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Spatial and Temporal Variability in Climate Variables Trends in the Marathwada Region of Maharashtra, India

Sunilkumar B R[1]; Krishna D K[2]; Sanjay Kumar Gupta[2]
[1]MSc. Scholar, Agricultural Economics
[2]PhD. Scholars, Agricultural Extension,
ICAR- Indian Agricultural Research Institute, New Delhi
*Corresponding Author: sanjay.gupta526@gmail.com

Abstract

India, a sub-tropical country is highly sensitive to climate change and its variability. The main reason for its high sensitivity is the variability in rainfall and temperature. About 80 percent of the total rainfall over India occurs during the four months from June to September as a result of the south-west monsoon. With this background, present study was conducted in marathwada region of Maharashtra to examine spatial and temporal variability in climate variables. The result shows that variation in seasonal rainfall was found more in post-monsoon period followed by pre-monsoon and monsoon period.The average rainfall was highest in August month. June and October rainfall over the years has decreased sharply while, august and September rainfall has increased. The principal rainstorm months are not contributing as normally. From an agronomic point of view dry spells at critical growth stages can be extremely hazardous and it is one of the prime reasons for dwindling crop yield. Analysis of trend in climatic variables reveals that Marathwada region is more affected with change in frequency of rainfall, less number of rainy days and frequent dry spells.

Introduction

The agriculture sector has paramount importance in the Indian economy, not only for its pivotal role in attaining food security but also in achieving overall economic growth. Agriculture in India is aptly labelled as ‘a Gamble with Monsoons’, which signifies both rainfed nature of farming and uncertainties associated with rainfall. Climate variability can be broadly defined as fluctuation of climatic variables in a year above or below a long-term average value or year-to-year fluctuation around the normal (normal -25 year average of a

weather variable). Common drivers of climate variability include El Niño and La Niña events, which are shifts of warm, tropical Pacific Ocean currents that can dramatically affect Indian summer monsoon rainfall (ISMR). Climate variability has been and continues to be, the principal source of fluctuations in conventional food production. It can be generalized that around sixty percent of the variation in crop yield is induced by fluctuations in critical weather parameters like rainfall (Jodha, 1972). India, being a sub-tropical country is highly sensitive to climate change and its variability. The main reason for its high sensitivity is the variability in rainfall and temperature. Indian agriculture is more vulnerable to climate change, variability and adverse impacts are severe for India because of their heavy dependence on agriculture and lack of financial resources for mitigation to climate change and its variability.

Climatic variability is particularly more in the semi-arid tropics, Over 75 per cent of the cropped area of the country is in the semi-arid tropics, and it is the place where most drought prone areas lie which includes Maharashtra, Andhra Pradesh, Tamil Nadu and Karnataka. Maharashtra is one of the states which experienced a series of rainfall deficient years on the trot. In Marathwada region, frequent droughts have led to the failure of the crop and pushed farmers in to the debt trap. This has been evident in the number of farmer suicides (>1000 in 2015) in Marathwada region.

Indian Agriculture despite its declining share in National income continues to be an important sector of the economy because of its strategic importance to food security, livelihood and poverty reduction. It contributes nearly 16 percent of total Gross Domestic product, employing 57 percent of the population and contributing 10 percent of annual exports. But compared to other economic activities, Indian agriculture is more vulnerable to climate change, variability and adverse impacts are severe for India because of their heavy dependence on agriculture and lack of financial resources for mitigation to climate change and its variability.

Among the agro-ecological zones in India, Semi-arid zone plays a prominent place in the economy, contributing about 42 percent of total food grain production, supporting 60 percent of livestock population and employing nearly 37 percent of marginal farmers through

agricultural activities. This zone comprises parts of Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Deccan plateau and parts of Gujarat with the cultivation of major crops like Rice, Wheat, Sugarcane, Pulses, Sorghum, and Red gram. Despite its larger area under vegetation with 62 percent of cropped area and 55 percent of net sown area, this zone is susceptible with famine, water shortages land degradation and consider as most drought area with 34% (112 of 329 million ha).

