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Spatial and Temporal Variability Investigations of Rainfall in Yerrakalava River Basin of Andhra Pradesh, India

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Abstract: - **The present study focuses on analysis of time series of annual rainfall and number of rainy days in Yerrakalava river basin of Andhra Pradesh, India. The results show that mixed trends of increasing and decreasing rainfall and rainy days for various rain gauge stations. The mean annual rainfall of the each station is calculated and shows that the values are in between 1016.54 mm to 1339.29 mm. Also, mean annual rainy days were calculated and are from 52.54 to 60.88 days. Mann Kendall test has applied to rainfall and rainy days, shows that some Rain gauge (RG) stations are increasing trend and some are in decreasing trend. The Zc Values from Mann-Kendall Test are varying in between -0.44 to 0.632 and for rainy days -1.09 to 0.74. It is observed that rainfall and rain days are in correlation with elevation of the area.**

Key words: Yerrakalava River Basin, Trend, Annual Rainfall, Mann-Kendall Test

INTRODUCTION:

Yerrakalava river watershed is located in coastal Andhra Pradesh. The basin receives majority of its rainfall from south west monsoon season. The area enjoys with hilly terrain in north eastern side and plains in southern side. Agriculture is the prime source of income to the people of this area. Flooding is the perennial problem in the Lower reaches of the area may be due to the low elevation and high rainfall intensities in the area. One major reservoir has been constructed on the river near konguvarigudem village of Jangareddygudem mandal to arrest the flood in the lower reaches and to supply the irrigation water during dry period. In the present study, rainfall data of different rain gauge stations were analyzed to assess the variability of the rainfall with time and space.

LITERATURE REVIEW:

Besides, land use/land cover many other factors which affecting strongly the runoff and erosion processes. Among these factors, the most mentioned is rainfall. Morin et al. (2006) found that complex interactions exist between the spatiotemporal distributions of rainfall systems and hydrological responses in a watershed. Trend analysis for limatological and hydrological parameters like precipitation and inflows (Brunetti,M., et al 2000, Buishand, T.A., 1982; Chiew, F.H.S., et al 1993; Delitala, A.,2000; Dinpashosh,Y., et al 2004; Hess,T.M., et al 1995; Hirsch,R.M and Slack, J.R., 1984. ,Gemmer,M., et al 2004; Lazaro, R., et al 2001; Novotny E.V and Stefan HG., 2007; Raziei,T., 2005; Kampata,J.M., et al 2008;Marengo,J.D.,2008, Xu K.et al 2010; Serrano A., 1999) have applied to study and asses the desertification (Abahussain, A.A., et al 2002) floods (Douglas, E.M.,2000). Variability study of rainfall data may provide a general gauge regarding changes in the natural behavior of ecosystems. A key step in this process is the ability to reveal that a change or trend in the rainfall records. The linear relationship is the most common method used for detecting rainfall trends (Hameed et al.,1997; Silva,2004). Besides, Mann-Kendall (MK) test has been widely used to assess the significant trends in hydrological and climotolocal data sets (Burn,1994; Chiew and McMahon, 1993; Douglas et al.,2000; Hirsch and Slack,1984; Yue et al.,2002). Silva (2004) analysed the temporal trends, to observe the climatic variability in the north east Brazil. More over, the knowledge in trends of climatological variables like annual rainfall and rainy days are very important for agriculture planning in any area.

In this study, the yearly rainfall data of 13 rain gauge stations have analyzed to assess the changes in the rainfall trends. Rainfall and Rain days how they are influenced by elevation is also studied.

MATERIALS AND METHODS:

Study area

The Yerrakalava River basin lies in between 80°53'51"E and 81°38'46"E in longitudes 16°50'29"N and 17°24'42"N in latitudes with an areal extent of 2379 Km^2. This is the part of Kolleru-Upputeru catchment in between Krishna-Godavari Rivers. The area is drained by major river Yerrakalava and its tributaries Jalleru, Sangamvagu, Jalavagu. Baineru, Padamatikalava, Thurpukalava and Paletivagu. The normal minimum and maximum temperatures recorded in West Godavari district are 19°C and 48°C respectively of which the minimum values correspond to December. During May and early June sometimes day temperature rises to 45°C to 48°C. The average annual rainfall of the study area is 1110.12 mm. The soils in the study area are red soils with clay base, black cotton soils and alluvial soils. The location map of the study area is given in Fig.1

Materials and methods:

The available daily rainfall data of 13 rain gauge stations located in the study area have been collected from the Bureau of Economics and Statistics Department, Andhra Pradesh, India. The available data period as given Table.1. The rain gauge stations named RG-1, RG-2….RG-13. The naming has given as per the elevation of that station. The station RG-1 has high elevation and RG-13 has low elevation. Yearly rainfall of the each station is calculated by summing the daily rainfall data. The analysis has made for yearly rainfall.

