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Rainfall Distribution and Trend Analysis of the Godavari River Basin, India during 1901-2012

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Abstract: ***India is mainly an agricultural-based country it is vital to understand the water consumption for its agricultural needs. This study made an attempt to perform rainfall trend analysis by estimating the key indicators of precipitation changes. The study has considered the tools namely linear trend analysis, Mann-Kendall test, and Sen.'s slope estimation. Rainfall data sourced from IMD for duration of 102 years (1901-2002) of 49 districts on the entire Godavari river basin is considered. Among the 49 districts, 20 districts have statistically significant annual rainfall at a 95% confidence level. Out of 20 districts, 13 districts are showing a positive trend with 95% confidence. 10 districts have shown a decreasing trend with the significance. The majority of districts that showed the upward trend are located in the regions of Manjira, Maneru, and Lower Godavari Sub basins. Seven districts are showing the downward trends that are located in the Wardha, Wainganga, and Indrāvati Sub basins. District-wise and river sub basin-wise studies have more necessary in order to understand the rainfall impact with climate changes.***

Keywords: Precipitation, Linear trend, Sub-basin, Monsoon, climate change

1. Introduction

Rainfall is a major source of water and also a major element in the hydrological cycle on the earth's surface. The spatial and temporal variability in the rainfall affects the availability of the water resources of concerned regions. Changes in the rainfall pattern result in climate changes and alarming for the hydrologists and water resource managers (Ben-Gai et al 1998). Changes in rainfall impact various sectors. The amount of precipitation determines the moisture content in the soil and agriculture production also (Gupta et al 2014). The changes in rainfall patterns may lead to floods and drought situations (Srivastava et al 2015). Hence, there is an absolute need for regular monitoring of the rainfall changes in the temporal and spatial regions for food security and productivity (Kumar et al 2010). The geographical location of India is getting nearly 80% of rainfall during monsoons (June-Sept). They (Monsoons) ensure a decrease in a number of rainfall days and an increase in the intensity of rainy events during the seasons which results in the serious threshold on water availability (Jain S.K and Kumar V 2012). Scarcity in water resources (rainfall) in the river basin causes water stress and difficulties in water sharing between the states especially during the drought/weak monsoon season. Proper understanding of long-term variability in rainfall trends will provide the key indicators on water availability and its management. In order to address these concerns, many studies have conducted rainfall data analysis. Guhatakurtha and Rajeevan have observed that there is no clear long-range trend in the average annual monsoon rainfall. Kumar et al 2010 found large variations in spatial and temporal regions regarding the rainfall in India. Gosain, A.K Rtal 2006 ensured that a decrease in the precipitation closely affects the decline of freshwater availability in many Indian River basins. Partahsarthy B and Dhow O.N (1976) found that there is an increasing trend in monsoon rainfall over Ganga, Indus, Brahmaputra, Krishna, and Cauvery basins. S. Bera 2015 studied the rainfall trends over the entire Ganga basin that there will be large spatial and temporal variability in the annual and seasonal rainfall trends in the Godavari basin. Gajbhiye et al. (2015) studied the trend analysis of the Sindh River basin and reported the increasing trend in the annual and seasonal rainfall. A.K. Taxak et al. 2014 studied the long term temporal and spatial rainfall trends in the Wainganga basin which is one of the sub basin of Godavari river basins for the period of 1901-2012. They revealed the upward trends in rainfall during 1901-1948, however it is reversed during the period of 1949-2012. Kalpesh Borse 2019 analyzed the long period rainfall data from 1901 to 2002 in the regions of upper Godavari basins using MK test and Sen's slope estimator. Results of these studies exhibited the decreasing patterns and shift in the rainfall. With a motivation of rational understanding of the variations of temporal and spatial rainfalls in different geographical locations, this study has carried out the long-term trend analysis of the rainfall in the entire Godavari river basin for the period of 1901-2012. Exploring and assessing the climatological situations of the Godavari basin through the rainfall during about 100 years of time duration is the targeted objective of this study.

2. Geographical location of Study Area

River Godavari is India's second longest after Ganga. It has its origin in Triambakeshwar, Maharashtra. It flows towards the east for 1,465 kilometers (910 miles) and ends its course into the Bay of Bengal. The beneficiary regions of river Godavari spreads in the states of Maharashtra (152199 sq.km) (48.6%), Andhra Pradesh (73201 sq.km) (23.4%), Madhya Pradesh (65255 sq.km) (10.0%), Chhattisgarh (10.9%), Orissa (17752 sq.km) (5.7%) &Karnataka (4405 sq.km) (1.4%) and Pondicherry (Yanam) through its extensive network of tributaries. The basin lies in the Deccan plateau and is situated between latitude 160 16' 00'' North and 22 0 36' 00'' North and longitude 730 26' 00'' East and 830 07' 00" East. This river basin receives maximum rainfall during south-west monsoon season. The monsoon current strikes the west coast of the peninsula from the west of the southwest that is Sahyadri range the barrier ranging from the 600m to 2100m in height. While crossing the barrier the monsoon current deposits all moisture to the windward side of the Konkan a small portion in Madhya Maharashtra i.e. upper Godavari sub-basin. The monsoon currents follow the eastward slope of the country from the crest of the Western Ghats. So, the conditions in the interior basin will yield maximum heavy rainfall. The quantum of rainfalls has a significant association with depressions and low-pressure systems formed in the Bay of Bengal. The river basin will witness the dry season during January and February months. During this period it receives rainfall at a maximum of 15mm. The pre-monsoon and post-season due to the thunderstorms and the cyclone forming in the Bay of Bengal receive the rainfall with the level of 20-50 mm. Maximum rainfall with a level of 600-1200 mm will be witnessed during the monsoon seasons. The Godavari basins as a whole receive 84% of the annual rainfall on average, during the Southwest monsoon. Some important irrigation projects that are built on the Godavari river basin are namely Kaleswaram Project, Polavaram Project, apart from some major and minor irrigation projects. The water that is received from the rainfall through this basin has been utilized for different purposes such as irrigation, drinking, industries, generation of electricity, etc.