Data and Methodology

Data Sources

District-wise data on Climatic variables like daily rainfall, temperature were collected from (Indian Metrological Organization) IMD. Although there are certain limitations of secondary data based assessments such as authenticity of data, data inconsistency in some cases and data gaps still the assessments provides a useful means of assessment at the macro level.

Methodology

a) Coefficient of variation of climatic variables in all districts of Marathwada region
b) Variation in annual and seasonal rainfall in all districts over period.
c) Spatial variation in rainfall across districts.
d) Correlation matrices of climatic variables across districts.

The initial segment portrays the pattern examination for climatic factors for all districts of Marathwada

1. Trend Analysis
2. The coefficient of variation of climatic variables of Marathwada region.
3. Variation in annual and seasonal rainfall in all districts over the period.
4. Spatial variation in rainfall across districts.
5. Correlation matrices of climatic variables across districts.

Table 1: Climate parameters in Marathwada region

	Rainfall(mm)			Number of rainy days(days)		
	Mean	SD	CV	Mean	SD	CV
Aurangabad	682.32	145.61	21.34	58	11.14	19.18
Beed	772.91	201.71	26.10	63	13.16	20.78
Jalna	738.13	151.79	20.56	64	12.38	19.25
Latur	840.58	272.10	32.37	58	10.05	17.21
Nanded	944.07	252.04	26.70	67	12.84	19.08
Osmanabad	725.33	192.99	26.61	71	11.62	16.35
Parbani	838.93	240.36	28.65	63	11.65	18.40
Hingoli	1003.93	594.77	59.24	59	10.87	18.30

Table 2: Temperature parameters in Marathwada region

	Maximum temperature(°C)			Minimum temperature(°C)		
Districts	Mean	SD	CV	Mean	SD	CV
Aurangabad	33.05	1.12	3.38	18.86	1.04	5.52
Beed	33.71	0.86	2.56	19.47	0.88	4.54
Jalna	33.77	0.84	2.49	19.40	0.89	4.61
Latur	33.85	1.24	3.66	20.31	0.85	4.19
Nanded	33.71	0.94	2.80	20.43	1.14	5.59
Osmanabad	33.72	1.42	4.21	20.22	0.95	4.72
Parbani	34.11	1.92	5.64	19.84	0.96	4.85
Hingoli	33.84	0.94	2.77	20.12	1.10	5.48

2. The coefficient of variation of climatic variables in Marathwada region.

The mean, standard deviation, and coefficient of variation of the climatic variables, namely, rainfall, the number of rainy days, maximum temperature, and minimum temperature for each district of Marathwada are calculated using daily data, results of which are illustrated in Table 1 and 2.

The study area Marathwada consists of eight districts namely Aurangabad, Beed, Jalna, Latur, Nanded, Osmanabad, Parbani, and Hingoli. The temporal analysis of climatic variables in each district indicated that in Aurangabad districts the mean annual rainfall was 682.32 mm during the study period (1990-2016), with a coefficient of variation of 21.34 percent.

Mean number of rainy days was about 58 with a variation of about 19.18 percent. Beed district having mean annual rainfall of about 772.91 coefficient of variation of (26.10%). As one can note both annual rainfall and its variability is higher for Beed compared to Aurangabad. In Beed average number of rainy days is 63, with a variation of 20.7 percent. Annual mean rainfall for Jalna district is about 738 mm with a variation of 20 percent and mean annual rainy days from study period was about 64 and with the variation of 19.25 percent. for Latur district the annual rainfall is about 840.58 mm with a coefficient of variation of 32.37 percent and annual mean rainy days is 58 with a variation of 17.21 percent, Nanded district annual mean rainfall is about 840.58 mm with coefficient of variation is 26.7 percent average number of rainy days is 67, with a variation of 19.08 percent, Osmanabad receiving an annual rainfall 725.33 mm with 26.6 percent of variation mean annual number of rainy days is 71, variation was about 16.3 percent, Parbhani receiving mean annual rainfall of 838.93 mm with 28.65 percent of variation and average number of rainy days is 63, with a variation of 18.4 percent, and finally Hingoli having high mean annual rainfall (1003.93) and also high variation(59.24) in rainfall compared with any other district of Marathwada and mean annual number of rainy days is 59, variation was about 18.3 percent.

