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Rainfall Analysis and Its Prediction for the Marathwada Region

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Abstract:
Rainfall is a crucial parameter of the water cycle. Knowledge of rainfall and its circulation in the water cycle is important for the development of the agricultural sector and water resource management. Rainfall is varied from location to location. Thus, the study of rainfall variability and its prediction having great significance for economic development. The present work aimed to find rainfall trends, rainfall patterns and predict future rainfall for the Marathwada region of Maharashtra, India. In this study, 120-years of monthly rainfall data of the Marathwada Region were collected and analyzed statistically. Precipitation concentration index (PCI) and Seasonality index (SI) were used to identify rainfall regimes. Also, the Analysis of Variance (ANOVA) model was used to find the rainfall trends and the Auto Regressive integrated moving average (ARIMA) model was used to predict future rainfall. Results show that there were monthly, seasonal and annual rainfall trends in the Marathwada region. South-west Monsoon alone contributes 80% or more rainfall of annual rainfall. All districts in the Marathwada have high precipitation concentrations and most rainfall is received in 3 months or less. From the study, it was concluded that in Marathwada, rainfall is strongly irregular and concentrated over 3 months and less. Predicted annual rainfall for the years 2021 to 2025 shows decreasing rainfall trend over the next five years. All the test results revealed a good agreement among them in the study.
***Key Word**: Rainfall Trend, ANOVA, Precipitation Concentration Index, Seasonality Index, ARIMA Model.*

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I. Introduction

Water is a valuable natural resource and vital for all living things. The main natural source of water is rain and it's an important part of the water cycle. Availability of water for specific areas largely depends upon the pattern of rainfall receive and its conservation. Developing countries like India largely depend upon rainfall for agriculture purposes. It is crucial for disaster management and hydrological planning for the country. (Adler et al. 2000) stated that region wise information about rainfall is important to study hydrology balance on a global scale. It helps to understand complex interactions among the components within the hydrologic cycle. The rainfall received in an area is an important factor in determining the amount of water available to meet various demands, such as agricultural, industrial, domestic water supply, and hydroelectric power generation. It is also important for the prediction of stream flow, reservoir inflow, and water quality variable as well as the simulation of climate change impact. Rainfall is a prime input source in all types of hydrological modeling. It also helps to predict flood and management of irrigation projects and agricultural production (Nirmala, 2015);(Kipkorir, 2000). Considering the increasing demand for water and the limitation of availability of freshwater its future prediction is necessary. Growing water demand for the agriculture sector and its optimized allocation is always a challenge for the government. Nowadays this demand has been further increased due to the increase in population and the associated expansion of urbanization and economic activities (Herath and Ratnayake, 2004). It imposes tremendous pressure on inadequate water resources. This, knowledge of rainfall pattern, its trend and study of its variability are important.

Many past researchers reported seasonality in rainfall (Rajakumara et al. 2019) (Guhathakurta and Rajeevan 2006). Seasonality is a meteorological phenomenon that shows increasing and decreasing patterns of rainfall. (Rai and Dimri 2019) studied 80% Indian summer monsoon (June-Sep) contributes 80% of the total rainfall and some contributions from winter monsoon (Nov-Jan). Hence, rainfall variations over India are seasonal. It makes this region have various rainfall regimes. This shows the need of understanding rainfall variability location wise/region wise. Hence Purpose of the present work is to study rainfall trends and prediction of future rainfall. According to (Sharma and Singh 2019) 40% Indian population depends on the monsoon for irrigation. Thus, it is very important to examine the changes in seasonality. From several past pieces of research, it observed that markedly seasonal rainfall variability over India. (Sharma and Singh 2019); (Nair et al. 2014). (Guhathakurta and Saji 2013) analyzed spatial rainfall patterns over the districts of Maharashtra, India. Their analysis indicated all the rain occurs in one to two months, in contrast to the western and eastern regions. Patil (2015) worked for the Sangli district of Maharashtra showed that most of the rainfall occurs in less than three months. (Rai and Dimri 2019) calculated rainfall seasonality over India, results show a declining trend in the seasonality index. (Nandargi et al. 2017) studied rainfall variability over the Indian region and concluded that rainfall is markedly seasonal with a long dry season and the most rainfall in less than three months. Therefore, the present study mainly focuses on rainfall variability over Marathwada Region, Maharashtra, India to get an idea about rainfall distribution. It will helpful for the decision-maker to optimize the planning of water resources. Even though a large amount of research work has been done and is still ongoing on rainfall variability so far, no studies have work for Marathwada as a whole region.

II. Material And Methods

The data used in the study consists of monthly mean values of rainfall in millimeters. The data spanned over 120 years, from the year 1901 to 2020. The data was collected district wise from the 'India Wris' website. (https://indiawris.gov.in).

Study Area:

Marathwada is a region of the Indian state of Maharashtra. The region coincides with the Aurangabad Division of Maharashtra. Geographical boundary latitudes 17°37' to 20°39' 19°.87' N and 74°33' to 78°22' East longitudes in the Maharashtra state of India. Fig. 1 shows the location. Total area coverage has 64,590 sq. km, which constitutes around 21% area of the Maharashtra state. The region comprising the eight districts of (divisional headquarters) Jalna, Aurangabad, Parbhani, Hingoli, Nanded, Latur, Osmanabad and Beed. The largest city of Marathwada is Aurangabad. The River Godavari acts as the lifeline for the selected study area. The region lies in the rain shadow zone of the Sahyadri mountain range in the Western Ghats of Maharashtra state. While almost three quarters of the land in the Marathwada division is cultivated.

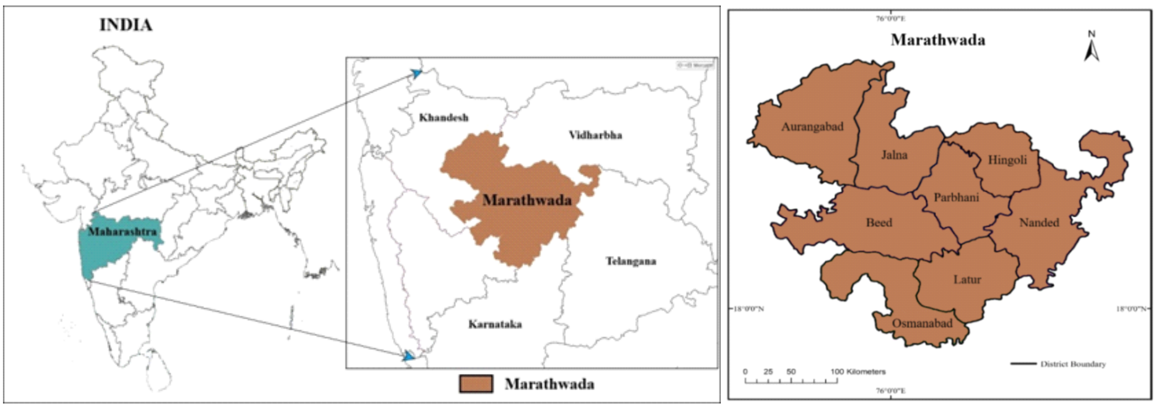


Fig:1 Location map of study area

Methodology Used:

(a) Statistical Analysis of rainfall data:

The statistical analysis was used to determine the measure of central tendency i.e. mean and to check the variation in rainfall data by using the coefficient of variability and standard deviation as a statistical parameter. Along with this skewness and Kurtosis were also used to check symmetry and peakedness or flatness in the data respectively. All calculations were performed in M S Excel using standard formulae.

