Impact of Climate Shift on Rainfall and Temperature Trend in Eastern Ganga Canal Command

Radha Krishan, Deepak Khare, Bhaskar R. Nikam, Ayush Chandrakar

***Abstract*—**Every irrigation project is planned considering long-term historical climatic conditions; however, the prompt climatic shift and change has come out with such circumstances which were inconceivable in the past. Considering this fact, scrutiny of rainfall and temperature trend has been carried out over the command area of Eastern Ganga Canal project for pre-climate shift period and post-climate shift periods in the present study. Non-parametric Mann-Kendall and Sen's methods have been applied to study the trends in annual rainfall, seasonal rainfall, annual rainy day, monsoonal rainy days, average annual temperature and seasonal temperature. The results showed decreasing trend of 48.11 to 42.17 mm/decade in annual rainfall and 79.78 tSo 49.67 mm/decade in monsoon rainfall in pre-climate to post-climate shift periods, respectively. The decreasing trend of 1 to 4 days/decade has been observed in annual rainy days from pre-climate to post-climate shift period. Trends in temperature revealed that there were significant decreasing trends in annual (-0.03 ºC/yr), Kharif (-0.02 ºC/yr), Rabi (-0.04 ºC/yr) and summer (-0.02 ºC/yr) season temperature during pre-climate shift period, whereas the significant increasing trend (0.02 ºC/yr) has been observed in all the four parameters during post climate shift period. These results will help project managers in understanding the climate shift and lead them to develop alternative water management strategies.

***Keywords*—**Climate shift, Rainfall trend, temperature trend, Mann-Kendall test, Sen slope estimator, Eastern Ganga Canal command.

I. Introduction

SOUND scrutiny of water resource potential is very valuable for profitable management of water resources, for which study of precipitation and temperature is the starting point. Data referring spatio-temporal variability in precipitation and temperature are quite significant from the scientific perspective [1]. Analysis has demonstrated that global warming has occurred at the pace of 0.74 ± 0.18 °C, over 1906–2005 [1], [2]. It has been found that between northern latitudes 10° to 30°, precipitation has raised considerably during 1900 to 1950, but it again downturns after 1970. Along with rainfall, air temperature is noticed as a positive signal for assessing the prominence of global climate [3]. A rise of 0.8 °C/decade in the upper Danube basin, Europe, during summertime temperature was observed by Reiter et al. [4]. Vose et al. have reported that boost in the heat of the Earth's surface is because of surging minimal temperature than the maximal temperature [5]. Sen Roy and Balling observed rise in temperature in the Deccan Plateau region of India; however, the periodic temperature series observed in the country was not momentous except for Kashmir region [6]. References [7]-[11] have observed an increase in temperature over India and the subcontinent.

The irregular precipitation pattern linked with climate change deserves quick attention as it disrupts the availability of fresh water and food production [12], [13]. Intergovernmental Panel for Climate Change [2] has described spatial, inter-seasonal and inter-annual instability in precipitation trends over Asia. It was observed that varying precipitation pattern has a remarkable brunt on water and agricultural sector of the Asia– Pacific region [13], [14]. The decadal change in precipitation pattern has turned feeble since the late 1970s over East Asia [13], [15]-[17]. Decrease in rainfall with increase in temperature and evapotranspiration have induced drying and added droughts in many regions. The tropics are getting extremely afflicted from the droughts [11].

Rising global surface temperatures are expected to affect the rainfall due to variations in atmospheric circulation [12]. Nitta and Yamada observed that the tropical sea surface temperature (SST) in the Pacific and Indian Ocean has been increasing since the late 1970's [18]. They have recorded 0.3 °C ~ 0.4 °C rise in average SST of tropical region during 1980's in comparison to 1970's. Folland et al. scrutinized inter-annual fluctuations of global SST and near-surface temperature of marine air for the period 1856-1981 and got various number of inter-decadal variations [19]. Folland et al. have demonstrated that wet and dry periods in the Sahel region of Africa are linked to the SST anomalies on a global scale [20]. Hsiung and Newell has analysed the global SST for the period thirty years (1949-1979) and obtained the El Nin˜o mode as the important non-seasonal pattern [21]. "A pattern of basin wide SST anomalies involved with a transition to the positive phase of the Inter-decadal Pacific Oscillation (IPO), occurred in the mid-1970s with effects that extended globally" [22], [23]. This integral decadal capriciousness linked with the IPO existed till 1970s and must have forced climate shift in the 1970s from a negative to the positive phase of the IPO [24]. People have viewed this change as natural phenomena caused by internally generated decadal variability of the Pacific climate system. However, during the mid-1970, there has been an increase in the global temperature due to changes in external forcing in the Pacific Ocean, and other metrological parameters have also undergone changes. It was argued that the increase in the temperature is caused by the increase of greenhouse gases from the burning of fossil fuel

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along with external forcing. But later on, IPCC report in 2011 revealed that the change in the climate in the 20th century was because of the shift of climate in the mid of 1970s rather than the burning fossil fuels [25]. Varying effects of this climate shift are observed globally [22].

