Analysis of Historical and Future Rainfall Projections in India's Lower Godavari Basin

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Changes in evaporation and precipitation in the climate are precursors to changes in the water cycle due to the increase in temperatures due to climate change. In recent years, enormous changes in precipitation patterns have led to an increase in extreme rainfall events, reflecting flash floods in smaller areas. To understand this, you must study the rainfall patterns of the district and the smaller watersheds. In the present study, we have observed the trend of rainfall in the lower Godavari basin, which was part of the Godavari River from 1970 to 2019, using IMD 0.25X0.25 °

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gridded rainfall data. According to the study, during the winter season and before the monsoon, there is no significant increasing or decreasing trend. In the post-monsoon season they are showing a negative and decreasing trend with a magnitude of 4 mm/year. But in the monsoon season, one end (the right end near the river mouth) of the basin or watershed is showing an increasing trend, while the left part is showing a significantly decreasing trend. In addition to that, future projections of the CMIP5 two scenarios data from 2000 to 2100 to understand the precipitation patterns in future projections. Lower Godavari basin from 2020–2040 and 2040-2100 with the RCP 4.5 and RCP 8.5 scenarios. With the RCP 4.5 scenario, the first 40 years (2020–2040) of the future projected mean seasonal rainfall are 4.5 mm/year higher in the western part of the sub-basin than in the eastern and river mouth regions.

1. INTRODUCTION

The increased concentrations of greenhouse gases in the atmosphere have been attributed to global warming and further to climate change [1]. The change in precipitation and temperature patterns caused by global warming has been studied and discussed in several regions of the world. Precipitation is an important climate variable as it determines types and distribution of natural vegetation and availability of water to meet the needs of agriculture, industrial, and hydroelectric power sectors. The spatial and temporal variability in trends of precipitation has been studied for interannual and interseasonal periods during the past few decades throughout Asia. The changes in rainfall patterns may lead to floods and drought situations [2]. Hence, there is an absolute need for regular monitoring of rainfall changes in the temporal and spatial regions for food security and productivity [3]. Various researchers have contributed to the study of climate change [4-7] with long-term data. A study of different time series data has shown that the trend is decreasing or increasing, both in the case of temperature and rainfall. Human interference also leads to climate change by changing land use due to the impact of agricultural and irrigation practices [8]. The geographical location of India receives almost 80% of its rainfall during monsoons (June to September). They (monsoons) ensure a decrease in the number of rainfall days and an increase in the intensity of rainy events during the seasons, which results in a serious threshold on water availability [9]. A proper understanding of the long-term variability in rainfall trends will provide key indicators of water availability and its management. To address these concerns, many studies have conducted rainfall data analysis. Guhatakurtha and Rajeevan [10] have observed that there is no clear long-range trend in average annual monsoon rainfall. Kumar et al. [3] found large variations in spatial and temporal regions with respect to rainfall in India. Gosain and A.K. Rtal [11] ensured that a decrease in precipitation closely affected the decline of freshwater availability in many Indian River basins. Partahsarthy B. and Dhar O.N. [12] and Suman Bera [13] found that there is an increasing trend in monsoon rainfall in the Ganga, Indus, Brahmaputra, Krishna and Cauvery basins. S. Bera (2015) studied the rainfall trends across the entire Ganga basin and found that there will be large spatial and temporal variability in the annual and seasonal rainfall trends in the Godavari basin. Gajbhiye et al. [14] and Aurn Kumar Taxak et al. [15] found increasing rainfall trends in Sindh River basin and Wainganga basin, with upward trends observed from 1901-1948 and reversed from 1949-2012. Biswas et al. [16] analysed the long-period rainfall data from 1901 to 2002 in the regions of the upper Godavari basins using the MK test and Sen's slope estimator Sravani. A et al. [17] In the present study, we have seen the rainfall trend analysis and future trend analysis for the lower Godavari basin using the linear trend analysis, Man-Kendall test, and Sens slope estimator methods. To understand the distribution of rainfall, future rainfall probabilities, and flood situations, we studied the future projection of rainfall destruction using the data from the CMIP5 model. The sub-basins play an important role in the seasonal

Understand the changes in the rainfall pattern by district and sub-basins and the strategies required to deal with climate change conditions, especially near the mouth of the river and the catchments, which are more prone to disasters.

2. MATERIALS AND METHODOLOGY

Geographical area of the Lower Godavari Basin: Fig. 1 (a, b) shows the geographical area

of the study region(Lower Godavari basin).lower Godavari sub basin is one of the tributaries of river Godavari. The beneficiary regions of the river Godavari spread 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. This river basin receives maximum rainfall during the south-west monsoon season. The quantum of rainfall has a significant association with depressions and low pressure systems formed in the Bay of Bengal. The Lower Godavari sub-basin receives the maximum of rainfall in the months of July and August in the monsoon season. In the post-monsoon season also receives the rainfall due to the formation and land falling the trocal systems in the Bay of Bengal. While in the crossing the tropical systems in the east coast, the lower Godavari sub-basins receive the intense rainfall and flood situations are also. Almost two to three floods occurred every year.

Data Used: The India Meteorological Department, Government of India [18] Climate Research Services (CRS) Pune provided the observed gridded climatology data for temperature and rainfall. Temperature data are further downscaled to 1 km resolution by adjusting temperatures in relation to a high-resolution digital elevation model. [19,20], and Reuter et al. [21]). IMD's gridded rainfall data have a much finer spatial resolution, i.e. 0.25 ° x 0.25 °[18]. This high-resolution observed rainfall dataset (1970–2019). Future projections for four Representative Concentration Pathways (RCP) scenarios are provided in global climate models. In this study, we used the RCP scenarios RCP4.5 and RCP8.5. RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5 are the four RCP scenarios.