Along with the above statistical parameters, the contribution of rainfall in each season i.e. winter (Jan-Feb), Pre monsoon (Mar-May), Monsoon (Jun-Sep), Post monsoon (Oct-Dec) out of annual rainfall was also calculated..

(b) Trend analysis of rainfall data:

To study seasonal variation and trend in rainfall Analysis of variance (ANOVA) were used. ANOVA is a collection of statistical models and their associated estimation procedures (such as the "variation" among and between groups) used to analyze the differences among means. ANOVA was evaluated for each month and season in Excel which gives us t value and P value. The t value shows increasing or decreasing trends of rainfall. P value uses to find whether the trends are significant or not significant. P value less than 0.05 represents trends significant at 95% significance level and P value less than 0.1 represents trends significant at 90% significance level otherwise trends are not significant. The t value shows increasing or decreasing trends of rainfall.

(c) Find the Precipitation Concentration Index:

The precipitation concentration index is recommended as an indicator of precipitation attentiveness. It is an index to analyze the heterogeneity of precipitation and the relationship between variability and monthly precipitation distribution. Precipitation Concentration Index (PCI) was proposed by Oliver (1980). The PCI was computed on an annual scale according to the following formula:

$$PCI_{annual} = \frac{\sum_{i=1}^{12} P_i^{\,2}}{(\sum_{i=1}^{12} P_i)^2}$$

Where,

PCI denotes the precipitation concentration index,

Pi represents the monthly precipitation in month 'i'.

Table 1 shows various classes of PCI and corresponding rainfall regime. Along with precipitation concentration index, frequency of classification of precipitation concentration index all ranges given in table also computed district wise to find rainfall concentration of particular district.

Table 1: Precipitation Concentration Index (PCI) classes wise different rainfall regime

PCI	Rainfall regime
<10	Uniform precipitation concentration
11 - 15	Moderate precipitation concentration
16 - 20	Irregular precipitation concentration
>20	Strongly irregular precipitation concentration

(d) Find the Seasonality Index:

Seasonality is a characteristic of a time series in which the data experiences regular and predictable changes that recur every calendar year. The seasonality index is a numerical value used to evaluate seasonal trends in rainfall. The seasonality Index helps in identifying the rainfall regimes based on the monthly distribution of rainfall. Seasonality Index was computed using the following formula:

$$SI = \frac{1}{R} \sum_{n=1}^{12} \left| Xn - \frac{R}{12} \right|$$

Where, Xn is the mean rainfall of month 'n' and R is the mean annual rainfall.

We already have mean rainfall and also calculate mean annual rainfall for each year in statistical analysis. So, the Annual seasonality index can calculate. Theoretically, they can vary from zero (if all the months have equal rainfall) to 1.83 (if all the rainfall occurs in one month). Table 2 shows the different class limits of SI and representative rainfall regimes.

Along with the annual seasonality index, the frequency of all ranges classification of seasonality index which is given in table also computed district wise to find rainfall regime of a particular district.

Table 2: Seasonality Index (SI) classes and the associated different rainfall behavior

SI	Rainfall Regime
≤ 0.19	Very equable
0.20 - 0.39	Equable but with a definite wetter season
0.40 – 0.59	Rather seasonal with a short drier season
0.60 – 0.79	Seasonal
0.80 – 0.99	Markedly seasonal with a long drier season
1.00 -1.19	Most rain in 3 months or less

≥ 1.2	Extreme, almost all rain in 1- 2 months

(e) Predict rainfall using ARIMA model:

The Auto regressive integrated moving average (ARIMA) model is fundamentally a linear statistical technique for modeling the time series and rainfall forecasting with ease to develop future predictions. The model consists of AR, I, and MA. Here AR represents the Autoregressive model, I represent the Integration indicating the order of a single integer, and MA represents the Moving Average model.

ARIMA modeling was done in XLSTAT, 2015 software by using past annual rainfall of 120 years, from the year 1901 to 2020. XLSTAT is an Excel data analysis add-on that allows time series analysis. The software was used to predict the future annual rainfall of the next five years from the year 2021 to 2025.

III. Result and Discussion

A. Statistical analysis of rainfall data:

Table 4 shows the statistical parameters of rainfall data of 120 years (i.e. 1901 to 2020) for the whole Marathwada region. July month shows the highest monthly rainfall followed by September, October, and June. Most of the rainfall (698.72mm) falls in the monsoon (SW monsoon) period. The average annual rainfall of Marathwada is about 832.44mm. The standard deviation and range of July, August and September has a high value which shows high uncertainty in rainfall data. The coefficient of variance of June, July, August, and September is less than 0.6 which indicates lower variability from the mean. The coefficient of variance of annual rainfall is 0.28 which is less. It indicates a high reliability of the experiment like trend analysis, forecasting, etc. All positive kurtosis value of data indicates a peaked distribution of rainfall data. Also, all positive values for the skewness indicate that data are skewed to the right to normal distribution.

Table 4: Statistical summary of rainfall data for Marathwada Region

Parameters →	Mean	S.D.	C.V.	Skewness	Kurtosis
Jan	5.54	11.71	2.11	3.37	13.18
Feb	5.20	11.10	2.14	3.49	15.40
Mar	7.88	13.75	1.75	3.09	12.31
Apr	8.64	12.36	1.43	3.56	19.34
May	16.23	23.20	1.43	2.89	10.66
Jun	144.52	70.28	0.49	0.82	1.22
Jul	197.10	102.50	0.52	1.49	7.20
Aug	179.38	101.1	0.56	1.29	2.63
Sep	177.73	94.75	0.53	0.69	0.47
Oct	61.79	56.72	0.92	1.44	3.05
Nov	21.41	35.80	1.67	2.74	9.03
Dec	7.04	16.46	2.34	3.99	20.16
Annual	832.44	235.13	0.28	1.20	5.48
Winter	10.73	15.67	1.46	2.17	5.12
Pre Monsoon	32.75	29.36	0.90	1.58	2.90
Monsoon	698.72	215.10	0.31	1.28	5.41
Post Monsoon	90.23	65.03	0.72	0.97	0.94

Table 5 and Table 6 show the mean rainfall (mm) and coefficient of variation of each eight districts of Marathwada for the months, annual, during the period 1901-2020. The highest annual rainfall receives over the Nanded district (980.91 mm) while the lowest annual rainfall receives over Aurangabad district (719.53 mm).

