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TREND ANALYSIS OF RAINFALL PATTERN IN UTTAR PRADESH AND ITS COMPARISON WITH OTHER STATES

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ABSTRACT
The rainfall in India is widely variable with respect to time and different regions. The study of precipitation trends is critically important for a country like ours whose food security and economy are almost completely dependent on the felicitous availability of water. The trend analysis of rainfall pattern in Uttar Pradesh is studied through time series analysis of rainfall for a long period of 50 years. The statistical analysis of the data relating with rainfall pattern during the period from 1968-2017 has been done by procuring the data from Open Government Data Platforms. The present paper is targeted towards analysing the trend of rainfall for the state of Uttar Pradesh (U.P.). Comparison of this trend with other states (namely Rajasthan, Odisha, Kerala, Madhya Pradesh and Arunachal Pradesh) has been done and average annual rainfall has been indexed for inter and intra state comparison.

KEYWORDS
Rainfall, Ratio to Moving Average, SPSS, t-test, Mann Whitney-U, Kruskal Wallis

INTRODUCTION
The changing pattern of rainfall is a topic within this field that deserves urgent and systematic attention, since it affects both the availability of freshwater and food production (Dore, 2005). It governs the overall cropping pattern, productivity and sustainability of agriculture enterprise. The standard of living and wellbeing of humans is largely dependent on rainfall intensity and frequency. Less than 2 percent of the earth's water is ground water, though it provides 30 percent of our fresh water.
The average annual rainfall in India is 119 cm, but it varies greatly. A change detection study using monthly rainfall data for 306 stations distributed across India was made by Rupa Kumar et al. (1992). They showed that areas of the northeast peninsula, northeast India and northwest peninsula experienced a decreasing trend in summer monsoon rainfall.
The rainfall in India generally orographic, cyclonic and convectional. During the south-west monsoon season, three subdivisions viz., Jharkhand, Chattisgarh, Kerala showed significant decreasing trend and eight subdivisions viz., Gangetic WB, West UP, Jammu and Kashmir, Konkan and Goa, Madhya Maharashtra subdivision, Rayalseema, Coastal AP and North Interior Karnataka showed significant increasing trends (Guhathakurta and Rajeevan, 2007). Mooley & Parthasarathy (1984), Sarkar & Tahpliyal (1988) and Thapliyal & Kulshrestha (1991) have however provided some studies relating to changes in rainfall over India but no clear-cut trends of increase or decrease in average annual rainfall over the country have been investigated.
The Secondary data has been taken from Open Government Data Platform and is analyzed using Statistical Package for the Social Sciences (SPSS) software. Methods of Simple Average and Ratio to Moving Average were incorporated to measure the Trend and the Seasonal variations. Independent sample t-test, Mann Whitney U test and Kruskal Wallis tests were used to examine the differences in the mean rainfall among different regions.
The major bearer of rain in most parts of U.P. is the Bay of Bengal branch of the Indian Monsoon. The South-West Monsoon brings most of the rain here while the western disturbances and North-East Monsoon contribute small quantities towards the overall precipitation. Annual rainfall in the state ranges from 40–80 inches (1,000–2,000 mm) in the east to 24–40 inches (600–1,000 mm) in the west. About 90 percent of the rainfall occurs during the southwest monsoon, lasting from about June to September.

MATERIAL AND METHODS

I. DATA:

The present study is based on Secondary Data. The data - Sub Divisional Monthly Rainfall from 1968 to 2017 in India is taken from Open Government Data (OGD) Platform and the contributors of this data are Ministry of Earth Sciences and India Meteorological Department (IMD).

II. STUDY AREA:

The intrastate analysis of rainfall has been done for the two zones of U.P., viz; Eastern Zone and Western Zone.

The Eastern region of U.P. comprises of Jaunpur, Ghazipur, Varanasi, Mirzapur, Sonbhadra, Bahraich, Gonda, Basti, Gorakhpur, Deoria, Ballia, Azamgarh, Faizabad, Sultanpur, Allahabad and Pratapgarh districts.