2.1 Methodology

Trend analysis: Trend is defined as the overall movement of a series over time [22]. It is also the long-term change in the dependent variable over time. The connection between the two variables of temperature and rainfall, as well as their temporal resolution, determines the trend. For the importance of temperature and rainfall trends, statistical methods such as regression analysis and coefficient of determination R^2 are applied. The trend was produced and evaluated using the Mann-Kendall (M-K) trend test and the slope of the regression line was calculated using the least squares technique. To investigate the link, the mean, standard deviation (SD), and coefficient of variation (CV) of rainfall and temperatures were calculated.
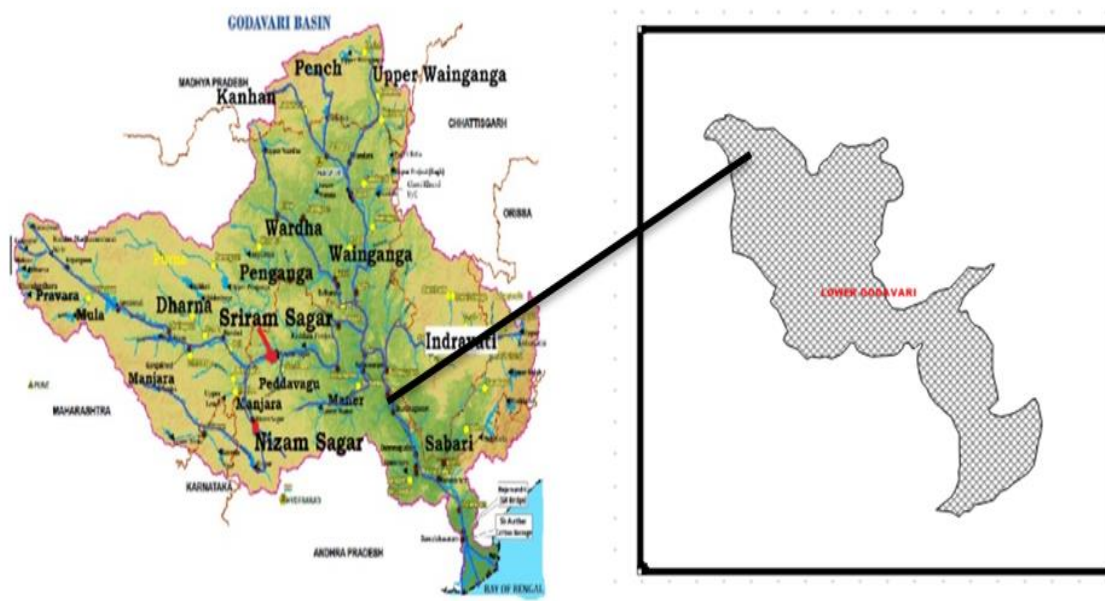

Fig. 1. Shows the study area of the lower Godavari sub-basin

Mann-Kendall test: The MK test is a non-parametric statistical test that is commonly used to analyze trends in climatological and hydrological time series Test [23], Kendall [24]) proposed the test in 1945, and it has been widely used in environmental time series. There are two benefits to using this test. First, it is a nonparametric test, which means that the data does not have to be distributed regularly. Second, the test exhibits limited sensitivity to sudden interruptions caused by inhomogeneous time series. The null hypothesis (H0) of this test implies that there is no trend. This is compared to the alternative hypothesis H1, which believes that there is a trend. The MK statistic is calculated as follows.

$$S = f(z) = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(xj - xk)$$

The trend test is used for a time series Xk, which is ranked from k = 1,2,3,…,n-1, and ranked from j = i + 1, i + 2, i + 3..... n. Each of the data points xj serves as a reference point.

sgn (xj-xk)　　　= 　1　　if xj-xk > 0
　　　　　　　　 = 　0　　if xj-xk = 0
　　　　　　　　 = 　-1　 if xj-xk < 0

Sen's slope estimator test: Sen's estimate (Sen, 1968) is a non-parametric approach for determining the amplitude of a trend in a time series. Sen's non-parametric technique is used to determine the real slope of an existing trend, such as the amount of change every year, and the test is carried out in R software. A positive value of Sen's slope indicates an upward or growing trend, whereas a negative value shows a downward or declining trend in the time series.

3. RESULTS AND DISCUSSION

The sub-basin rainfall analysis is important to understand the seasonal fluctuations and distribution of water inflow in the river sub-basin. Many rivers in India are showing a declining trend in sediment discharge due to the impact of climate change as well as human interference. According to (Sravani et al. [17]), there is a significant Increasing trend in the upper Godavari (G1), Manjira (G4), middle Godavari (G5), Maneru (G6) and lower Godavari (G10) sub-basins in the river Godavari basin. Fig. 2 shows the variability and trend of rainfall in the lower Godavari basin for the past 40 years (1970–2019). It indicates that there will be an increasing trend in rainfall in the lower Godavari basin. Fig. 3 shows the monthly average rainfall of the lower