The mean values of other important climatic factors, namely, average annual maximum temperature, and minimum temperature in the entire district were in the range of 33.05°C to 34.11°C and 18.86°C to 20.41°C, respectively. The variation of maximum temperature was found more in Parbhani and Osmanabad, variation for minimum temperature was found more in Nanded and Aurangabad. However, the coefficients of variation of the previously mentioned climatic variables were much less than the rainfall variability.

Table 3: Seasonal Distribution of Rainfall across Years

	Pre-monsoon (mm)			Monsoon (mm)			Post-monsoon (mm)		
Districts	MEAN	SD	CV	MEAN	SD	CV	MEAN	SD	CV
Aurangabad	142.6	85.1	59.7	436.0	99.4	22.8	86.6	68.0	78.5
Beed	158.3	70.9	44.8	476.0	163.0	34.3	102.2	67.1	65.7

Jalna	137.7	65.7	47.7	499.1	122.8	24.6	80.1	54.6	68.2
Lathur	158.4	72.4	45.7	551.0	226.8	41.2	106.5	67.5	63.4
Nanded	190.6	92.2	48.4	630.4	150.9	23.9	93.7	90.9	96.9
Osmanabad	152.7	65.1	42.6	451.9	147.9	32.7	100.2	53.8	53.7
Parbani	162.1	90.1	55.5	566.7	188.5	33.3	83.0	67.1	80.9
Hingoli	156.7	87.9	55.7	609.0	188.4	30.9	75.1	55.1	73.4

2. Variation in annual and seasonal rainfall in all districts over the period.

Table 3 represents seasonal rainfall received during pre-monsoon periods, monsoon period and post monsoon period in each district of Marathwada over the study period (1990-2016). The pre-monsoon periods indicates rainfall from April to June, monsoon period from July to September and post monsoon period from October to November. Variability was highest in case of post mansoon rainfall ranges from 53% to 96%, Aurangabad district was found to have highest variability followed by Hingoli. In pre monsoon rainfall variability ranges from 42% to 59%, Nanded is having highest variation followed by parbani, and monsoon rainfall variability ranges from 22% to 40% and Latur observed to be highest followed by parbani.

Table 4: Monthly average contribution of rainfall in different months

		Aurangabad			
Year	1990-1995	1996-2000	2001-2005	2006-2010	2011-2015
Jun	25.18	17.51	20.51	15.28	15.53
Jul	23.41	20.51	19.67	17.21	23.42
Aug	17.71	21.77	24.92	26.22	21.97
Sep	16.8	19.22	22.56	26.12	22.73
Oct	10.05	11.59	8.38	6.02	6.74
		Nanded			
Year	1990-1995	1996-2000	2001-2005	2006-2010	2011-2015
Jun	18.47	16.03	17.64	15.36	16.78
Jul	29	22.81	27.45	22.85	27.75
Aug	20.33	28.38	27.18	28.43	25.24
Sep	10.12	17.29	13.42	22.3	15.39
Oct	15.49	9.08	7.22	4.44	5.48

