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STATISTICAL AND TREND ANALYSIS OF RAINFALL OF KANTHATMAKURVAGU CATCHMENT AREA OF WARANGAL URBAN AND RURAL DISTRICTS OF TELANGANA STATE

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Abstract : This study focused on the statistical and trend analysis of rainfall of over eleven years from 2010 to 2021 of Kanthatmakurvagu catchment area of Warangal urban and rural districts of Telangana state. The data was collected from the six rain gauge stations falling in the catchment area. The study involved analysis of annual and seasonal statistical analysis such as mean, median, standard deviation, coefficient of variation, skewness and kurtosis. Trend analysis of same seasons are also analysed and reported. The results indicated that annual mean rainfall was found to be 1153.3 mm. About 82% of the rainfall was contributed in southwest monsoon period. Maximum rainfall in the southwest monsoon was 1590.5 and minimum was 549.8 mm. Annual maximum rainfall was found to be 1870.6 mm and minimum was 717.5 mm. Annual and all seasonal standard deviation considerably large, this indicates there is larger variation in rainfall pattern. The coefficient of variation indicates the erratic nature of rainfall. Positive skewness indicating the region is asymmetric and it lies to the right of mean that is right skewed. Annual kurtosis value indicating slightly leptokurtic in nature. The northeast and winter and summer seasons showed a negative kurtosis which indicated a flat distributions during this seasons and in southwest seasons it showed a positive kurtosis which indicated a peaked distribution. Highest standard deviation considerably high in July and August indicates there is larger variation, while remaining months has low indicates smaller variation in rainfall pattern. The coefficient of variation ranges between 0.1 and 0.9, which indicates February, was more varied than other months. Positive months showed a positively skewed distribution in the area. The months showed a negative kurtosis indicated a flat distributions and positive kurtosis which indicated a peaked distribution.

***IndexTerms* – trend analysis, rainfall, Warangal, statical analysis, kanthatmakurvagu**

I. INTRODUCTION

Climate change is great cause of concern for all over the world especially rain fed developing country since change in amount and intensity of rainfall adversely affect all sectors of country (Kailas, 2018). The main important source of water in any area is rain and it has a dramatic effect on agriculture and other sectors (Avadesh, 2021). There is need to analyse the rainfall data across the country to get the status, so that future rainfall criteria and its effects on various places can be determined (Vittal, 2019). Water is ours natural resources and it is vital to all the forms of the life. Water is used in various fields like transportation, source of power, for the purposes for domestic consumption, agriculture and industrial purpose (Avik, 2010). As the main economy of the study area is still agriculture, we need to understand the nature of distribution of monsoon rain in order to decide the agricultural strategy (Hussain, 2015, Saini, 2020). Rainfall plays a key role in socio-economic development of any region (Chakraborty, 2019). Rainfall should sustain the increasing needs of agricultural irrigation, the growing population, and rapid industrialisation (Sulafa, 2008, Arvind, 2017). The scientific tempered community has always supported the practice to analyse the trend of a homogeneous climatic region with appropriate statistical techniques (Chhaya, 2015). The rainfall and temperatures are the most important fundamental physical parameters among the climate as these parameters determine the environmental condition of the particular region which affects the agricultural productivity (Panda, 2019, Vasanthakumary. 2018). Rainfall and its precipitation (hydro-metrological conditions) are the key factors associated with the planning of water resources, water allocation and overall development of the locality (Sharma, 2016). Rainfall is the meteorological phenomenon that has the greatest impact on human activities and the most important environmental factor limiting the development of the semi-arid region (Nyatuame, 2014). Any change in the rainfall (seasonal or annual) and its precipitation in a locality lead to variation in runoff flow in that region with consequent influence on the water resources management (Mahadevan, 2020). The trend analysis of rainfall recorded for long term periods provides information about rainfall patterns and variability (Khavse, 2015). Rainfall is one of the key inputs in hydrological modelling. The generation of rainfall, both temporally and spatially, is a relatively recent research topic in rainfall simulation and downscaling. The distribution of rainfall amounts over time and space can be an important input to decision making tools that provide information on rainfall variability and help in understanding the hydrological processes (Sabyasachi, 2015). Trend analysis is a method to determine the spatial variation and temporal changes for different parameters associated to climate (M.M.Rashid, 2013).

Hence, the purpose of this study is to investigate the variability of the rainfall of the study area. Annual, seasonal and monthly statistical trend analysis of rainfall has been investigated. This includes an understanding of the area's rainfall trends and variability. Understanding the uncertainties associated with rainfall patterns will provide a knowledge base for better management of agriculture, irrigation and other water related activities in the selected area.

