CLIMATE CHANGE IMPACT ON RAINFALL AND SANTROD CATCHMENT HYDROLOGY FOR PANAM UPSTREAM RIVER BASIN WATERSHED, INDIA

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Abstract : The climatic variables has been showing an increasing and/or decreasing trend across the India spatially as well as temporally. Other factors are also affecting the climate change like, land use land cover changing pattern, urbanization, deforestation, carbon gas emission etc. Rainfall is the important parameter of changing climate. It is very important to analyse the trend and behavior of rainfall pattern. This study is carried out to analyze the trend of rainfall and runoff over a catchment area of Santrod i.e. Panam upstream river basin. The trend of rainfall for the monsoon month i.e. June to October and annual rainfall and the surface runoff for this catchment have been examined. To control the natural disaster, detailed analysis of the variables i.e. rainfall, runoff will help in effective management and operation of water resources structures, urban planning and infrastructure development.

IndexTerms **- Climate change, Annual and monthly rainfall, Trend analysis, Rainfall-Runoff correlation.**

I. INTRODUCTION

There is a change in the statistical patterns of weather distribution over extended period of time from decades to millions of years (IPCC 2007), called as climate change. The climatic variables, mainly rainfall and temperature observed in the local and regional scale has been clearly indicating the climate change. It may also be noted that the changing pattern of rainfall affects the volume and distribution of runoff. Climate is changing in terms of rising global mean temperature, rise level of sea and variability in precipitation (IPCC 2014). Climate change will likely to affect the surface and groundwater resources due to the expected changes in precipitation and evapotranspiration (Navneet Kumara et. al. 2017). Rainfall is the most important component or parameter for the hydrology and inflows in river basin. Change in rainfall pattern can have significant impact on runoff. During monsoon period, most of the runoff received in river is in the form of direct runoff resulted from the rainfall in the river basin. Changes in the frequency or total amount of precipitation over a river basin can cause changes in the magnitude and timing of the river's discharge. In India, the rainfall is occurring only for four months i.e. during June to October month in India. So that the inflows in the river is mainly during monsoon season and is affecting by the rainfall. Due to these reasons there is a need of examining the influence of the climate change on rainfall variability and trend of the rainfall. The runoff from precipitation is stored during monsoon seasons in huge reservoirs to cater to domestic and industrial needs.

Mann-Kendall test had been formulated by Mann (1945) as non-parametric test for trend detection and the test statistic distribution had been given by Kendall (1975) for testing non-linear trend. Mann-Kendall hypothesis test is a nonparametric, rank-based method for evaluating the presence of trends in time series data. (Sharma, Sanjay,2018 et. al.)

This study examines the rainfall variability in the small scale region of the watershed within the Panam river basin. One of the driving factor for changing the climate is the change in the land use pattern i.e. deforestation and urbanization. Due to increase built up area and paved surfaces, the falling rain is resulting into direct runoff without being absorbed into soil and thus runoff in the stream/river increases. Hence, assessing the impact of projected climate change is a vital issue in present day hydrologic research.

Panam is a Left bank tributary of Mahi. Panam river rises near Bhadra on Northern slopes of the Vindhyas near Jhabua district in Madhya Pradesh and flows in the North - West direction and joins the main river in the Panchmahal district of Gujarat. It has a total length of about 127 km and drainage area of about 2470 sq.km. The rain gauging stations namely Gultora and Panam are the nearby raingauging stations located in Panam upstream river basin. Gultora and panam station data is adopted for analysis in the catchment area of Santroad river gauging stations located in Panam upstream river basin.

The variability observed in precipitation patterns is one of the prominent signals of climate change. It is observed that a change in the regional precipitation pattern has a direct impact on magnitude, frequency of floods, droughts and water availability (IPCC, 2007). Many of the previous studies performed the trend analysis for the Indian monsoon rainfall in various scale (Subramanyya and Naidu, 1992). Ramesh and Goswami (2007) analyzed daily gridded rainfall data for the period of 1951-2003 and reported that a decreasing trend both in late monsoon rainfall and number of rainy days over the entire Indian scale. Rupa Kumar et al. (1992) reported a significant positive trend in monsoon rainfall along the west coast, central peninsula and northwest India.