A very important cycle that draws the attention of the researchers is the deep study of the atmosphere and how it contributes to climate variability. Since understanding and analysing the pattern will not only help the economy but the whole ecosystem. For a good agriculture production, rainfall and temperature both play a major role and affect the agricultural developments all over the globe. There are industries also which are dependent on climate, if not directly then indirectly, e.g. agro-based industries. This climate variability also affects the food chain and food web causing severe threats to various valuable species of plants and animals. In the recent years, there has been a lot of research going on related to precipitation and temperature variability but at local scales [26]-[29]. In the last decade, the precipitation time series showed variability at random scales. However, finer examination showed regularity but in the case of temperature, it showed some variability. India's climate is generally outlined by monsoon precipitation and aids to maximum number of agricultural zones. Therefore, change in precipitation and temperature pattern between pre-climate and post-climate shift periods may incomparably affect the economy of the nation. The analysis of impact of climate shift on water resources is mandatory in all the climatic zones of India. Major parts of India are facing decrease in rainfall during the monsoon period. A decreasing trend in annual rainfall has been noticed in west-central, north-eastern, and central north-eastern India [13], [30]. Agriculture being the backbone of Indian economy, it is extremely important to study the distribution of climatic parameters that govern the output from the agriculture sector. Much of a research has been carried out in context of climate change but very few works are done regarding climate shift. To analyse the impact of the climate shift on status and trends of climatic parameters, an attempt is being made in the present study, to quantify the long-term trend of rainfall and air temperature for both pre-climate and post-climate shift periods across the agricultural dominated command area of Eastern Ganga Canal project. Eastern Ganga canal command has chosen for this study, as it is a part of the longest canal system in Asia, i.e. Ganga canal system, so this will be a very useful study for such a system. Ganga basin is the largest basin in India, which shows no trend in average annual rainfall and increasing trend in rainy days over the century [31]. However, Kothyari and Singh found decreasing trend in number of rainy days and precipitation during monsoon season over the Ganga basin [32]. Rajeevan et al. [33] and Guhathakurta and Rajeevan [34] analysed a rainfall series created using a network of 1476 rain gauges for the period 104 years (1901–2003), which showed a significant increasing trend in the monsoon season for over Western Uttar Pradesh which comes under Ganga basin and also is in proximity of the present study area. Analysis of observed data from 316 rain gauge stations done by Singh et al. showed an increasing trend in annual rainfall over Ganga basin [35]. In case of air temperature, Kothyari and Singh observed rising annual maximum temperature over the Ganga basin [32]. In this regard, the present study has been carried out to check the shifts in climate during pre-implementation and post-implementation of EGC command.

Incidentally, the Eastern Ganga Canal (EGC) project was operationalised during 1970s and the data used for designing the project belong to pre-climate shift era and actual implementation of this project belongs to post-climate shift period. This is the reason that makes EGC project an ideal location for analysing the impact of climate shift on climatic availability and demand of water. Keeping this in mind, an effort has been made in the present study to analyse and discuss the trends in annual and seasonal rainfall as well as annual and seasonal temperature during pre-climate shift and post-climate shift periods over EGC command area, India.

II. Study Area and Data Used

EGC system is a part of Ganga Canal system which is one of the Asia's longest canal system. EGC originates from the left bank of Bhimghorda barrage at Haridwar, India. Command area of EGC project covers major part of two districts, i.e. Haridwar (in Uttarakhand) and Bijnor (in Uttar Pradesh), which extends from 29° to 30° N and from 78° to 78°45' E. EGC project was implemented 1970 onwards to utilize the surplus water of River Ganga during monsoon period for the development of *Kharif* cultivation in the districts of Bijnor, Haridwar and a very small part of Moradabad. The project has a gross command area (GCA) of 3.01 lakh ha, among which 2.33 lakh ha is culturable command area (CCA) and ultimate irrigation potential (IP) of the project is around 1.05 lakh ha. In the period other than *Kharif* season, the command area mainly depends on precipitation occurred in the region, as the EGC project is designed to supply water only in *Kharif* season. The location map of the study area is shown in Fig. 1.

Daily gridded rainfall data of 0.25°×0.25° and temperature data of 1° x 1° spatial resolution were collected from Indian Meteorological Department (IMD), Pune for the EGC command area. The daily precipitation data were extracted for the EGC command and surrounding area, which covers 12 grids of IMD data, as shown in Fig. 1. Further, the daily precipitation data were converted into monthly, seasonal and annual and divided into two time periods, called as pre-climate shift period i.e. 1947 to 1976 (30 years) and post-climate shift period, i.e. 1978 to 2012 (35 years). Incidentally, in the present case, the pre-climate shift period is pre-implementation period of EGC project and post-climate shift period is post-implementation phase of the project. A study done by Kumar et al. [36] expresses an overall downturn in the number of rainy days in India with the increase in the rainfall intensity for the future time periods thus indicating greater risk of exposure to extreme events and prolonged dry spells. So, to analyse the long-term trend in the rainy days in the study area, the IMD criteria of the rainy day (rainfall equal to or greater than 2.5 mm per day) have been used in the present study, to estimate rainy days of each year and each monsoon season (July to October).

The daily temperature data (1951 to 2012) were extracted for the EGC command and surrounding area, which covers two grids of IMD data. The daily mean temperature data were converted into seasonal (*Kharif*, *Rabi* and Summer) and annual scale in two time periods as discussed above; however, the time span of pre-climate and post-climate shift periods are modified to 1951 to 1976 and 1977 to 2012, respectively due to non-availability of gridded temperature data prior to 1951 and after 2012. The conversion of daily temperature data into seasonal temperature data are done by using the weighted temporal average of four months, i.e. July to October for *Kharif* season; November to March for *Rabi* season and April to June for summer season.