2. STUDY AREA

Kanthatmakurvagu catchment area is lies between 79^0 24' 14.50" E to 79^0 39’ 29.10" E and 17^0 53’ 17.79" N to 18^0 13’ 50.23“ N (Fig.1). This area is covering 440.4 sq.km. Administratively, it covers 8 mandals (Blocks) of Warangal urban and Warangal rural. Kanthatmakurvagu is a tributary of Peddavagu, which is tributary of Godavari River.

Geology

The Kanthatmakurvagu watershed comprises of Archaen and lower to middle Proterozoic era of formations. There are three types of rock formations of peninsular gneissic complex group of Archaen era are formed as basement in the watershed. Garnet-biotite gneiss are the oldest formations rests on the older metamorphic rocks. These are formed at southwest of the watershed. Chronologically grey granodiorites and porphyritic granites are formed above gneiss. Grey granodiorite is formed on north, south and southwest of the watershed. Porphyritic granite is occurred in the remaining area of watershed. Intrusions of Dolomites are seen in the southeast of watershed.

Drainage

The Kanthatmakurvagu is the major stream in the study area. The drainage of the study area is characterised by dendritic to sub dendritic. It rises on the uplands situated on the south west and east of the watershed.

Drainage order

1st order streams of the watershed drain from the southwest and form higher order stream and flows towards east. Higher order streams change its direction towards north. Similarly, some of the 1st order streams originated on the eastern and western part and flows southwest and east as formed higher order streams. These higher order streams join together at Nagaram village and runs towards north and formed Kanthatmakurvagu. This vagu is joining Peddavagu at Battirajanipalli village of Parkal mandal.

Flood control

There are about 253 small and big surface water bodies were constructed across the streams to control the risks of flooding. Notable surface water bodies in the watersheds are Waddepally reservoir, which is located at Waddepally village at southwest corner of the watershed. Streams draining from the southwest direction contributing water to this reservoir. Bhadri reservoir located between Hanamkonda and Warangal formed across the stream, which are contributing the drains from the southwest and north direction. Kotha cheruvu built at Peddammagadda, which are contributing the drains from the east direction. Nagaram cheruvu was built for storage of local catchment area around Hanamkonda south. Egulacheruvu and Uracheru are another small water bodies constructed by contributing streams flows from the west. Over flow of all these water bodies is joins in the Nagaram Peddacheruvu which was constructed at Nagaram village of Hasanparthy mandal. All the over land flow from this point and other small tributaries which are draining in the downstream of Nagaram Pedda Cheruvu formed as Kanthatmakurvagu and drains towards north and joining in Peddavagu.

Land forms

Principle geomorphic units are pediplain moderate, pediplain shallow, pediment, pediment inselberg complex, sheet rock, dyke ridges, residual hill and inselbergs.

Highest area in the Kanthatmakur watershed pediplain moderately is occupied about 240.8 sq.km (54.7%) of area, followed by pediplain shallow by 171.8 sq.km (39%). Pediplain inselberg complex was formed in 16.6 sq.km (3.8%). Pediment zone was existed in 2 sq.km (0.4%), Dyke ridges was formed in 0.8 sq.km (0.2%) and sheet rock was covered by 0.6 sq.km (0.1%).

Morphology

Kanthatmakurvagu watershed has 5th order stream. Area and perimeter is 440.4 sq.km and 119.7 km respectively. The length of the watershed is 45.5 km. The higher amount of first order streams indicates the intensity of permeability and infiltration. Bifurcation ratio designates that 3rd and 4th order has structural control and hilly area. First, second and fifth order drainage area has flat and less structural disturbance. Total length of the all stream orders are 481.8 km and mean length is 3.74 km. Stream length ratio revealed that watershed has variations in slope and topography. Length of overland flow value about 0.55 shows relatively mature stage of the drainage development.

Drainage density reveals that it has highly resistant sub soils, dense vegetative cover, low relief, very coarse drainage basin and less flood levels. The watershed has poor drainage frequency, permeable subsurface material and moderate texture. The watershed has peak flow as well as moderate to slightly steep slope. In the watershed infiltration is high and run off will be low.

Depth to Water levels

Analysis of depth to water level data of 31 wells from 2015 to 2021 in pre monsoon month shows that water levels vary between 2.13 and 24.40 m bgl. The average water level of the watershed is 9.36 m bgl. In the post monsoon water levels vary between 0.12 and 13.00. The average water level of the watershed is 4.19 m bgl. Aquifer in the study area has semi confined to confined characteristics.

Rainfall recharge

CGWB 2013 groundwater resources estimations categorized that Dharmasagar, Hasanparthy and Atmakur mandals as semi critical and Hanamkonda, Warangal and Parkal mandals as safe.

