and its date is given in Table 2.6 During the tenure maximum peak discharge values are 251.28 cumecs (3/10/1996), 216.87 cumecs (26/9/1988), 139.81 cumecs (9/10/1998) and 101.43 cumecs

(28/8/2007). In the remaining years peak discharge released less than 60 cumecs, in which most of the value lies in between 0 to 7 cumecs.

Table 3 Peak Discharge in Ambavade station

Year	Peak Discharge (Cumecs)	Date	Year	Peak Discharge (Cumecs)	Date
1982	1.42	29/9/1982	**1995**	2.33	3/10/1995
1983	0.703	14/6/1983	**1996**	251.28	3/10/1996
1984	0.984	9/10/1984	**1997**	00	1997
1985	0.35	24/7/1985	**1998**	139.81	9/10/1998
1986	0.18	5/10/1986	**1999**	30.90	15/10/1999
1987	0.18	18/10/1987	**2000**	0.14	3/1/2000
1988	216.87	26/9/1988	**2001**	3.41	19/10/2001
1989	22.58	30/9/1989	**2002**	00	2002
1990	3.51	9/10/1990	**2003**	00	2003
1991	63.51	29/9/1991	**2004**	11.27	4/10/2014
1992	00	1992	**2005**	42.00	3/8/2005
1993	39.09	17/10/1993	**2006**	27.96	8/10/2006
1994	7.02	11/9/2014	**2007**	101.43	28/8/2007

Average discharge of the Yerla River at Ambavade station is 426.07 m^3/second for the monsoonal months. Maximum discharge is 2133.11 cumecs observed in the year 1998 and minimum or no discharge released in the year 1992, 1997, 2002 and 2003 (Figure 8). Strong positive correlation (0.7868) is found between the average annual rainfall and mean monsoonal discharge of the study area.

Conclusion

The study area lies in the semi-arid region of Deccan Traps and receives an average of 552.72 mm rainfall. In the study area correlation between annual rainfall and rainy days is found strong positive to positive relationship between these two parameters indicates annual rainfall increases when rainy days increased. Average discharge of the Yerla River at Ambavade station is 426.07 m^3/second for the monsoonal months. Maximum discharge is 2133.11 cumecs observed in the year 1998 and minimum or no discharge released in the year 1992, 1997, 2002 and 2003. Strong positive correlation (0.7868) is found between the average annual rainfall and mean monsoonal discharge of the study area. Nature and distribution of rainfall and runoff is essential for watersheds management and allied studies.

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References

1. Fu C, Chen, J and Zeng, S (2012) Observation and Analysis of Rainfall-Runoff Characteristics in a Coastal Granite Catchment in Southern China. Journal of Hydrologic Engineering · January 2012 DOI: 10.1061/(ASCE) HE.1943-5584.0000413
2. Gadgil, A. (2002). Rainfall characteristics of Maharashtra. In: Diddee J. et al., Geography of Maharashtra, Rawat Publication, Jaipur, pp. 89-90.
3. GSDA (2009). Satara District Information. Groundwater Surveys Development Agency, http://www.gsda.org/satara_info.htm
4. Mutreja, KN (1995). Applied Hydrology, Tata Mc Graw Hill
5. Sepaskhah, AR and Moosavi-Fard, SR (2010) Determination of Rainfall-Runoff Relationship based on Soil Physical Properties for use in Microcatchment Water Harvesting System Design. Iranian J Science & Technology, Transaction B: Engineering, Vol. 34, No. B4, pp 447-460
6. Shikalgar, R.S. (2014). Spatio-Temporal Drought Density in Yerla River Basin, Maharashtra State. Indian Stream Research Journal, Vol.4, Issue 1, Feb. 2012, pp. 1-7.
7. impson, F. (2006). Conjunctive use of water resources in the Deccan Trap, India. In: Highlighting the impacts of North-South research collaboration among Canadian and southern higher education partners, Ass. of Univ. & Colleges of Canada, Ottawa, pp. 55-65. http://www.aucc.ca/publications/auccpubs/auccpubs_e.html
8. Singh, D.N., Singh, J. and Raju K.N.P. (eds.) (2003). Water Crisis and Sustainable Management. XXV IIG Conference Volume, Tara Book Agency, Varanasi.
9. Subramanya, K (2000) Engineering Hydrology, Tata Mc Graw Hill
10. Thigale, S. (2013). Dushkal: Panyacha aan Saksham Manushyabalachahi! (in Marathi), Daily Lokmat, Nashik, 3rd Feb. 2013, pp. 1 & 8.
11. Unde, M.G. and Telore, N.V. (2012). Role of Watershed Development Programme in Sustainable Development: Nidhal Experience from Satara District, Maharashtra. Journal of Shivaji University (Science and Technology) Vol. 42, 2012, pp. 68 - 71. Link: www.unishivaji.ac.in/uploads/journal/Journal_42/16.pdf