Godavari basin. The line graph shows that the rainfall is slowly increasing in the month of May, the maximum rainfall peak is in the months of July and August, which indicates the monsoon season, is the major rainfall season, with the secondary maximum rainfall in the month of October. The season variation of the rainfall for the period of 41 years is shown in Fig. 4. In Fig. 4 (a), shows the linear trend analysis of the seasonal rainfall in the lower Godavari basin. In the winter season, the rainfall trend is showing a decreasing trend, while in the pre-monsoon season, there is no significant increasing or decreasing trend. In the monsoon season, which is the main rainfall season, the trend is showing a slight increase. The post-monsoon season (October to December) also shows a downward trend in rainfall. Fig. 5 shows the spatial distribution of the mean seasonal rainfall of the Lower Godavari basin, which ranges between 150 and 2000 mm and varies from G1 to G30. Maximum (80%) rainfall occurred in the months of June to September (monsoon season). During the monsoon season, rainfall ranges from 1500-2000mm to a maximum of 2110mm. Values are less in the eastern part than in the western part because the eastern part is connected to the Eustery(River Mouth) region, which connects to the ocean, and backwater will come and inundate the inland areas near the river mouth region, followed by the post-monsoon season, which contributes 10% of rainfall with a range of 250-450mm in the pre-monsoon season, which is from March to May, and 4% of rainfall in the winter season. Fig. 6 shows the rainfall covariance of the Lower Godavari basin. Covariance is a measure of the relationship between two random variables and the degree to which they change together. The figures show that the monsoon season has a high covariance in the upper part of the basin rather than the lower.

For a deep understanding of the hydrological distribution, we have carried out a trend analysis of the 30 points of the grid that fall in the entire Lower Godavari basin. Tables (1-4) for trend analysis, the MK and Sens slope estimator method is used.

Significance of the Trend: The entire sub-basin is covered by 30 grid points (G1-G30).The seasonal and trend analysis is shown in Tables (1-4). Tables 1-2 show that during the premonsoon and winter seasons, during the winter season, there is no significant increasing or decreasing trend, but in the premonsoon

season, grids 1 and 3 show a significant increasing trend with 3.6 mm/yr. The monsoon season is the main rainy season for the Lower Godavari basin. During the monsoon season, the G1 and G8 grid points showed a significant decreasing trend of -3.5mm/year. The last G21 to G30 shows an increase, indicating that the river mouth region is on the rise, implying that floods are more common in the western part of the sub-basin. In the post-monsoon rainfall,, lower Godavari will get the maximum rainfall occurrence due to the passage of the systems, in the post-monsoon season, 25 grid points (55%) are showing that a negative and decreasing trend with the magnitude of 4 mm/year. The monsoon is the significant rainfall season, and the G1-G6 grids are showing a decreasing trend with 95% significance, respectively, have been identified as the two poles in the lower Godavari basin. The time series and regression analysis for the monsoon seasons in Fig. 7 resulted in the time series analysis and statistical forecast for the next 5 years.

Fig. 8 shows the projected future values of the mean average rainfall for the lower Godavari basin. From 2020–2040 and 2040–2100 with the scenarios RCP 4.5 and RCP 8.5. With the RCP 4.5 scenario, the first 40 years (2020-2040) of future projected mean seasonal rainfall are 4.5 mm/year higher over the western part of the sub-basin than in the eastern and river mouth regions. In the second part, 2041-2100, the projected mean seasonal rainfall for the future is 4.7 mm/year higher in the western and southwestern parts of the sub-basin than in the eastern and river mouth regions. The projected mean rainfall is different with other scenarios; with RCP8.5, the projected rainfall is higher than with RCP4.5. With RCP8.5, the first 40 years (2020-2040) and the second part (241-2100) of the projected future mean seasonal rainfall are 30.5mm/year higher in the river mouth region than in the western part. With both scenarios, it shows that there will be a significant increase in rainfall over the Lower Godavari basin.
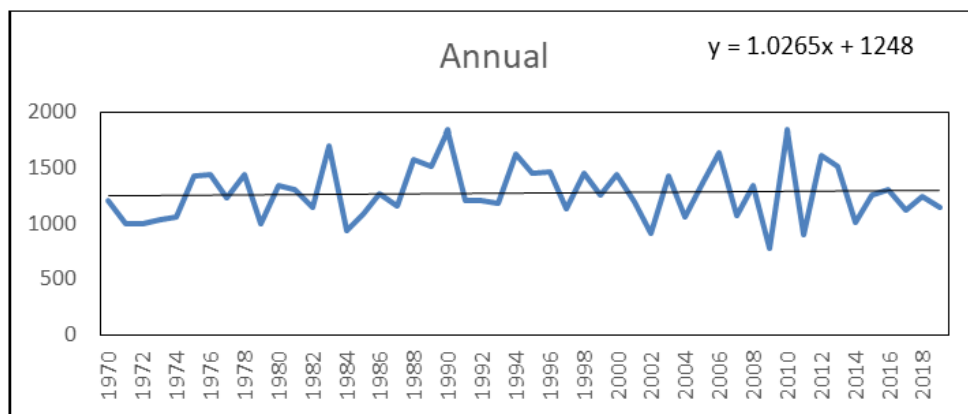

Fig. 2. Shows the time series (1970-2019) of annual rainfall in the Lower Godavari basin
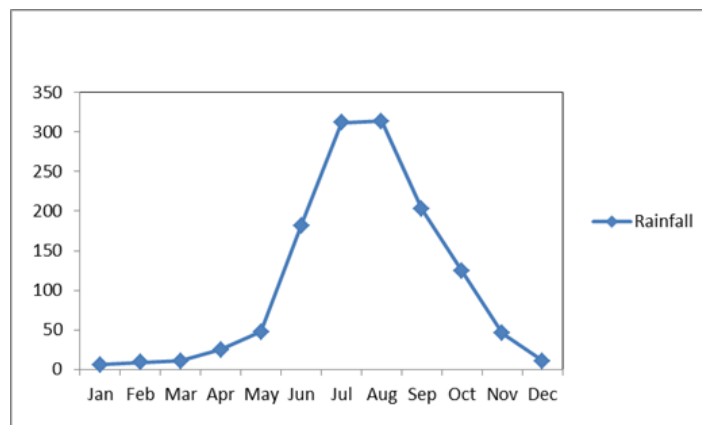