3. MATERIAL AND METHODS

Eleven years i.e., from 2010 to 2021 monthly rainfall of six rain gauge stations such as Dharmasagar, Hasanparthy, Hanamkonda, Warangal, Atmakur and Parkal falling in the study area were used to analyse monthly, seasonal and annual rain fall trends, as well as, statistical analysis by using MS Excel. Monthly rainfall was calculated by computing mean of monthly rainfall of six stations of particular month. Similarly, annual and seasonal rainfall was also calculated. Four seasons has been considered for this study, via, Southwest monsoon (June to September), northeast monsoon (October to December), winter (January to February) and summer (March to May). Mean, Median, Standard Deviation (SD), Coefficient of variation (CV), Skewness, Kurtosis, minimum and maximum was computed and presented in this study.

Mean

Mean is the arithmetic average of a set of values or distribution and represents the average of the data set.

$$\text{Mean } (\bar{X}) = \frac{\sum x}{N}$$

where x is the rainfall data and N= Number of years

Median

The median M of a sample is the middle value of the ranked sample, if N is odd. If N is even it is the average of the two middle values. For a symmetrical distribution the mean (m) and the median (M) are similar. If the distribution is skewed to the right, then M < m and when skewed to the left M > m.

Standard deviation

The Standard deviation (STD) is measure of the dispersion of a set of data from its mean.It is the root of the variance and provides as such a measure for the dispersion of the data in the sample set in the same dimension as the sample data. It is estimated by:

$$\text{STD} = \sqrt{\frac{\sum_{i=1}^{N}(X_i-\bar{X})^2}{N-1}}$$

Coefficient of variation

The Coefficient of Variation is a normalized measure of dispersion of a probability distribution which is defined as the ratio of the standard deviation 'σ' to the mean ($\bar{X}$).

$$\text{CV} = \frac{\sigma}{\bar{X}} \text{ X } 100$$

Skewness

The Skewness is a measure of the asymmetry of the probability distribution. The skewness value can be positive or negative, or even undefined. It is a dimensionless quantity.When the bulk of data in a dataset fall to the left, and the right tail is longer, the distribution is positively skewed; when the peak is towards the right, and the left tail is longer, the distribution is negatively skewed. Skewness is measured using the Pearson coefficient:

$$\text{Skewness} = \frac{Mean-Mode}{Standard\ Deviation}$$

The value obtained using coefficient of skewness is rarely very high and usually remains between +1 to −1.

Kurtosis

Kurtosis refers to the extent of peakedness or flatness of a probability distribution in comparison with the normal distribution. The kurtosis is seen to be the 4^{th} moment of the distribution about the mean, scaled by the 4^{th} power of the standard deviation. The kurtosis for a normal distribution is 3. The normal distribution is said to be **mesokurtic**. If a distribution has a relatively greater concentration of probability near the mean than does the normal, the kurtosis will be greater than 3 and the distribution is said to be **leptokurtic**. If a distribution has a relatively smaller concentration of a probability near the mean than does the normal, the kurtosis will be less than 3 and the distribution is said to be **platykurtic**.

$$\text{Kurtosis} = \frac{N^2-2N+3}{(N-1)(N-2)(N-3)} \frac{\sum_{i=1}^{N}(X_i-m)^4}{S^4}$$