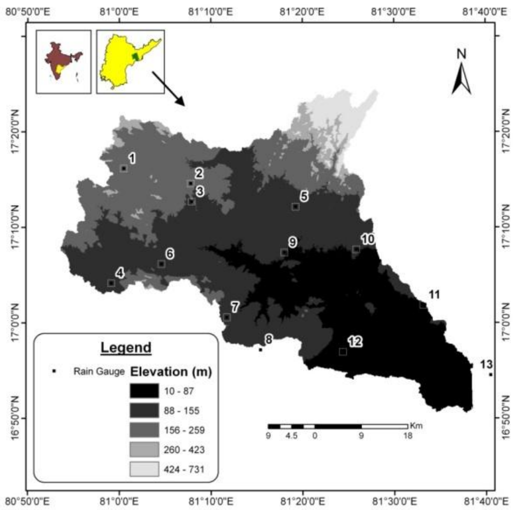

Fig.1 Location map of the study area

Table 1 Rain Gauge (RG) stations located in the study area

RG. No	Rain gauge Name	Altitude, m	Start year	Sample size, Years
1	Dammapeta	214	1989	24
2	Aswaraopeta	180	1987	26
3	Jeelugumilli	157	1989	24
4	Chintalapudi	139	1981	32
5	Buttayagudem	135	1989	24
6	T Narasapuram	122	1989	24
7	Kamavarapukota	113	1989	24
8	Dwaraka Tirumala	100	1989	24
9	Jangareddigudem	96	1981	32
10	Koyyalagudem	92	1988	25
11	Devarapalle	58	1988	25
12	Nallajerla	51	1981	32
13	Nidadavole	24	1989	24

Man Kendall Test:

Trend analysis has been done by using non-parametric Man-Kendall test. This is a statistical method which is being used for studying the spatial variation and temporal trends of hydro climatic series.

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_i - x_j)$$

The application of trend test is done to a time series x_i that is ranked from i = 1,2,………n-1 and x_j, which is ranked from j = i+1,2,……….n. Each of the data point x_i is taken as a reference point which is compared with the rest of the data points x_j so that,

$$sign(x_j - x_i) = \begin{cases} +1, > (x_j - x_i) \\ 0, = (x_j - x_i) \\ -1, < (x_j - x_i) \end{cases}$$

It has been documented that when n ≥ 8, the statistic S is approximately normally distributed with the mean.

$E(S) = 0$The variance statistic is given as

$$Var(s) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i\,(i)(i-1)(2i+5)}{18}$$

where ti is considered as the number of ties up to sample i. The test statistics Zc is computed as

$$Z_c = \begin{cases} \dfrac{s-1}{\sqrt{Var(S)}}\ if\ S > 0 \\ 0, if\ S = 0 \\ \dfrac{s+1}{\sqrt{Var(S)}}\ if\ S < 0 \end{cases}$$

Zc here follows a standard normal distribution. A positive value of Z signifies an upward trend and a negative value of Z signifies an downward trend. A significance level α is also utilised for testing either an upward or downward monotone trend (a two-tailed test). If Z_c appears greater than $Z_{\alpha/2}$ where α depicts the significance level, then the trend is considered as significant.

Results and discussion:

Trend analysis of 13 rain gauge(RG) stations in Yerrakalava river basin has been done in the present study. The RG stations are operating from dates so that, the sample sizes are varying between 24 to 32 years.

Minimum and maximum Rain fall and Rain days:

Yearly rainfall and rain days of each station have arranged in ascending order and noted the high and lows of rainfall and rain days for each station. An overall analysis result shows that, in the year 2002, 6 (46.15%) RG stations have recorded low rainfall out of 13 RG Stations similarly, in the year 2010, 7 (53.85%) RG stations have recorded high rainfall out of 13 stations. From the above result it is concluded that, Most of the area in 2002, has got very less rainfall and in 2010, very high rainfall. In the year 2002, 10 (76.9%) RG Stations have recorded the low rain days out of 13 RG stations and in 2010, 7(53.8%) RG stations have recorded high rain days out of 13 RG Stations. This result indicates that most of the area has got its high number of rainy days in 2010 and low number of rainy days in 2002. In the entire basin, Minimum rainfall of 392 mm has recorded at Aswaraopeta (RG-2) station in 2002 and Maximum of rainfall of 2267 mm has recorded at Dammapeta (RG-1) station in 2000. Similarly, Minimum rainy days of 27 have recorded at the Nidadavolu (RG-13) station in 1996 and Maximum rainy days of 81 have recorded at Nallagerla (RG-12) in 2010. The results are given in Table.2 & Table.3. The minimum and maximum rainfall and rain days of different stations as given Fig.2.