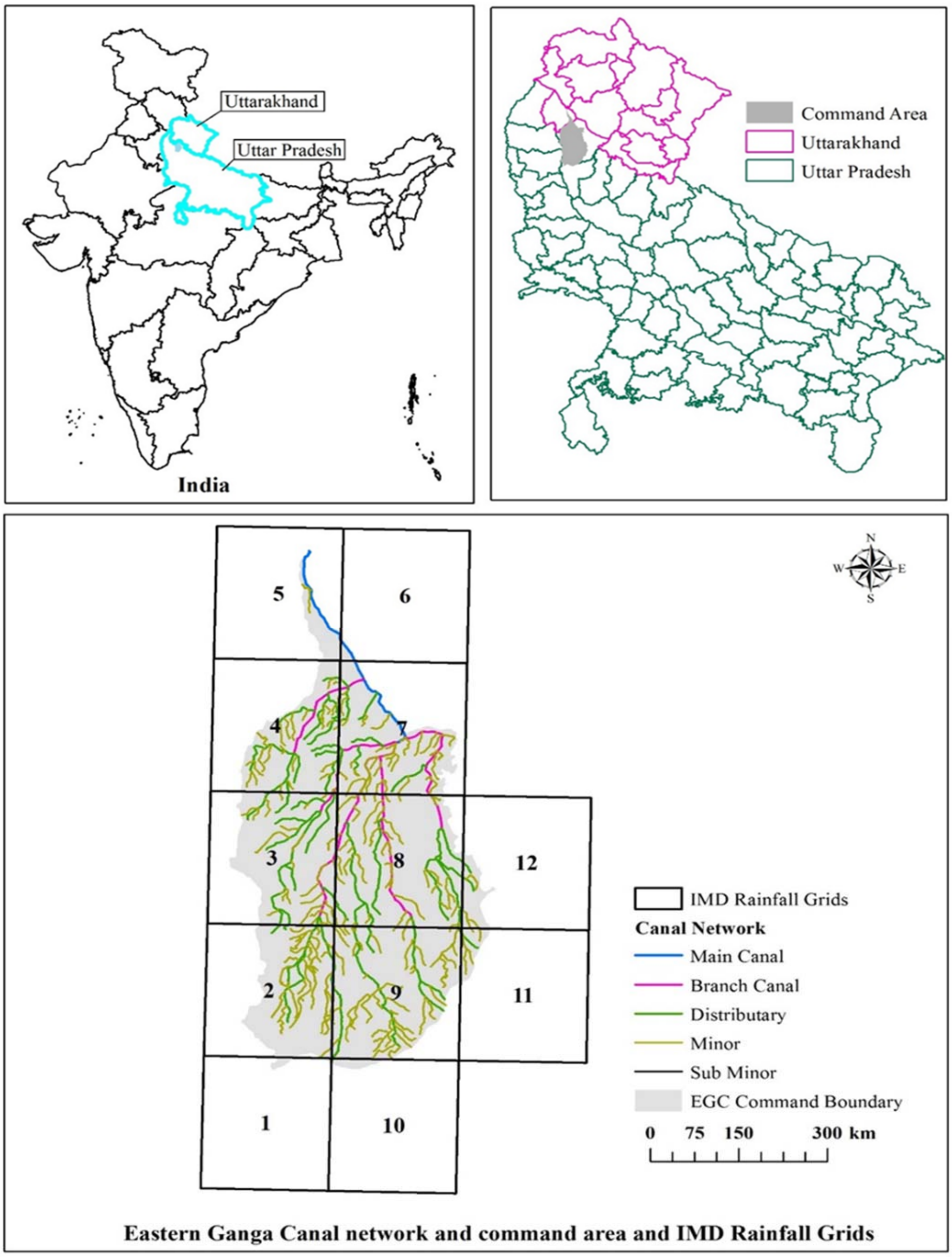

Fig. 1 Location map of the study area with the coverage of IMD rainfall data grids

III. Analysis of Trend and Variability

Attempts for the disclosure of significant trends in climatologic time series can be formulated as parametric and non-parametric approaches. Parametric trend tests require data to be independent and normally distributed, while non-parametric trend tests do not require independent or normally distributed data, instead it requires data which can be assumed to be actual [37]. In this study, two non-parametric techniques, e.g. Mann-Kendall (MK) test and Sen's slope estimator technique, were used to detect and quantify the trends in the rainfall, rainy days, annual temperature and seasonal temperature (*Kharif*, *Rabi* and Summer season). Before employing the MK test, all the data series were proven for serial correlation using Lag-1 autocorrelation at 1%, 5%, and 10% significance level to eliminate the effect of serial correlation [38], [39]. All the series were found to be serially absolute, hence, MK test was directly enforced to original data series to disclose the trend using the two-sided hypothesis at 5% significant level [40], [41]. The value of statistically significant trend was calculated using the Sen's estimator. The statistical and qualitative tests/methods used in the present study, to analyse the trend and pre-post-climate shift in the rainfall, rainy days and temperature are briefly described below:

(i) Mann-Kendall Test

The Mann Kendall test [42], [43] searches for a trend in a time series without specifying whether the trend is linear or nonlinear. The trend test is applied to a time series x_i ranked from i = 1,2……….n-1, and x_j ranked from j = i+1,2,……….n. Each data point x_i is used as a reference point and is compared with all other data points x_j such that

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

The Kendall statistics S is estimated as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i) \quad (2)$$

The variance of the statistic S is defined by

$$\mathrm{Var(S)} = \frac{n(n-1)(2n+5) - \sum_{i=1}^{n} ti(i)(i-1)(2i+5)}{18} \quad (3)$$

where t_i denotes the number of ties up to sample i.

The test statistics Z_c is estimated as

$$Z_c = \begin{cases} \frac{S-1}{\sqrt{\mathrm{Var(S)}}}, S > 0 \\ 0, \quad S = 0 \\ \frac{S+1}{\sqrt{\mathrm{Var(S)}}}, S < 0 \end{cases} \quad (4)$$

where, Z_c follows a standard normal distribution. The null hypothesis, H_0, meaning that no significant trend is present, is accepted if the test statistic (Z_c) is not statistically significant, i.e. $-Z_{a/2} < Z < Z_{a/2}$, where $Z_{a/2}$ is the standard normal deviate. A significance level (α) is also used to test for either an upward or downward monotone trend (a two-tailed test). If Z_c is greater than $Z_{\alpha/2}$ where α denotes the significance level, then the trend is significant.