Data Used

To study the rainfall trend analysis from 1901-2012 for the 49 districts and 7 states that fall under the Godavari river basin. The monthly rainfall data is obtained from the India Meteorological Department (IMD) and the India Water Portal (http://indiawaterportal.org/met_data/). The monthly rainfall distribution is analyzed on annual basis and four seasons namely Monsoon season (June-September), Pre-monsoon Season (Mar-May), Post Monsoon Season (Oct-Dec), and winter season (Jan-Feb). The Season average rainfall of the Godavari basin is disclosed in Fig (2).

3. Methodology

This study has considered the methodologies like (i) Linear trend analysis of each sub-basin for all the seasons; (ii) Mann - Kendall test is applied to detect the presence and significance of the trend the annual and seasonal rainfall Series; and (iii) Sen's Slope estimator method(Sen,1968) is used for the estimate the Magnitude of the trend in the time series (True Change per year). The data is showing the patterns of moving averages and autoregressive relations among the current and previous time-series variables. Usual linear regression methods are appropriate when the data is defined on the interval or ratio scales. Whereas the data that we considered for the study of daily rainfall distribution is dealing with the time series data for a period of approximately 100 years. Hence the method of the M-K test is more relevant.

The methodology deals with Mann-Kendall Test (Mann,1945, Kendall 1946). This test is also referred as M-K test which can be used for analyzing the data by verifying the consistency in time series data regarding the monotonic ups and downs in trends. This test is well suited for handling the categorical data and is classified as non parametric test. This test has potential applicability in the circumstances of non normality assumption and there will be no serial correlation among the data values. However, Conventional regression methods may be considered if the data exhibiting the normality assumptions for studying the relationship between the time series variables.

The null hypothesis for this test is that the monotonicity in rain fall distribution and trend has neither increasing nor decreasing. The actual test hypothesis is that the monotonicity of rain fall distribution and trend is either increasing or decreasing. Our data have all the data points irrespective of seasons. Hence, the methodology has not considered the seasonality in testing. Further, the data is not considered any other covariates related to rainfall in Godavari basin over period of time.

The Mann-Kendall Statistic is denoted as

$$S = \sum_{j=1}^{n-1} \sum_{j=k+1}^{n} Sign(X_j - X_k) \;;$$

where the Sign(X_j-X_k) is defined as

$$Sign(X_j - X_k) = \begin{cases} +1, if\,(X_j - X_k) > 0 \\ 0, if\,(X_j - X_k) = 0 \\ -1, if\,(X_j - X_k) < 0 \end{cases}$$

Where n is the size of the sample, X_j and X_k are form k=1, 2, …., n-1 and j =k+1, k+2, ….., n. If the sample is larger (conventionally if it is more than 8), then the test statistic S follows Normal distribution. The Mean of S is equal to 0 and the variance of S can be calculated from the formula $Var(S) = \dfrac{n(n-1)(2n+5)}{18}$ by making use of mean variances of test statistic the standard normal value will be

$$Z = \begin{cases} \dfrac{s-1}{\sqrt{\operatorname{var}(s)}}, if \;\; s > 0 \\ 0, \;\; if \;\; s > 0 \\ \dfrac{s+1}{\sqrt{\operatorname{var}(s)}}, if \;\; s > 0 \end{cases}$$

The usual interpretation with Mann- Kendall statistic will be as if Z>0, it indicates an increasing trend in the overall time series data, and vice versa. Assuming at the given confidence level 'α', the time series data. The trend increment shall be considered as significant when $|Z| > Z(1-\alpha/2)$ where $Z(1-\alpha/2)$ is the respective value of p= α/2 following the standard normal distribution. Usually the studies will consider either 5% or 1% level of significance. However, we considered the p value at 5% level of significance.

Besides, the magnitude of time series was evaluated by a suitable non-parametric measure developed by Sen's Slope 'β', where the Sen's slope estimate can be obtained as

$$\beta = Median\left(\frac{X_j - X_i}{j-i}\right), j > i.$$

Further, the slope coefficient will be used for getting the interpretations based the sign of it. If $\beta > 0$, it indicates the trend is positive and it is in increasing nature, the time series data exhibiting the uptrend. Whereas if $\beta < 0$, it indicates the trend is negative/it is in decreasing nature, the data series is representing the down trend.

4. Results and Discussions

Figure 2 shows that the average annual and seasonal rainfall over the Godavari River Basin. The average annual rainfall varies from 850-1200mm. The maximum (80%) rainfall occurred in the months of June-September (monsoon season). Monsoon season followed by the post-monsoon season is contributing the 10% of rainfall with a range of 91-160mm in the pre-monsoon season that is from March-May 4% of rainfall in the winter season.

Figures 3-7 show that the linear trend analysis of the rainfall series from the year 1901-2012 for the annual, monsoon, pre-monsoon, winter seasons for the sub-basins in the Godavari river. The annual rainfall series(1901-2012) is showing an increasing trend in the upper Godavari(G1), Manjira(G4), middle Godavari(G5),Maneru(G6) and lower Godavari(G10) sub basins on the other hand there will be significant decreasing trend in the Wardha(G8), Wainganga(G9), Indrāvati(G11) sub basins.

Rainfall in the monsoon season Series followed by the Annual Series. However, the post-monsoon season shows a strong positive trend in the upper Godavari (G1), Manjira (G4), Middle Godavari (G5), Maneru (G6) sub basins. But there is no negative trend. There is no significant increasing or decreasing trend in the Pre monsoon (Mar-May) and Winter Seasons (Jan-Feb).

From the linear trend analysis for the entire rainfall series, though monsoon is the major contributor for the rainfall over the Godavari basin that in the post monsoon season showing significant increasing trend although this season constitutes a smaller part of about 10% of average annual rainfall it is very important to understand the hydrological distribution of the Godavari basin.

Trend Analysis

For a deep understanding of hydrological distribution, we have carried out the trend analysis of the 49 districts which were fall in the entire Godavari basin Table (2). The MK and Sen's Slope estimator method is used for the trend analysis. The trend analysis is carried out by the total each of the districts which fell in the Godavari basin magnitude and the slope has been calculated.

