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Statistical analysis of seasonal rainfall variability in Nasik district by using GIS interpolation technique

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Abstract
Rainfall is the most important single factor determines the success or failure of agriculture and affects the availability of water resources. The proper understanding of precipitation pattern and its trends may help water resources development and take decisions for the developmental activities of that place. In view of this the present attempt was made to analyze spatial pattern and distribution of rainfall variability using statistical method and represented with the help of GIS interpolation technique. Present analysis includes the seasonal and spatial variations of rainfall in Nasik District of Maharashtra. The study was used 20 years monthly rainfall data from 1998 to 2017. The results revealed that spatial pattern of rainfall variability are not uniform. Nasik is characterized, by general dryness throughout the year except during the south west monsoon season. In Nasik District, tehsils Trambakeshwar, Igatpuri, Peth and Surgana were received highest rainfall compared to rest of tehsils. Igatpuri tehsils received highest rainfall *i.e.* 2991.0 mm and the lowest rainfall *i.e.* 494.0 mm were in Deolali rain guage station. Whereas, the Trambakeshwar tehsils has highest co-efficient of variation (35.18%) and Niphad tahsil has lowest variability (24.45%). The rainfall in the study area from western part to eastern showed decline. The maximum rainfall received during the south west monsoon season contributes 90.11% of total rainfall and average annual rainfall received 1062.59 mm.

Keywords: coefficient of variation, interpolation technique, rainfall variability, spatial variation

Introduction
Rainfall is one of the major climatic factors influencing agriculture. The crop production and productivity depends on the amount of rainfall received, intensity and distribution of the rainfall over a particular area during particular year which indicates the growth of the economy of the country and affect both the spatial and temporal patterns on water availability (Find *et al*. 2014) [1]. Rainfall characteristics over an area vary from one part to another so analysis of the rainfall pattern is an important to understand the micro-level variability which in turn useful to planning the agriculture; land and water development activities for future use. Hence understanding its nature and trend at any place has a great significance in water storage for future use. Under changing climate the variability of rainfall significantly insufficient was observed past years in developing and under developed countries (Thornton *et al*. 2014) [6]. Deviation of rainfall from the mean or the ratio of standard deviation to the mean or the variability of coefficient of variation is called rainfall variability, the study of the rainfall variability and its trends is a good tool for the policy makers for agricultural planning, water resource assessment, hazard mapping, flood frequency analysis etc. India gets rainfall through South-west monsoon during June to September and North-east monsoon during October to December. The intra-seasonal and inter annual variability of the summer monsoon has a great impact on agriculture (Krishnamurthy and Kinter 2002) [4]. In addition to rainfall spatial variability modeling is an important element in predicting the rainfall distribution and to predict the precipitation relates with other climatic elements. Hence, environmental management and research need this rainfall change as a rule for realizing many processes. Therefore, spatial variation modeling of monthly precipitation, are of interest for climatologists and hydrologist. Different interpolation methods have been used for modeling the geo-statistical patterns of precipitation. The most widely used interpolation methods are deterministic and geo-statistical methods, deterministic interpolation techniques, global and local models. Importance of monsoon to Indian economy and as major global circulation parameter has motivated many scientists to study the variability of Indian monsoon variability across the country, in the past. Rainfall has been rigorously examined by several researchers, notably by Parthasarathy and Dhar (1976) [5], Wang *et al*. (2015) [7], Gouda *et al*. (2017) [2]. Understanding monsoon rainfall at multiple scales and advanced prediction of southwest

monsoons are crucial for India. It is also important to know the relationship between monsoons and ocean atmospheric processes variability studies are having great significance. The present study was made to understanding the rainfall variability and seasonal rainfall incidence of Nasik District with the following objectives are; to find out and analyze the spatial distribution, variability of rainfall and seasonal rainfall variations in the Nasik District from 1998 to 2017, to analyze and identify the regional disparities of rainfall of individual tehsils in the studied area, and to analyze rainfall frequency of the area.