Table 5: Monthly average contribution of rainfall in different months

		Beed			
Year	1990-1995	1996-2000	2001-2005	2006-2010	2011-2015
Jun	21.54	14.74	17.68	15.04	12.68
Jul	21.34	18.58	22.98	16.44	26.26
Aug	19.2	22	22.08	24.88	23.65
Sep	16.38	21.28	17.19	26.81	19.27
Oct	12.14	12.9	11.6	6.99	8.21
		Osmanabad			
Year	1990-1995	1996-2000	2001-2005	2006-2010	2011-2015
Jun	17.37	14.83	16.46	16.31	11.9
Jul	22.33	17.56	19.7	15.62	25.6
Aug	16.22	21.24	22.28	23.16	22.86
Sep	15.29	24.14	19.2	28.32	19.5
Oct	15.81	13.91	11.14	6.93	8.91

Table 6: Monthly average contribution of rainfall in different months

		Jalna			
Year	1990-1995	1996-2000	2001-2005	2006-2010	2011-2015
Jun	16.2	18.99	15.43	13.22	14
Jul	19.56	18.75	33.14	23.7	26.35
Aug	24.91	21.63	18.89	28.31	22.95
Sep	20.03	17.13	19.47	22.72	22.34
Oct	12.18	14.28	7.52	4.3	6.93
		Parbani			
Year	1990-1995	1996-2000	2001-2005	2006-2010	2011-2015
Jun	26.36	14.09	16.43	13.71	13.89
Jul	26.43	19.46	32	25.38	27.9
Aug	18.43	27.81	22.71	30.9	22
Sep	11.92	21.66	13.65	20.4	19.01
Oct	7.41	11.45	11.18	3.85	5.53

Table 7: Monthly average contribution of rainfall in different months

		Lathur			
Year	1990-1995	1996-2000	2001-2005	2006-2010	2011-2015
Jun	18.79	12.06	12.56	14.96	12.23
Jul	22.61	19.36	33.28	17.88	27.36
Aug	19.66	26.68	19.55	25.87	24.83
Sep	13.64	18.88	16.4	26.11	15.85
Oct	13.72	13.16	9.85	6.31	9.47

		Hingoli			
Year	1990-1995	1996-2000	2001-2005	2006-2010	2011-2015
Jun	58.68	16.06	27.35	13.51	17.31
Jul	17.95	24.23	27.89	29.23	27.87
Aug	8.6	26.18	22.48	28.95	23.16
Sep	6.16	19.39	11.94	19.79	19.24
Oct	4.74	9.59	7.19	2.93	5.39

The table 3 to 7 indicates that contribution of the month to total rainfall. In Marathwada region, peak rainfall is during the month of June, July, August, September, and October contributing nearly 90 percent of total rainfall. The month August has the average highest contribution of total rainfall. It is observed that June and October rainfall has decreased sharply while, August and September rainfall has increased significantly. The main monsoon months are contributing less than the expected amount. It can be inferred from the above data that the distribution of rainfall became scattered than before and this indicates the clear deviation of rainfall pattern from the existing one.

Table 8: Rainfall in different cropping seasons of Marathwada

	Kharif			Rabi			Summer		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Aurangabad	561.2	109.2	19.5	95.1	75.2	79.1	26.0	34.9	134.0
Beed	601.2	176.4	29.3	111.5	76.7	68.8	45.3	44.1	97.3
Jalna	620.0	133.2	21.5	89.6	63.8	71.2	28.5	24.7	86.8
Latur	670.2	231.5	34.5	115.8	73.7	63.7	54.6	38.8	71.1
Nanded	795.5	188.8	23.7	106.9	109.2	102.2	41.7	35.3	84.8
Osmanabad	564.8	164.6	29.1	108.7	61.6	56.7	51.8	34.0	65.7
Parbani	709.9	203.1	28.6	94.3	74.8	79.3	34.7	40.6	116.9
Hingoli	891.3	577.8	64.8	85.9	65.7	76.5	26.7	32.4	121.3

In Maharashtra, the Kharif season from June to September, Rabi season from October to January and summer season from February to May. Rainfall during each of the seasons is calculated and presented in table 8. Amongst the seasons, Kharif season received the highest rainfall followed by Rabi and summer season. The coefficient of variation was highest for summer season followed by Rabi and Kharif. In Kharif rainfall Hingoli district receiving

highest mean rainfall it's also having high variation of 64%. In Rabi rainfall highest variation was found highest in Nanded followed by Aurangabad.