(ii) Sen's Slope Estimator Test

In cases where a linear trend is present in a time series, then the true slope can be predicted by employing a simple non-parametric operation developed by Sen (1968). The slope estimate of N pairs of data is first measured by

$$Q_i = \frac{xj - xk}{j-k} \quad \text{for i=1…………N} \quad (5)$$

where, x_j and x_k are the data values at times j and k (j>k), respectively. The meridian of these N values of Q_i is Sen's estimator of slope. If N is odd, then the Sen's estimator is calculated by $Q_{med} = Q_{(N+1)/2}$ and if N is even, then Sen's estimator is calculated by $Q_{med}= [Q_{N/2}+Q_{(N+2)/2}]/2$ [44]. Finally, Q_{med} is tested by a two sided test at 100(1-α)% -confidence interval and true slope may be achieved by the non-parametric test.

IV. Results and Discussion

The trend in climatic parameters such as rainfall and temperature at various time scale has been studied for critical irrigation command area of EGC project with the objective of quantifying the change in trends of climatic parameters during pre and post climate shift periods, which coincides with pre and post- implementation periods of the project. Trends in annual rainfall, seasonal rainfall, annual number of rainy days, monsoon number of rainy days, annual mean temperature and seasonal mean temperature for *Kharif*, *Rabi* and Summer seasons were estimated for both the time periods (e.g. pre-climate shift and post-climate shift) using the MK test and the Sen's slope estimator. For the qualitative analysis, the spatial pattern before and after the climate shift periods has been assessed for both rainfall and temperature. The results obtained in the present study are deliberated subsequently.

A. Rainfall Analysis

In the case of rainfall analysis, 30 years data (1947-1976) for pre-climate shift period and 35 years data (1971-2012) for post-climate shift period have been used. Analysis of trends in annual rainfall, seasonal rainfall, annual number of rainy days and seasonal number of rainy days for both the periods has been done. Trends are plotted for all the four variables mentioned above in Figs. 2 and 3.

Annual average rainfall in the EGC command area (within 12 rainfall grids of IMD) region varies from 681.11 mm/yr to 1555.82 mm/yr during pre-climate shift period while it ranges from 545.01 mm/yr to 1741.30 mm/yr during post-climate shift. The weighted average rainfall of the EGC command area during pre-climate shift period is around 1168.27 mm/yr, whereas it becomes 1122.87 mm/yr during post-climate shift period. A total of 81.72% and 75.02% of total annual rainfall occurred in monsoon season, in pre-climate shift and post-climate shift period, respectively, over entire EGC command area. Monsoon rainfall varies from 567.36 mm/yr to 1394.58 mm/yr for pre-climate shift period where as in post-climate shift period the variations are from 321.02 mm/yr to 1369.73 mm/yr, within 12 grids, with the weighted average monsoon rainfall of 954.68 mm/yr and 842.36 mm/yr, respectively, for command area. Annual number of rainy days in before and after climate shift period within EGC command area varies from 47 days to 78 days and 42 days to 80 days, respectively. The preliminary statistics related to mean annual rainfall, monsoon rainfall, annual rainy days and monsoon rainy days for all the grids are given in Table V for pre-shift and in Table VI for post shift.

The results of trend analysis showed that annual rainfall, monsoon rainfall, annual rainy days and monsoon rainy days for the period 1947 to 1976, doesn't have a significant trend, this might be due to variability in the data of pre-climate shift period. While in post climate shift period, 1978 to 2012, there is a significant decreasing trend at 95% confidence level in annual rainy days. Though insignificant, however, decreasing trend in annual rainfall, monsoon rainfall and monsoon rainy days during post-climate shift and in all the four parameters during pre-climate shift period can be observed through the qualitative analysis of trend plots (Figs. 2 and 3).

It is clear from Tables I and II, that there is decreasing trend in all the four parameters considered (i.e. annual rainfall, monsoon rainfall, annual rainy days and monsoon rainy days) in pre-climate shift period, over EGC command area; which may reduce the water availability with time. Though these trends are statistically insignificant, may be due to high variability in the dataset, however, the decrease in annual and seasonal rainfall is evident through the qualitative analysis (visual inspection, primary trend analysis technique) of these trend plots. This continuously reducing annual and seasonal rainfall may create an alarming situation for the farmers in the command area, which may divert their attention towards exploitation of groundwater resources to fulfil the irrigation water requirement, leading to depletion of water table in the area. This may also trigger the change in cropping pattern to archive adaptability with the changing climate. In a case of any of these changes, the water resources managers of the area have to develop improved water management strategies to encompass the hydrological impacts of these changes.