The magnitude of the Trend

The magnitude of the trend of this time series (1901-2012) is determined using Sen's slope estimator method. Fig.8 shows the magnitude of the trend on the annual data series. The annual rainfall time series is experienced a positive trend in the Manjira (G4), Upper Godavari, Maneru, and Lower Godavari sub-basins. Wardha and Wainganga, Indrāvati are showing a negative trend. Out of the 49 districts, nearly 60% (22) of districts are experienced the increasing trend in rainfall with a maximum of 3.17 mm/year, 20% of districts are showing the decreasing trend with a maximum decrease of -2.57 mm/year, 20% districts are not showing any trend. In order to have a suitable understanding of the complex hydrological situations of the rainfall distribution, only the data of annual rainfall is not sufficient. Hence, the trend analysis is also extended for the Monsoon, Pre Monsoon, Post Monsoon, and Winter Seasons. The seasonal and trend analysis shows that during the Pre monsoon season and winter season rainfall decreased in 10 districts. During monsoon season 15 districts (44%) are showing increased rainfall and 20 (52%) districts are showing decreasing rainfall. In the post monsoon rainfall 25 districts (55%) are showing a positive trend and only 2 districts are showing negative (decreasing) rainfall.

Post monsoon contributed about 20% of average rainfall and is very vital in the hydrological distribution in the present analysis. Almost 55% (18 districts) is showing positive trend with the maximum of rainfall order Latur (G4) 3.18 mm/day, Bidar 3.09 mm/year, Medak 2.83 mm/year, Osmansabad 2.76 mm/year, Beed 2.73 mm/year, Gurlbarga 2.43 mm/year, Solapur 2.34 mm/year, Pharbhani 2.32 mm/year, Karimnagar 2.25 mm/year, Khamam 2.25 mm/year, Nanded 2.24 mm/year, Danthewada 2.22mm/year, Ranga Reddy 2.21 mm/year, West Godavari 2.21 mm/year, Nizamabad 2.19 mm/year, Adilabad 2.11 mm/year, Visakhapatnam 2.09 mm/year, Malakangiri 2.05 mm/year, East Godavari 1.77 mm/year, Nalgonda 1.64 mm/year. Most of the districts are showing a positive trend. A very less number of districts are showing a negative trend (decreasing rainfall). The distribution of the trends is shown in Fig (10). Figure 9 shows the magnitude of trend in the monsoon season for the entire Godavari basin. A maximum number of districts are showing a decreasing trend. The Maximum value of increasing rainfall over Medak district with 2.01 mm/year in Manjira sub basin; Karimnagar 1.74 mm/year, Nizamabad 1.12 mm/year in Middle Godavari; Warangal 1.6 mm/year, Nalgonda 1.41 mm/year, East Godavari 1.93 mm/year, West Godavari 1.37 mm/year, Visakhapatnam 1.23 mm/year. The maximum decrease in the districts Rajnandegaon -2.77mm/year Gondia -2.72 mm/year, Durg -2.65 mm/year, Bhandar -2.5 mm/year , Nagapur -2.46 mm/year ,Betul-2.24 mm/year Kanekar -2.16 mm/year. Dhamtari -2.15 mm/year, Wardha-1.19 mm/year Chindwara -1.77 mm/year therefore these maximum districts are in the sub basin of Wainganga, Wardha, Indravathi, are showing negative trend. Most of the districts in the sub basins in the Lower Godavari, Maneru, and Middle Godavari are showing the positive rainfall trend.Figures 11 & 12 shows the trend of the Pre-monsoon and winter seasons. In the Pre monsoon season the highest value of increasing trend found over Nanded District 1.12 mm/year. The maximum value of Negative trend is in Warangal District -0.58 mm/Year. No significant trend is found in the winter season.

Significance of Trend

The significance of the trend in seasonal, annual of the time series (1901-2012) is calculated through Mann-Kendall Test. Tables 2-5 show the trend for the annual & seasonal rainfall time series. Among the 49 districts, 20 districts have statistically significant annual rainfall at 95% confidence level. 13 districts in the river basin Gulbarga, Medak, Nizamzbad, Rangareddy, Solapur, Karimnagar, Nalgonda, Warangal, East Godavari, Khammaam, West Godavari, Nowrangapur, and Visakhapatnam have detected significant positive trend at 95% confidence level. The significant negative annual rainfall trend is found over 7 districts like Betul, Bhandara, Gondia, Rajnandegaon, Dhamtari, Durg, and Kanekar. During monsoon season, 10 districts Medak, Betul, Wardha, Bhandara, Gondia, Nagpur, Rajnandegaon, Dhamtari, Durg, and Kanekar have indicated significant rainfall at 95% confidence level, in which only Medak district has an increasing rainfall trend. During post-monsoon season, 18 districts Beed, Nanded, Pharbhani, Bidar, Gulbarga, Latur, Medak, Nizamzbad, Osmanabad, Rangareddy, Solapur, Adilabad, Karimnagar, Khammaam, West Godavari, Danthewada, Malkangiri and Visakhapatnam have indicated significant rainfall at 95% confidence level, in which none of the districts have decreasing rainfall trend.

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5. Conclusions

In the present study, we have seen the district wise and sub basin wise rainfall trend analysis of the entire Godavari basin using the Linear Trend Analysis, Man-Kendall Test, and Sen's Slope Estimator methods. In the linear trend analysis, it is clearly showing that there is an increasing trend in annual rainfall of the Upper Godavari, Manjira, Maneru, Middle Godavari, and lower Godavari sub basins. On other hand in the Wardha, Waingangā, and Indrāvati are showing the decreasing of rainfall. In the MK test, the Z Value represents both the negative and positive trend of the rainfall series of 1901-2012. In the annual rainfall analysis, the z value is negative in the maximum districts of the sub basins of Wardha, Waingangā, Indrāvati basins. While the other hand some of the districts are showing a positive trend in the Manjra maneru, Middle Godavari Sub basins. As analyzing the seasons it gives a clear picture in the monsoon season there will half of districts are showing decreasing rainfall over the Wardha, Waingangā and Indrāvati sub basins. In the post monsoon season the maximum districts in sub basins of Maneru, Middle Godavari, and Lower Godavari are showing increasing of rainfall trend. In the upper Godavari Sub basin some of the districts are showing a positive z value in the annual rainfall. But in the monsoon Season the maximum districts in the upper Godavari basin showing a negative z value (trend) while in the post monsoon season most of the districts are showing positive/ increasing Z value (trend). This study indicates there will be a large variability is there in the seasonal and annual rainfall trends over the Godavari River Basin. Due to the spatial and temporal variability in rainfall are more susceptible to floods and drought conditions in the River Basin. So, the analysis of the rainfall over the sub basins plays a significant role in the seasonal fluctuations and distribution and water flow and in the River Basin. By understating and analyzing the rainfall in the sub basin and district wise very helpful to the irrigation and agricultural water managing in the climate-changing conditions over the Basin.