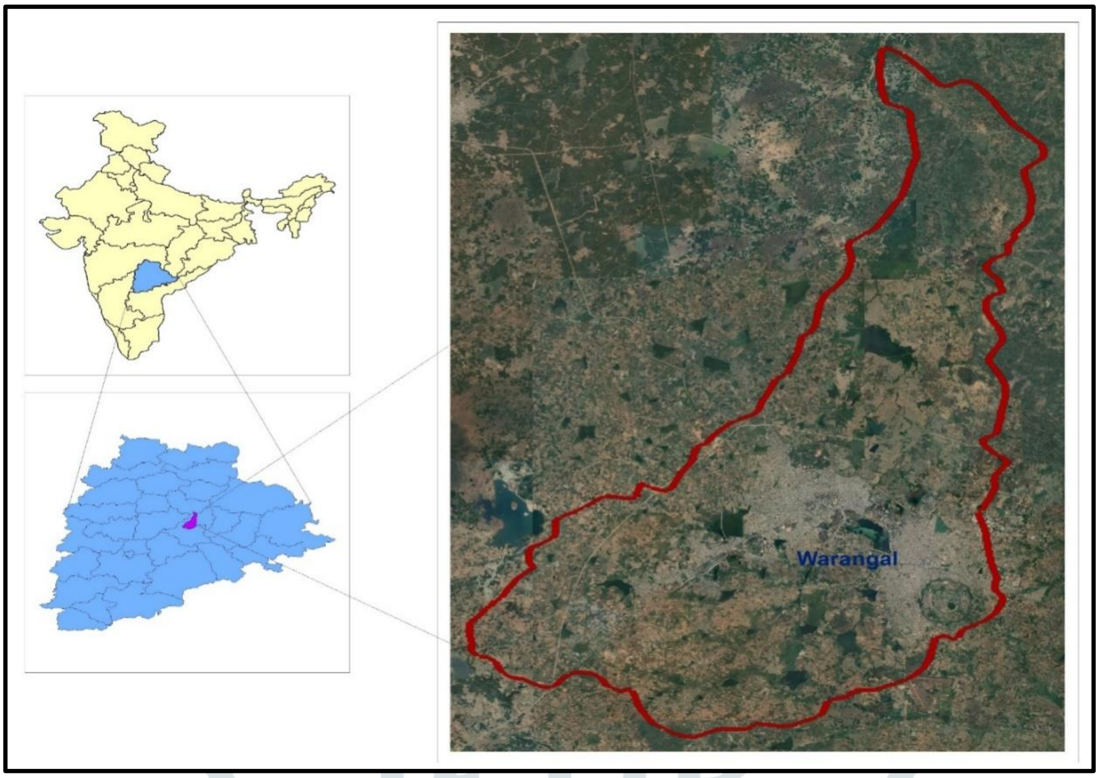

Fig.1 Location map of the Study area

4.0 RESULTS AND DISCUSSIONS

4.1 Annual rainfall analysis

Characteristics of rainfall of Kanthatmakurvagu are shown in Table 1. Annual mean rainfall over the study area was 1153.3 mm. Median and standard deviations of annual rainfall were 1130 and 331.2 respectively. Standard deviation considerably large, that indicates there is larger variation in rainfall pattern. The coefficient of variation of annual rainfall was 0.3, which shows the erratic nature of rainfall. Annual maximum rainfall, 1870.6 mm which was recorded in 2020-21 whereas minimum 717.50 mm was measured in 2011-12 (Fig. 2). Of the eleven years, five years have received more than average rainfall and remaining six years have less than average rainfall. Positive skewness value 0.6 indicating annual precipitation in the region is asymmetric and it lies to the right of mean that is right skewed. Kurtosis is the measure of peakedness or flatness of frequency distribution having value of 0.2, indicating slightly leptokurtic in nature.

4.2 Seasonal rainfall analysis

Mean southwest rainfall over the study area was 946.8 mm. Median and standard deviations of southwest monsoon were 905 and 291.1 respectively. The coefficient of variation of southwest rainfall was 0.3, which shows the erratic nature of rainfall. Mean northeast rainfall over the study area was 130.7 mm. Median and standard deviations of northeast monsoon were 148.2 and 93.7 respectively. The coefficient of variation of northeast rainfall was 0.7, which shows the erratic nature of rainfall. Mean winter rainfall over the study area was 11.4 mm. Median and standard deviations of winter were 12.2 and 11.3 respectively. The coefficient of variation of winter rainfall was 1.0, which shows the erratic nature of rainfall. Mean summer rainfall over the study area was 64.4 mm. Median and standard deviations of summer were 61.7 and 42.7 respectively. The coefficient of variation of summer rainfall was 0.7, which shows the erratic nature of rainfall. Maximum rainfall was observed in southwest monsoon, which contributed about 82%, followed by northeast monsoon by 11% to the annual rainfall. Winter and summer rainfall noticed about 1 and 6% respectively. During southwest, northeast, winter and summer standard deviation considerably large, this indicates there is larger variation in rainfall pattern. Positive skewness value 0.6 of summer and winter well as 0.9 and 0.4 in southwest and northeast indicating the region is asymmetric and it lies to the right of mean that is right skewed.

During southwest monsoon period, maximum rainfall, 1590.5 mm, was recorded in 2020-21 whereas minimum 549.8 mm was measured in 2014-15 (Fig. 3). Of the eleven years, four years have received more than and remaining seven years have less than average rainfall. During northeast monsoon period, maximum rainfall, 291.1 mm which was recorded in 2019-20 whereas minimum 20.8 mm was measured in 2015-16 (Fig.4). Of the eleven years, six years have received more than and remaining five years have less than average rainfall. During winter season, maximum rainfall, 29.2 mm was recorded in 2018-19 (Fig.5). Of the eleven years, six years have received more than and remaining five years have less than average rainfall. In 2010-11 and 2016-17, there was no rainfall during winter season. During summer season, maximum rainfall, 145.7 mm was recorded in 2014-15, whereas minimum 10.7 mm was observed in 2016-17 (Fig.6). Of the eleven years, four years have received more than and remaining seven years have less than average rainfall. The northeast and winter and summer seasons showed a negative kurtosis which indicated a flat distributions during this seasons and in southwest seasons it showed a positive kurtosis which indicated a peaked distribution.