The Western region of U.P. includes Firozabad, Mainpuri, Shamli, Bijnor, Farrukhabad, Ghaziabad, Noida, Bulandshahr, Meerut, Hapur, Baghpat, Bareilly, Badaun, Agra, Mathura, Moradabad, Amroha, Saharanpur, Aligarh, Hathras, Muzaffarnagar, Rampur, Shahjahanpur, Etah, Etawah and Auraiya.

The interstate analysis of rainfall has been done for the six zones of the country, viz; North, South, East, West, Central and North East. The states Uttar Pradesh, Kerala, Odisha, Rajasthan, Madhya Pradesh and Arunachal Pradesh of the respective zones have been compared in regard to trend analysis of rainfall in the proposed work.

III. METHODOLOGY:

a) *Major Tools for Measuring Trend are:*

i. Simple Average Method:

- The average $\overline{x}$ of the monthly averages, i.e.

$$\overline{x}=\frac{1}{12}\sum_{i=1}^{12}\overline{x}_i \text{ , where } \overline{x}_i \text{ – average for the } i^{th} \text{ month for all the years.}$$

- Seasonal indices for the i^{th} month are obtained by expressing monthly averages as percentage of $\overline{x}$.

$$Seasonal\ index\ for\ ith\ month\ = \frac{\overline{x}_i}{\overline{x}} * 100, \text{ for } i = 1,2,3\ldots\ldots12$$

ii. *Ratio to Moving Average Method*:

- For monthly data, 12 point moving average which is centered by further taking 2 point moving average is used.
- Divided the original data by 12 points moving average and express them as percentage except for 6 months of the first year and 6 months of the last year.
- Expressed the data as months and calculate monthly averages. (These monthly averages are unadjusted seasonal indices for various months.)
- The adjusted seasonal indices are obtained by multiplying unadjusted seasonal indices by Correction Factor (C.F.) as:

$$C.F. = \frac{1200}{Sum\ of\ unadjusted\ seasonal\ indices}$$

Table 1: U.P. East - Simple Average Method

Months	Total	Monthly Average	Seasonal Index
January	678	13.56	17.93
February	690.6	13.81	18.26
March	371.2	7.42	9.81
April	305.4	6.11	8.07
May	981.9	19.64	25.96
June	5684.8	113.7	150.31
July	13852.4	277.05	366.26
August	11845.7	236.91	313.2
September	8751.3	175.03	231.38
October	1790.3	35.81	47.34
November	171.4	3.43	4.53
December	262.8	5.26	6.95

Table 2: U.P. West - Simple Average Method

Months	Total	Monthly Average	Seasonal Index
January	678.0	13.6	17.9
February	690.6	13.8	18.3
March	371.2	7.4	9.8
April	305.4	6.1	8.1
May	981.9	19.6	27.2
June	5684.8	113.7	150.3
July	13852.4	277.0	366.3
August	11845.7	236.9	313.2
September	8751.3	175.0	231.4
October	1790.3	35.8	47.3
November	171.4	3.4	4.5
December	262.8	5.3	6.9

Table 3: U.P. East - Ratio to Moving Average Method

Months	Seasonal Indices (Arithmetic Averages)	Adjusted Seasonal Indices (Seasonal Indices x C.F)
January	17.5333	17.5582
February	18.5604	18.5868
March	10.1584	10.1728
April	8.2849	8.2966
May	26.9754	27.0137
June	146.6501	146.8585
July	368.7016	369.2255
August	313.6934	314.1392
September	228.3515	228.6760
October	47.4351	47.5024
November	5.0380	5.0451
December	6.9145	6.9247

Total = 1198.2970
Correction Factor (C.F.) = 1.0014

Table 4: UP West - Ratio to Moving Average Method

Months	Seasonal Indices (Arithmetic Averages)	Adjusted Seasonal Indices (Seasonal Indices x C.F)
January	21.0421	21.0551
February	27.5727	27.5897
March	17.6005	17.6114
April	9.9717	9.9779
May	25.6059	25.6218
June	125.7968	125.8746
July	375.2937	375.5259
August	352.7695	352.9879
September	197.5232	197.6455
October	31.6389	31.6582
November	5.3691	5.3725
December	9.0739	9.0795

Total = 1199.2576
Correction Factor (C.F.) = 1.00062

b) *Tests for Normality*: Shapiro-Wilk test is used for small sample sizes i.e. no. of observations is less than 50 and for large sample we used Kolmogorov–Smirnov test.