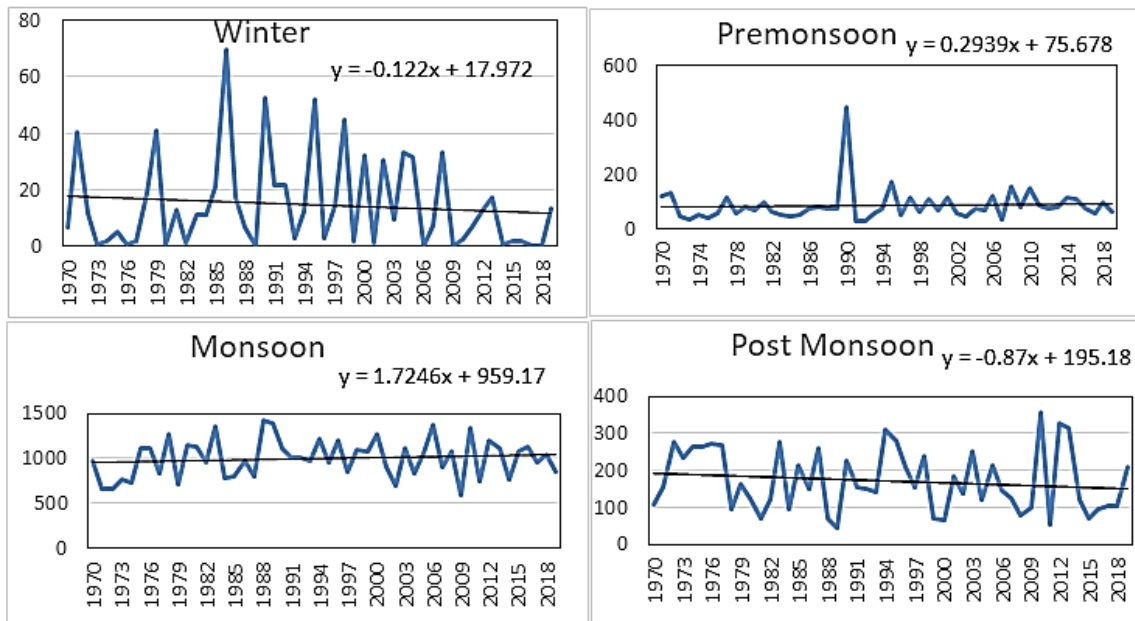**Fig. 3. Shows the mean monthly rainfall of the lower Godavari basin**