Table 9: Total rainfall in Marathwada region over the period (1990-2016)

Year	Mean(mm)	SD	CV	Year	Mean(mm)	SD	CV
1990	1143.76	272.92	23.86	2004	670.68	95.55	14.25
1991	623.45	93.27	14.96	2005	1207.96	426.24	35.29
1992	886.46	443.67	50.05	2006	905.19	85.58	9.45
1993	728.81	112.65	15.46	2007	713.21	58.48	8.2
1994	643.14	128.71	20.01	2008	660.4	75.04	11.36
1995	889.93	264.32	29.7	2009	705.21	72.56	10.29
1996	872.12	67.71	7.76	2010	1070.34	173.58	16.22
1997	862.48	141.8	16.44	2011	623.92	84.74	13.58
1998	1070.67	143.62	13.41	2012	600.34	159.42	26.56
1999	849.64	149.98	17.65	2013	1015.53	244.28	24.05
2000	778.04	134.79	17.32	2014	563.53	40.08	7.11
2001	822.3	128.72	15.65	2015	573.08	93.86	16.38
2002	742.14	102.21	13.77	2016	958.84	173.55	18.1
2003	699.71	178.17	25.46				

4.3 Spatial variation in rainfall across districts.

The rainfall across the district over the years is illustrated in Table 9 from 1990 to 2016. The spatial analysis of annual rainfall in each year measured in terms of coefficient of variation ranged from 23.86 per cent in 1990 to 18.10 per cent in 2016. Amongst the variability observed more in the year 1990, 1992, 1994, 1995, 2003, 2005, 2012, and 2013 ranging from 20 percent to 50 percent.

Table 10: Percent deviation of rainfall from mean in different years

	percent deviation of rainfall from mean				
Annual Rainfall(%)		South-west Monsoon Rainfall(%)		Post-Monsoon Rainfall(%)	
Negative years		Negative years		Negative years	
<-10%	1993,2000,2002	<-10%	1995, 2001, 2002	<-10%	1992,
-10 to -20%	2003, 2004, 2007, 2008, 2009	-10 to -20%	1991, 1993, 1997, 2008, 2009, 2011	-10 to -20%	2004
-20 to -30%	1991,1994,2011, 2012	-20 to -30%	1994, 2004	-20 to -30%	2012
-30 to -40%	2014,2015	-30 to -40%	2015	-30 to -40%	2000
-40 to -50%		-40 to -50%	2000, 2014	-40 to -50%	2007,
>-50%		>-50%		>-50%	1991, 2002, 2003, 2007 , 2008, 2011 , 2014, 2016
Positive years		Positive years		Positive years	
<10%	1995, 1996, 1997, 1999, 2001	<10%	1996 ,1999, 2000, 2007	<10%	1994, 2016
10 to 20%	2006,2016	10 to 20%	2006	10 to 20%	
20 to 30%	2013	20 to 30%	1990, 1998, 2013, 2016	20 to 30%	2009, 2010,
30 to 40%	1990,1992	30 to 40%	2010	30 to 40%	2013
40 to 50%	1998,2005	40 to 50%	1992, 2005	40 to 50%	1996
>50%		>50%		>50%	1990, 1993, 1995, 1997, 1998, 2001,

The extent of deviation of actual rainfall from the mean in Marathwada region was estimated using mean deviation represented in the table 10. The percentage deviations are grouped according to sign(positive year and negative year) are sub-grouped into six categories, less than 10 percent,10% to 20 %, 20% to 30%, 30% to 40%, 40% to 50% and more than 50% deviation from mean rainfall. A number of mean deviation years from annual rainfall seen more in the current decades except 2001, 2005, 2006, 2013, 2016. The actual annual rainfall was as low as 2014 and 2015, excess during 1998 and 2005. More Number of