Table 1: Statistical analysis of seasonal and annual rainfall of the study area

Year	Southwest	Northeast	Winter	Summer	Annual
2010-11	1134.6	156.6	0.0	43.8	1335.0
2011-12	648.3	29.4	27.3	12.5	717.5
2012-13	905.0	170.6	27.9	26.5	1130.0
2013-14	1015.4	269.9	0.4	127.6	1413.3
2014-15	549.8	52.9	12.5	145.7	760.9
2015-16	883.0	20.8	3.5	88.9	996.3
2016-17	1305.5	66.3	0.0	10.7	1382.5
2017-18	752.8	148.2	0.2	90.1	991.4
2018-19	705.6	27.0	29.2	37.9	799.6
2019-20	923.8	291.1	12.7	61.7	1289.3
2020-21	1590.5	205.3	12.2	62.6	1870.6
Mean	946.8	130.7	11.4	64.4	1153.3
Median	905.0	148.2	12.2	61.7	1130.0
Standard Deviation	291.1	93.7	11.3	42.7	331.2
Coefficient of variation	0.3	0.7	1.0	0.7	0.3
Contribution (%)	82	11	1	6	100
Skewness	0.9	0.4	0.6	0.6	0.6
Kurtosis	0.6	-1.2	-1.4	-0.6	0.2