Table 5: K-S test and Shapiro-Wilk test values for the parameters with their respective level of significance

Parameter No.	Parameters	Kolmogrov-Smirnov Z	d.f.	Significance (p-value)
1.	**Annual Rainfall for U.P. East**	0.080	50	0.200
2.	**Annual Rainfall for U.P. West**	0.066	50	0.200
3.	**Annual Rainfall for U.P.**	0.056	100	0.200
4.	**Annual Rainfall for all 6 States**	0.069	300	**0.001***

c) *Independent Sample t-Test:* The independent sample t test is used to test the hypothesis that means of two populations are the same. The test statistic for this testing is used as-

$$t = \frac{\overline{x_1} - \overline{x_2}}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where $\overline{x}_1$ and $\overline{x}_2$ are the means in groups 1 and 2, with n_1, n_2 , sample sizes and s is the pooled standard deviation calculated as-where

$$s_p = \sqrt{\frac{(n_1-1)s_{x_1}^2 + (n_2-2)s_{x_2}^2}{n_1 + n_2 - 2}}$$

Table 6: Levene's test and Independent t-test statistics

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Annual Rainfall (in mm)	**Equal variances assumed**	0.39	0.54	3.41	98.00	**0.001***
	Equal variances not assumed			3.41	97.28	**0.001***

d) *Kruskal - Wallis Test:* The Kruskal-Wallis H test is a rank-based nonparametric test that is used to determine if there are statistically significant differences between two or more groups of an independent variable on a continuous or ordinal dependent variable. The following table provides the Kruskal-Wallis H test values:

Table 7: Kruskal Wallis test with chi square statistic and asymptotic significance.

	Indian States	N	Mean Rank	Chi Square	df	Asymp. Sig.
Annual Rainfall (in mm)	North - Uttar Pradesh	50	124.24	241.983	5	**0.000***
	South - Kerala	50	247.04			
	East - Odisha	50	87.34			
	West - Rajasthan	50	31.06			
	North East - Arunachal Pradesh	50	237.04			
	Central - Madhya Pradesh	50	176.28			
	Total	300				

e) *Mann Whitney U test:* The Mann–Whitney U test is a nonparametric test of the hypothesis that it is equally likely that a randomly selected value from one sample will be less than or greater than a randomly selected value from a second sample. The results obtained for this Mann–Whitney U test are provided in the following table:

Table 8: Mann Whitney-U test for all the possible combinations of States.

Number of Combinations	States	Mean rank	Mann-Whitney U	p-value
1.	Uttar Pradesh	26.66	58.000	**0.000***
	Kerala	74.34		
2.	Uttar Pradesh	61.88	681.00	**0.000***
	Odisha	39.12		
3.	Uttar Pradesh	73.32	109.000	**0.000***
	Rajasthan	27.68		
4.	Uttar Pradesh	27.88	119.000	**0.000***
	Arunachal Pradesh	73.12		
5.	Uttar Pradesh	36.50	550.000	**0.000***
	Madhya Pradesh	64.50		
6.	Kerala	75.48	1.000	**0.000***
	Odisha	25.52		
7.	Kerala	75.50	0.000	**0.000***
	Rajasthan	25.50		
8.	Kerala	53.22	1114.000	0.348
	Arunachal Pradesh	47.78		
9.	Kerala	70.50	250.000	**0.000***
	Madhya Pradesh	30.50		
10.	Odisha	72.12	169.000	**0.000***
	Rajasthan	28.88		
11.	Odisha	25.54	2.000	**0.000***
	Arunachal Pradesh	75.46		
12.	Odisha	27.04	77.000	**0.000***
	Madhya Pradesh	73.96		
13.	Rajasthan	25.50	0.000	**0.000***
	Arunachal Pradesh	75.50		
14.	Rajasthan	25.50	0.000	**0.000***
	Madhya Pradesh	75.50		
15.	Arunachal Pradesh	67.18	416.000	**0.000***
	Madhya Pradesh	33.82		