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Figures & Tables

Figure 1: Godavari River basin

Table 1: Districts are fall under the Godavari River basin

River basin	Districts	River basin	Districts
G1	Aurangabad	G9	Adilabad
	Beed		Balaghat
	Nanded		Betul
	Nashik		Bhandra
G2	Ahmadnagar		Chandrapur
G3	Aurangabad		Chhindwara
	Jalna		Gadchiroli
	Parbhani		Durg
G4	Bidar		Mandla
	Gulbarga		Nagpur
	Latur		Rajnandegaon
	Medak		Seoni
	Nizamabad	G10	East Godhavari
	Osmanabad		Khammam
	Rangareddy		Warangal
	Solapur		West Godavari
G5	Adilabad	G11	Bastar
	Karimnagar		Danthewada
	NIzamabad		Dhamtari
G6	Karimnagar		Durg
	Nalgonda		Kalahandi
	Warangal		Kanekar
G7	Buldhana		Nawarangapur
	Washim		Rayagada
	Yavatamal	G12	Koraput
G8	Amaravathi		Malkangiri

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	Betul		Viskhapatnam
	Chandrapur		
	Wardha		

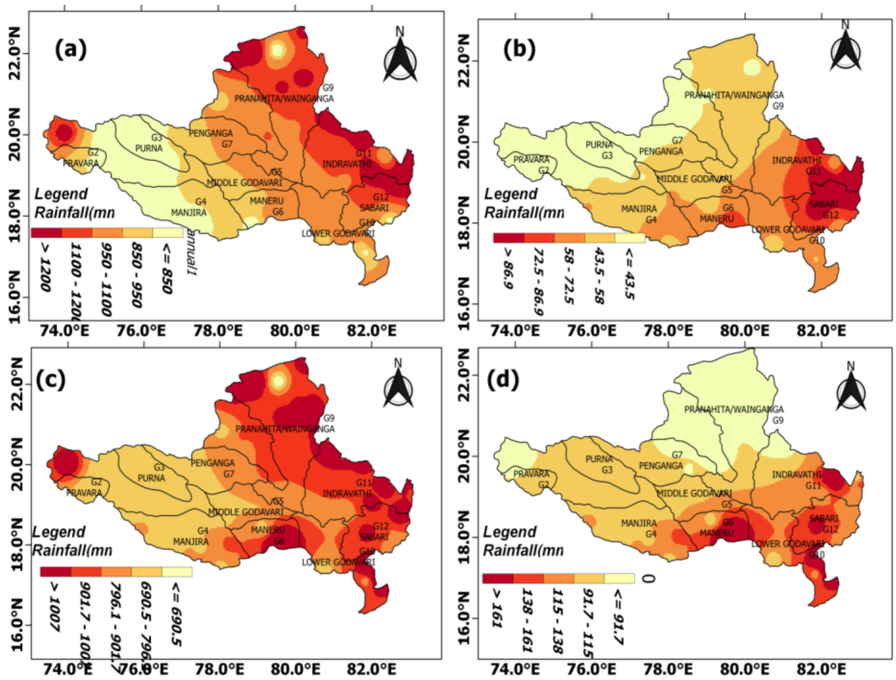
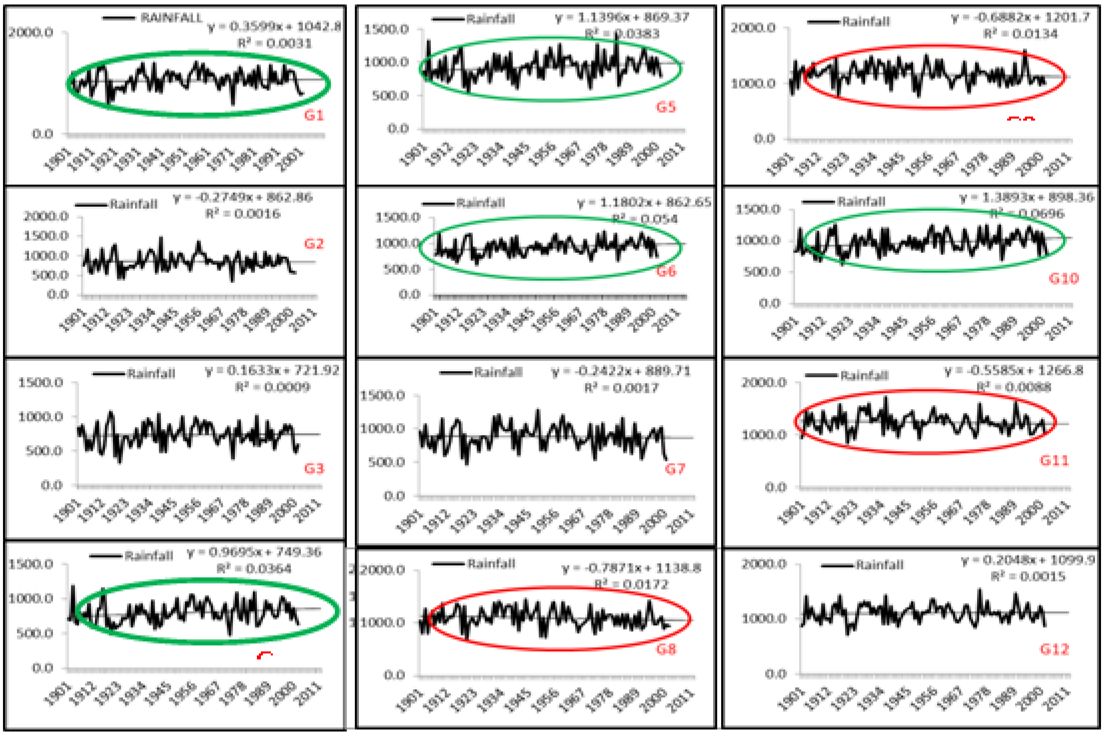
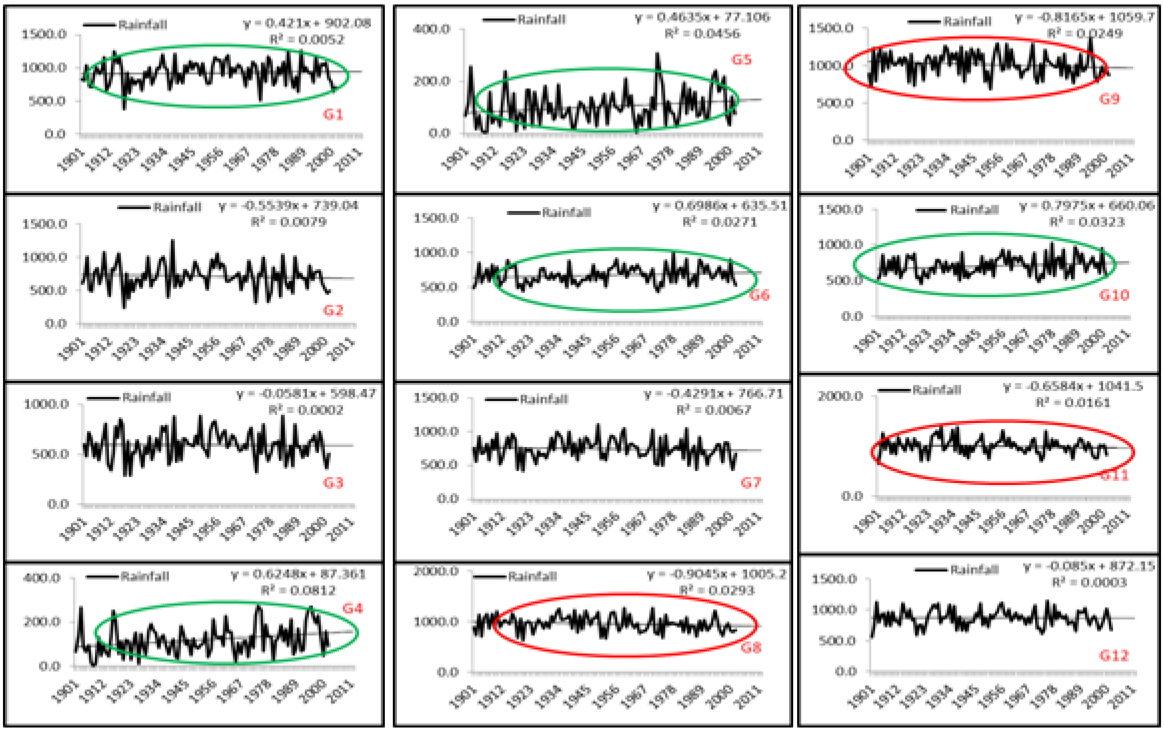