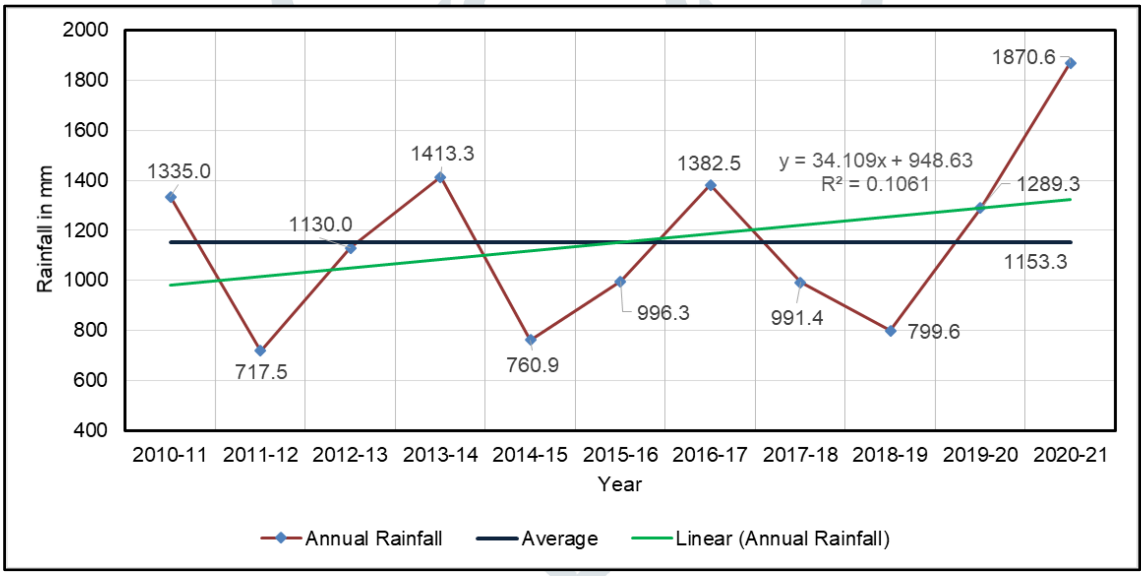

Fig. 1 Annual rainfall of the study area

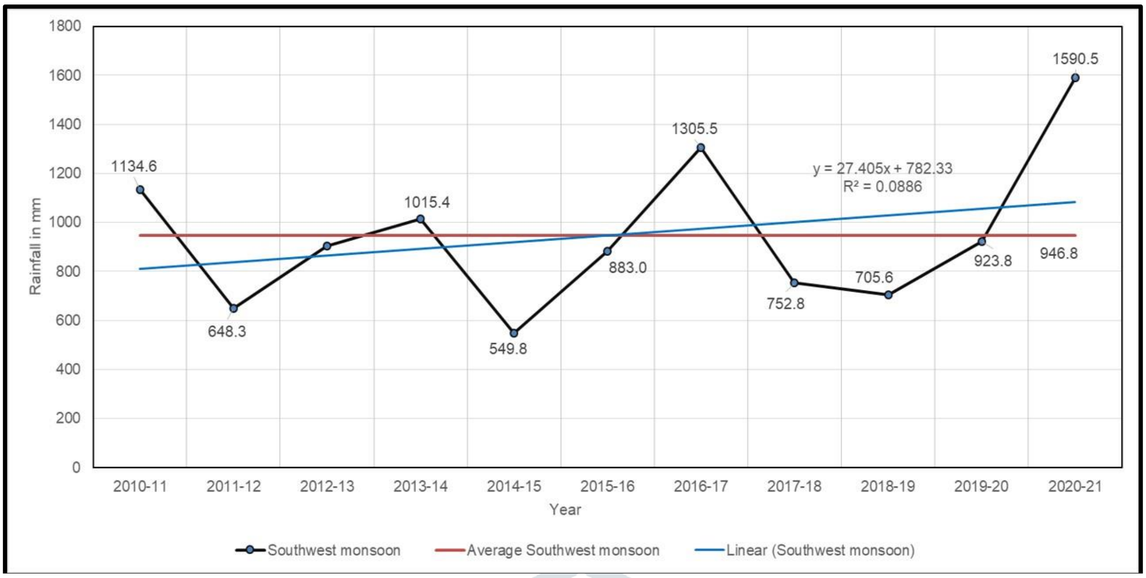

Fig. 2 Rainfall of Southwest monsoon of the study area

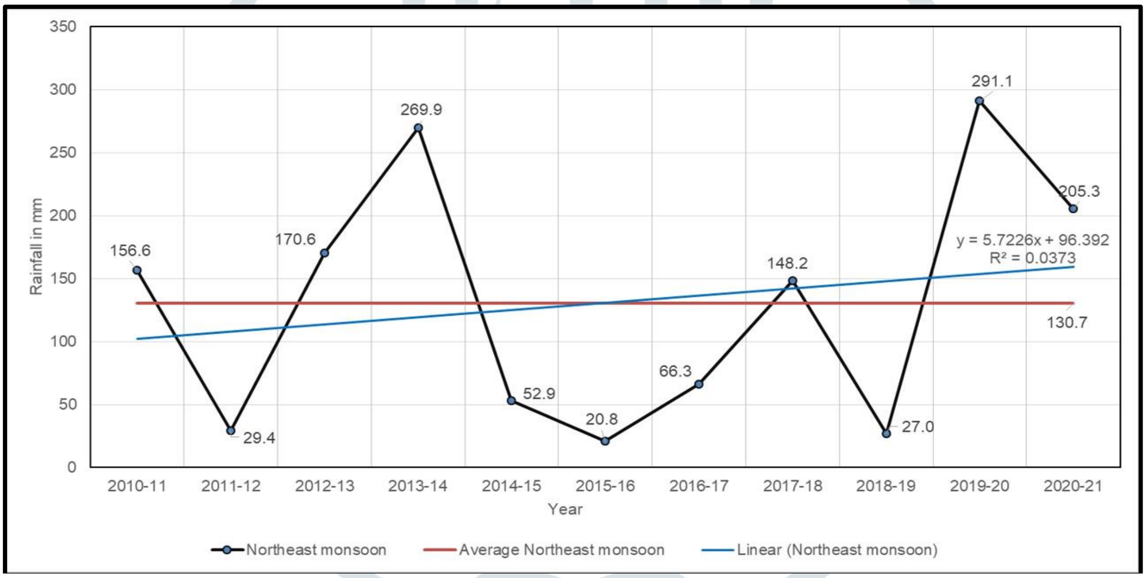

Fig. 3 Rainfall of Northeast monsoon of the study area

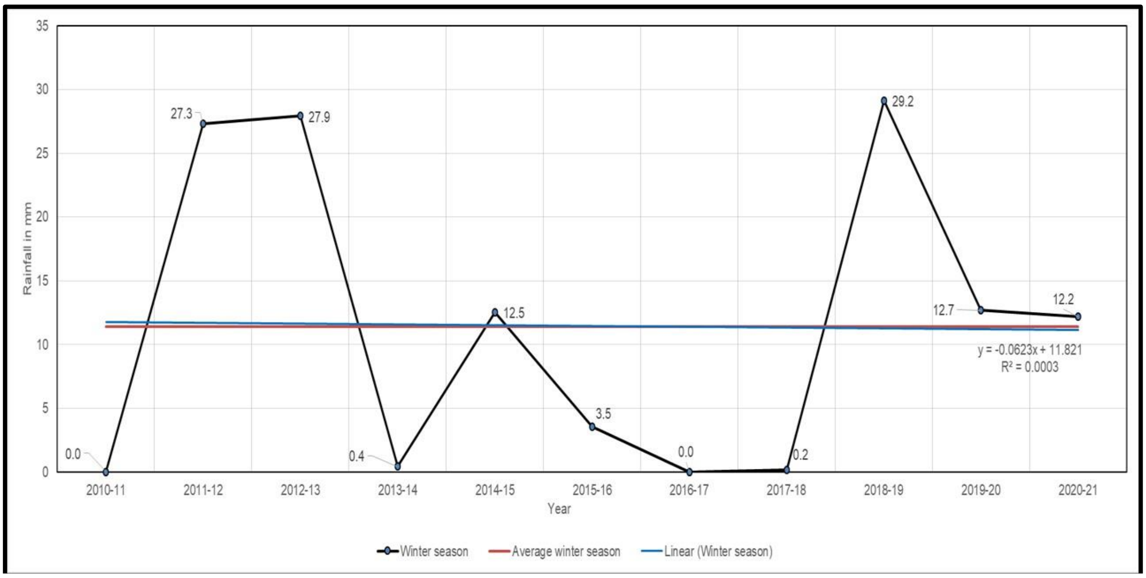

Fig. 4 Rainfall of winter season of the study area

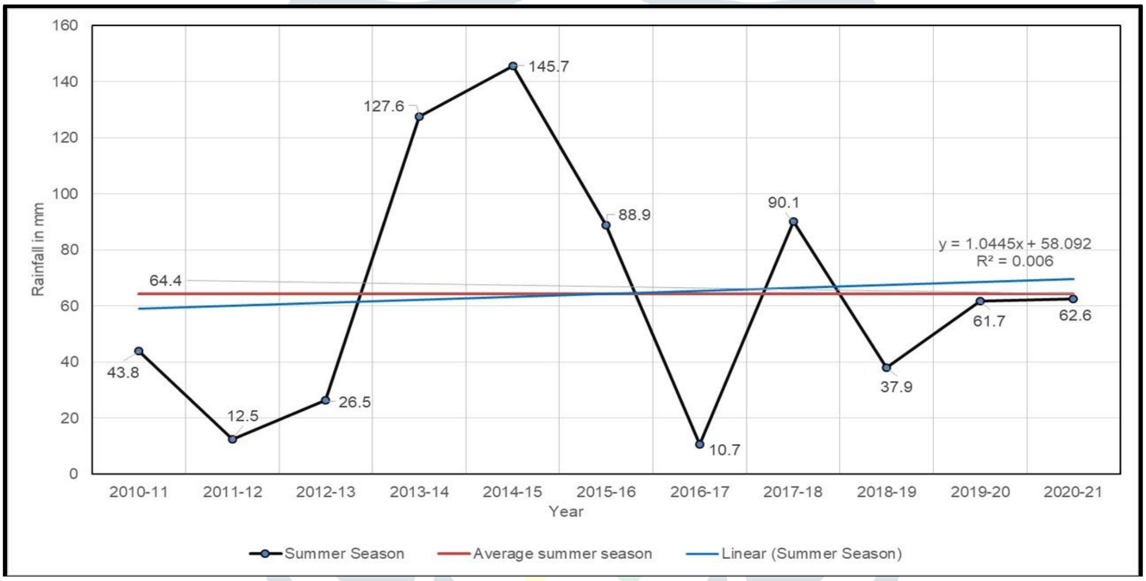

Fig. 5 Rainfall of summer season of the study area

4.3 Monthly rainfall analysis

Mean monthly rainfall analysis is presented in the Table 2. It shows that the July has the maximum mean rainfall (291.7 mm), followed by August (277 mm), September (207.2 mm) and June (170.9 mm) in southwest monsoon season, whereas minimum rainfall (3.8 mm) was recorded in December. During northeast monsoon, October has received highest (109.7 mm) rainfall, followed by November (17.3 mm) and December (3.8 mm). During winter season, January and February was experienced 6.4 and 5 mm of rainfall. During summer season, highest rainfall (27.6 mm) was recorded in May, followed by April (24.5 mm) and March (12.2 mm). Monthly median of rainfall analysis shows that the July has the maximum median (280.9) whereas minimum (3.2) was recorded in February, followed by August (277), September (205.6) and June (170.6) in southwest monsoon season. During northeast monsoon, October has highest (111.7), followed by November (16.7) and December (3.5). During winter season, January and February was experienced 6.4 and 3.2. During summer season, highest median (26.6) was calculated in May, followed by April (22.7) and March (12.1).

Standard deviation of rainfall shows that the July has the maximum (45.6), followed by August (33.2), September (9.5) and June (9) in southwest monsoon season, whereas minimum (0.7) was recorded in December. During northeast monsoon, October has highest (7.2), followed by November (3.9) and December (0.7). During winter season, January and February was experienced 1.3 and 4.6. During summer season, highest (4.3) was calculated in April, followed by May (3.8) and March (3.3). Highest standard deviation considerably high in July and August indicates there is larger variation, while remaining months has low indicates smaller variation in rainfall pattern.