** Significance level of 0.05*

RESULTS

- We conclude from Table 1, 2, 3 and 4 that the total seasonal indices for all 50 years is 1200. Maximum seasonal index value lies with the month of July followed by August. November has the Minimum value for seasonal index. Thus, the effect of seasonal swings on the rainfall pattern (for the given years) is maximum for the month of July and August and is least for the month of November.
  It is also observed that in the last 50 years i.e. from 1968-2017, 75% of the rainfall in Eastern and Western Uttar Pradesh occurred in the months of June, July, August and September, with maximum rainfall in the month of July.
  While the rest of the months experienced very little rainfall. Maximum rainfall of 13852.4 mm. in Eastern. occurred in July and minimum rainfall of 171.4 mm. occurred in November. Maximum rainfall of 11876.9 mm. in Western U.P. occurred in the month of July and minimum rainfall of 159.2 mm. occurred in the month of November.

The seasonal index value by both Simple Average method and Ratio to Moving Average method is high for July and lowest for November, showing that, due to environmental imbalance created from various man-made factors and natural factors, the rainfall pattern in the last 50 years (1968-2017) has changed a lot.

Fig 1. Monthly Total Rainfall (in mm) in Eastern U.P.

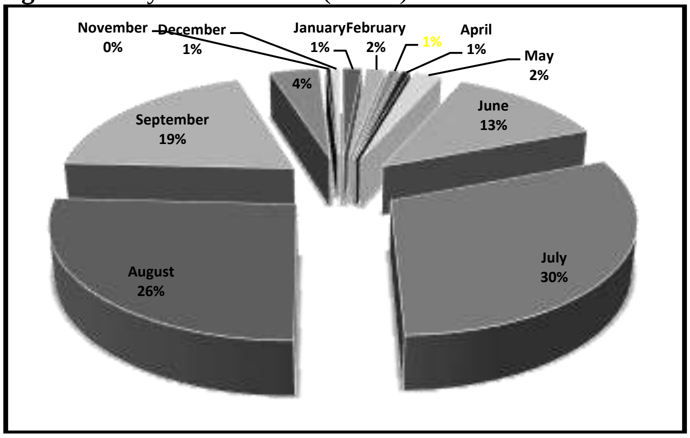
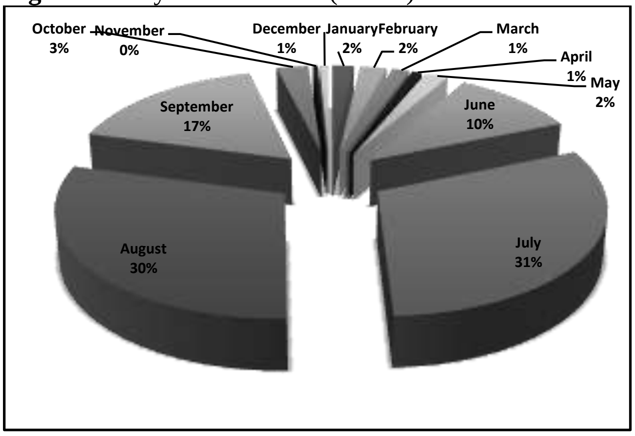