TABLE I
SEN'S ESTIMATOR TEST VALUES FOR PRE-CLIMATE AND POST-CLIMATE SHIFT

Shift	Annual Rainfall	Rainfall in monsoon	Annual rainy days	*Monsoon Rainy Days*
Pre Climate Shift	-4.8109	-7.9783	-0.037	-0.175
Post Climate Shift	-4.217	-4.9671	-0.3417	-0.119

TABLE II
TREND RESULT USING MANN-KENDALL AND SEN'S ESTIMATOR TEST AT 5% SIGNIFICANCE LEVEL

Shift	Annual Rainfall	Rainfall in monsoon	Annual rainy days	*Monsoon Rainy Days*
Pre Climate Shift	No	No	No	No
Post Climate Shift	No	No	Yes	No

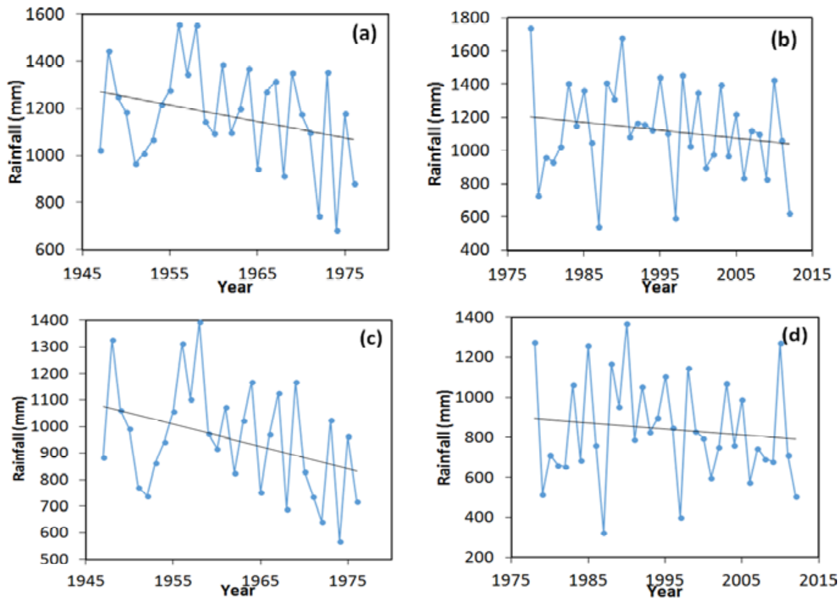

Fig. 2 Trend in annual rainfall for (a) pre-climate shift period, (b) post-climate shift period and monsoon rainfall (c) pre-climate shift period, (d) post-climate shift period of EGC

Trends' results at 5% significance level for annual rainfall, monsoon rainfall, annual number of rainy days and monsoon number of rainy days for pre-climate and post-climate shift periods are shown in Figs. 2 (a)-(d), Figs. 3 (a)-(d), respectively. Values slope quantified through the Sen's estimator reflect the decreasing trend of 48.12 mm/decade in annual rainfall during pre-climate shift period flattens a little bit to 42.17 mm/decade during post-climate shift period. This indicates a reduction in the rate of decrease of annual rainfall in post-climate shift period, however, it is clear from Figs. 2 (a) and (b) that the amount of annual rainfall is still smaller in post-climate shift period as compared to pre-climate shift period. In *monsoon* rainfall, the Sen's slope values have a large downfall from 79.78 mm/decade in pre-shift to 49.67 mm/decade in post-shift (Figs. 2 (c) and (d)). The visual analysis of trend is also a well-practiced technique in the field of trend analysis for long term data. In such case, the conclusion drawn from the visual analysis will be only refined using statistical tests. However, in the above cases, the results of visual analysis and statistical analysis are not complementary to each other. The main reason for this contradictory result may be the significance level of the test and the variability of the data itself.

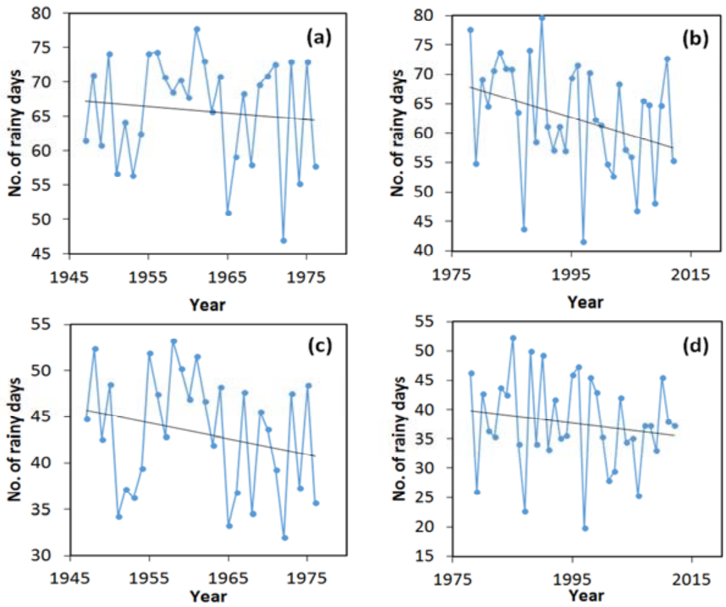

Fig. 3 Trends in annual rainy days (a) pre-climate shift period, (b) post-climate shift period and *monsoon* rainy days for (a) pre-climate shift period, (b) post-climate shift period of EGC

B. Temperature Analysis

Analysis of trend in average of annual temperature and average of seasonal (*Kharif*, *Rabi* and summer) temperature has been carried out for 27 years data (1951-1976) for pre-climate shift period and 36 years data (1977-2012) for post-climate shift period over EGC command area. Trends are plotted for average annual and seasonal temperature for whole EGC command area in Figs. 4 (a)-(h).

Annual average temperature in the region varies from 22.07 °C to 23.66 °C during pre-climate shift period while it reduces to 21.83 °C to 23.64 °C during post-climate shift period. *Kharif* season temperature varies from 25.66 °C to 27.84°C for pre-climate shift while 25.63 °C to 28.07 °C for post climate shift period in the EGC command area. Pre and post climate shift period temperature in *Rabi* season varies from 15.40 °C to 17.58 °C and 15.29 °C to 17.74 °C, respectively. During summer season temperature varies from 27.11 °C to 30.39 °C during pre-shift and 26.56°C to 30.43 °C in post-shift periods, respectively. The preliminary statistics related to average of all i.e. for annual temperature, *Kharif* season temperature, *Rabi* season temperature and summer season temperature, are given in Table VII for pre-shift and in Table VIII for post shift period.