Fig. 4. Shows the time series (1970-2019) of Season-wise rainfall over lower Godavari basin
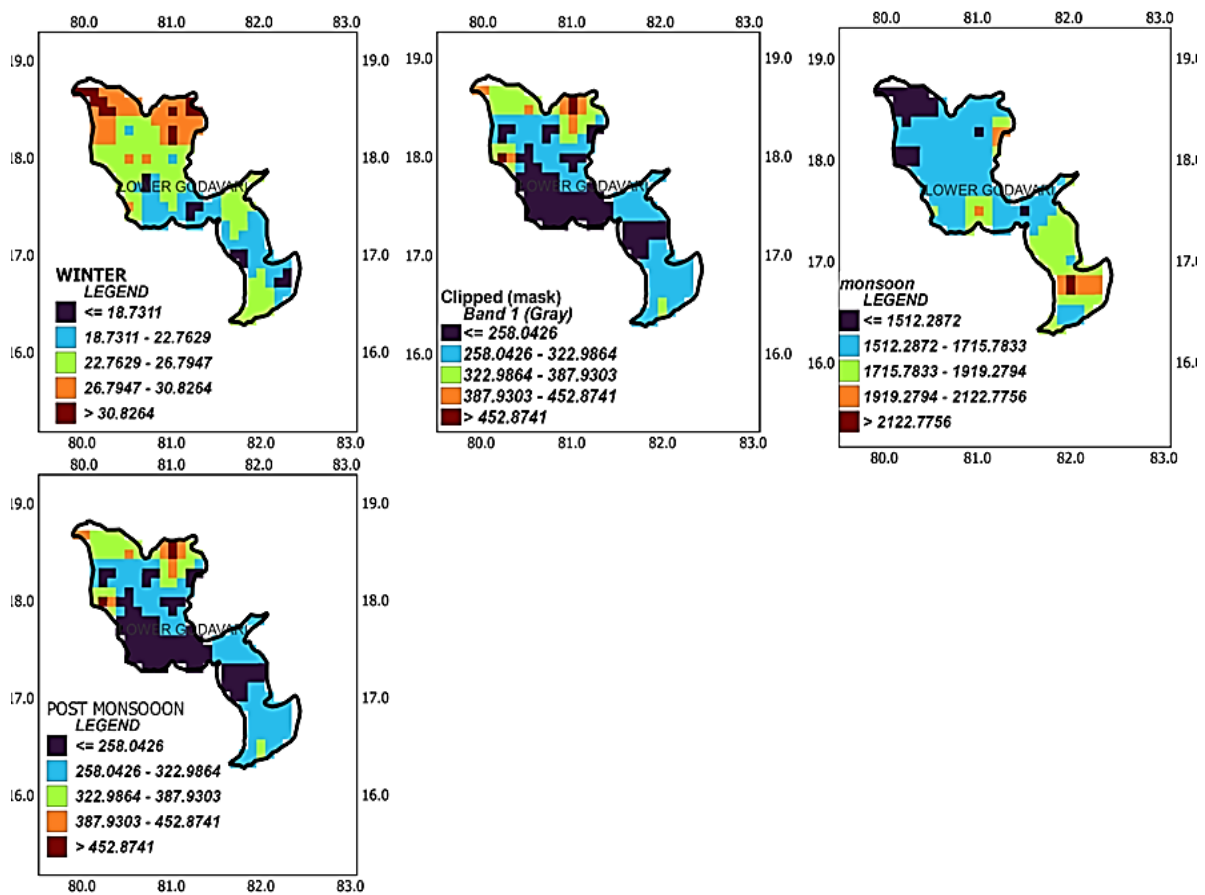
Fig. 5. Shows the spatial distribution of the mean seasonal rainfall for the lower Godavari basin
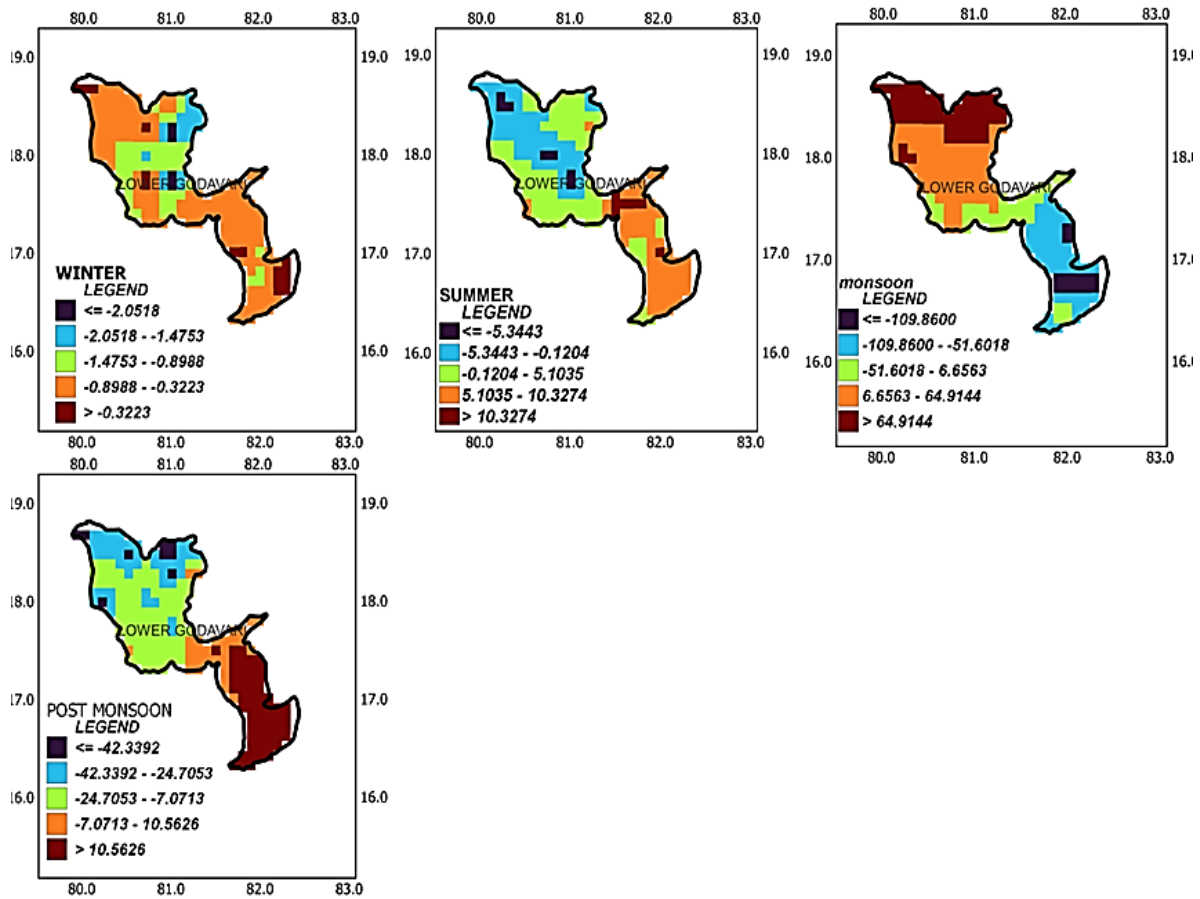
Fig. 6. Shows the rainfall covariance of the lower Godavari basin

Table 1. Is the analysis of the rainfall trends for the winter season

	GRID NO.	Z VALUE	P VALUE	Sen's SLOPE	Trend
1	G1	3.086741	0.001012	0.040168	↑
2	G2	1.455485	0.072767	0.018736	no
3	G3	0.384783	0.350199	0.004494	no
4	G4	3.580159	0.000172	0.047718	↑
5	G5	1.631204	0.051424	0.03089	no
6	G6	2.241782	0.012488	0.035056	↑
7	G7	1.530823	0.062907	0.022142	no
8	G8	1.714856	0.043186	0.023527	↑
9	G9	1.564283	0.058876	0.028828	no
10	G10	4.559007	2.57E-06	0.074749	↑
11	G11	3.889795	5.02E-05	0.057482	↑
12	G12	-0.10875	0.456702	0.013496	no
13	G13	0.82815	0.203793	0.010411	no
14	G14	2.384068	0.008561	0.034925	↑
15	G15	0.744498	0.228288	0.013496	no
16	G16	-1.34679	0.089024	-0.01948	no
17	G17	1.137621	0.127639	0.018512	no
18	G18	-0.22586	0.410656	-0.00395	no
19	G19	0.125477	0.450073	0.002915	no
20	G20	0.711038	0.23853	0.00786	no
21	G21	-1.73159	0.041674	-0.03044	↓
22	G22	-2.85252	0.002169	-0.05731	↓