The objective of the present study is to detect the trend in rainfall pattern in terms of magnitude of annual rainfall, number of rainy days in a year, magnitude of monthly rainfall in the monsoon months, number of rainy days in each month, recurrence interval and frequency of a storm in base-line and in advance scenario and rainfall –runoff correlations in base line and in advance scenario within Panam upstream river basin of Santrod catchment area. The study will be useful for the river basin planning, flood mitigation work, design of hydraulic structures.

II. DATA ANALYSIS AND METHODS

This section comprises of methods to analyse the trend of annual rainfall as well as the monthly rainfall for each month of the monsoon season. The rain gauging stations shown in Figure 1 namely Gultora and Panam station and rivergauging site Santrod having catchment area 1049.22 sq.km. The annual rainfall at stations Gultora, and Panam dam is found to be 717 mm, and 854 mm respectively. These two stations in the study are found adequate as the optimum number of rain gauging stations, even with 8.7% error in determining mean rainfall.

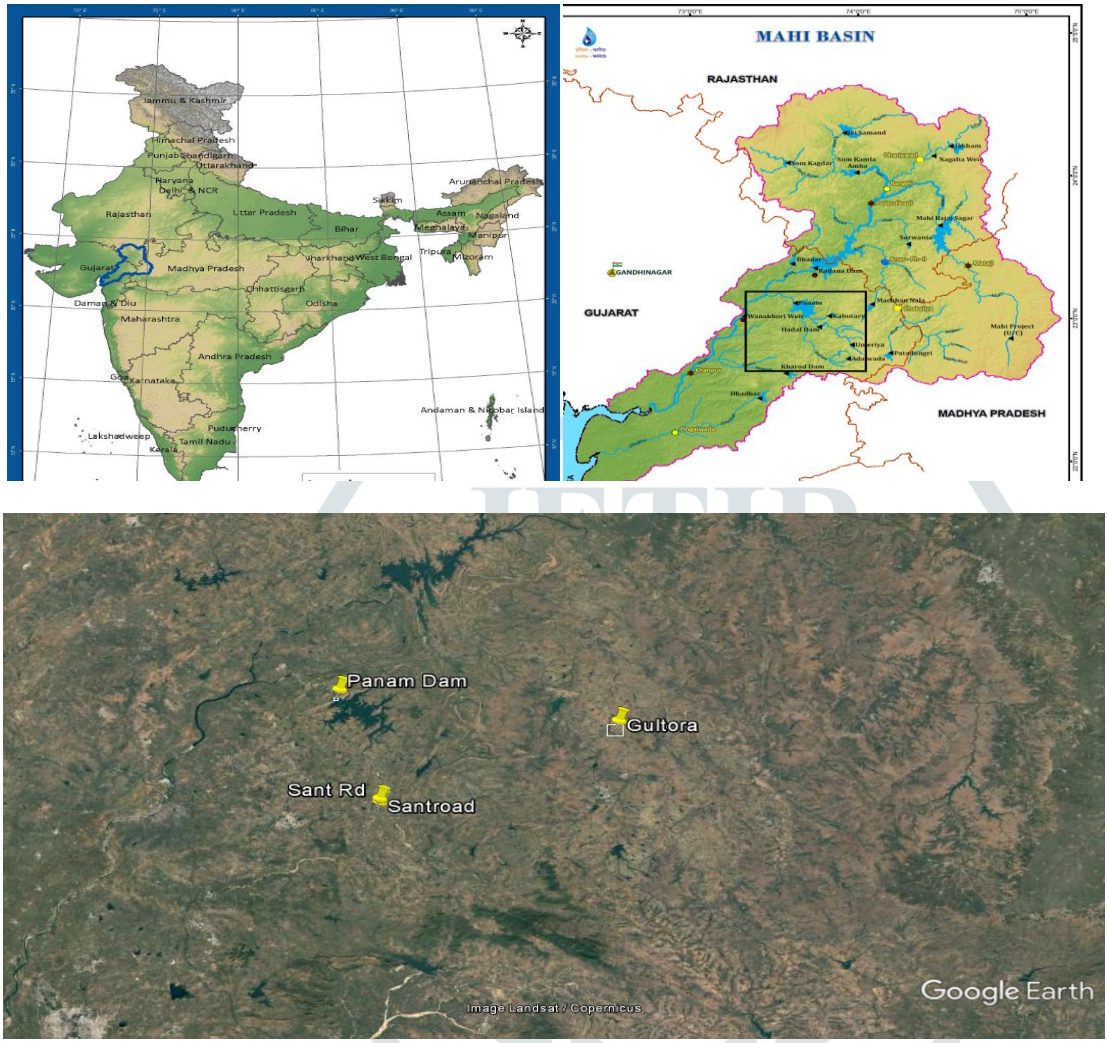

Fig. 1 Upstream watershed of Santrod catchment and Panam dam projcet

2.1Regression Analysis of Rainfall at Panam Dam Station