Table 5: Mean rainfall and coefficient of variance of Aurangabad, Beed, Hingoli, Jalna.

Districts	Aurangabad		Beed		Hingoli		Jalna	
Parameters	Mean	C.V.	Mean	C.V.	Mean	C.V.	Mean	C.V.
Jan	4.73	2.11	4.52	2.31	6.94	1.84	5.59	1.98
Feb	2.62	2.17	3.34	2.05	7.64	2.04	3.93	2.17
Mar	4.90	2.13	6.68	1.86	9.13	1.65	6.59	1.94
Apr	3.88	1.85	8.50	1.34	7.44	1.61	5.88	1.96
May	14.23	1.69	16.26	1.36	11.92	1.56	14.25	1.65

Jun	132.61	0.45	133.38	0.46	166.99	0.49	148.67	0.47
Jul	167.30	0.47	154.61	0.50	244.31	0.43	197.39	0.59
Aug	146.65	0.52	144.75	0.57	218.44	0.52	170.02	0.55
Sep	155.50	0.52	182.92	0.50	172.14	0.56	158.80	0.54
Oct	53.32	1.03	66.00	0.84	53.90	0.97	55.13	0.99
Nov	25.68	1.70	23.32	1.61	18.59	1.69	23.34	1.73
Dec	8.10	2.30	7.74	2.27	7.35	2.52	8.54	2.29
Annual	719.53	0.26	752.03	0.25	924.79	0.25	798.12	0.32

Table 6: Mean rainfall and coefficient of variance of Latur, Nanded, Osmanabad, Parbhani.

Districts	**Latur**		**Nanded**		**Osmanabad**		**Parbhani**	
Parameters	Mean	C.V.	Mean	C.V.	Mean	C.V.	Mean	C.V.
Jan	5.25	2.16	7.20	1.97	4.12	2.46	5.94	2.13
Feb	6.08	1.85	8.81	1.81	3.21	2.24	5.95	1.87
Mar	9.31	1.51	10.25	1.54	6.88	1.57	9.30	1.78
Apr	13.66	1.12	10.54	1.23	12.37	1.12	6.87	1.42
May	21.46	1.20	14.27	1.43	23.83	1.13	13.62	1.51
Jun	137.05	0.45	161.44	0.48	125.41	0.46	150.56	0.53
Jul	190.01	0.46	260.15	0.42	143.70	0.51	219.36	0.47
Aug	178.51	0.51	238.05	0.47	139.81	0.58	198.78	0.53
Sep	191.93	0.50	185.98	0.54	189.08	0.49	185.47	0.56
Oct	70.39	0.80	62.48	0.97	73.49	0.77	59.57	0.98
Nov	21.07	1.54	16.36	1.55	23.55	1.50	19.35	1.86
Dec	5.55	1.88	5.39	2.22	5.83	2.06	7.79	2.49
Annual	850.28	0.24	980.91	0.25	751.29	0.24	882.59	0.26

B. Contribution of seasonal rainfall:

Table 7 shows the seasonal rainfall of winter, pre-monsoon, monsoon, post-monsoon and annual for all eight districts in Marathwada. In monsoon, Nanded receives the highest rainfall (845.61 mm) while Aurangabad receives the lowest rainfall (602.06 mm). In Post monsoon i.e. In the North-East monsoon Osmanabad has topped with rainfall 102.87 mm while Aurangabad and Hingoli have the lowest rainfall of 79.85 mm.

Table 7: Seasonal Rainfall of Districts in mm.

Districts	**Winter**	**Pre Monsoon**	**Monsoon**	**Post Monsoon**	**Annual**
Aurangabad	7.35	23.01	602.06	87.11	719.53
Beed	7.86	31.44	615.67	97.06	752.03
Hingoli	14.58	28.48	801.87	79.85	924.79
Jalna	9.51	26.72	674.88	87.01	798.12
Latur	11.33	44.43	697.51	97.01	850.28
Nanded	16.01	35.06	845.61	84.22	980.91
Osmanabad	7.33	43.08	598.01	102.87	751.29
Parbhani	11.89	29.80	754.18	86.71	882.59

Table 8 shows the percentage of share of seasonal rainfall out of total annual rainfall. All districts contribute above 80% of Monsoon rainfall except Osmanabad contributes 79.60% which close to 80%. It shows that most of the rainfall falls in the monsoon period (South-West monsoon). Winter contributes below 2%, Pre-monsoon contributes below 4% and Post monsoon contributes below 14% of total annual rainfall.

Table 8: Contribution of seasonal rainfall of district in each season in % of annual rainfall

District	**Winter**	**Pre Monsoon**	**Monsoon**	**Post Monsoon**
Aurangabad	1.02 %	3.20 %	83.67 %	12.11 %
Beed	1.05 %	4.18 %	81.87 %	12.91 %
Hingoli	1.58 %	3.08 %	86.71 %	8.63 %
Jalna	1.19 %	3.35 %	84.56 %	10.90 %

Latur	1.33 %	5.23 %	82.03 %	11.41 %
Nanded	1.63 %	3.57 %	86.21 %	8.59 %
Osmanabad	0.98 %	5.73 %	79.60 %	13.69 %
Parbhani	1.35 %	3.38 %	85.45 %	9.83 %

C. **Trends in district rainfall**:

Table 9 shows the details of the result of trend analysis in monthly, seasonal (winter, pre-monsoon, monsoon, post-monsoon) and annual rainfall for all districts in Marathwada. Trend analysis was done by the ANOVA model which gives us P value and corresponding t value. P value indicates whether trends are significant or not significant. P value less than 0.05 represents trends significant at 95% significance level and P value less than 0.1 represents trends significant at 90% significance level. If P value is greater than 0.1 then the trend is not significant. The t value shows increasing or decreasing trends of rainfall.

Table 9: Increasing/decreasing trends in rainfall for the districts of Marathwada.