Materials and Methods

Study Area

The Nasik District is surrounded by Dhule District in the north, Jalgaon and Aurangabad Districts in the east, Ahmednagar District in the south, and Thane District in the south-west and Gujarat state in the north-west. The main system of hills is the Sahyadri, which run north-south in the western portion of the District. From the main Sahyadri range three prominent spurs stretch out to the east. In the extreme north is Selbari range, which approximately forms and boundary between Nasik and Dhule District. Next is the Satmala range which runs right across District. Kalsubai range is located in the south part of the District. The District has three main rivers the Godavari, Girna and Vaitarna.

Nasik District is located between 18°33' N and 20°53° N latitudes and 73°16' E and 75°16' E Longitude at Northwest part of the Maharashtra state and about 565 meters above mean sea level and has an area of 15,530 km^2. The location of the study area is showed in Figure 1. Nasik falls in the agro-climate zone of western plateau and hill region. The area is dominated by four kind of soil namely Black, Red, Red and Black (Koral) and Light Brown (Barad) soil. Grape, Onion, Pomegranate and Tomato is the most dominant horticulture crop of this study area. The weather of Nasik District is pleasant experiences mainly four distinct seasons namely, winter (January-February), Pre-Monsoon (March-May), South west Monsoon (June-September) and Post Monsoon (October- December). The District is divided in to three Regions, Western Region - In the western region the edge of Sahyadri's and Deccan plateau, Central Region- This area is covered by hills it ranges from north to east and west to east direction and East Region- the height of this plate varies toward east. The study area is situated partly in the Tapi basin and partly upper Godavari basin.

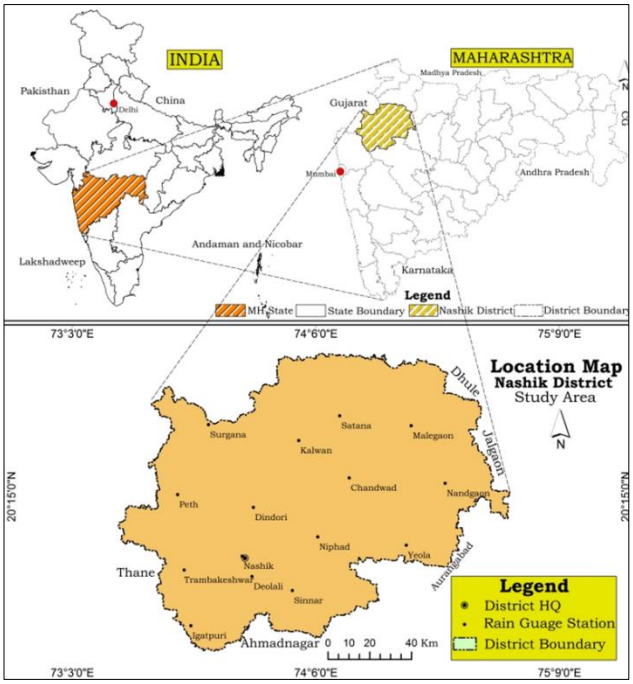

Fig 1: Location Map of 15 Rain Guage Staion of Nasik District is used in the analysis

Methodology

The present research paper is based on the spatial (tehsil-wise) rainfall distribution & variability of Nasik District. The 20 years from 1998 to 2017 rainfall data collected from Meteorological Department of Maharashtra. The rainfall trend calculated by statistical tools *i.e.* mean, standard deviation and coefficient of variation and the spatial distribution represented on map using spatial analyst tools interpolation technique. Interpolation is one of such geo-statistical methods in which use known values at sampled points to generate a continuous surface giving us prediction of values at unknown points. The obtained trend values at each grid point were entered into ArcGIS 10, and the Inverse Distance Weighting (IDW) interpolation approach was used to interpolate the obtained trends.

Abnormalities of rainfall at different locations calculated by simple ratios of precipitation. It is the difference between maximum and minimum rainfall of over the series of expressed in the term of mean. The formula used to calculate precipitation ratio is as follow;

$$\text{Precipitation ratio} = \frac{[Px-Pn]}{Pm} \times 100$$

Where; Px = Maximum of Rainfall; Pn = Minimum of Rainfall and Pm = Mean rainfall

Result and Discussion

Nasik district annual rainfall

The annual average rainfall for the period from 1998 to 2017 was analyzed and presented in (Table 1) that significant variations were observed during the 20 years study period. The highest average rainfall (2991.0 mm) was recorded in Igatpuri followed by Trambakeshwar (2072.0 mm), Peth