Panam dam station is located in the Santampur tehsil of Panchmahal district. The daily rainfall data was available from 1974 to 2013 from State Water Data Center (SWDC). The annual rainfall data series and trend of rainfall at Panam dam station is shown in Figure 2 and the number of rainy days in a year is shown in Figure 3.

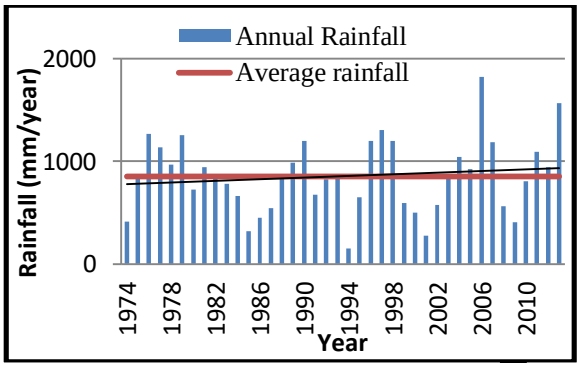

Figure 2. Annual rainfall trend at Panam dam Rain gauging station

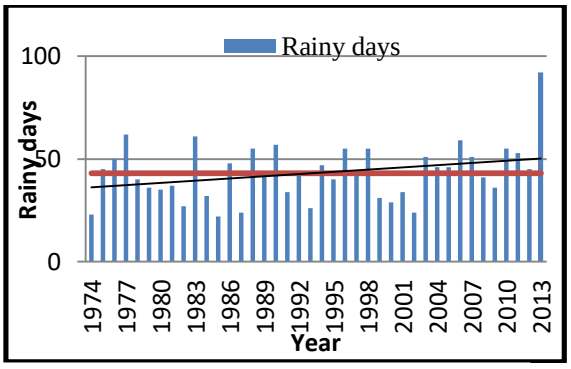

Figure 3. Trend of annual Rainy days at Panam dam raingauging station

Figure 2 shows increasing trend of annual rainfall at Panam dam station. Figure 3 shows increasing trend of rainy days in a year. The monthly rainfall and rainy days of the month of June have been shown in Figure 4 and 5.

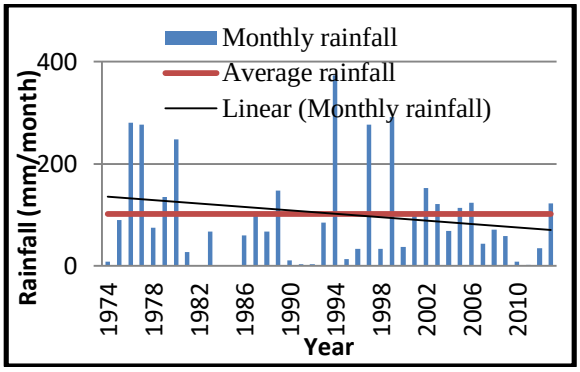

Figure 4. Rainfall trend of June month at Panam dam station

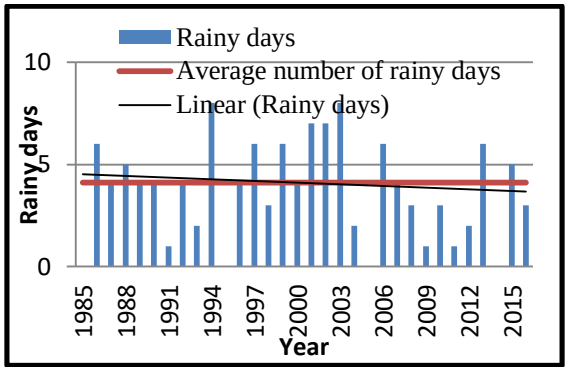

Figure 5. Trend of rainy days of June month at Panam dam station

Figure 4 shows decreasing trend in June month from year 1974 to 2013 at Panam dam station. Figure 5 shows that the rainy days in month of June is also having decreasing trend at Panam dam station. The monthly rainfall and rainy days of the month of July have been shown in Figure 6 and 7.