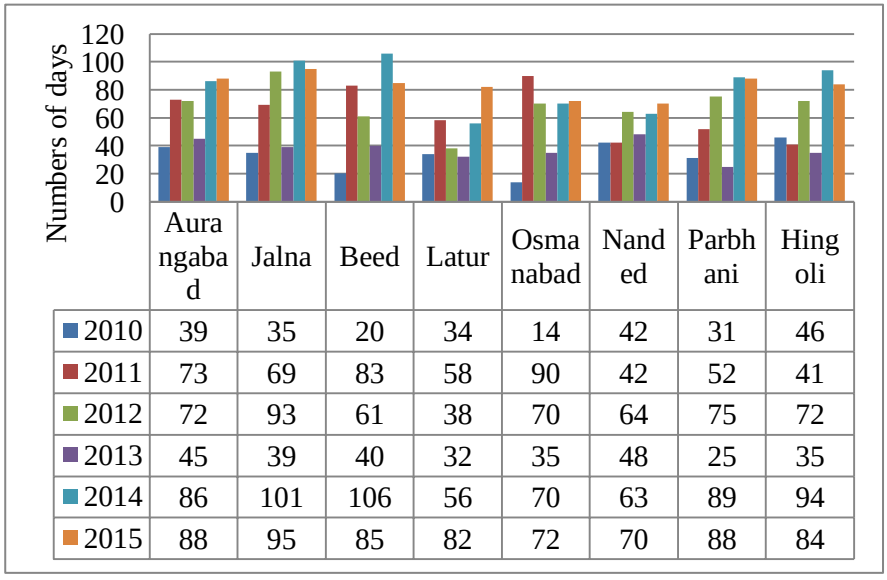
The mean deviation years are found from post-monsoon rainfall, with is widening more than 50% from its mean. A number of mean deviation years from southwest rainfall are found more in between -10% to -20%.

Table 11: Percent deviation of rainy days from mean annual rainy days

Negative years	
<-10%	1994, 2003, 2004, 2006, 2007, 2009
-10 to -20%	2000, 2001, 2008, 2011, 2012
-20 to -30%	1991, 1992
Positive years	
<10%	1993, 2005
10 to 20%	1996, 1997, 1999, 2013
20 to 30%	1990,1998, 2010,

Rainy days are most important for critical stages of crop plant. The percentage deviations of rainy days from mean are illustrated in Table 11. Most of the recent years have recorded less number of rainy days than the mean number of rainy days. Farmers in marathwad region was most vulnarable because of frequent drought years unable to cope with socioeconomical parameter.

Graph 1: Dry spell in Marathwada region



	Aurangabad	Jalna	Beed	Latur	Osmanabad	Nanded	Parbhani	Hingoli
2010	39	35	20	34	14	42	31	46
2011	73	69	83	58	90	42	52	41
2012	72	93	61	38	70	64	75	72
2013	45	39	40	32	35	48	25	35
2014	86	101	106	56	70	63	89	94
2015	88	95	85	82	72	70	88	84

From the agronomic point of view dry spell are equivalent to drought, though it is not considered as drought in terms of climatic magnitude. The dry spell is an interval between two wet spells of seven-day magnitude with at least 25 mm of rain. Five of these seven days must have rainfall of more than 1 mm or more. Dry spell at critical growth stages affects the growth and the ultimate production of the crop. The dry spell in a number of days is illustrated in the graph 1. Shows that dry spell in all districts in Marathwada is increasing sharply indicates distribution rainfall was scatty and agronomic rainy days were decreasing which is necessary during different growth period of plant.