(1955.0 mm) and Surgana (1788.0 mm), while lowest rainfall (494.0 mm) was recorded Deolali followed by Malegaon (548.0) and Nandgaon (569.0 mm) While Nasik District average rainfall is 1062.59 mm. Since twenty years, the rainfall was above normal recorded for 9 years *viz*. 1998, 1999, 2003, 2004, 2005, 2006, 2007, 2008 and 2010. The highest annual rainfall *i.e*. 1746.92 mm and actual rainfall (1748.10 mm) were recorded in year 2006. The severe drought year recorded as 2015 with lowest rainfall and actual rainfall (598.16 mm and 605.50 mm) followed by 2014 (720.71 mm and 667.0 mm) and 2000 (761.76 mm and 768.10 mm) (Figure 2). Linear line of spatial distribution shown that downward trend in the annual mean rainfall of the District and also found that percentage of rainfall increases in the westward direction of the District, which includes Igatpuri, Trambakeshwar, Peth and Surgana tehsil's, where higher annual rainfall was recorded. The pattern of rainfall is decreasing western direction to eastern part tashils of District such as Malegaon, Satana, Nandgaon and Yeola (Figure 3). Nasik District rainfall frequency was classified into 6 rainfall classes viz. 500-700 mm, 700-900 mm, 900-1100 mm, 1100-1300 mm, 1300-1500 mm and >1500 mm and the number of frequency are covered in this rainfall class are 1, 4, 7, 5, 2 and 1 respectively. The most of the frequency covered 900- 1100 mm rainfall class followed by 1100-1300 mm rainfall class (Table 2). Nasik District is characterized by sharp areal differences in the quantum of rainfall due to the varying nature of topography and the influence due to orientation and configuration of Westerns ghats. The data further revealed that highest frequency (9.0) was recorded in 900-1100 rainfall class, while lowest frequency is in >1500, 500- 700, 1300-1500 as well as 700- 900 *i.e.* 1, 1, 2 and 4.0 frequency, respectively.

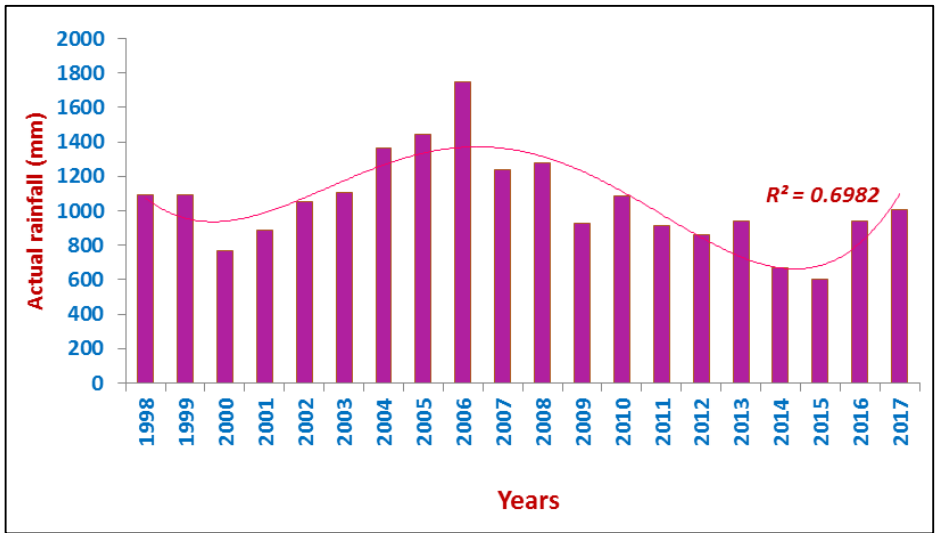

Fig 2: Nasik District year -wise rainfall (mm) from 1998 to 2017.