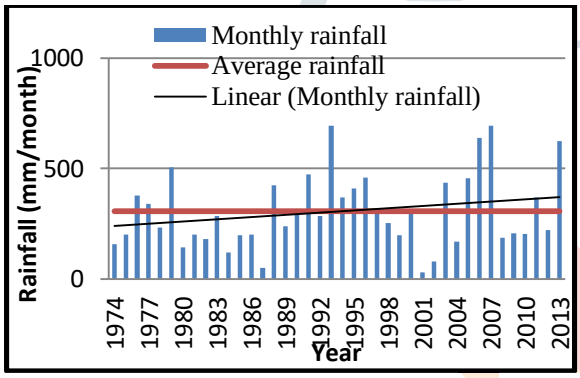

Figure 6. Rainfall trend of July month at Panam dam station

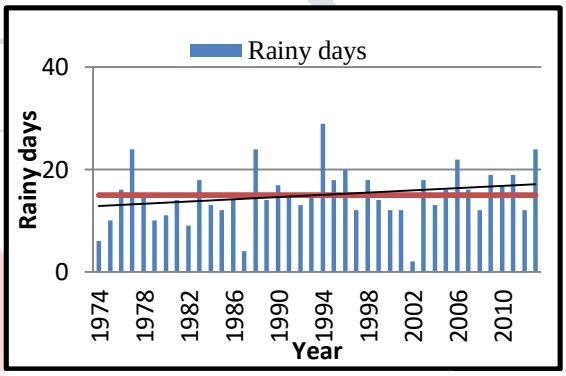

Figure 7. Trend of rainy days of July month at Panam dam station

Figure 6 shows increasing trend in July month from year 1974 to 2013 at Panam dam station. Figure 7 shows that the rainy days in month of July is having increasing trend at Panam dam station. The monthly rainfall and rainy days of the month of August have been shown in Figure 8 and 9.

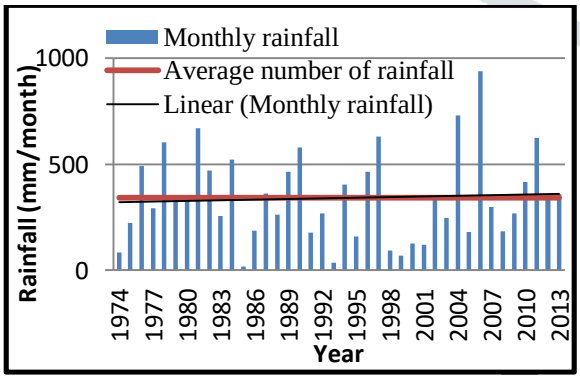

Figure 8. Rainfall trend of August month at Panam dam station

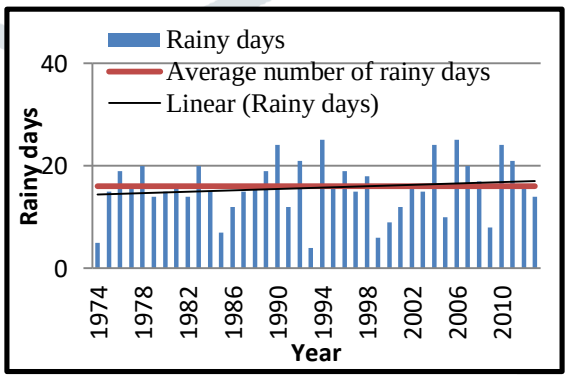

Figure 9. Trend of rainy days of August month at Panam dam station

Figure 8 shows increasing trend in August month from year 1974 to 2013 at Panam dam station. Figure 9 shows that the rainy days in month of August is having increasing trend at Panam dam station. The monthly rainfall and rainy days of the month of September have been shown in Figure 10 and 11.