Trends' results at 5% significance level for annual temperature, *Kharif* season temperature, *Rabi* season temperature and summer season temperature for pre and post climate shift within EGC command are shown in Fig. 4 (a to h), respectively. The results of trend analysis for the pre-climate shift period (1951 to 1976) showed that average annual temperature, average *Kharif* season temperature and average *Rabi* season temperature have significant decreasing trend at 95% confidence level with Sen's slope value of -0.03 °C, -0.02 °C, and -0.04 °C, respectively. Average summer season temperature shows decreasing trend with Sen's slope value of -0.02 °C; however, this trend appears to be statistically insignificant at 95% confidence level. On the contrary to the trends observed during pre-climate shift period, the average annual and seasonal (*Kharif* and *Rabi*) temperature during post-climate shift period (1977 to 2012), exhibits increasing trend of 0.02 °C in each case respectively, which is statistically significant at 95% confidence level. The trend in summer temperature is increasing with the Sen's slope value of 0.02 °C; however, here too this slope value is statistically insignificant at 95% confidence level, which may be due to high variability in summer temperature data.

From Tables III and IV, it is clear that there is decreasing trend for all the four parameters considered (i.e. annual temperature, *Kharif* season temperature, *Rabi* season temperature and summer season temperature) during pre-climate shift period while these parameters exhibit increasing trend during post-climate shift period; which may lead to increased evapotranspiration loss. Reduced annual and seasonal rainfall and increase in annual and seasonal evapotranspiration losses may lead to reduced water availability in the spatial or temporal domain in the command area. On one side water availability is decreasing, simultaneously population is increasing, resulting in increased water demand leading to adverse cumulative effect. In such situation, the knowledge of annual and seasonal assured water availability (rainfall) and losses (evapotranspiration) may help decision makers in proper planning of optimum utilization of existing water resources. Proper operation of canal system should be done to get the maximum benefit of the canal water considering these inputs.

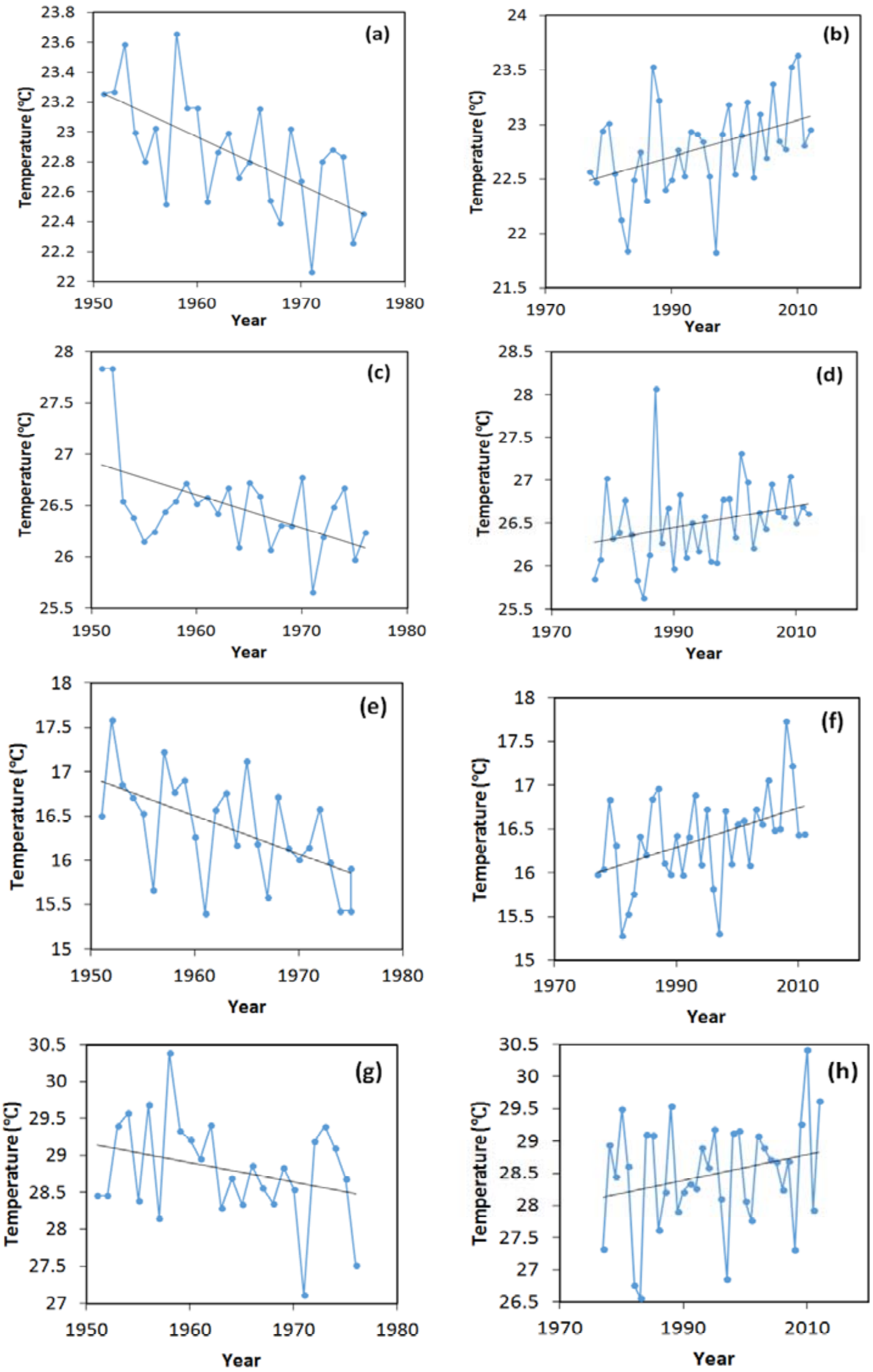

Fig. 4 Trend in pre and post climate shift period in annual temperature (a), (b), *Kharif* season temperature (c), (d), *Rabi* season temperature (e), (f), summer season temperature (g), (h) of EGC