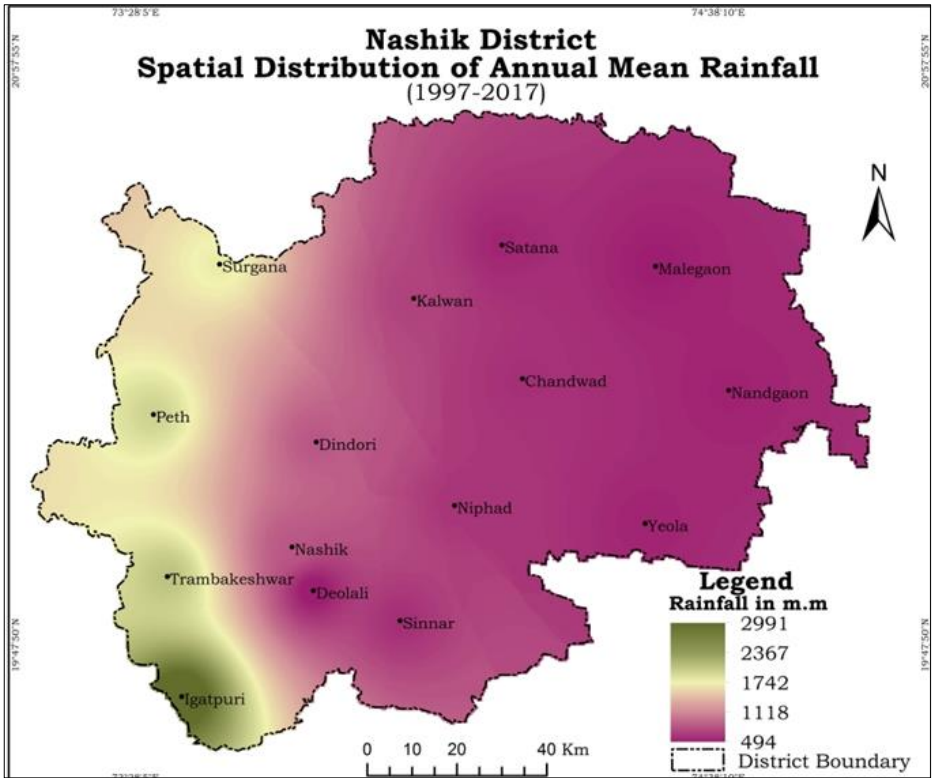

Fig 3: Spatial distribution of Annual Mean Rainfall of Nasik District (1998-2017).

Table 1: Tahsil wise rainfall Distribution & variability of Nasik District during the period 1998-2017.

Nasik District (Rainfall in mm)																
Year	**Malegaon**	**Baglan**	**Kalwan**	**Nandgaon**	**Surgana**	**Nasik**	**Dindori**	**Igatpuri**	**Peth**	**Niphad**	**Sinnar**	**Yeola**	**Chandwad**	**Trambak**	**Deolali**	**Nasik District**
1998	647.6	563	748	882	1734.2	941.1	744	3826.2	2140	798.5	854.4	721.8	658	935	751	1129.65
1999	797.9	636	653	736	2144	802.6	693	2732.5	1898.2	790	740.1	691	690.1	1879	541	1094.96
2000	408.6	327	318	696	1110.5	772.5	536	2083.6	1233	540	554.7	497.5	463	1477	409	761.76
2001	383.4	381.7	490	382	1526.7	645.7	487	2993	1683.5	499.6	421	484	559	1799.3	447.5	878.89
2002	552.9	582.7	868	584	2047.6	813.2	866.7	2847.3	1771.9	693.6	465.2	443.8	715.7	2119.7	377	1049.95
2003	394.9	577	772	400	1927	912.4	859.5	3569.2	2160.2	619	811.4	392	438	2312	391	1102.37
2004	672.2	745	1031	517.4	2474	1058	1093	3902	2602.7	1043.7	702.1	863	828	2459	464.8	1363.73
2005	422.4	603.2	874	413	3066.8	1202.4	798.7	4463	2846.6	884.5	676.3	506.6	639.8	3749	491	1442.49
2006	851	960	1414	877.5	2992.2	1323.1	1082.2	4778	3345.3	879.2	951	931.5	1160.5	3794	864.3	1746.92
2007	739.1	810	826	629.2	1947.3	833.1	772	3663.9	1957	780.7	688.8	678.6	791.4	2515	675	1220.47
2008	558	545	807	780	2012	1234	1090	3869	2226	733.4	684.6	722.6	709	2298	455	1248.24
2009	763.5	750	785	792	1340	526	600.5	2195	1508	568	772.5	510	818	1414	597	929.30
2010	872	520	589	790	1443	770	742	3084	1840	725	804	881.6	879	1634	443.4	1067.80
2011	396	552	480.3	571	1815	568	568	3030	1832	383.5	429	634	552	1642	286	915.92
2012	509	463	533	308	1512	504	645	2789	1693	507	447	482	649	1523	384	863.20
2013	663.8	622.8	765.9	640.1	1853.4	730.9	961.7	2213	1956.6	568.1	479.7	465.8	440.3	2029.4	530.7	994.81
2014	399.1	468.4	611	243.7	1088	621.4	712.8	1801.4	1299.7	486.4	398.8	342	368.7	1579	390.2	720.71
2015	280.6	392.3	620.9	260.3	652.2	594.4	744.3	1462.9	940.9	484.2	414.2	296.8	345.6	1198	284.8	598.16
2016	327.9	596	739.1	413.9	1123.7	1126.2	1131.4	2099.8	2017.9	648.7	656.3	507.9	486.8	2356.4	562.2	986.28
2017	322.3	568	687.5	473.4	1942	1050.9	1819.9	2412.5	2147.5	644.4	639.7	487.5	583.3	2735.4	527.6	1136.13
Mean	*548*	*583*	*731*	*569*	*1788*	*851*	*847*	*2991*	*1955*	*664*	*630*	*577*	*639*	*2072*	*494*	*1062.59*
SD	*185.00*	*146.59*	*223.83*	*197.75*	*592.50*	*240.99*	*291.86*	*881.06*	*535.00*	*162.29*	*163.80*	*175.11*	*192.96*	*729.17*	*142.20*	*257*
CV %	33.75	25.14	30.64	34.73	33.15	28.30	34.44	29.46	27.37	24.45	26.02	30.35	30.21	35.18	28.81	24