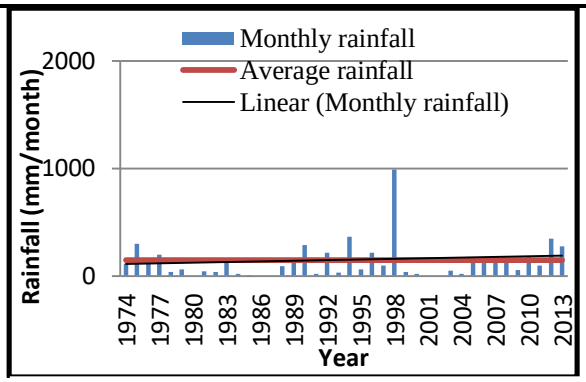

Figure 10. Rainfall trend of September month at Panam dam station

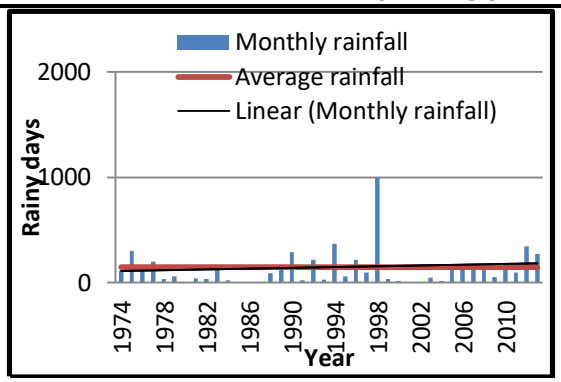

Figure 11. Trend of rainy days of September month at Panam dam station

Figure 10 shows increasing trend in September month at Panam dam station. Figure 11 shows that the rainy days in month of September is having increasing trend at Panam dam station. The monthly rainfall and rainy days of the month of October have been shown in Figure 12 and 13.

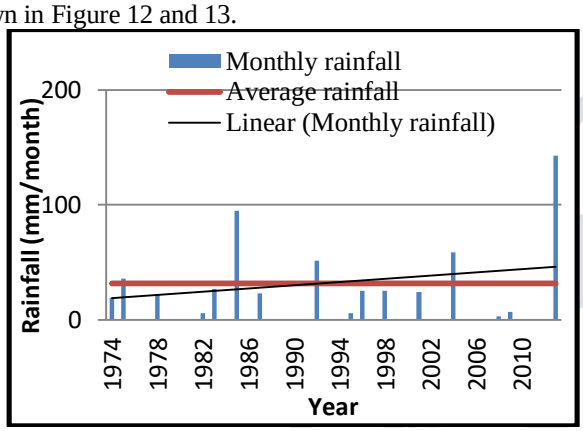

Figure 12. Rainfall trend of October month at Panam dam station

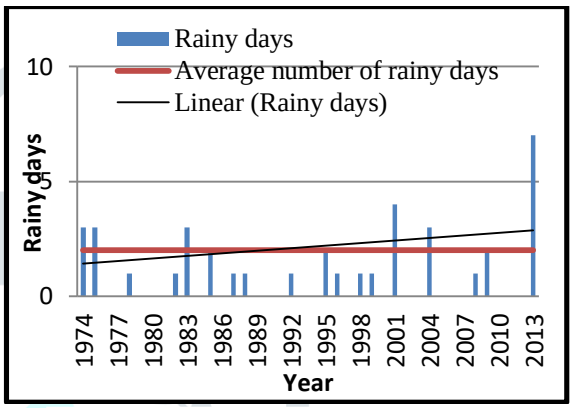

Figure 13. Trend of rainy days of October month at Panam dam

Figure 13 shows that the monthly rainfall and rainy days in month of October is having increasing trend at Panam dam station.

Thus, it is analyzed from Figure 2 and 3 that for Panam station, the annual rainfall shows increasing trend, while number of rainy days in a year shows increasing trend. Further, it is analyzed from Figure 4 and 5 for the month of June that rainfall and number of rainy days both shows decreasing trend. For the month July, it is analyzed from Figure 6 and 7 that the rainfall and rainy days shows increasing trend. Further, it is analyzed for the month of August, from Figure 8 and 9 that the monthly rainfall shows increasing trend, while the rainy days of this month shows increasing trend too. It is further analyzed from the Figure 10 and 11 for the September that the monthly rainfall shows little increasing trend while the rainy days shows little increasing trend. From Figure 12 and 13 it is analyzed that the monthly rainfall shows increasing trend and the rainy days shows increasing trend in the month of October month. Figure 14 represents the maximum value of the daily rainfall of each year of the study period and shows that maximum value of the year for daily rainfall shows increasing trend.