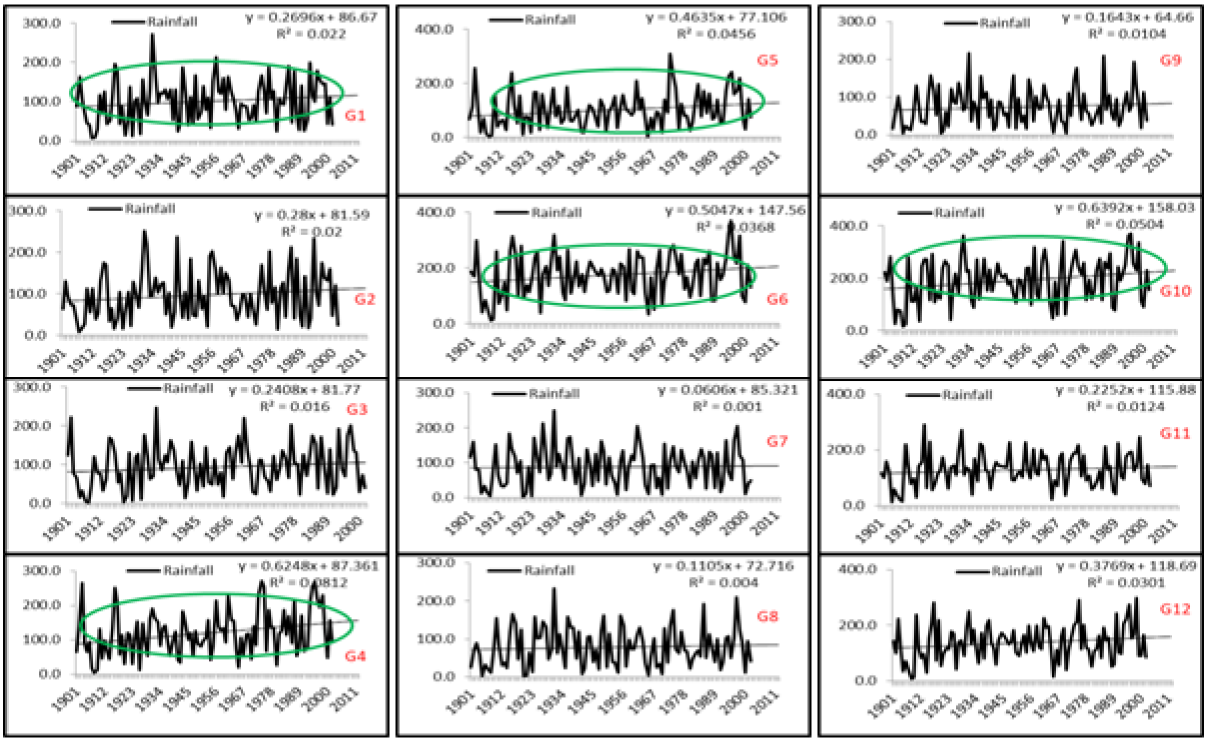
Figure 2: The Season wise Average rainfall a) Annual b) Pre monsoon season c) Monsoon Season d) Post Monsoon Season



Figures 3: shows that the Annual linear trend analysis of the rainfall series from the year 1901-2012



Figures 4: Shows that the linear trend analysis of the rainfall series from the year 1901-2012 for the Monsoon Season