District	Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter	Pre	Mon	Post	Annual
Aurangabad	P value	0.012	0.171	0.262	0.079	0.295	0.440	0.257	0.041	0.431	0.219	0.573	0.486	0.005	0.329	0.788	0.662	0.697
	t value	-2.553	-1.376	1.127	-1.773	-1.053	-0.774	-1.139	2.061	-0.790	1.235	-0.565	-0.698	-2.871	-0.981	-0.270	0.439	-0.391
Beed	P value	0.080	0.179	0.191	0.288	0.519	0.423	0.792	0.063	0.325	0.008	0.200	0.367	0.021	0.704	0.962	0.223	0.853
	t value	-1.763	-1.353	1.314	-1.067	-0.646	-0.804	-0.264	1.873	-0.988	2.683	-1.289	-0.905	-2.339	-0.381	-0.047	1.226	0.185
Hingoli	P value	0.155	0.016	0.924	0.095	0.085	0.556	0.589	0.169	0.091	0.057	0.141	0.322	0.004	0.054	0.941	0.566	0.709
	t value	-1.432	-2.440	0.096	-1.685	-1.737	0.591	-0.542	1.385	-1.705	1.918	-1.481	-0.996	-2.959	-1.945	-0.074	0.576	-0.374
Jalna	P value	0.014	0.049	0.529	0.142	0.197	0.051	0.269	0.284	0.309	0.071	0.201	0.105	0.001	0.182	0.277	0.818	0.221
	t value	-2.500	-1.992	0.631	-1.479	-1.298	-1.973	-1.110	1.077	-1.021	1.821	-1.286	-1.632	-3.298	-1.341	-1.092	0.231	-1.230
Latur	P value	0.345	0.159	0.411	0.218	0.839	0.566	0.283	0.235	0.017	0.003	0.338	0.103	0.077	0.689	0.173	0.058	0.394
	t value	-0.949	-1.417	0.825	-1.239	-0.203	-0.575	-1.079	1.193	-2.419	3.002	-0.962	-1.642	-1.785	-0.401	-1.370	1.914	-0.855
Nanded	P value	0.785	0.010	0.581	0.117	0.530	0.334	0.596	0.104	0.050	0.030	0.246	0.194	0.029	0.396	0.991	0.177	0.938
	t value	-0.274	-2.626	0.553	-1.581	-0.629	0.970	-0.531	1.639	-1.982	2.202	-1.167	-1.307	-2.217	-0.853	0.011	1.359	0.078
Osmanabad	P value	0.230	0.390	0.173	0.244	0.870	0.788	0.991	0.118	0.354	0.013	0.232	0.106	0.120	0.855	0.880	0.230	0.667
	t value	-1.207	-0.862	1.372	-1.172	-0.164	-0.269	0.011	1.575	-0.930	2.525	-1.202	-1.629	-1.567	-0.183	0.152	1.207	0.431
Parbhani	P value	0.218	0.052	0.803	0.421	0.280	0.513	0.766	0.205	0.081	0.045	0.159	0.274	0.019	0.329	0.540	0.510	0.531
	t value	-1.238	-1.966	0.250	-0.808	-1.086	-0.657	-0.299	1.275	-1.759	2.024	-1.417	-1.098	-2.381	-0.980	-0.614	0.661	-0.629

Significant Increasing (95%)
Significant decreasing (95%)
Significant Increasing (90%)
Significant decreasing (90%)
Increasing but not significant
Decreasing but not significant

Fig.2 shows the trends in the monthly rainfall, seasonal and annual rainfall over the districts of Marathwada in the pictorial map. June rainfall has shown a significant decreasing trend in the district Jalna while no district has shown any significant trend. For July month, there is no significant trend has been noticed. Aurangabad and Beed's districts have shown a significant Increasing trend in August rainfall while September rainfall of Parbhani, Hingoli, Latur, Nanded has shown a significant increasing trend. During pre-monsoon season only one district viz. Hingoli has shown a significant decreasing trend. In the monsoon season, there is no significant trend has been noticed. During Post monsoon (Southwest monsoon) significant increasing trend has been noticed in the Latur district. The annual rainfall shows no significant trend.

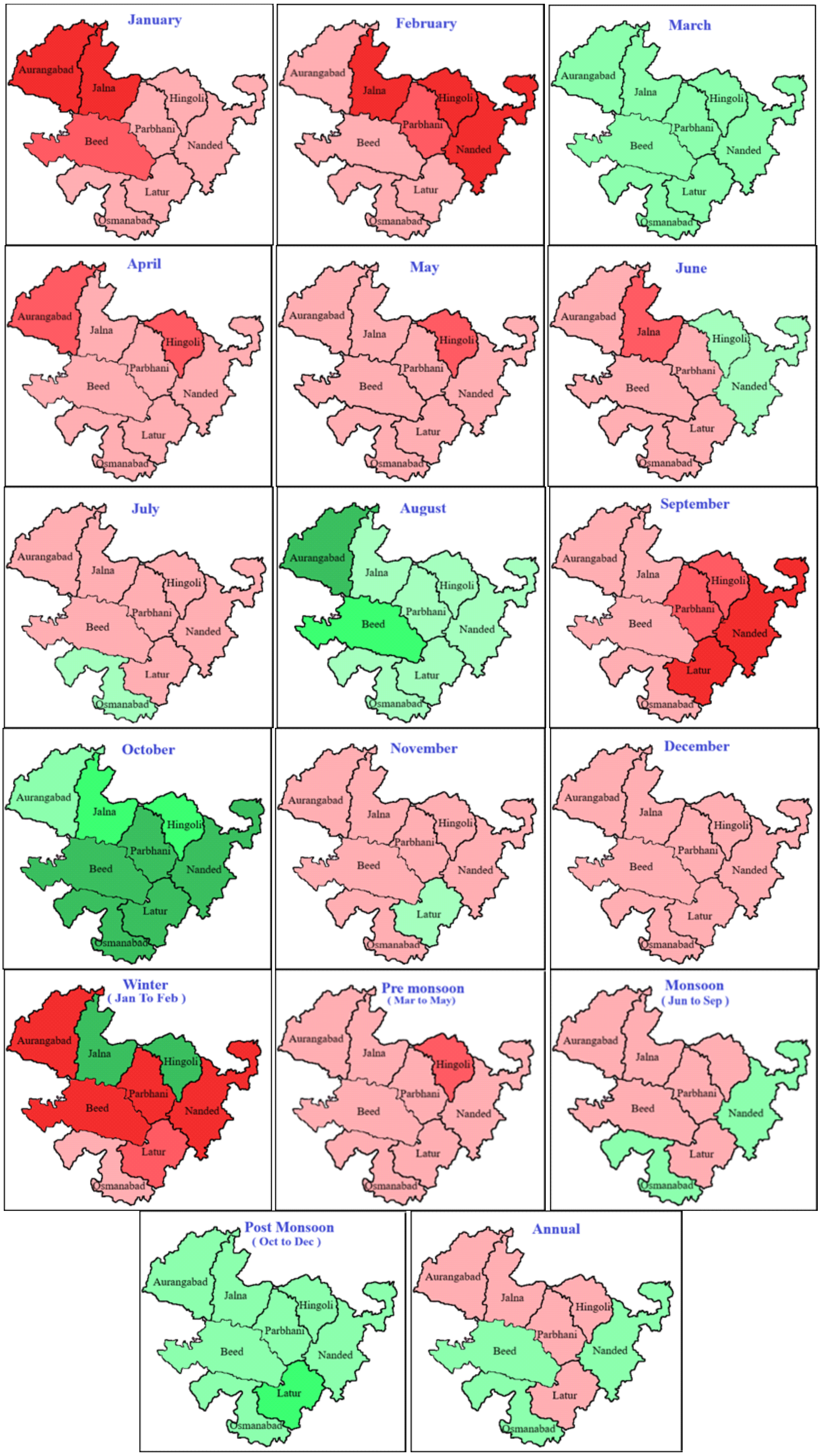


Fig.2 Trends in monthly rainfall, seasonal rainfall and annual rainfall in all districts of Marathwada.