Mann-Kendall test:

In the non parametric Mann-Kendall test, it has been observed that the trend of rainfall and rainy days are varying from station to station. Rainfall of Rain gauges RG-4, RG-5, RG-6, RG-9, RG-10 and RG-13 are in the evidence of increasing trend while the Rain gauges RG-1, RG-2, RG-3, RG-7, RG-8 and RG-12 are shows decreasing trend. No change in the trend of rainfall for RG-11. Similarly, for rainy days, Rain gauges of RG-2 RG-5, RG-7, RG-9, RG-10, RG-11 and RG-

13 are in the evidence of increasing trend while the Rain gauges RG-1, RG-3, RG-4, RG-6 and RG-8 are in decreasing trend. For rain gauge RG- 12 no change of rainy days has observed. The Z-statistics for different stations as given Fig.3

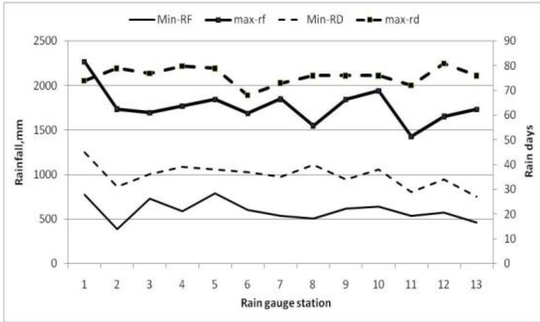

Fig.2 Minimum and Maximum rainfall and rainy days of the study area

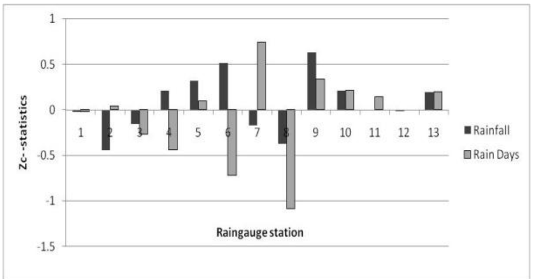

Fig.3 Trend of Z_c Statistic for individual stations

Mean Rainfall and Rain days:

Mean annual rainfall and rainy days of individual stations are differed from station to station. For rain days, the maximum mean value of 60.88 days observed at RG-5 and minimum mean value of 52.54 days at RG-6. Similarly, for rainfall, the maximum mean value of 1339.29 mm observed at RG-1 and minimum mean value of 1016.54 at RG-6. From the above result it is concluded that RG-6 (T.Narasapuram) is receiving the lowest rainfall and rainy days. While RG-1(Dammapeta) receives the highest rainfall and RG-5(Buttayagudem) receives the high rain days. Mean rainfall and rain days map is given Fig.4.

Table.2 Observed yearly rain days for the sample period - Minimum rain days(RD_{Min}), Maximum rain days(RD_{Max}), Minimum Year (RD-Year $_{Min}$), Maximum Year (RD-Year$_{Max}$), Mean rain days (RD_{Mean}), Standard deviation(RD_{SD}) and Mann Kendall (MK)-Z statistic

RG. No	RD_{Min}	RD_{Max}	RD-Year $_{Min}$	RD-Year$_{Max}$	RD_{Mean}	RD_{SD}	MK
1	45	74	2002	1999	59.62	9.14	-0.02
2	31	79	2002	2010	58.12	10.30	0.04
3	36	77	2002	2010	56.58	9.82	-0.27
4	39	80	2002	1990	56.75	10.26	-0.44
5	38	79	2002	1994	60.88	10.10	0.10
6	37	68	2002	1994	52.54	10.58	-0.72
7	35	73	1992	2012	53.04	12.10	0.74
8	40	76	2002	2010	55.79	10.83	-1.09
9	34	76	2002	2010	57.16	10.71	0.34
10	38	76	2002	2007	57.80	10.44	0.21
11	29	72	1992	2010	58.12	24.91	0.14
12	34	81	2002	2010	54.06	11.87	0
13	27	76	1996	2010	53.55	12.09	0.2

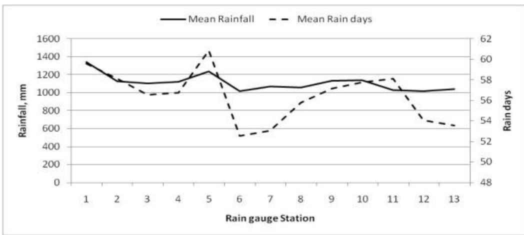

Fig.4 Mean annual Rainfall and Rain days of individual stations

Correlation of Rainfall and rain days with altitude:

Correlation line between rainfall and altitude for different rain gauges shows that as the elevation increases, rainfall is also increase. Similarly as the elevation increases the rain days also increase. The correlation maps as given Fig.5 and Fig.6.