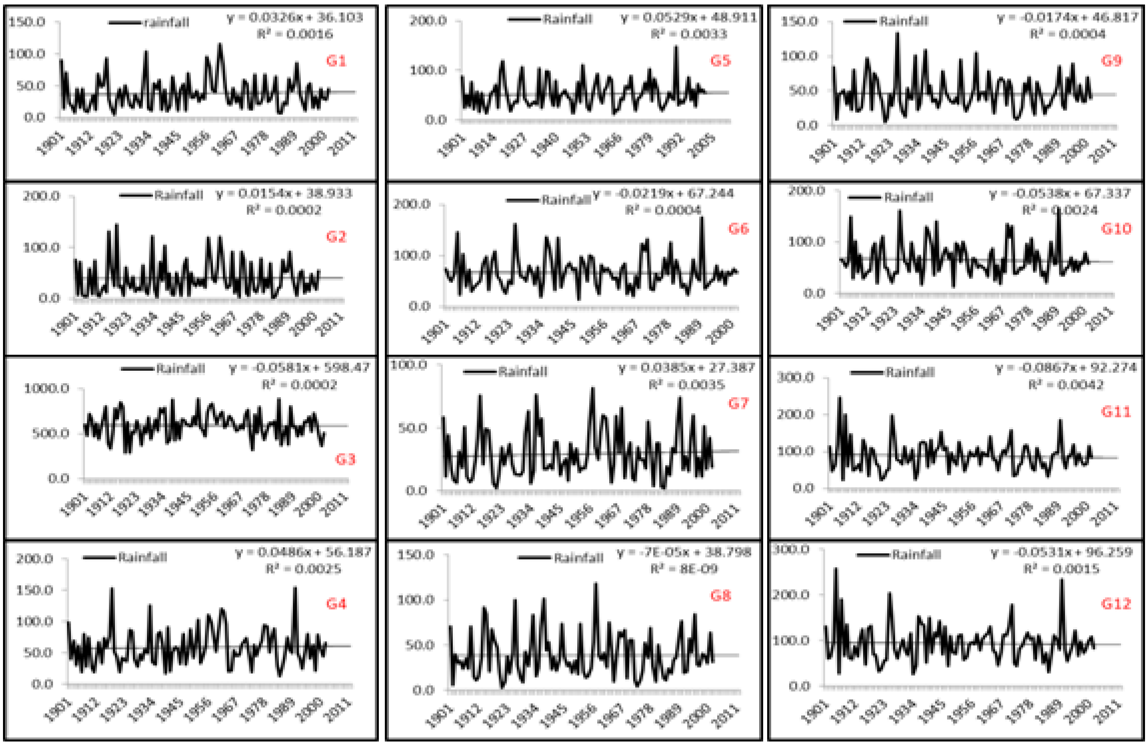


Figures 5: Shows that the linear trend analysis of the rainfall series from the year 1901-2012 for the Post Monsoon Season

Table 2: Trends and Slope from the Sens Slope Estimator of the Annual Rainfall Series

Group	District	Annual Rainfall			Group	District	Annual Rainfall			Group	District	Annual Rainfall		
		Z	Sen's estimate	P			Z	Sen's estimate	P			Z	Sen's estimate	P
G1	Aurangabad	-0.16	-0.09	0.87	G6	Karimnagar	2.37	1.47	0.02	G10	East Godavari	3.04	2.01	0.002
	Beed	0.65	0.43	0.51		Nalgonda	2.46	1.37	0.01		Khammaam	2.37	1.47	0.02
	Nanded	1.43	0.98	0.15		Warangal	1.97	1.34	0.048		Warangal	1.97	1.34	0.048
	Nashik	0.27	0.25	0.79	G7	Bhuldhana	-1.04	-0.55	0.3		West Godavari	2.45	1.27	0.01
G2	Ahmednagar	-0.38	-0.32	0.7		Washim	-0.22	-0.21	0.83	G11	Baster	-1.74	-1.46	0.08
G3	Aurangabad	-0.16	-0.09	0.87		Yoetmal	0	-0.02	1		Danthewada	1.21	0.71	0.22
	Jalna1	-0.21	-0.13	0.83	G8	Amroti	-1.08	-0.71	0.28		Dhamtari	-2.3	-1.64	0.02
	Pharbhani	0.88	0.51	0.38		Betul	-2.17	-1.61	0.03		Durg	-2.57	-1.61	0.01

G4	Bidar	1.41	0.86	0.16		Chandrapur	-0.52	-0.33	0.6		Kalahandi	-1.65	-1.24	0.1
	Gulbarga	2.33	1.18	0.02		Wardha	-1.57	-1.13	0.12		Kanekar	-2.13	-1.6	0.03
	Latur	1.26	0.74	0.21	G9	Adilabad	1.65	1.08	0.1		Nowrangapur	2.82	1.97	0.004
	Medak	3.17	1.96	0.001		Balaghat	-1.05	-0.88	0.29		Rayagada	-0.24	-0.17	0.81
	Nizamzbad	2.21	1.21	0.03		Betul	-2.17	-1.61	0.03	G12	Koraput	-1.74	-1.46	0.08
	Osmanabad	1.73	0.86	0.08		Bhandara	-2.24	-2.02	0.03		Malkangiri	1.69	1.09	0.09
	Rangareddy	2.36	1.61	0.02		Chandrapur	-0.52	-0.33	0.6		Visakhapatnam	2.27	1.32	0.02
	Solapur	2.07	1.03	0.04		Chindwara	-1.46	-1.04	0.14					
G5	Adilabad	1.65	1.08	0.1		Gadchiroli	-0.59	-0.42	0.56					
	Karimnagar	2.37	1.47	0.02		Gondia	-2.48	-2.01	0.01					
	Nizamzbad	2.21	1.21	0.03		Mandla	-1.12	-0.86	0.26					
						Nagpur	-1.95	-1.42	0.051					
						Rajnandegaon	-2.4	-1.79	0.02					
						Seoni	1.01	0.69	0.31					



Figures 5: Shows that the linear trend analysis of the rainfall series from the year 1901-2012 for the Pre Monsoon and winter Seasons

Table 3: Trends and Slope from the Sens Slope Estimator of the Monsoon Rainfall Series