	GRID NO.	Z VALUE	P VALUE	Sen's SLOPE	Trend
23	G23	2.25867	0.011952	0.034176	↑
24	G24	0.192398	0.423715	0.003429	no
25	G25	2.936168	0.001661	0.038228	↑
26	G26	-0.82815	0.203793	-0.0161	no
27	G27	-1.74832	0.040205	-0.03015	↓
28	G28	2.049462	0.020208	0.031023	↑
29	G29	2.016001	0.0219	0.027254	↑
30	G30	2.534641	0.005628	0.035981	↑

Table 2. Is the trend analysis of rainfall for the pre-monsoon season

S.NO.	GRID NO.	Z VALUE	P VALUE	Sen's SLOPE	Trend
1	G1	-0.31402	0.376754	0	no
2	G2	-0.54484	0.292933	0	no
3	G3	0.337784	0.367763	0	no
4	G4	-0.9226	0.178107	-0.00055	no
5	G5	-0.14389	0.442793	0	no
6	G6	0.294475	0.384198	0	no
7	G7	0.228535	0.409615	0	no
8	G8	-0.23157	0.408437	0	no
9	G9	0.411692	0.340282	0	no
10	G10	0.05925	0.476377	0	no
11	G11	-0.17086	0.432168	0	no
12	G12	-0.15324	0.439106	0	no
13	G13	0.317335	0.375495	0	no
14	G14	-0.50827	0.305633	0	no
15	G15	-0.85131	0.197299	0	no
16	G16	-1.03024	0.151448	-0.00068	no
17	G17	-0.18794	0.425461	0	no
18	G18	-0.52317	0.300427	0	no
19	G19	0.008577	0.496578	0	no
20	G20	-0.37589	0.353501	0	no
21	G21	-1.5609	0.059274	-0.00351	no
22	G22	-2.09798	0.017954	-0.00499	↓
23	G23	-0.67072	0.251198	-0.00044	no
24	G24	-0.17594	0.430172	-0.0002	no
25	G25	-0.91708	0.179551	-0.00097	no
26	G26	-1.74388	0.04059	-0.0064	↓
27	G27	-0.37082	0.355385	0	no
28	G28	-0.72479	0.23429	-0.00036	no
29	G29	-1.94079	0.026142	-0.0072	↓
30	G30	-0.68745	0.245901	0	no

Table 3. Is the trend analysis of rainfall for the Monson season

S.NO.	GRID NO.	Z VALUE	P VALUE	Sen's SLOPE	Trend
1	G1	-3.68054	0.000116	-0.44117	↓
2	G2	-3.39613	0.000342	-0.65506	↓
3	G3	-3.64708	0.000133	-0.53901	↓
4	G4	-4.28281	9.23E-06	-0.55229	↓
5	G5	-3.49651	0.000236	-0.85944	↓
6	G6	-3.86456	5.56E-05	-0.59571	↓
7	G7	-1.53913	0.061886	-0.12818	no
8	G8	0.669189	0.251688	0.061548	no
9	G9	0.936864	0.174414	0.073075	no
10	G10	-0.71938	0.235954	-0.06635	no

S.NO.	GRID NO.	Z VALUE	P VALUE	Sen's SLOPE	Trend
11	G11	-2.77713	0.002742	-0.32124	↓
12	G12	-0.75284	0.225774	0.103741	no
13	G13	0.803026	0.21098	0.062863	no
14	G14	-1.05397	0.145948	-0.09354	no
15	G15	1.020513	0.153743	0.103741	no
16	G16	1.321648	0.093143	0.133063	no
17	G17	4.232618	1.15E-05	0.421048	↑
18	G18	3.111727	0.00093	0.274853	↑
19	G19	2.593106	0.004756	0.199105	↑
20	G20	1.371837	0.085057	0.123184	no
21	G21	1.923917	0.027182	0.179989	↑
22	G22	2.877511	0.002004	0.245386	↑
23	G23	4.450104	4.29E-06	0.378185	↑
24	G24	4.767969	9.30E-07	0.476771	↑
25	G25	5.32005	5.19E-08	0.547653	↑
26	G26	5.219671	8.96E-08	0.543369	↑
27	G27	3.914753	4.52E-05	0.406476	↑
28	G28	4.68432	1.40E-06	0.447345	↑
29	G29	5.554266	1.39E-08	0.58895	↑
30	G30	2.459268	0.006961	0.288829	↑

Table 4. is the trend analysis of rainfall for the post-Monson season.