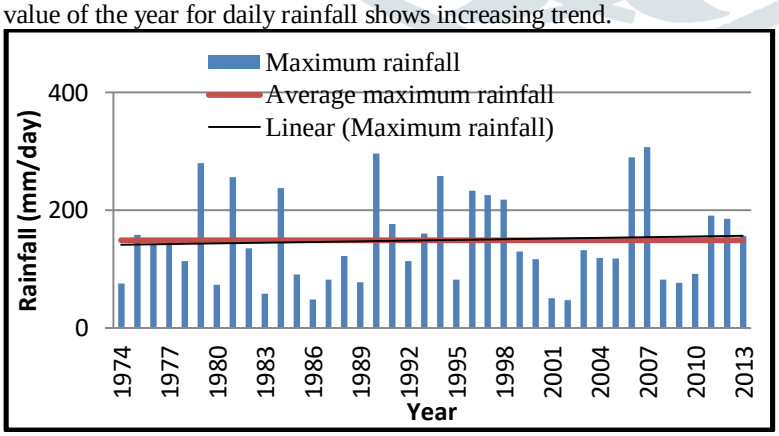

Figure 14. Maximum rainfall of each year

2.2 Regression Analysis of Rainfall at Gultora Station

As described in section A for Panam dam station, the analysis have also been carried out for Gultora station in similar manner to identify the 1) trend of annual rainfall and rainy days in a year; 2) trend of monthly rainfall and rainy days for Monsoon months; and 3) trend of the maximum daily rainfall of each year. The daily rainfall data was available from 1985 to 2016 from State Water Data Center (SWDC).

The results obtained for Gultora station are as follow:

1) Annual rainfall and number of rainy days in a year shows decreasing trend.
2) The monthly rainfall and number of rainy days in a month for monsoon months i.e. June, July, August, and October shows decreasing trend.
3) Maximum of daily rainfall of the year shows decreasing trend.

2.3 Result of Regression Analysis in the catchment

It is analyzed from the results of rainfall trend analysis of the Rain gauging stations short listed below:

1. Annual rainfall and rainy days shows decreasing trend at Gultora station.
2. Annual rainfall and rainy days shows increasing trend at Panam dam station.
3. In the month of June, rainfall is decreased at Gultora, and Panam dam stations.
4. Rainy days in the month of June is reduced at Panam dam station.
5. In the month of July, and August; Rainfall and rainy days is increased at Panam dam station..
6. In September month, Rainfall trend is increased at Panam dam station and Gultora stations.
7. In October month, Rainfall trend is increased at Panam dam station.
8. Rainy days is increased at both Gultora and Panam dam stations in the month of October.
9. Maximum rainfall shows increasing trend at Panam dam station.

2.4 Results of Sen's slope and Mann- Kendall test for annual and monthly rainfall

Result of Mann-Kendall test and Sen's slope estimator for the Gultora and Panam dam stations are tabulated below. This result also verified the trend analysis of the different stations described above.

Table 1. Result for Panam dam station

	June	July	August	September	October	Annual
Statistics(S)	**-7**	**110**	**21**	**82**	**-30**	**-1**
Variance of S	**7363**	**7366.67**	**7365.67**	**7350**	**6108**	**6833.67**
Test statistics(Z)	**-0.07**	**1.27**	**0.23**	**0.94**	**-0.37**	**0**
Sen's slope	**-0.047**	**3.078**	**0.386**	**1.316**	**0**	**1.8**

From Table 1 Mann-Kendall test analysis result shows that test statistics for June and October month having negative test statistics value with non-significance. But for the other month, i.e. July, August, September having positive test statistics value with non-significance**.**

Table 2. Result of Sen's slope and Mann- Kendall test for annual and monthly rainfall Gultora station

	June	July	August	September	October	Annual
Statistics(S)	**-35**	**-88**	**-38**	**35**	**-40**	**-72**
Variance of S	**3793**	**3802.67**	**3802.67**	**3785**	**3307.33**	**3802.67**
Test statistics(Z)	**-0.55**	**-1.41**	**-0.6**	**0.55**	**-0.68**	**-1.15**
Sen's slope	**-**	**-3.75**	**-2.31**	**0.747**	**0**	**-6.687**

From Table 2 Mann-Kendall test analysis result shows that test statistics for June, July, August and October month having negative test statistics value with non-significance. But for the September month having positive test statistics value with non-significance.