Group	District	Annual Rainfall			Group	District	Annual Rainfall			Group	District	Annual Rainfall		
		Z	Sen's estimate	P			Z	Sen's estimate	P			Z	Sen's estimate	P
G1	Aurangabad	-0.42	-0.18	0.67	G6	Karimnagar	1.41	0.59	0.16	G10	East Godavari	1.93	0.89	0.054
	Beed	-0.25	-0.12	0.8		Nalgonda	1.6	0.79	0.11		Khammaam	1.74	0.96	0.08
	Nanded	0.58	0.4	0.56		Warangal	-1.41	-0.64	0.16		Warangal	1.6	0.79	0.11
	Nashik	0.1	0.09	0.92	G7	Bhuldhana	-0.71	-0.39	0.48		West Godavari	1.37	0.63	0.17
G2	Ahmednagar	-0.88	-0.56	0.38		Washim	-0.45	-0.3	0.66	G11	Baster	-1.39	-1.06	0.16
G3	Aurangabad	-0.42	-0.18	0.67		Yoetmal	-1.34	-0.76	0.18		Danthewada	0.39	0.2	0.69
	Jalna1	-0.64	-0.35	0.52	G8	Amroti	-2.24	-1.58	0.03		Dhamtari	-2.15	-1.31	0.03
	Pharbhani	0.26	0.15	0.79		Betul	-1.06	-0.58	0.29		Durg	-2.65	-1.44	0.01
G4	Bidar	-0.08	-0.02	0.94		Chandrapur	-1.98	-1.28	0.047		Kalahandi	-1.74	-1.08	0.08
	Gulbarga	0.45	0.16	0.65		Wardha	0.98	0.55	0.33		Kanekar	-2.16	-1.48	0.03
	Latur	-0.06	-0.04	0.95	G9	Adilabad	-1.39	-0.97	0.17		Nowrangapur	1.5	0.81	0.13
	Medak	2.01	1.03	0.04		Balaghat	-2.24	-1.58	0.03		Rayagada	-0.5	-0.33	0.62
	Nizamzbad	1.12	0.57	0.26		Betul	-2.53	-2.12	0.01	G12	Koraput	-1.39	-1.06	0.16
	Osmanabad	0.09	0.05	0.93		Bhandara	-1.06	-0.58	0.29		Malkangiri	0.98	0.46	0.33
	Rangareddy	1.43	0.94	0.15		Chandrapur	-1.77	-1.07	0.08		Visakhapatnam	1.23	0.61	0.22
	Solapur	0.66	0.3	0.51		Chindwara	-1.2	-0.65	0.23					
G5	Adilabad	0.98	0.55	0.33		Gadchiroli	-2.72	-2.06	0.01					
	Karimnagar	1.74	0.96	0.08		Gondia	-1.47	-1.02	0.14					

	Nizamzbad	1.12	0.57	0.26		Mandla	-2.46	-1.88	0.01					
						Nagpur	-2.77	-1.58	0.01					
						Rajnandegaon	0.62	0.31	0.54					
						Seoni	1.01	0.69	0.31					

Table 4: Trends and Slope from the Sens Slope Estimator of the Post Monsoon Rainfall Series

Group	District	Annual Rainfall			Group	District	Annual Rainfall			Group	District	Annual Rainfall		
		Z	Sen's estimate	P			Z	Sen's estimate	P			Z	Sen's estimate	P
G1	Aurangabad	0.62	0.13	0.54	G6	Karimnagar	2.25	0.51	0.02	G10	East Godavari	1.77	0.79	0.08
	Beed	2.73	0.54	0.01		Nalgonda	1.64	0.48	0.1		Khammaam	2.25	0.51	0.02
	Nanded	2.24	**0.42**	0.02		Warangal	1.47	0.66	0.14		Warangal	1.47	0.66	0.14
	Nashik	0.62	0.11	0.53	G7	Bhuldhana	0.2	0.04	0.84		West Godavari	2.21	0.57	0.03
G2	Ahmednagar	1.42	0.25	0.16		Washim	0.31	0.07	0.76	G11	Baster	0.46	0.11	0.65
G3	Aurangabad	0.62	0.13	0.54		Yoetmal	1.14	0.22	0.25		Danthewada	2.22	0.58	0.03
	Jalna1	1.12	0.19	0.26	G8	Amroti	-0.38	-0.08	0.7		Dhamtari	0.49	0.07	0.63
	Pharbhani	2.32	0.44	0.02		Betul	0.93	0.14	0.35		Durg	0.83	0.11	0.41
G4	Bidar	3.09	0.67	0.002		Chandrapur	1.6	0.28	0.11		Kalahandi	0.09	0.01	0.93
	Gulbarga	2.43	0.63	0.01		Wardha	0.67	0.12	0.5		Kanekar	0.87	0.15	0.39
	Latur	3.18	0.76	0.001	G9	Adilabad	2.11	0.41	0.03		Nowrangapur	1.59	0.66	0.11
	Medak	2.83	0.85	0.004		Balaghat	-0.01	-0.005	0.99		Rayagada	0.58	0.16	0.56
	Nizamzbad	2.19	0.52	0.03		Betul	0.93	0.14	0.35	G12	Koraput	0.46	0.11	0.65
	Osmanabad	2.76	0.67	0.01		Bhandara	1.11	0.18	0.27		Malkangiri	2.05	0.63	0.04
	Rangareddy	2.21	0.53	0.03		Chandrapur	1.6	0.28	0.11		Visakhapatnam	2.09	0.48	0.04
	Solapur	2.34	0.59	0.02		Chindwara	0.68	0.13	0.5					
G5	Adilabad	2.11	0.41	0.03		Gadchiroli	1.72	0.33	0.09					
	Karimnagar	2.25	0.51	0.02		Gondia	0.98	0.15	0.33					
	Nizamzbad	2.19	0.52	0.03		Mandla	0.32	0.07	0.75					
						Nagpur	0.97	0.15	0.33					
						Rajnandegaon	0.94	0.12	0.35					
						Seoni	-0.27	-0.02	0.78					

Table 5: Trends and Slope from the Sens Slope Estimator of the Pre Monsoon and Winter Rainfall Series