D. **Identify rainfall regime using Precipitation Concentration Index:**

Figure 4 shows the Rainfall Seasonality Index of all eight districts in Marathwada for 120 years (1901-2020). It was observed that most of the value of the Precipitation Concentration Index (PCI) was greater than 20.

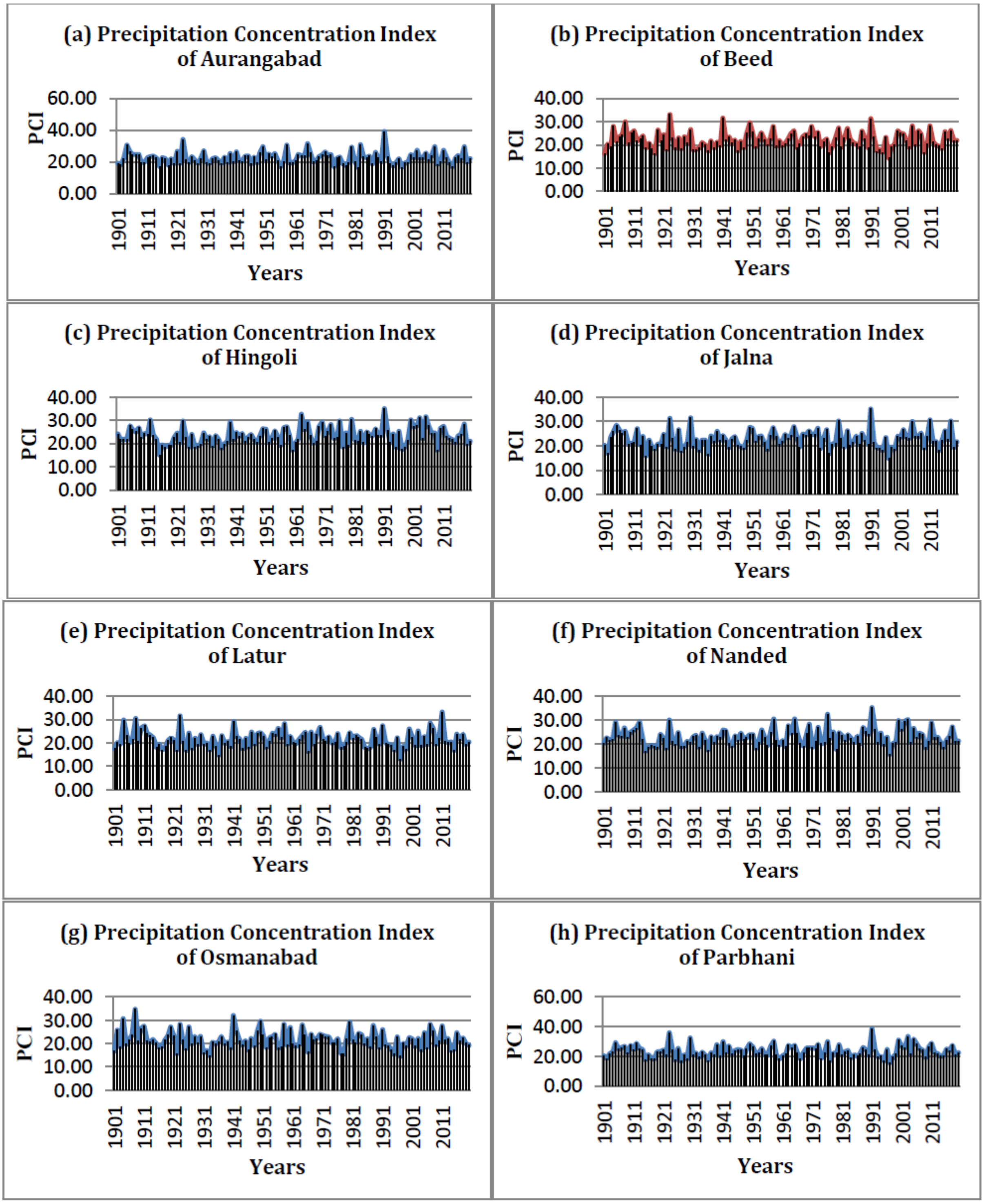


Fig.4 Precipitation Concentration index of district (a) Aurangabad, (b) Beed, (c) Hingoli, (d) Jalna, (e) Latur, (f) Nanded, (g) Osmanabad and (h) Parbhani for years 1901 to 2020

On the other hand, Fig. 5 shows 'the frequency of PCI values' plot under 'Classification of PCI' for all districts of Marathwada. It was used to identify how many PCI values fall under various classes of PCI. In the following plots, it was observed that all districts show maximum frequency of PCI values for class 'greater than

20'. It indicates that all districts (Aurangabad, Beed, Hingoli, Jalna, Latur, Nanded, Osmanabad and Parbhani) have strongly irregular precipitation distribution i.e. high precipitation concentration.