Table 2: Nasik district rainfall frequency from 1998 to 2017.

Rainfall class	Frequency Tally bar
500-700	1
700-900	4
900-1100	7
1100-1300	5
1300-1500	2
Above 1500	1

Spatial variability of the rainfall of Nasik district

Variability is the deviation from mean or ratio of the standard deviation to the mean rainfall, the spatial variability of the rainfall (Figure 4) showed that co- efficient of rainfall variation during the period of 1998 to 2017 in Nasik District varies with magnitude from 24.45% to 35.18%. Highest variation was recorded in eastern part tashils namely Malegaon, Kalwan, Nandgaon, Surgana, Dindori and Yeola, medium variation is in Nasik, Igatpuri, Peth, Sinnar, Chandwad and Deolali and lowest variation is in Baglan and Niphad.

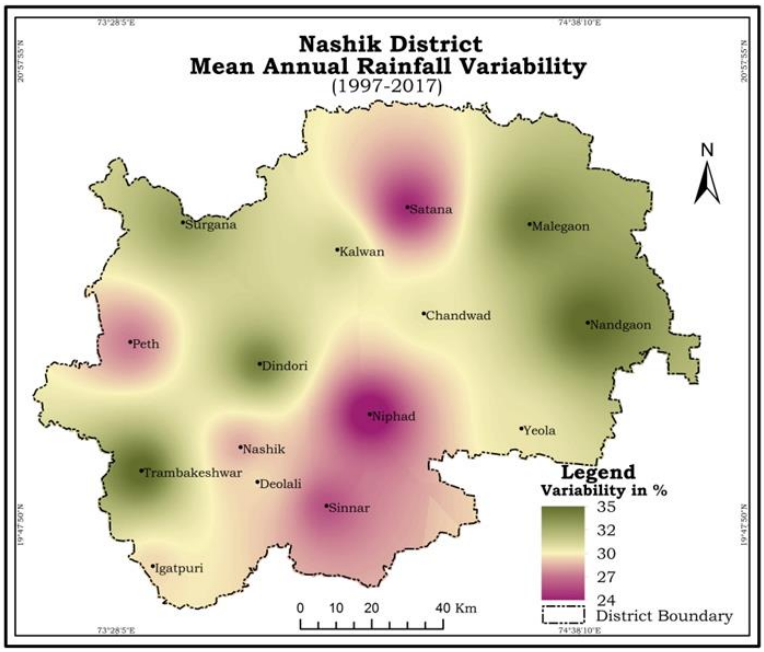

Fig 4: Annual Rainfall Variability of Nasik District (1998-2017)

