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***Short Comminucation***

# Trend analysis and change point detection of rainfall of Andhra Pradesh and Telangana, India

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Rainfall and temperature are the key elements of weather systems due to their temporal and spatial variability at different scales. Hence, analysis of their behaviour is vital for understanding of climate variability. Rainfall is the most important climate parameter which has direct effect on crop growth and yield under rainfed condition. Among the total cultivated area in Andhra Pradesh and Telangana, 50 to 63 per cent of the area is rainfed. Long term weather analysis are useful in deciding future directions and/or alterations required in existing system for sustainable crop production. Various parametric and non-parametric tests have been used for trend analysis of hydro-meteorological time series variables such as rainfall. Time series data of such variables have missing values, zero values, non-normal distribution which limit application of parametric tests. Mann-Whitney test, Kruskal-Wallis, Mood's median test, etc. are some of the non-parametric tests usually employed for trend analysis (Kisi and Ay, 2014). Such tests have been applied by various workers for Indian region (Yadav *et al.,* 2014; Lunagaria *et al.,*2012 and Prabhakar *et al.,* 2017).

Hence, this study was carried out to find the trend in the rainfall series to get idea on rainfall patterns and variability in different regions of Andhra Pradesh and Telangana.

## MATERIALS AND METHODS

The state of Andhra Pradesh is having two regions i.e.Coastal Andhra comprised of 9 districts and Rayalaseema comprised of 4 districts. The AP state has average rainfall of about 940 mm of which south west monsoon contributes 64 per cent and north east monsoon 36 per cent.The Telangana state is comprised of 10 districts with mean annual rainfall of 923 mm of which SW monsoon contributes about 80 per cent and NE monsoon contributes 13 per cent of the annual rainfall (Annon., 2017 a,b).

Monthly rainfall data for 102 years (1901-2002) of 23 stations of two states were collected from India water portal site (http://www.indiawaterportal.org/metdata last accessed on 25.09.2017). Non parametric tests such as Mann Kendall test (Mann, 1945; Kendall, 1975) and Sen's slope estimator (Sen, 1968) were conducted to test magnitude and direction in series. Mann Whitney Pettitt test (Pettitt, 1979) was used for change detection (Prabhakar *et al.,* 2017).

In Andhra Pradesh state, the mean annual rainfall varied from 717.3 mm (Prakasham station) to 1114.8 mm (Vizianagaram station) while in Coastal Andhra and Rayalaseema regions, it varied from 542.2 mm (Kurnool station) to 867.3 mm (Chittor station).In Telangana state, the mean annual rainfall varied from 676.9 mm (Mehboobnagar station) to 997.8 mm (Adilabad station). The coefficient of variation varied from 17 to 23 per cent across different stations.The coefficient of variation which gives the inter-annual variability of annual rainfall varied from 16.9 to 23 per cent across all the stations.

***Trend analysis for annual and seasonal rainfall***

The non-parametric MKtest showed rising trend in annual rainfall for all the stations (Table 1). It was found that 16 stations (East Godavari, Cuddappa, Guntur, Hyderabad, Karimnagar, Khammam, Krishna, Kurnool, Medak, Mehboobnagar, Nalgonda, Nizamabad, Prakasham, Vishakhapatnam, Warangal and West Godavari) showed statistically significant rising trend in annual rainfall. The magnitude of the trends in annual rainfall varied from+0.38 mm per year (Vizianagaram station) to +1.97 mm per year (West Godavari station). The maximum increase of 22.17 per cent in percentage change in annual rainfall was observed

**Table 1:** Mann Kendall test statistic (Z), Sen Slope estimator (β) test and % change for annual and monsoon season rainfall during 1901–2002 for different stations in Andhra Pradesh and Telangana

| State/region/ | Annual | | | Monsoon | | |
|---|---|---|---|---|---|---|
| station | Z | β | Per cent change | Z | β | Per cent change |
| **Telangana** | | | | | | |
| Adilabad | 1.64 | 1.08 | 11.04 | 0.98 | 0.14 | 6.56 |
| Nizamabad | 2.36* | 1.61 | 17.78 | 1.43 | 0.27 | 12.66 |
| Karimnagar | 2.36* | 1.47 | 16.11 | 1.74 | 0.24 | 12.81 |
| Medak | 2.20* | 1.20 | 14.34 | 1.12 | 0.14 | 8.50 |
| Warangal | 2.45* | 1.27 | 15.49 | 1.37 | 0.16 | 9.98 |
| Rangareddy | 2.27 | 1.32 | 16.57 | 1.23 | 0.15 | 9.92 |
| Hyderabad | 2.39* | 1.59 | 19.29 | 1.68 | 0.23 | 14.29 |
| Mehboobnagar | 2.82* | 1.47 | 22.17 | 1.61 | 0.18 | 15.52 |
| Nalgonda | 2.45* | 1.37 | 18.63 | 1.41 | 0.15 | 11.40 |
| Khammam | 3.17* | 1.96 | 21.76 | 2.00* | 0.26 | 15.35 |
| Telangana region | 2.70* | 1.40 | 16.80 | 1.70 | 0.20 | 12.40 |
| **Coastal Andhra** | | | | | | |
| Shrikakulam | 0.73 | 0.42 | 4.48 | 0.54 | 0.06 | 3.76 |
| Vishakhapatanam | 1.97* | 1.34 | 12.46 | 1.60 | 0.20 | 11.08 |
| Vizianagaram | 0.58 | 0.38 | 3.45 | 0.49 | 0.07 | 3.50 |
| East Godavari | 3.04* | 2.00 | 20.01 | 1.93 | 0.22 | 13.46 |
| West Godavari | 2.82* | 1.97 | 20.99 | 1.50 | 0.20 | 13.18 |
| Guntur | 2.11* | 1.42 | 18.35 | 1.64 | 0.14 | 13.47 |
| Krishna | 2.18* | 1.60 | 18.54 | 1.35 | 0.16 | 12.36 |
| Prakasham | 2.50* | 1.34 | 19.07 | 1.50 | 0.13 | 13.65 |
| Nellore | 1.34 | 0.71 | 8.59 | 1.50 | 0.15 | 16.67 |
| Coastal Andhra region | 2.30* | 1.30 | 14.20 | 1.70 | 0.15 | 11.00 |
| **Rayalaseema** | | | | | | |
| Anantpur | 1.50 | 0.79 | 12.31 | 0.63 | 0.05 | 5.74 |
| Chittor | 1.30 | 0.77 | 9.07 | 1.42 | 0.15 | 13.88 |
| Cuddappa | 2.19* | 0.93 | 14.16 | 0.98 | 0.09 | 9.89 |
| Kurnool | 2.64* | 1.09 | 20.45 | 1.16 | 0.08 | 10.35 |
| Rayalaseema region | 2.0* | 0.93 | 13.90 | 0.97 | 0.08 | 8.8 |