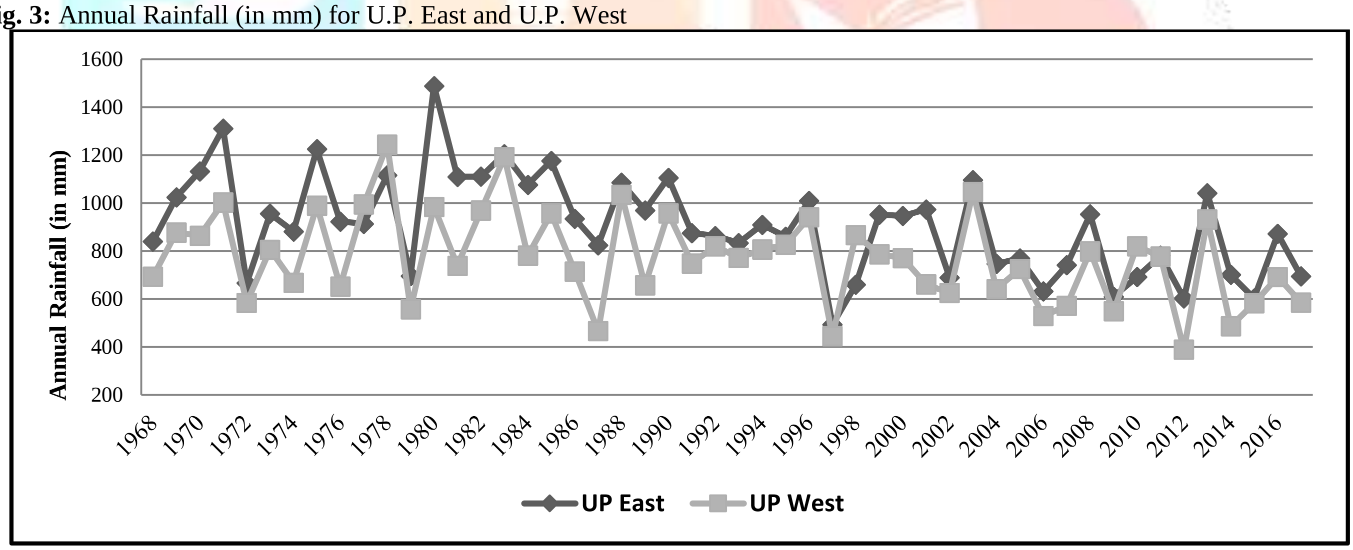
Fig 2. Monthly Total Rainfall (in mm) in Western U.P.



- Table 5 indicates that the data for the parameters numbered 1,2 and 3 follows normal distribution whereas parameter number 4 is non normal in nature.

  As the null hypothesis for Levene's test states that the variances are same, thereby, with the help of Table 6, we see that the p-value for Levene's test is 0.535 (greater than 0.05). Thus, hypothesis for equality of variance is accepted.
  Now, as the p value of t-test for equal variances assumed is 0.01, (less than 0.05), we conclude that the annual mean rainfall of both the regions differs significantly.
  On comparing the annual mean rainfall of U.P. East and U.P. West, we observe that the annual mean rainfall of both the regions is not same. The annual rainfall of U.P. East is higher than that of U.P. West. This indicates that in Northern India, rainfall decreases westwards.