2.5 Recurrence interval and frequency of a storm

The recurrence interval and frequency of a storm for various rainfall at each rain gauging station have been prepared for baseline and advanced scenario. The baseline scenario is considered as the earlier half time span (year) of the total data length, while the advanced scenario is considered as the later half time span (year). The results of recurrence interval and frequency of annual rainfall at Gultora and Panam dam rain gauging stations are shows in Fig. 15 and 16.

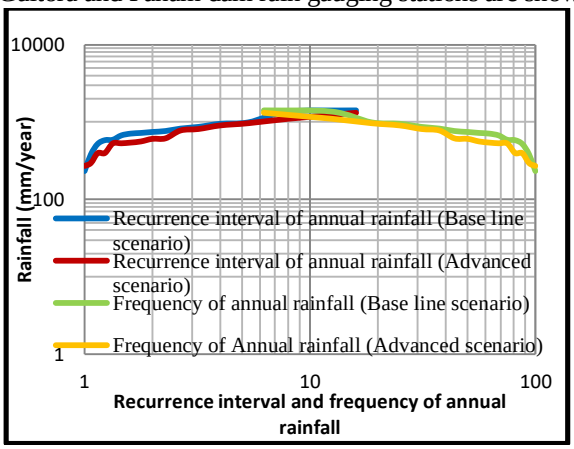

Figure 15. Recurrence interval and frequency of annual rainfall at Gultora station

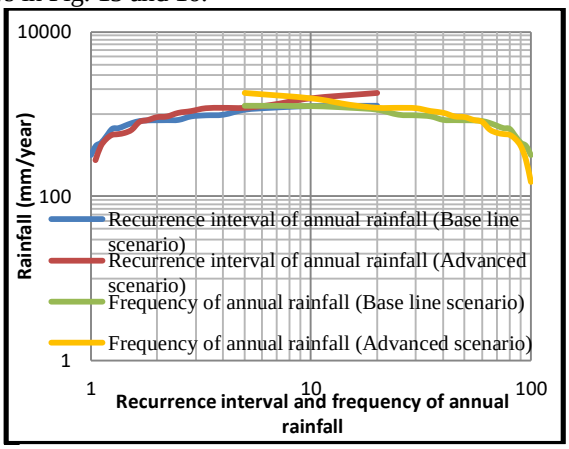

Figure 16. Recurrence interval and frequency of annual rainfall at Panam dam station

From Figure 15 annual rainfall decreases for recurrence interval and frequency values in advanced scenario (represented by red line) in comparison to base line scenario (represented by blue line). From Figure 16 for Panam dam station, it is visualized that annual rainfall is increased in advanced scenario (represented by red line) for recurrence interval and frequency values in comparison to the base line scenario (represented by blue line).

2.6 Analysis of rainfall –runoff correlation in base line and advance scenario

The discharge and annual rainfall at Panam dam station have been presented in Figure 17.

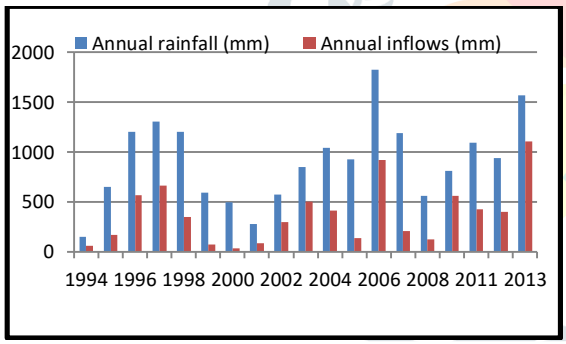

Figure 17. Annual rainfall (Panam dam station) and Annual inflow (Santroad station) for Panam river basin at Santroad station

The inflows and annual rainfall at Santrod station within Panam river basin have been presented in Figure 17. Figure 17 represents annual rainfall and annual inflows. It is observed from Figure 17 that the runoff/inflow increases in advance scenario. The rainfall - runoff correlations are established for advance scenario and baseline scenario and that presented in figure 18.