TABLE III
SEN'S ESTIMATOR TEST VALUES FOR PRE AND POST CLIMATE SHIFT FOR TEMPERATURE

Shift	Avg. Annual Temp.	Avg. *Kharif* Temp.	Avg. *Rabi* Temp.	Avg. Summer Temp.
Pre-Climate Shift	-0.03	-0.02	-0.04	-0.02
Post-Climate Shift	0.02	0.02	0.02	0.02

TABLE IV
TREND RESULT USING MANN-KENDALL AND SEN'S ESTIMATOR TEST AT 5% SIGNIFICANCE LEVEL FOR TEMPERATURE

Shift	Avg. Annual Temp.	Avg. *Kharif* Temp.	Avg. *Rabi* Temp.	Avg. Summer Temp.
Pre-Climate Shift	Yes	Yes	Yes	No
Post-Climate Shift	Yes	Yes	Yes	No

TABLE V
MEAN VALUES FOR CONSIDERED FOUR SCENARIOS UNDER PRE-CLIMATE SHIFT

Year	Mean Annual Rainfall (mm)	Mean Rainfall in monsoon Season (mm)	Mean for Annual rainy days	Mean for rainy days in monsoon Season
1947	1020.12	884.6	61.5	44.8
1948	1443.36	1329.04	71.0	52.3
1949	1248.85	1063.16	60.83	42.6
1950	1182.69	991.74	74.1	48.4
1951	964.367	771.81	56.7	34.3
1952	1006.48	739.21	64.1	37.2
1953	1066.07	863.57	56.3	36.3
1954	1214.86	944.05	62.4	39.3
1955	1275.71	1057.96	74.1	51.8
1956	1555.82	1315.49	74.3	47.3
1957	1344.07	1102.52	70. 7	42.8
1958	1552.54	1394.58	68.5	53.2
1959	1143.83	974.50	70.3	50.2
1960	1093.17	918.36	67.8	46.8
1961	1383.69	1075.3	77.8	51.5
1962	1095.75	826.22	73.1	46. 7
1963	1197.51	1022.79	65. 7	41.9
1964	1367.01	1169.6	70.8	48.2
1965	941.26	753.85	51.0	33.3
1966	1269.46	971.59	59.2	36.8
1967	1314.88	1127.11	68.3	47.6
1968	911.60	689.69	57.9	34.6
1969	1350.54	1169.66	69.6	45.5
1970	1176.26	830.82	70.9	43.6
1971	1096.13	735.44	72.6	39.3
1972	740.68	642.04	47.0	31.9
1973	1351.26	1026.34	72.9	47.4
1974	681.11	567.36	55.2	37.3
1975	1178.36	963.60	72.9	48.3
1976	880.61	718.51	57.8	35. 7

V. CONCLUSIONS

During pre-climate and post-climate shift period, the analysis of annual precipitation, monsoon precipitation, annual rainy days and monsoon rainy days over EGC command area showed decreasing trends. Except for annual rainy days in post climate shift period, all other trends were statistically insignificant for both the periods (pre and post climate shift period). The noteworthy thing is that, though trends of annual and seasonal precipitation are statistically insignificant in both the pre and post climate shift periods, the visual analysis of these trends indicates the reduction in decreasing trend in rainfall in post climate shift period compared to pre-climate shift period. The trend analysis for temperature showed opposite trends between pre-climate shift and post climate shift periods for annual average temperature, average *Kharif* season temperature, average *Rabi* season temperature, and average summer season temperature. During pre-climate shift period (1951 to 1976), the temperature is showing significant decreasing trends at 95% confidence level in case of annual average temperature, average *Kharif* season temperature and average *Rabi* season temperature, whereas in post climate shift period (1977 to 2012). There are significant increasing trends in these variables. In a case of average summer season temperature, the same opposite trends are observed during pre and post climate shift periods; however, both the trends were found to the statistically insignificant at 95% confidence level.

TABLE VI
MEAN VALUES FOR CONSIDERED FOUR SCENARIOS UNDER POST CLIMATE SHIFT

Year	Mean Annual Rainfall (mm)	Mean Rainfall for monsoon Season (mm)	Mean for Annual rainy days	Mean for rainy days in monsoon Season
1978	1741.30	1274.96	77.7	46.3
1979	729.08	518.98	54.9	26.0
1980	964.24	712.45	69.3	42.8
1981	934.51	662.54	64.6	36.4
1982	1026.71	657.5	70.8	35.3
1983	1406.29	1064.37	73.8	43.8
1984	1152.09	687.2	71.1	42.5
1985	1363.90	1257.36	70.9	52.3
1986	1049.43	761.94	63.6	34.1
1987	545.01	324.02	43.8	22. 7
1988	1411.82	1169.33	74.2	50.0
1989	1314.48	951.78	58.6	34.1
1990	1681.85	1369.73	79.8	49.3
1991	1084.29	789.92	61.2	33.3
1992	1168.44	1054.34	57.2	41. 7
1993	1161.06	829.55	61.2	35.1
1994	1124.3	897.65	57.1	35.6
1995	1442.04	1104.07	69.4	46
1996	1106.71	851.28	71.6	47.3
1997	594.43	400.34	41. 7	19.8
1998	1456.03	1145.86	70.3	45.5
1999	1027.59	831.94	62.3	42.9
2000	1353.09	796.36	61.4	35.4
2001	898.85	600.01	54.8	27.9
2002	977.2435	752.24	52.8	29.5
2003	1397.3	1071.68	68.4	42.1
2004	969.61	761.56	57.3	34.5
2005	1220.17	990.87	56.0	35.1
2006	835.38	576.55	46.8	25.3
2007	1120.84	746.67	65.5	37.3
2008	1100.97	695.25	64.8	37.3
2009	829.76	682.5	48.2	33.1
2010	1426.64	1269.47	64.75	45.5
2011	1063.15	713.76	72.8	37.9
2012	621.72	508.56	55.3	37.3