S.NO.	GRID NO.	Z VALUE	P VALUE	Sen's SLOPE	Trend
1	G1	0.694307	0.243745	0.0231475	-
2	G2	0.510274	0.30493	0.0193032	-
3	G3	0.610656	0.270714	0.0226716	-
4	G4	1.480632	0.069352	0.0554505	-
5	G5	1.631204	0.051424	0.0692449	-
6	G6	1.915619	0.027707	0.072624	↑
7	G7	1.831968	0.033478	0.0782386	↑
8	G8	-1.78178	0.037393	-0.0459465	↓
9	G9	-1.27987	0.100296	-0.0345056	-
10	G10	0.27605	0.391255	0.010801	-
11	G11	0.82815	0.203793	0.0273141	-
12	G12	-1.81524	0.034744	-0.0657785	↓
13	G13	-1.21295	0.112575	-0.0292455	-
14	G14	-1.17949	0.119102	-0.0359094	-
15	G15	-2.33388	0.009801	-0.0657785	↓
16	G16	-3.88979	5.02E-05	-0.1165946	↓
17	G17	-1.53924	0.061873	-0.0357791	-
18	G18	-1.86543	0.031061	-0.041145	↓
19	G19	-0.3597	0.359535	-0.0096131	-
20	G20	-2.26696	0.011696	-0.0457818	↓
21	G21	-4.7765	8.92E-07	-0.1667198	↓
22	G22	-4.49209	3.53E-06	-0.1788658	↓
23	G23	-4.09056	2.15E-05	-0.2705587	↓
24	G24	-4.49209	3.53E-06	-0.2682623	↓
25	G25	-4.29132	8.88E-06	-0.2906275	↓
26	G26	-3.52173	0.000214	-0.1699552	↓
27	G27	-3.82287	6.60E-05	-0.1626151	↓
28	G28	-3.97345	3.54E-05	-0.1901434	↓
29	G29	-4.27459	9.57E-06	-0.2108459	↓
30	G30	-0.00837	0.496663	-0.0002295	-
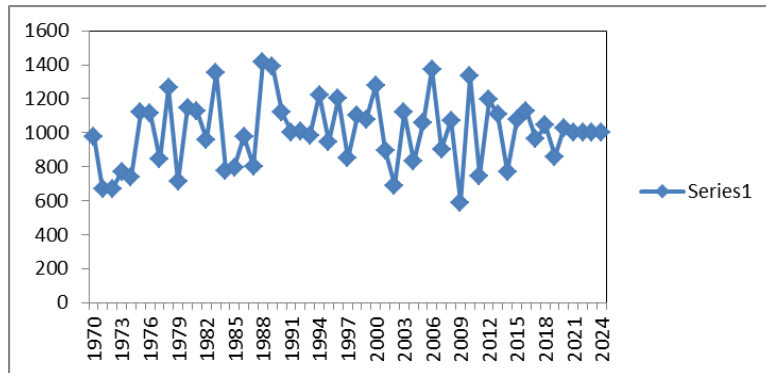
Fig. 7. Time series and regression analysis for the monsoon seasons, the time series analysis and the forecast for the next 5 years statistically
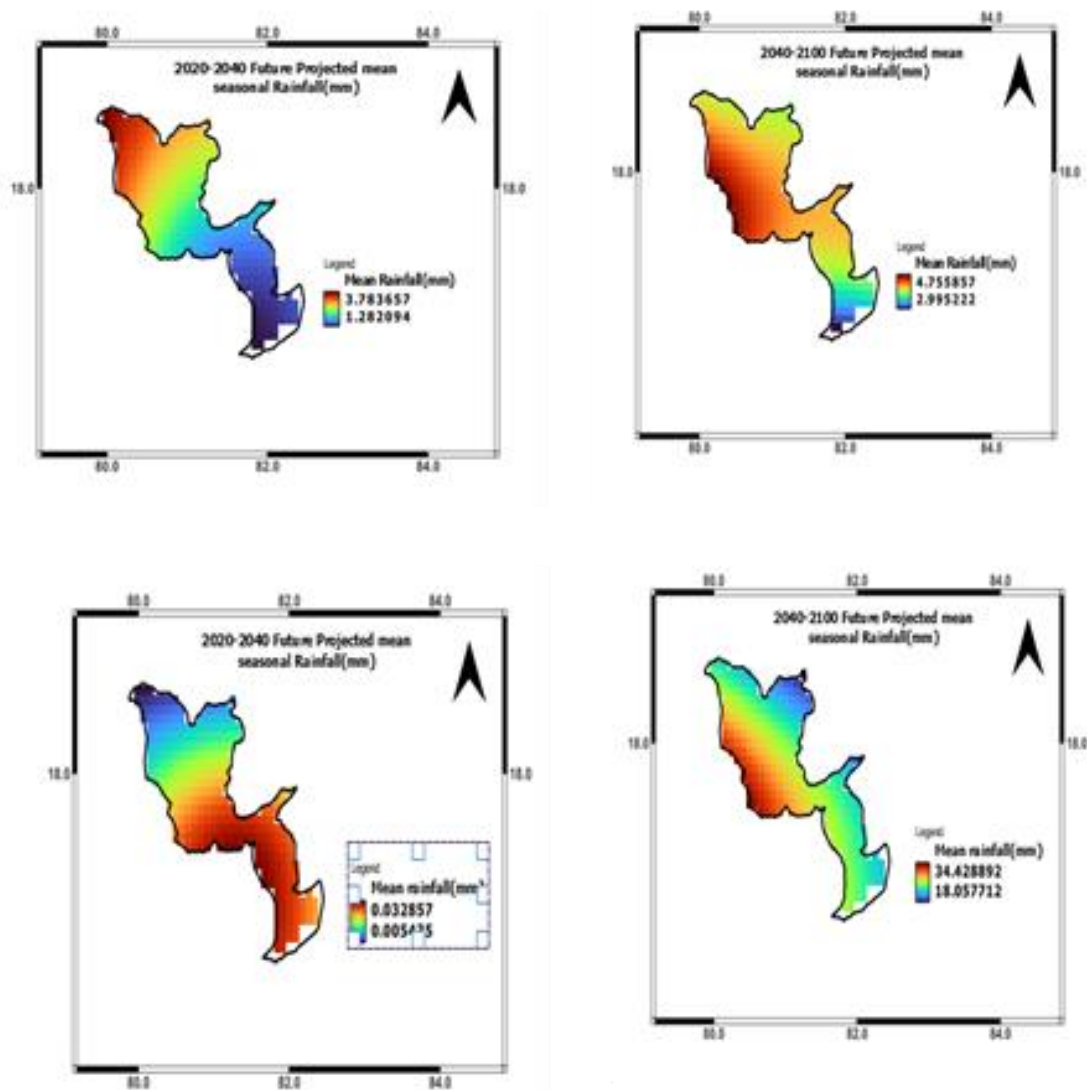
Fig. 8. Shows future projects of the mean average rainfall for the lower Godavari basin from 2020-2040, 2040-2100 with RCP 4.5 and RCP 8.5 scenarios