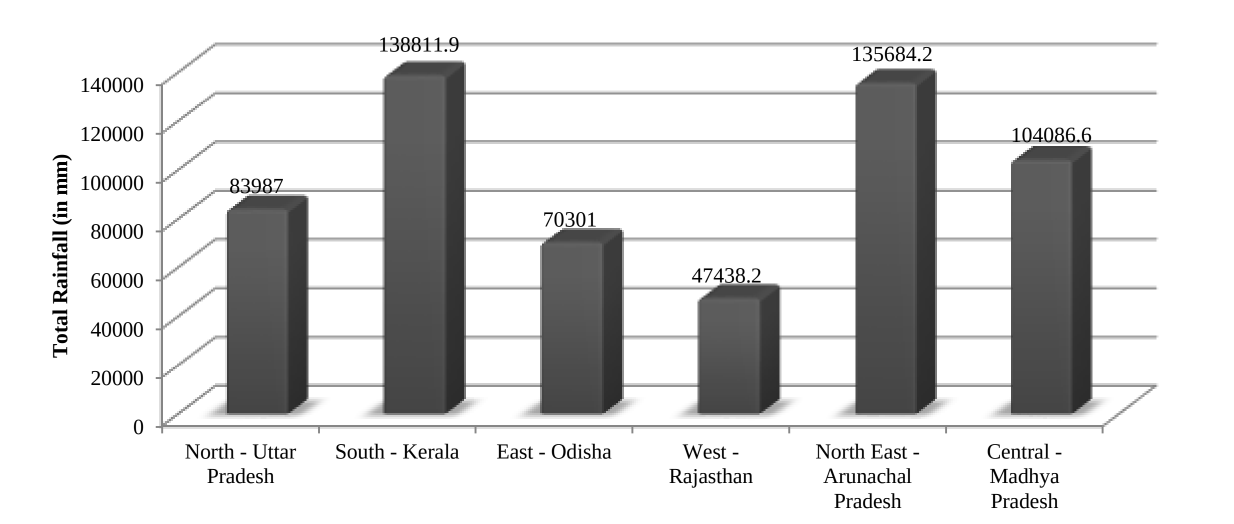
Fig. 3: Annual Rainfall (in mm) for U.P. East and U.P. West



- Table 7 gives us ample evidence that median annual rainfall for the states is not equal as the p-value is 0.00<0.05.

  From the multiple comparisons (Table 8), it is derived that, excluding combination number 8, i.e. Kerala and Arunachal Pradesh (which have no significant difference in the amount of rainfall they receive), all the other combination of states, have a significant difference in the amount of rainfall that they receive.
  While, on the other hand, comparing the average annual rainfalls of Uttar Pradesh, Kerala, Odisha, Rajasthan, Arunachal Pradesh and Madhya Pradesh, it has been observed that their average annual rainfall differs significantly. With the help of pair-wise comparisons, we notice that the average annual rainfall for each state differs significantly, except for Kerala and Arunachal Pradesh.

Fig 4: Total Rainfall in 50 years (in mm) for all the six states.



CONCLUSION

The average annual rainfall of Uttar Pradesh is higher than Rajasthan and Odisha but lower than Kerala, Arunachal Pradesh, and Madhya Pradesh. The average annual rainfall of Kerala is higher than that of Uttar Pradesh, Rajasthan, Odisha, Madhya Pradesh and Arunachal Pradesh. The average annual rainfall of Odisha is higher than Rajasthan but lower than Madhya Pradesh, Arunachal Pradesh and Uttar Pradesh. The average annual rainfall of Arunachal Pradesh is higher than Madhya Pradesh, Rajasthan, Odisha, Uttar Pradesh but lower than Kerala. The average annual rainfall of Madhya Pradesh is higher than Rajasthan, Odisha, Uttar Pradesh but lower than Kerala and Arunachal Pradesh. Accordingly, it is observed, that Kerala has highest average annual rainfall and Rajasthan has lowest average annual rainfall among Uttar Pradesh, Rajasthan, Odisha, Madhya Pradesh, Kerala and Arunachal Pradesh.

States like Kerala and Arunachal Pradesh receives more rainfall not only because of their geographical location but mainly because of their green cover. But massive deforestation to support the growing population has caused loss of this green blanket. Thus, for every cutting of mature and big trees, provisions for planting and nurturing of equal number of trees should be done. Strict policies and proper implementation in this regard is the need of the hour.

Pollution has drastically affected the arrival, retrieval and amount of rainfall. Governments came up with various laws and policies to combat the increasing pollution level. But due to improper implementation, such measures are not yielding the desired results.

The findings of this study recommend that Method of rooftop rainwater harvesting should be adopted by every household, public buildings or institutions. Required material and assistance need to be made easily accessible to all. Also, strict policy which makes rooftop water harvesting system compulsory in commercial buildings and houses needs to be made.

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