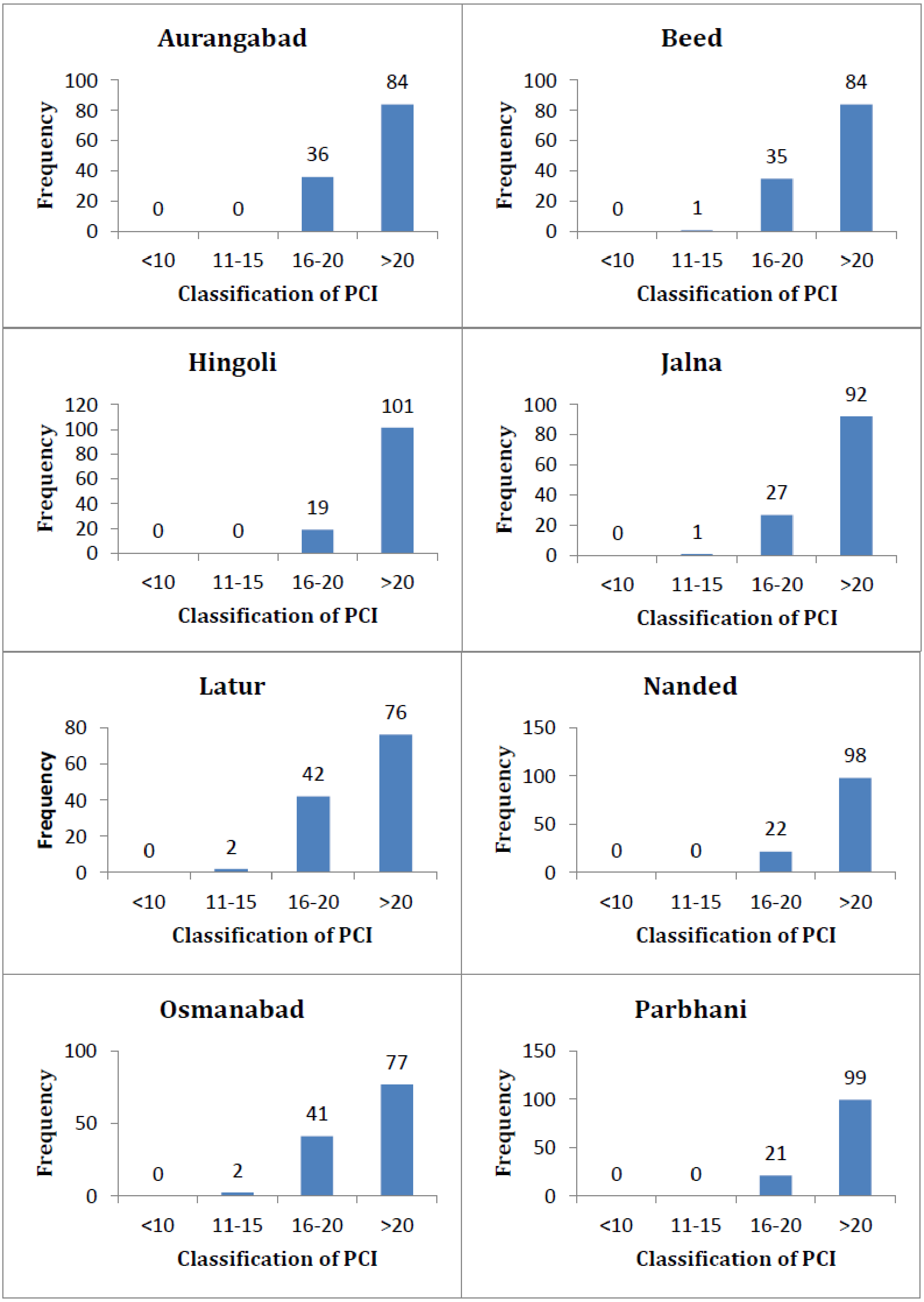


Fig. 5 District wise frequency of Precipitation concentration index

E. Identify rainfall regime using Seasonality Index:

Figure 6 shows the Rainfall Seasonality Index of all eight districts in Marathwada. The change of Seasonality Index depends on the variation of amount Rainfall therefore the fluctuations are clear in figures.

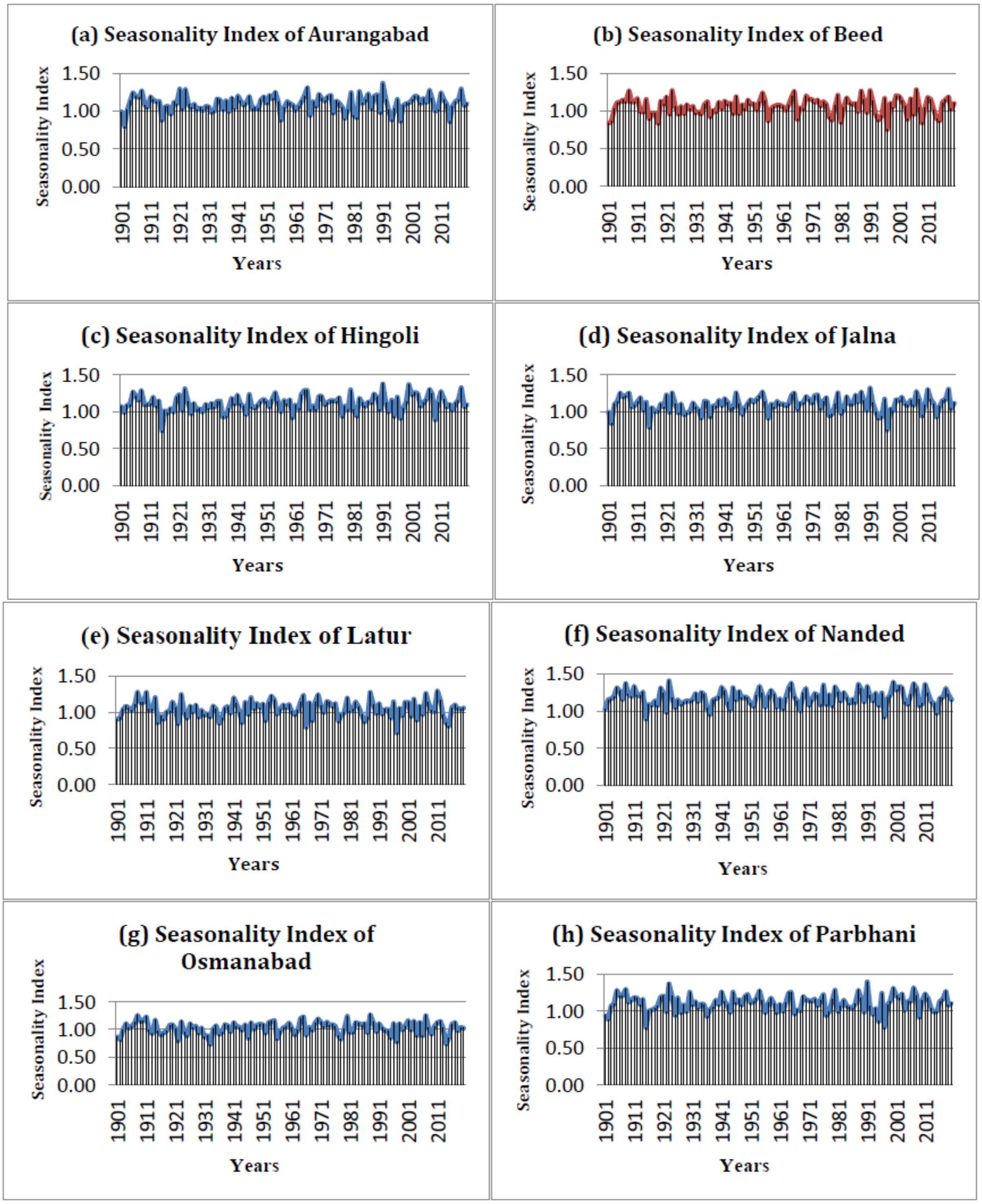


Fig.6 Seasonality index. of district (a) Aurangabad, (b) Beed, (c) Hingoli, (d) Jalna, (e) Latur, (f) Nanded, (g) Osmanabad and (h) Parbhani for years 1901 to 2020