Highest coefficient of variation (0.9) was calculated in February whereas lowest (0.1) was recorded in September, followed by March (0.3), July, November, December, January and February (0.2); and June, August, October and May (0.1).The coefficient of variation ranges between 0.1 and 0.9, which indicates February was more varied than other months.
Highest skewness (2.4) calculated in February, followed by July (1.6), April (1.5), May and September (1.2), December (0.8), August and June (0.5), November, January and March (0.1) and lowest skewness (-0.5) was recorded in October. The skewness

of months was found between 2.4 to -0.5. From the Table 2 it is clear that monthly rainfall data is positive in all months, except October. Positive months that showed a positively skewed distribution in the area.

Highest Kurtosis (5.7) calculated in February, followed by July (3.3), April and September (1.9), May (1.6), November (0.3), December (-0.3), June (-0.5), August (-0.8), January (-0.9) October (-1.9) and lowest kurtoses (-2) was recorded in March. The kurtosis of all the data series varies between -0.3 to 5.7. The months of June, August, October, December, January and March showed a negative kurtosis which indicated a flat distributions during the months and in all the remaining months it showed a positive kurtosis which indicated a peaked distribution.

Table 2: Statistical Analysis of Monthly Rainfall of the Study Area

Month	Mean	Median	Standard Deviation	Coefficient of variation	Skewness	Kurtoses	Contribution (%)
June	170.9	170.6	9.0	0.1	0.5	-0.5	14.8
July	291.7	280.9	45.6	0.2	1.6	3.3	25.3
August	277.0	270.1	33.2	0.1	0.5	-0.8	24.0
September	207.2	205.6	9.5	0.1	1.2	1.9	18.0
October	109.7	111.7	7.2	0.1	-0.5	-1.9	9.5
November	17.3	16.7	3.9	0.2	0.1	0.3	1.5
December	3.8	3.5	0.7	0.2	0.8	-0.3	0.3
January	6.4	6.4	1.3	0.2	0.1	-0.9	0.6
February	5.0	3.2	4.6	0.9	2.4	5.7	0.4
March	12.2	12.1	3.3	0.3	0.1	-2.0	1.1
April	24.5	22.7	4.3	0.2	1.5	1.9	2.1
May	27.6	26.6	3.8	0.1	1.2	1.6	2.4

The above table revealed that about 25.3% of rainfall was contributed in July, followed by August (24%), September (18%) and June (14.8%). October has been contributed 9.5%, followed by May (2.4%), April (2.1%), November (1.5%) and March (1.1%). December, January and February had received 0.3, 0.6, 0.4% respectively.

4.4 Trend of Rainfall

The trends of annual and seasonal rainfall were obtained using linear regression best fit lines. The linear regression trends with their linear regression equations and coefficient of determination for all the years from 2010 to 21 are represented in Fig.2 and Fig.3. It is evident that annual, southwest, northeast and summer seasons have increased trend whereas winter season, in which observed decreasing trend. It was observed from the annual rainfall trend having an increase of 34.1 mm per year. It was found that trend of southwest monsoon have an increase of 27.4 mm per year, northeast monsoon shows an increase of 5.7 mm per year and summer trends an increase of 1.0 mm per year. During winter season rainfall occur decreasing trend by 0.08 mm per year.

5. CONCLUSIONS

The present study is an attempt to make a preliminary analysis of the rainfall pattern in Kanthatmakurvagu Catchment area of Warangal and Urban Rural Districts of Telangana State over the period between 2010 and 2021. The study concluded that the annual rainfall of this area that is 82% of the rainfall was influenced by the southwest monsoon. The rainfall in the area highly variable, uneven and heterogeneous. The annual average rainfall varies from a maximum of 1870.6 mm in 2020-21 to the minimum of 717.5 mm in 2011-12. The month of July received maximum average rainfall and December received lowest average rainfall. Annual rainfall in the region is indicate asymmetric and it lies to the right of mean that is right skewed. Kurtosis is indicating slightly leptokurtic in nature. The northeast and winter and summer seasons showed a negative kurtosis which indicated a flat distributions during this seasons and in south west seasons it showed a positive kurtosis which indicated a peaked distribution. Coefficient of variation and standard deviation shows that area has erratic and large nature of rainfall in all seasons. Positive skewness value indicating the region is asymmetric and it lies to the right of mean that is right skewed. Negative kurtosis which indicated a flat distributions and positive kurtosis indicated a peaked distribution.

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