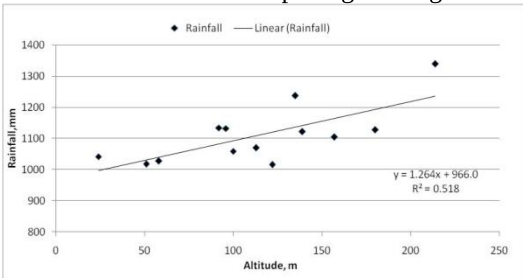

Fig.5 Correlation of Mean annual Rain days and Altitude

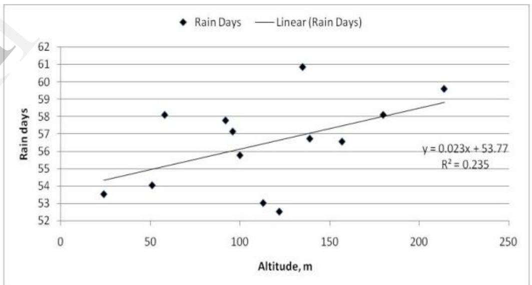

Fig.6 Correlation of Mean annual Rainfall and Altitude

Standard Deviation (SD):

Standard deviation of rainfall and rain days for each station is calculated and the results as given in Fig.7. For rainfall, Standard deviation is more for RG-11 (533.16 mm) and low for RG-3 (266.38). Similarly, For rain days, Standard deviation is more for RG-11(24.91 days) and low for RG-1 (9.14 days). From results, it is concluded that rainfall variability is high for RG-11 (Devarapalli) and low for RG-3(Jeelugumilli). Similarly, rain days are more varying for RG-11(Devarapalli) and less varying for RG-1(Dammapeta). Standard deviation graph for different staions as given in Fig.7.

CONCLUSIONS:

From the investigation of yearly rainfall data of 13 rain gauge stations in Yerrakalava River basin, the following conclusions have been made.

30 years of rainfall data shows that most of the area has got very less rainfall in 2002 and very high rainfall in 2010. Similarly, most of the area has got its high number of rainy days in 2010 and low number of rainy days in 2002.

Table.3 Observed yearly rain fall for the sample period - Minimum rain fall(RF_{Min}), Maximum rain fall(RF_{Max}), Minimum Year (RF-Year $_{Min}$), Maximum Year (RF-$Year_{Max}$), Mean rain fall (RF_{Mean}), Standard deviation(RF_{SD}) and Mann Kendall (MK)-Z statistic

RG. No	RF_{Min}	RF_{Max}	RF-Year $_{Min}$	RF-$Year_{Max}$	RF_{Mean}	RF_{SD}	MK
1	769.1	2267.0	2002	2000	1339.3	379.9	-0.02
2	392.0	1735.6	2002	2010	1127.3	305.4	-0.44
3	727.0	1695.2	2009	2010	1104.5	266.4	-0.15
4	586.8	1767.2	1993	2010	1122.2	301.6	0.21
5	786.6	1842.8	1992	2010	1237.9	288.6	0.32
6	607.2	1686.6	2002	2010	1016.5	290.2	0.52
7	539.7	1848.7	2003	1998	1069.4	359.6	-0.17
8	509.0	1549.6	2002	1998	1059.6	275.5	-0.37
9	619.1	1842.9	1984	1983	1132.6	313.6	0.63
10	640.4	1938.9	1988	2010	1134.8	310.9	0.21
11	541.4	1428.3	2002	1996	1028.2	533.2	0.00
12	573.6	1653.1	2001	1998	1017.4	289.5	-0.01
13	463.3	1730.8	2002	1998	1041.9	367.5	0.20

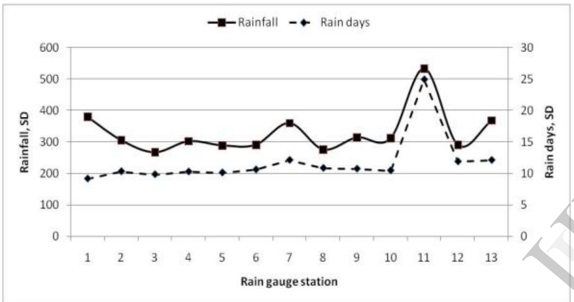

Fig.7 Standard deviation in Rainfall and Rain days for individual stations

Entire study period, Lowest rainfall (at RG-2) in 2002 and rain days (at RG-13) in 1996 have occurred. Trend statistic using Mann-Kendall test shows that rainfall and rain days are increasing in some stations and decreasing in some stations. Some station shows no change. The mean maximum and minimum rainfall and rain days are varying from station to station. Regression between rainfall – altitude and rain days – altitude shows that rainfall and rain days are increasing with the increase of elevation. Lastly, yearly rainfall and rain days of various RG stations have investigated using Mann-Kendall test and some other statistical methods shows that there is much variability from station to station. Certainly, there is a need for much more detailed analysis on this topic in future.

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