Also, Fig. 7 shows the 'frequency of seasonality index' to 'classifications of seasonality index' plot for all districts of Marathwada. It shows a frequency distribution of SI values over various classes of SI. Aurangabad, Beed, Hingoli, Jalna, Latur, Osmanabad and Parbhani recorded the maximum frequency of SI for range (1.00 – 1.19) which shows most rains received in 3 months or less. Nanded district recorded range (1.00 –

1.19) and (≥ 1.2) at frequency 59 and 56 respectively which shows the most rainfall received in 3 months or less or rainfall receives in almost all rain in 1- 2 months.

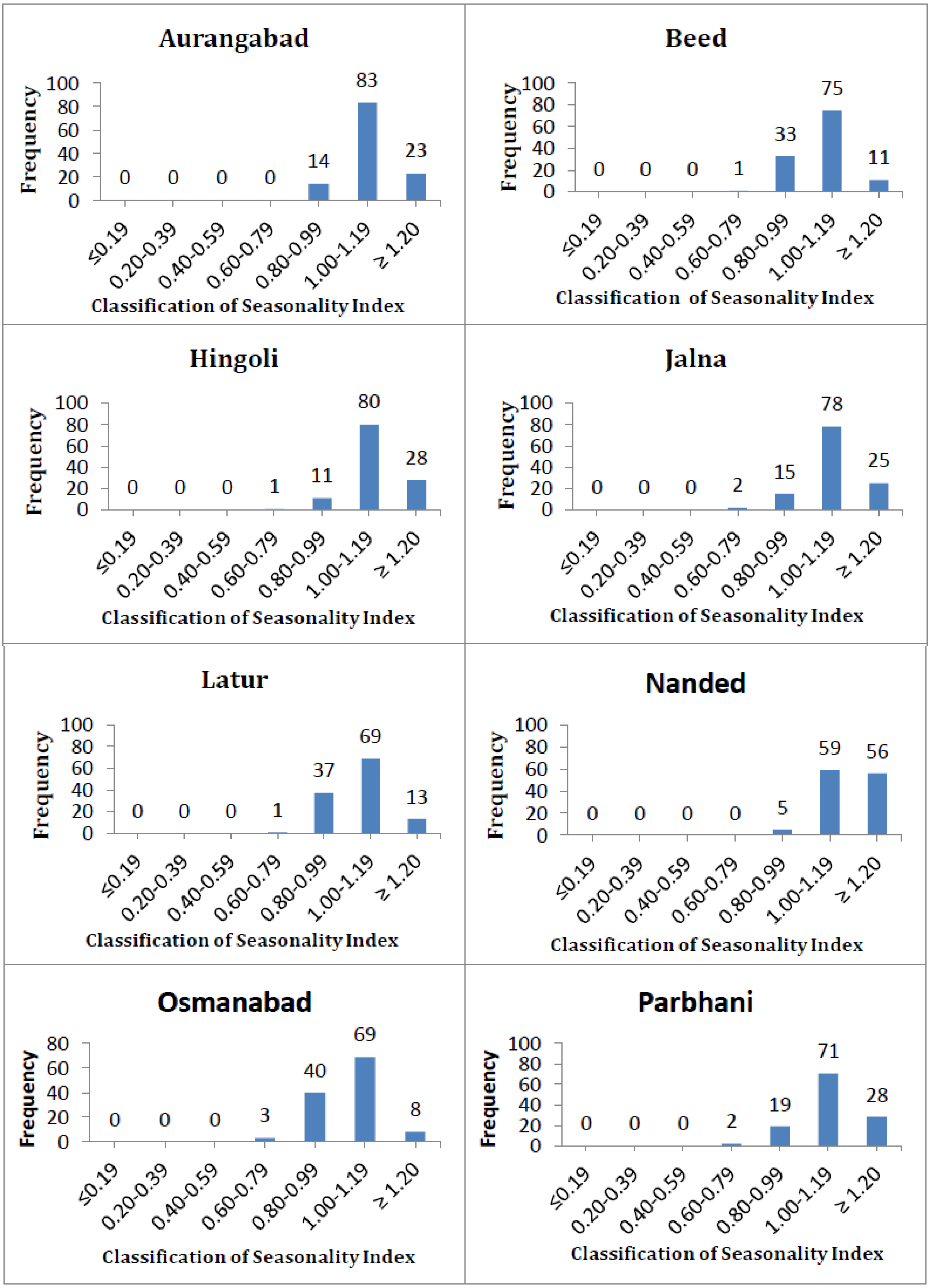


Fig.7 District wise frequency of Seasonality Index.