4.4 Correlation matrices of climatic variables across districts.

The correlation across the all-district of Marathwada region for all climatic variables(mean annual) study period was estimated to know if the districts climatic variability is moving in same direction or not. Correlation matrixes for each of the climate variables, (viz., rainfall, maximum temperature, minimum temperature) are illustrated in Table 12, 13 and 14 respectively.

Table 12: Correlation matrix of rainfall across the districts of Marathwada

	Aurangabad	Beed	Jalna	Latur	Nanded	Osmanabad	Parbani	Hingol
Aurangabad	1.000							
Beed	0.472	1.000						
Jalna	0.156	0.483	1.00					
Latur	0.172	0.835	0.51	1.00				
Nanded	0.322	0.674	0.49	0.74	1.000			
Osmanabad	0.518	0.829	0.32	0.71	0.603	1.000		
Parbani	0.546	0.816	0.53	0.81	0.821	0.729	1.000	
Hingoli	0.028	0.293	0.35	0.32	0.291	0.080	0.431	1.000

In the case of the rainfall, the highest positive correlation was observed between Beed and Osmanabad districts (0.8298) followed by Latur and Beed (8.359) and Parbani and Nanded (0.821).

Table 13: Correlation matrix of maximum temperature across the districts of Marathwada

	Aurangabad	Beed	Jalna	Latur	Nanded	Osmanbad	Parbani	Hingoli
Aurangabad	1.0000							
Beed	0.7069	1.00						
Jalna	0.6358	0.95	1.00					
Latur	0.6669	0.96	0.95	1.00				
Nanded	0.6558	0.87	0.86	0.84	1.000			
Osmanabad	0.6171	0.88	0.91	0.90	0.736	1.0000		
Parbani	0.3403	0.35	0.33	0.35	0.158	0.2167	1.000	
Hingoli	0.5295	0.83	0.87	0.83	0.801	0.8164	0.286	1.0000

Correlation matric for maximum temperature illustrated in table 13, the highest positive correlation was observed between Latur and Beed districts (0.967) followed by Jalna and Beed (0.954), Osmanabad and Latur (0.912).

Table 14: Correlation matrix of minimum temperature across the districts of Marathwada

	Aurangabad	Beed	Jalna	Latur	Nanded	Osmanabad	Parbani	Hingoli
Aurangbad	1.000							
Beed	0.739	1.000						
Jalna	0.758	0.971	1.00					
Latur	0.574	0.942	0.91	1.00				
Nanded	0.778	0.976	0.95	0.89	1.000			
Osmanabad	-0.060	-0.036	0.00	-0.04	0.030	1.000		
Parbani	0.771	0.974	0.95	0.88	0.990	0.035	1.000	
Hingoli	0.749	0.988	0.96	0.92	0.989	-0.015	0.976	1.000

Table 14 indicate correlation matrix in minimum temperature, the highest positive correlation was observed between Parbani and Nanded (0.9899), followed by Hingoli and Nanded (0.9889), followed by Jalna and Beed districts (0.9716) followed by Parbani and Hingoli (0.9768). A negative correlation was observed between districts Aurangabad and Osmanabad (-0.06044), Osmanabad and Beed (-0.03621), Latur and Osmanabad (-0.04308), Osmanabad and Hingoli (-0.01518).

Summary

Agriculture in rainfed regions entirely depends on blessings of weather gods. Variability in climatic variables, affect the performance of crops and induce shifts in cropping pattern. It is important to study the behaviour of climatic variables over the years and farmer's perception about them as it can help in better understanding of intricacies of rainfed farming. With this thought in mind, the present study aims at understanding climatic variability in Marathwada region of Maharashtra. The climatic variables trend in last 25 years showed significant changes in total annual rainfall and annual average temperature. The amount of rainfall and minimum winter temperature has decreased from past while, the maximum temperature has increased. The deviations of rainfall and rainy days have increased indicating erratic rainfall pattern.

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