*represents the significant trend at 5% significance level.

at Mehboobnagar station. The MK test applied to the monsoon rainfall series also showed increasing trend for all 23 stations and but the significant rising trend at Khammam station only. The magnitude of the trends in monsoon rainfall varied from +0.06 mm per year (Shrikakulam station) to +0.27 mm per year (Nizamabad station). The maximum increase of 16.67 per cent in percentage change in monsoon rainfall was observed at Nellore station over the 102 years.

***Determination of change point***

The change point has been determined using the MWP and CD test (Table 2).The change point was found quite variable but the most probable change year was 1953 as observed over five stations. Based on change point year 1953, the mean annual rainfall values were calculated for two sub-periods (1901-1953 and 1954-2002). Using these

**Table 2:** Detection of change point using the cumulative deviation and Mann Whitney Pettit statistic test and percentage change for rainfall of different stations in Andhra Pradesh and Telangana

| State/region station | Change point (CD) | $Q/\sqrt{n}$ | Change point (MWP) | Value of p(k) (MWP statistics) | Change percentage |
|---|---|---|---|---|---|
| **Telangana** | | | | | |
| Adilabad | 1931 | 1.152 | 1931 | 0.051 | 5.52 |
| Nizamabad | 1947 | 1.448 | 1947 | 0.009 | 12.13 |
| Karimnagar | 1953 | 1.355 | 1953 | 0.028 | 9.84 |
| Medak | 1947 | 1.305 | 1947 | 0.013 | 10.08 |
| Warangal | 1953 | 1.31 | 1953 | 0.019 | 9.37 |
| Rangareddy | 1947 | 1.291 | 1947 | 0.009 | 9.57 |
| Hyderabad | 1947 | 1.247 | 1947 | 0.008 | 10.42 |
| Mehboobnagar | 1943 | 1.589 | 1943 | 0.002 | 11.46 |
| Nalgonda | 1953 | 0.996 | 1953 | 0.041 | 8.08 |
| Khammam | 1953 | 1.597 | 1944 | 0.010 | 12.32 |
| **Coastal Andhra** | | | | | |
| Shrikakulam | 1925 | 0.742 | 1925 | 0.287 | 2.76 |
| Vishakhapatanam | 1927 | 1.082 | 1927 | 0.105 | 6.95 |
| Vizianagaram | 1925 | 0.761 | 1925 | 0.21 | 1.19 |
| East Godavari | 1936 | 1.365 | 1936 | 0.026 | 9.97 |
| West Godavari | 1944 | 1.249 | 1930 | 0.037 | 0.08 |
| Guntur | 1974 | 0.923 | 1930 | 0.119 | 6.03 |
| Krishna | 1915 | 0.876 | 1915 | 0.142 | 7.52 |
| Prakasham | 1974 | 1.011 | 1944 | 0.046 | 7.68 |
| Nellore | 1955 | 0.982 | 1955 | 0.102 | 7.88 |
| **Rayalaseema** | | | | | |
| Anantpur | 1953 | 0.906 | 1953 | 0.186 | 6.46 |
| Chittor | 1955 | 0.622 | 1971 | 0.312 | 4.74 |
| Cuddappa | 1956 | 1.299 | 1956 | 0.02 | 10.06 |
| Kurnool | 1946 | 1.431 | 1943 | 0.009 | 9.99 |

mean annual rainfall values, the percentage change in the mean of one sub-period (1901-1953) over the mean of other sub-period(1954-2002)was determined (Table 2). The data reveals the rise in annual rainfall over all the stations with more than 10 per cent rise at six stations (Nizamabad, Medak, Hyderabad, Mehboobnagar, Khammam and Cuddappa).

Thus, the analysis of 102 years rainfall data using MK test and Sen's slope estimator test revealed the presence of increasing trend in annual rainfall series in Andhra Pradesh and Telangana states. The monsoon rainfall series showed a presence of increasing trend but statistically significant trend at Khammam station only. The change point analysis revealed that the most probable year of change was 1953 for annual rainfall.

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