Spatial variability of the seasonal rainfall of Nasik district

Prediction of monsoon and its variability is the most challenging problems in atmospheric studies and monsoon governs the pulse of life for the millions. Understanding and predicting the variability of the Indian monsoon is very important because it has a large impact on the agriculture and economy of the country. Indian Rainfall categorized into four distinct seasons, winter season (January - February), pre-monsoon (March- May), south west monsoon (June - September) also called the monsoon season and post monsoon (October - December). Inter annual variability of monsoon rainfall is also computed for the period 1998–2017 Table 3, 4

and Figure 5 shows mean spatial rainfall variability of 15 teshils of Nasik District for the four seasons. During the winter season lowest rainfall received followed by pre monsoon and post monsoon season, whereas highest rainfall was received during the south west monsoon season and contributes 90.11% of total rainfall and the highest rainfall received by Igatpuri teshil followed by Trambakeshwar in the month of August. During winter season variability varies from 190% to 436 %, highest variability was recorded in Trambakeshwar and Peth tahsils, while lowest was in Sinnar tahsil. During pre-monsoon variability varies from 107 to 261%. The lowest variability was observed during south-west monsoon season followed by post-monsoon season. In District lowest variability occupies in south western and north-eastern part.

Precipitation ratio of Nasik district

Nashik District long term precipitation ratio from 1998 to 2017 revealed that the maximum annual precipitation ratio abnormality was recorded in Dindori tahsil (157%) and minimum abnormality was at Sinnar (88%). High abnormality zone (Above >125) are Dindori, Surgana, Kalwan, Chandwad and Trambakeshwar tahsil, moderate abnormality zone (100-125) are Malegaon, Satana, Nandgaon, Igatpuri, Peth, Yeola and Deolali and low abnormality zone (Bellow > 100) are Nasik, Niphad and Sinnar (Figure 6).

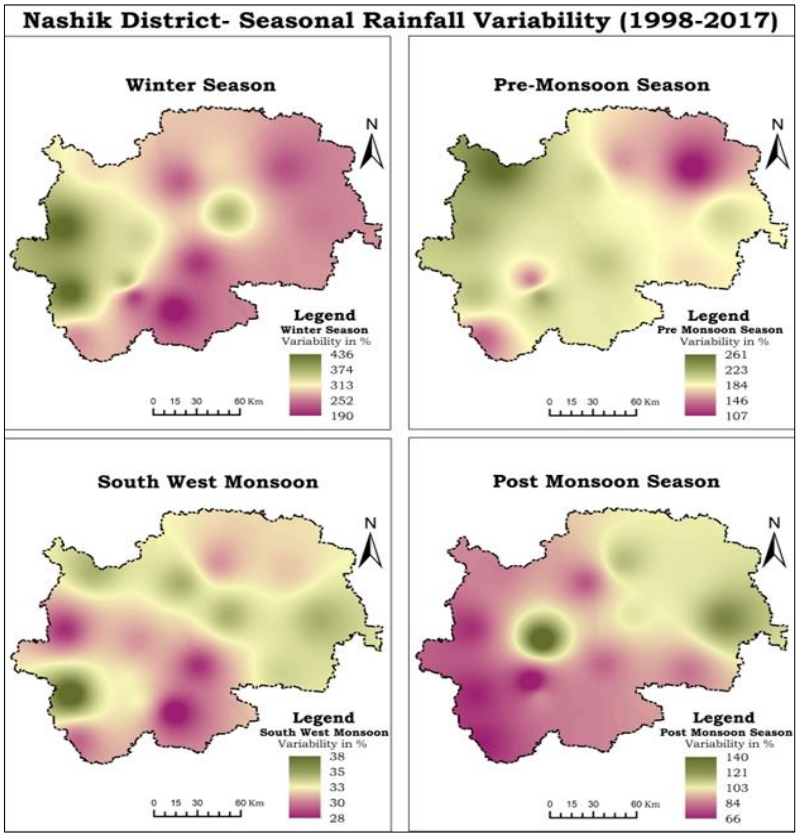

Fig 5: Seasonal Rainfall Variability of Nasik District (1998-2017).