TABLE VII
AVERAGE TEMPERATURE FOR CONSIDERED FOUR SCENARIOS UNDER PRE-CLIMATE SHIFT PERIOD

Year	Avg. Annual Season Temperature (℃)	Avg. *Kharif* Season Temperature (℃)	Avg. *Rabi* Season Temperature (℃)	Avg. Summer Season Temperature (℃)
1951	23.26	27.84	16.50	28.46
1952	23.27	27.84	17.58	28.46
1953	23.59	26.54	16.86	29.40
1954	23.00	26.38	16.71	29.57
1955	22.80	26.15	16.53	28.39
1956	23.03	26.25	15.67	29.68
1957	22.52	26.44	17.22	28.15
1958	23.66	26.54	16.77	30.39
1959	23.16	26.72	16.91	29.33
1960	23.16	26.51	16.27	29.21
1961	22.54	26.58	15.40	28.96
1962	22.87	26.42	16.58	29.41
1963	22.99	26.67	16.77	28.29
1964	22.70	26.09	16.17	28.69
1965	22.80	26.72	17.12	28.34
1966	23.16	26.59	16.19	28.86
1967	22.55	26.06	15.59	28.56
1968	22.39	26.31	16.72	28.36
1969	23.02	26.30	16.14	28.84
1970	22.67	26.77	16.01	28.55
1971	22.07	25.66	16.14	27.11
1972	22.80	26.19	16.59	29.19
1973	22.88	26.48	15.98	29.39
1974	22.84	26.67	15.43	29.10
1975	22.26	25.97	15.43	28.69
1975	22.26	25.97	15.91	28.69
1976	22.46	26.24	-	27.52

This opposite trends in annual and seasonal temperature, with significantly increasing trend in post climate shift period, which is also post implementation phase of EGC project, poses questions on the irrigation distribution strategies. These irrigation distribution strategies have been designed during project design phase, which coincides with pre-climate shift phase. The data and trends (trends in data) used to design these irrigation water distribution strategies have now changed in post implementation phase of the project (post climate shift period), especially the trends. The increasing trend in annual and seasonal temperature will increase evapotranspiration losses from the command area and the continually decreasing trends of annual and seasonal rainfall will reduce natural water availability for the agriculture in the command area. The reduction in natural water availability has to be compensated by increased irrigation supply in the area. To plan the increase/change in irrigation supply spatially or temporally the knowledge of existing and future natural water availability and losses is the prerequisite. Based on this study, various policies can be derived for the better management of water resource in the command area. Furthermore, there is a need of a unified governmental plan for change detection, impact assessment, adaptation and mitigation pertaining to changes in climatic parameters. This particular study highlights the climatic variable along with their trends were changed from pre to post climate shift periods with in the EGC command region, so for better implementation of long term water resources management, proper planning should be incorporated to overcome the effect of the climate shift in the EGC command area.

TABLE VIII
AVERAGE TEMPERATURE FOR CONSIDERED FOUR SCENARIOS UNDER POST-CLIMATE SHIFT PERIOD

Year	Avg. Annual Season Temperature (℃)	Avg. *Kharif* Season Temperature (℃)	Avg. *Rabi* Season Temperature (℃)	Avg. Summer Season Temperature (℃)
1977	22.57	25.85	15.98	27.34
1978	22.47	26.07	16.05	28.95
1979	22.95	27.02	16.84	28.45
1980	23.02	26.32	16.32	29.51
1981	22.55	26.39	15.29	28.61
1982	22.13	26.77	15.54	26.77
1983	21.84	26.37	15.76	26.56
1984	22.50	25.84	16.42	29.11
1985	22.75	25.63	16.21	29.10
1986	22.31	26.13	16.85	27.63
1987	23.53	28.07	16.96	28.21
1988	23.23	26.28	16.11	29.55
1989	22.40	26.68	15.98	27.92
1990	22.49	25.97	16.43	28.22
1991	22.77	26.83	15.98	28.33
1992	22.53	26.10	16.41	28.27
1993	22.94	26.51	16.89	28.90
1994	22.92	26.17	16.10	28.59
1995	22.84	26.58	16.73	29.19
1996	22.53	26.05	15.83	28.11
1997	21.83	26.04	15.31	26.86
1998	22.92	26.78	16.71	29.13
1999	23.19	26.79	16.11	29.16
2000	22.55	26.34	16.56	28.08
2001	22.90	27.31	16.60	27.77
2002	23.21	26.98	16.08	29.09
2003	22.52	26.21	16.73	28.90
2004	23.10	26.63	16.55	28.72
2005	22.70	26.43	17.06	28.69
2006	23.38	26.95	16.49	28.25
2007	22.85	26.63	16.50	28.70
2008	22.77	26.58	17.74	27.32
2009	23.53	27.05	17.23	29.28
2010	23.64	26.50	16.44	30.43
2011	22.81	26.70	16.45	27.93
2012	22.96	26.61	-	29.63

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