4. SUMMARY AND CONCLUSIONS

The current study examined the trend and homogeneity of trends for annual and seasonal rainfall series for the Lower Godavari basin from 1970 to 2019 using IMD 0.25X0.25 ° gridded rainfall data. From the study, it is concluded that annual and monsoon rainfall is increasing in the Lowe Godavari basin during the period 1970–2019. There has been an increasing trend in the basin during the period 1970–2019. There has been a general decrease (2.20%) in annual rainfall in the basin during the period 1970–2019. It is also found that the trends are homogeneous across the basin. It has also been discovered that there will be a significant increase in the future. Projections are also important.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. IPCC. Special report on managing the risks of extreme events and disasters to advance climate change adaptation; 2008. http://WWW.ipcc-wg2 . Gov/

2. Yaduvanshi A, Srivastava PK, Pandey AC. Integrating TRMM and MODIS satellite with socio-economic vulnerability for monitoring drought risk over a tropical region of India. Physics and Chemistry of the Earth, Parts a/b/c. 2015 Jan 1;83:14-27.

3. Kumar V, Jain SK, Singh Y. Analysis of long-term rainfall trends in India. Hydrol. Sci. J. 2010;55 (4):484–496.

4. Dessens J, Bucher A. Changes in minimum and maximum temperatures at the Pic du Midi relation with humidity and cloudiness, 1882–1984. Atmospheric Research. 1995;37:147–162.

5. Serra C, Burgueno A, Lana X. Analysis of maximum and minimum daily temperatures recorded at Fabra Observatory (Barcelona, NE Spain) in the period 1917–1998. International Journal of Climatology. 2001;21:617–636.

6. Marengo JA. Interdecadal variability and trends of rainfall across the Amazon basin. Theoretical and Applied Climatology. 2004;78:79–96.

7. Manish Kumar Goyal, Vivek Gupta. Identification of homogeneous rainfall regimes in northeast region of india using fuzzy cluster analysis. Water Resources Management. 2014;28:4491– 4511.

8. Kalnay E, Cai M. Impact of urbanization and land-use change on climate. Nature. 2003;423: 528–531.

9. Jain SK, Kumar V. Trend Analysis of Rainfall and Temperature Data for India. Current Science. 2012;102:37-49.

10. Guhathakurta P, Rajeevan M. "Trends in the rainfall pattern over India. International journal of Climatology; 2007.

11. Gosain AK, Sandhya Rao, Debility Basuray, Climate change impact assessment on hydrology of Indian river basins, Current Science. 2006;90(3):346-353.

12. Parthasarathy B, Dhar ON. A Study of Trends and Periodicities in the Seasonal and Annual Rainfall of India. Indian Journal of Meteorology, Hydrology and Geophysics. 1976;27:23-28.

13. Suman Bera. Trend Analysis of Rainfall in Ganga Basin, India during 1901-2000". American Journal of Climate Change. 2017;6:116-131.

14. Sarita Gajbhiye. Estimation of Surface Runoff Using Remote Sensing and Geographical Information System". International Journal of u- and e- Service, Science and Technology. 2015;8(4):113-122

15. Arun Kumar Taxak AR, Murumkar DS, Arya N. Long term spatial and temporal rainfall trends and homogeneity analysis in Waingangā basin, Central India". Weather and Climate Extremes. 2014;4:50-61.

16. Biswas B, Jadhav RS, Tikone N. Rainfall distribution and trend analysis for upper Godavari basin, India, from 100 years record (1911–2010). Journal of the Indian Society of Remote Sensing. 2019 Oct;47:1781-92. DOI:10.1007/s12524-019-01011-8.

17. Sravani, A, Rao, Vennapu & Padi, Tirupathi Rao & Padi, Nagaratna, K. Rainfall Distribution and Trend Analysis of the Godavari River Basin, India during 1901-2012. International Journal of Science and Research (IJSR). 2021;10:1030-1039. DOI:10.21275/SR2141512005.

18. Pai et al. Pai DS, Latha Sridhar, Rajeevan M., Sreejith O.P., Satbhai N.S. and Mukhopadhyay B., 2014: Development of a new high spatial resolution (0.25° X 0.25°)Long period (1901-2010) daily

gridded rainfall data set over India and its comparison with existing data sets over the region; MAUSAM. 2014;65: 1-18.

19. Farr TG, Rosen PA, Caro E, Crippen R, Duren R, Hensley S, et al. The shuttle radar topography mission. Reviews of geophysics. 2007 Jun, 45(2).

20. Gerlitz C, Lury C. Social media and self-evaluating assemblages: On numbers, orderings and values. Distinktion: Scandinavian Journal of Social Theory. 2014 May 4;15(2):174-88.

21. Reuter HI, Nelson A, Jarvis A. An evaluation of void- filling interpolation methods for SRTM data. International Journal of Geographical Information Science. 2007 Oct 1;21(9):983-1008.

22. Webber J, Hawkins C. Statistical Analysis Application to Business and Economics. New York: Harper and Row; 1980.

23. Mann HB. Nonparametric tests against trend. Econometrica. 1945;13:245-259.

24. Kendall MG. The Advanced Theory of Statistics,2 ed. Charles Griffin: London. 1946;521.

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