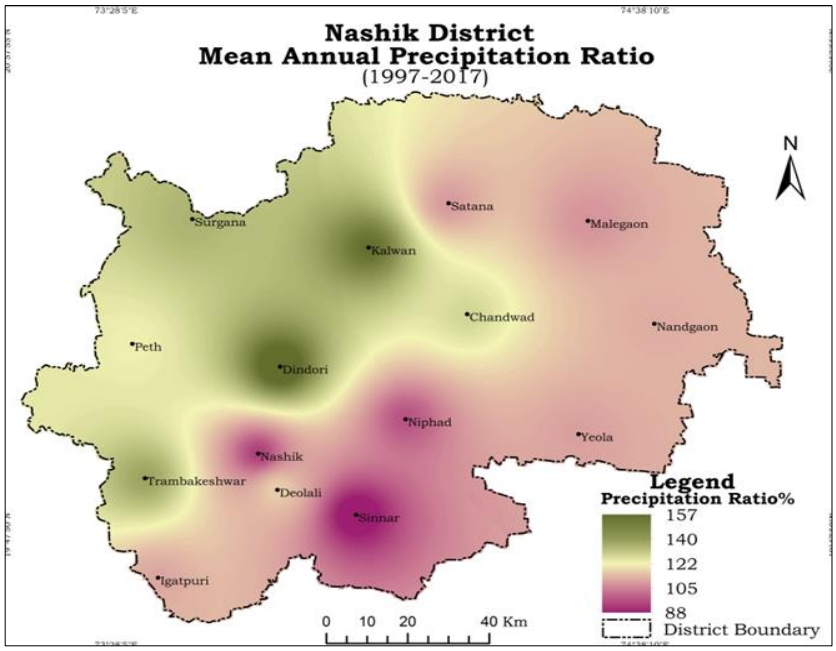

Fig 6: Annual Precipitation Ratio of Nasik District.

Table 3: Nasik district Season wise rainfall and contribution from 1998 to 2017.

Sr. No	Month	Season	Rainfall (mm)	Contribution (%)
1	January	Winter Season	0.88	0.20
2	February		1.29	
Total Rainfall			2.17	
3	March	Pre-monsoon Season	1.69	1.22
4	April		1.17	
5	May		10.12	
Total Rainfall			12.98	
6	June	South West Monsoon Season	174	90.11
7	July		320	
8	August		277	
9	September		187	
Total Rainfall			958	
10	October	Post Monsoon Season	69	8.47
11	November		20	
12	December		1	
Total Rainfall			90	
Total Rainfall of Nasik district			*1063*	*100*

Table 4: Nasik district long term precipitation ratio from 1998 to 2017.

District	Teshils	Winter Season	Pre Monsoon season (summer)	South west monsoon season	Post monsoon season	Mean Annual
Nasik	Malegaon	958	340	109	376	108
	Baglan	1327	452	138	520	109
	Kalwan	991	733	156	275	150
	Nandgaon	1075	749	117	530	112
	Surgana	1000	1158	143	294	135
	Nasik	1682	487	112	245	96
	Dindori	1546	740	94	668	157
	Igatpuri	1061	412	115	256	111
	Peth	2000	1001	126	261	123
	Niphad	700	855	99	313	99
	Sinnar	612	850	108	299	88
	Yevla	1024	641	119	285	110
	Chandwad	1696	614	144	368	128
	Trimbakeshwar	2000	817	148	227	138
	Deolali	829	955	137	337	117
Mean		*1233*	*720*	*124*	*350*	*119*
Percentage (%)		*51*	*30*	*5*	*14*	*100*

Conclusion

The present attempt was made to compare seasonality and inter annual variability of monsoon rainfall at a smaller domain. Results indicated that there are various temporal-spatial variation patterns that affect precipitation. The spatial distribution of rainfall is uneven in the north and south eastern part of the tehsils is relatively lower compared to western part of tehsils. The findings indicated that among the rainfall data which were influential on precipitation, seasonal then monthly and annual precipitation had the highest spatial variations in the rate of precipitation. Geo-statistical interpolation methods can show the magnitude of these variations on the precipitation rate changes and can well examine the variation patterns.

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