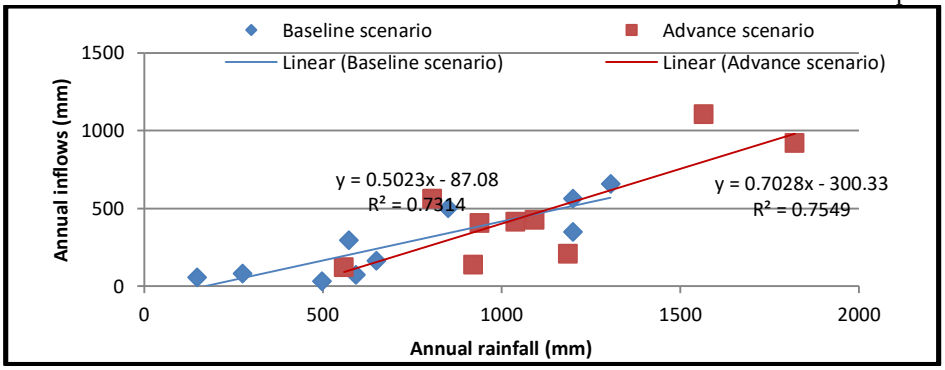

Figure 18. Annual Rainfall and Annual runoff correlation for baseline and advanced scenario for Panam river basin at Santroad station

For Santroad station base line scenario is considered from year 1994 to 2003 and advance scenario is considered from year 2004 to 2013. The results of the Rainfall - Runoff correlations verifies that the runoff potential increases in the advanced scenario in comparison to the base line scenario. The rainfall-runoff correlation is expressed through the equations as given below for baseline scenario and advance scenario. Equation for rainfall-runoff correlation for baseline scenario in given below.

$$R = 0.5023\ P - 87.08$$

where, R = Annual runoff / inflows (mm) in the Panam river basin at Santrod station in baseline scenario,

P = Annual rainfall (mm) in the Panam river basin at Panam dam station in baseline scenario.

Equation for rainfall-runoff correlation for advanced scenario in given below.

$$R = 0.7028\ P - 300.33$$

where, R = Annual runoff / inflows (mm) in the Panam river basin at Santrod station in advance scenario,

P = Annual rainfall (mm) in the Panam river basin at Panam dam station in advance scenario

From Figure 18, it is revealed that annual rainfall-runoff correlation coefficient is 0.7314 in base line scenario and 0.7549 in advance scenario at Santroad station. It can be seen that coefficient of correlation between rainfall and runoff is high in advance scenario in comparison to the base line scenario. It is also noticed that in advance scenario the runoff is more as rainfall is more and runoff is less as rainfall is less as compared to base line scenario. This is indicative of greater contribution of the direct runoff or surface runoff in the total runoff volume in advanced scenario. This could be due to change in land use pattern i.e. reduced vegetation, reduced in agricultural use of land, due to deforestation or due to increased urbanization and built up area.

IV. CONCLUSIONS

The selected area for the study is a small scale region of the 1049.22 sq.km. within the Panam river basin. The objective of the study is to analyse the impact of climate change on small watershed of Panam upstream river basin. The results of this study is summarized below.

- Monthly rainfall and rainy days both shows decreasing trend in the month of June in study basin which shows that the monsoon season starts late as compared to early time span. This is indicative for the study area that monsoon season tend to start late in the month of June.
- Monthly rainfall and rainy days presents increasing trend in the month of September and October which shows that the monsoon season shifted till to the October month.
- Mann-Kendall test and Sen's slope results also verifies the results obtained from the regression analysis.
- Rainfall – runoff correlations reveals that the inflows/surface runoff increases in the advance scenario for high value of rainfall.

It is summarized that the climate change impacts on the small regional scale study area confirms the monthly rainfall reduces in the month of June and increases in the month of September, thus shifting of the monsoon season to start and finish late. The runoff is more for more rainfall and less for less rainfall in advance scenario compare to base line scenario.

V. ACKNOWLEDGMENT

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