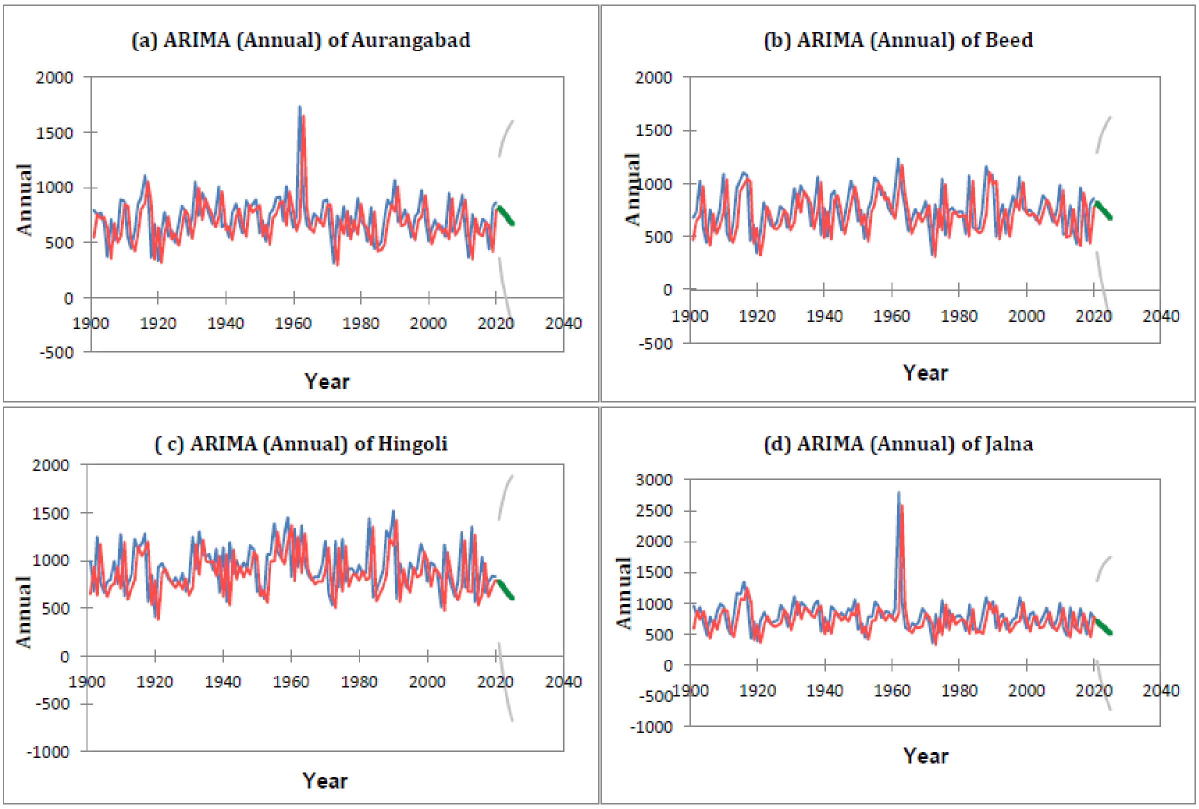
F. Prediction of Annual rainfall:

Rainfall of the next 5 years from the year 2021 to 2020 was computed by using the ARIMA model in XLSTAT software. Predicted annual rainfall for the 2021-2025 periods is given in Table 10 and Table 11.

Fig.8 shows the ARIMA annual rainfall with actual rainfall of all districts. The blue graph shows actual annual rainfall while the red graph shows ARIMA Annual and the green line shows the predicted annual rainfall values. ARIMA shows a decreasing trend in annual rainfall for all districts.

Table 10: Predicted annual rainfall for Aurangabad, Beed, Hingoli, Jalna districts for 2021-2025 periods

Years	Aurangabad	Beed	Hingoli	Jalna	Latur	Nanded	Osmanabad	Parbhani
2021	819.36	820.20	779.38	711.74	917.16	920.49	911.52	806.83
2022	778.46	780.23	730.64	655.34	872.09	864.20	870.48	757.64
2023	739.61	742.20	684.95	603.42	829.24	811.35	831.28	711.44
2024	702.70	706.02	642.11	555.61	788.49	761.73	793.85	668.07
2025	667.62	671.61	601.95	511.59	749.75	715.14	758.11	627.33



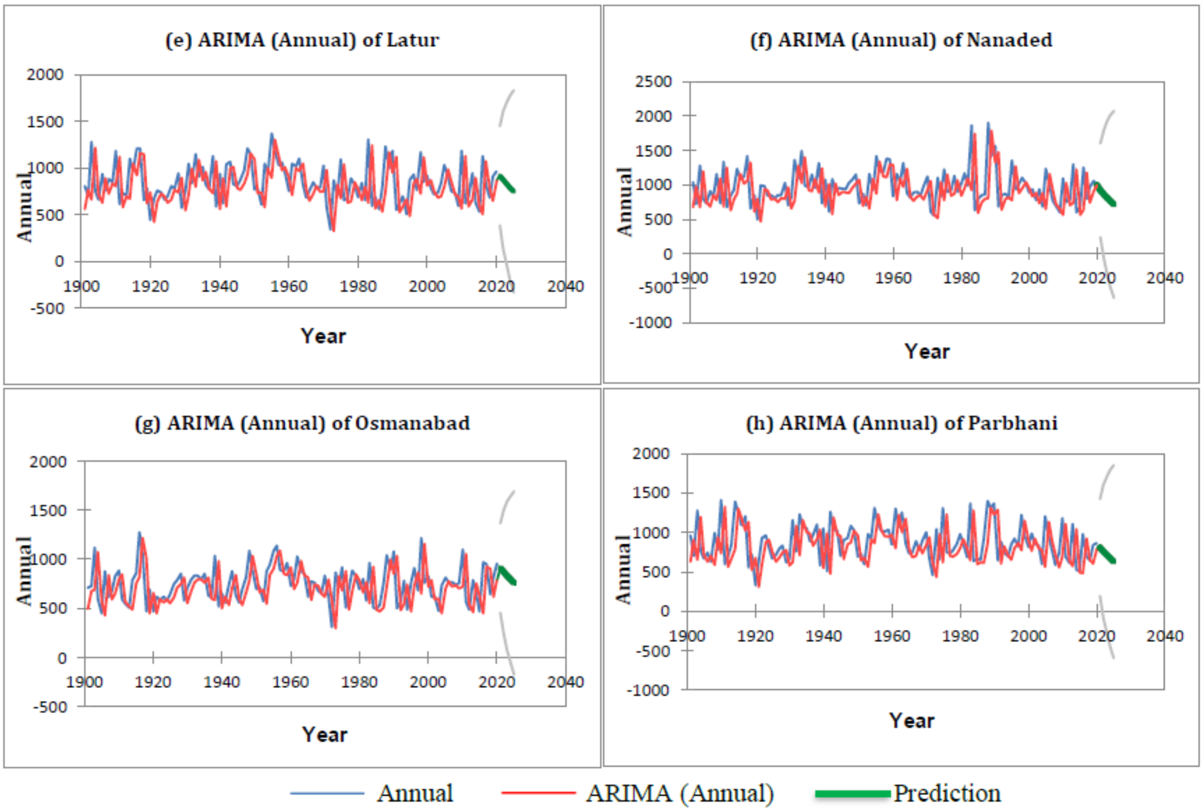


Fig. 8 ARIMA annual rainfall with predicted annual rainfall of district (a) Aurangabad, (b) Beed, (c) Hingoli, (d) Jalna, (e) Latur, (f) Nanded, (g) Osmanabad and (h) Parbhani.

IV. Conclusion

From the study, it was concluded that all districts in the Marathwada have strongly irregular precipitation distribution and most rainfall is received in 3 months or less. The average annual rainfall of Marathwada is about 832.44 mm. Marathwada gets maximum rainfall in July (23.68 % of SW monsoon rainfall) followed by August and September. 83.93% of annual rainfall receives during southwest monsoon rainfall (June –September). Maximum mean rainfall receives over the Nanded district (980.91mm) while Aurangabad district receives the lowest rainfall of 719.53mm. Predicted annual rainfall for 2021-2025 periods shows decreasing rainfall trends over five years.

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