Group	District	Annual Rainfall			Group	District	Annual Rainfall			Group	District	Annual Rainfall		
		Z	Sen's estimate	P			Z	Sen's estimate	P			Z	Sen's estimate	P
G1	Aurangabad	0.74	0.06	0.46	G6	Karimnagar	0.66	0.06	0.51	G10	East Godavari	-0.96	-0.12	0.34
	Beed	0.38	0.03	0.71		Nalgonda	-0.02	-0.003	0.99		Khammaam	0.66	0.06	0.51
	Nanded	1.12	0.1	0.26		Warangal	-0.58	-0.08	0.56		Warangal	-0.58	-0.08	0.56
	Nashik	1.03	0.05	0.3	G7	Bhuldhana	0.68	0.06	0.5		West Godavari	-0.18	-0.02	0.86
G2	Ahmednagar	0.83	0.07	0.41		Washim	0.79	0.07	0.43	G11	Baster	0.31	0.05	0.76
G3	Aurangabad	0.74	0.06	0.46		Yoetmal	1.46	0.14	0.14		Danthewada	0.02	0.002	0.98
	Jalna1	0.17	0.02	0.87	G8	Amroti	0.99	0.08	0.32		Dhamtari	-0.01	-0.003	0.99
	Pharbhani	0	-0	1		Betul	-0.36	-0.04	0.72		Durg	-0.15	-0.01	0.88
G4	Bidar	0.35	0.04	0.73		Chandrapur	0.64	0.08	0.52		Kalahandi	-0.04	-0.01	0.97
	Gulbarga	1.37	0.16	0.17		Wardha	0.84	0.11	0.4		Kanekar	-0.14	-0.02	0.89
	Latur	-0.02	-0	0.99	G9	Adilabad	1.53	0.14	0.13		Nowrangapur	-0.99	-0.14	0.32
	Medak	-0.7	-0.1	0.48		Balaghat	0.45	0.05	0.66		Rayagada	0.29	0.08	0.77
	Nizamzbad	0.68	0.07	0.5		Betul	-0.36	-0.04	0.72	G12	Koraput	0.31	0.05	0.76
	Osmanabad	0.22	0.02	0.83		Bhandara	-0.28	-0.04	0.78		Malkangiri	-0.61	-0.09	0.54
	Rangareddy	0.93	0.12	0.35		Chandrapur	0.64	0.08	0.52		Visakhapatnam	1.03	0.11	0.3
	Solapur	0.64	0.08	0.52		Chindwara	-0.69	-0.11	0.49					
G5	Adilabad	1.53	0.14	0.13		Gadchiroli	0.36	0.04	0.72					
	Karimnagar	0.66	0.06	0.51		Gondia	-0.13	-0.01	0.89					
	Nizamzbad	0.68	0.07	0.5		Mandla	-0.33	-0.05	0.74					
						Nagpur	0.28	0.04	0.78					
						Rajnandegaon	-0.13	-0.01	0.9					
						Seoni	1.31	0.16	0.19					

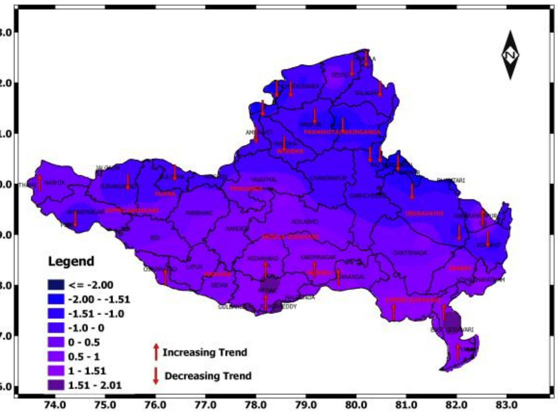


Figure 8: Show that the Magnitude of the Trend of the Annual Series

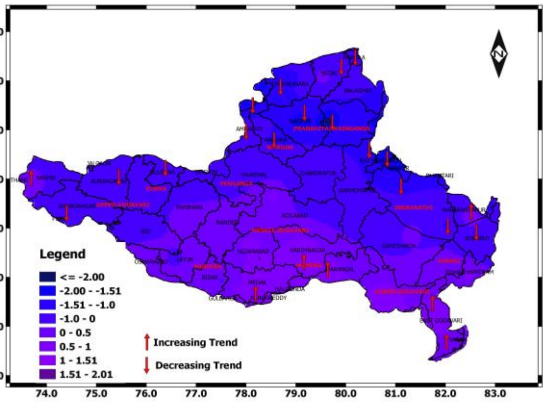


Figure 9: Show that the Magnitude of the Trend of the Monsoon period

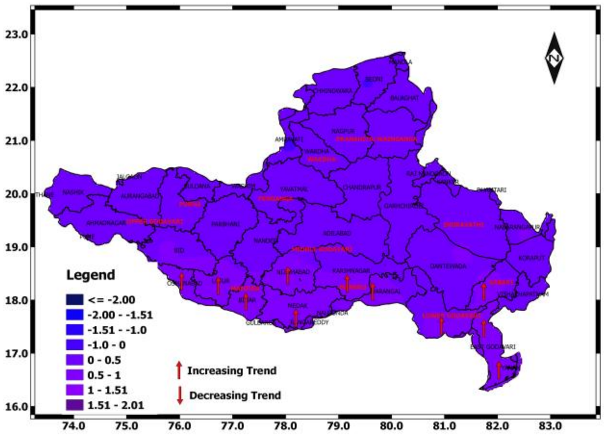


Figure 10: Show that the Magnitude of the Trend of the Post Monsoon

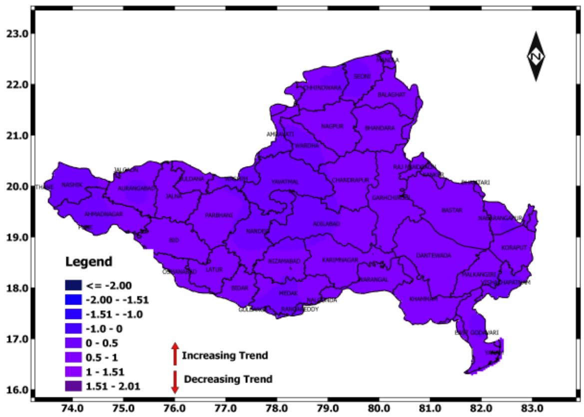


Figure 11: Show that the Magnitude of the Trend of the Pre Monsoon and winter period