International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(3): 2724-2733

Received: 16-03-2019
Accepted: 18-04-2019

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Groundwater behavior in relation to climatic scenario of Kharun watershed

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Abstract
Climate change poses uncertainties to the supply and management of water resources. Climate change on precipitation and surface water ultimately affects groundwater systems. Looking to the importance of groundwater use, availability in the state and major role of climate; a study on groundwater behavior in relation to climate change has been conducted for the Kharun watershed of Seonath sub-basin in Chhattisgarh. Kharun river originates from Petechua in the south-east of the Balod district. From the analysis of 30 years data of different stations of Kharun watershed, it was found that rainfall pattern and amount of rainfall both was changed and rainfall showed a slight increasing trend and the mean temperature of the all stations was increased significantly from past 30 year and the difference of temperatures was found to be 0.6 ^{0}C approx. Raipur station was found in increasing trend that means depth of water level below ground level was increased from 1992 to 2016. Groundwater availability of Kharun watershed was found 0.4842 BCM and highest availability was 0.6641 BCM in the year of 1992. Census was increased drastically and it affects all parameters directly and indirectly. Mann Kendall trend test was performed for trend analysis for each parameter.

Keywords: Groundwater behavior, relation, climatic scenario, Kharun watershed

Introduction
Chhattisgarh state is exploiting its water resources mainly for domestic and industrial water supply and developing irrigation schemes. The surface and groundwater resources of the state play a major role in agriculture, livestock production, industrial activities, forestry, fisheries, recreational activities, etc. Water is indispensable for life, but its availability at a sustainable quality and quantity is threatened by many factors, of which climate plays a leading role. The Intergovernmental Panel on Climate Change (IPCC) defines climate as “the average weather in terms of the mean and its variability over a certain time-span and a certain area” (C. P Kumar 2012) [7]. Climate change means the difference in the Earth's global climate or in regional climates over time. It describes changes in the state of the atmosphere over time scales ranging from decades to millions of years.

Groundwater aquifers are recharged mainly by precipitation or through interaction with surface water bodies, the direct influence of climate change on precipitation and surface water ultimately affects groundwater systems. Climate change also may affect soil characteristics, perhaps through changes in water logging or cracking, which in turn may affect soil moisture storage properties. Infiltration capacity and water-holding capacity of many soils are influenced by the frequency and intensity of freezing.

Materials and Methods
Description of study area
Kharun watershed which is the part of Seonath sub-basin of well-known Mahanadi river basin in Chhattisgarh. Fifteen blocks of six districts including Balod, Dhamtari, Durg, and Raipur covers the area of Kharun watershed fully/partially. Total area of watershed was reported to be 4118 km^2. The Kharun watershed is situated between 20^{0}52' 30" N to 21^{0}54' 36" N latitude and 81^{0}27' 18" E to 82^{0}06' 18" E longitude. Kharun originates from Petechua in the south-east of the Balod district and after flowing 164 km joins Seonath river near Somnath in Raipur district (Sinha, 2011). It has geology of Chandrapur Group-Gunderdihi, and Churmuri with the lithology of shale, sandstone, siltstone and limestone (Kumar *et al*. 2017) [9].

Data Acquisition

The daily rainfall and temperature data of Kharun watershed from 1987- 2016 was collected from Water Resource Department (WRD) Raipur (C.G.). Location of Rainfall Gauging station can be seen in Fig.2. Groundwater level data was collected from CGWB, Raipur. Availability of groundwater data was from 1990 - 2016 but most of the stations data availability was from 2005-2016. Location of observation wells are shown in Fig.3. Census data of all the blocks of the study area was collected from the Department of Statistics, Collectorate Office, Raipur (C.G.).

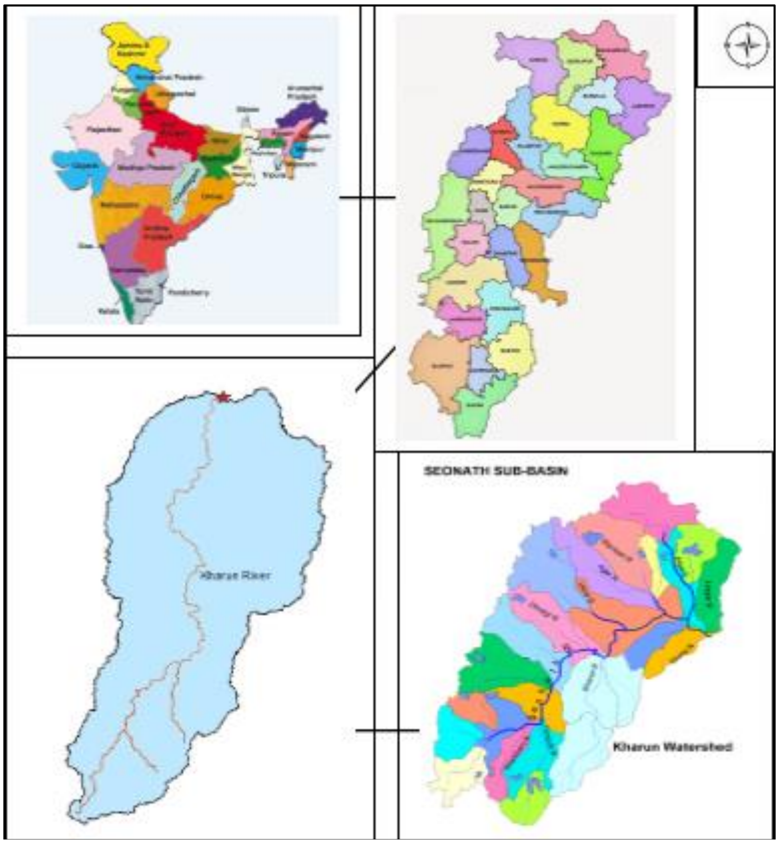

Fig 1: Location map of study area

Analysis of data

Rainfall and temperature data

The daily rainfall and temperature data of different rain gauge (RG) stations in Kharun watershed were collected from WRD Raipur (C.G.). The thematic map showing locations of the rain gauge stations in the study area were prepared by utilizing geographical location of each rain gauge station in the environment of ArcGIS (Fig. 1). Rainfall and temperature data were arranged for processing. Then mean temperature was calculated from minimum and maximum temperature and daily rainfall and mean temperature data were processed and converted into monthly and weekly data. Processed data was again arranged in yearly and season wise for the preparation of graph. Five years interval graph were prepared for RG station on monthly and weekly basis.

Groundwater data

With the use of pre and post monsoon data groundwater fluctuation was calculated and further used for groundwater assessment. Then for the preparation of groundwater fluctuation graph pre and post monsoon data was used.

Census data

Census data of 2001 and 2011 was plotted against groundwater, rainfall and mean temperature and then analyzed for the changes. 10 years average for each parameter was taken for the preparation of graph.

Assessment of groundwater

Assessment of groundwater recharge from rainfall

Under this method the change in storage is computed by multiplying water level fluctuation between pre and post monsoon season with the area of assessment and specific yield (GEC, 2009).

$$S = h * Sy * A \qquad ....1$$

Where, S = change in storage (m^3)

h = Rise in water level due to monsoon (fluctuation between pre-monsoon and post-monsoon water level),

A = Area for computation of recharge,

Sy = Specific yield.

Value of specific yield recommended by GEC (2009) for sandstone formation is 3%.

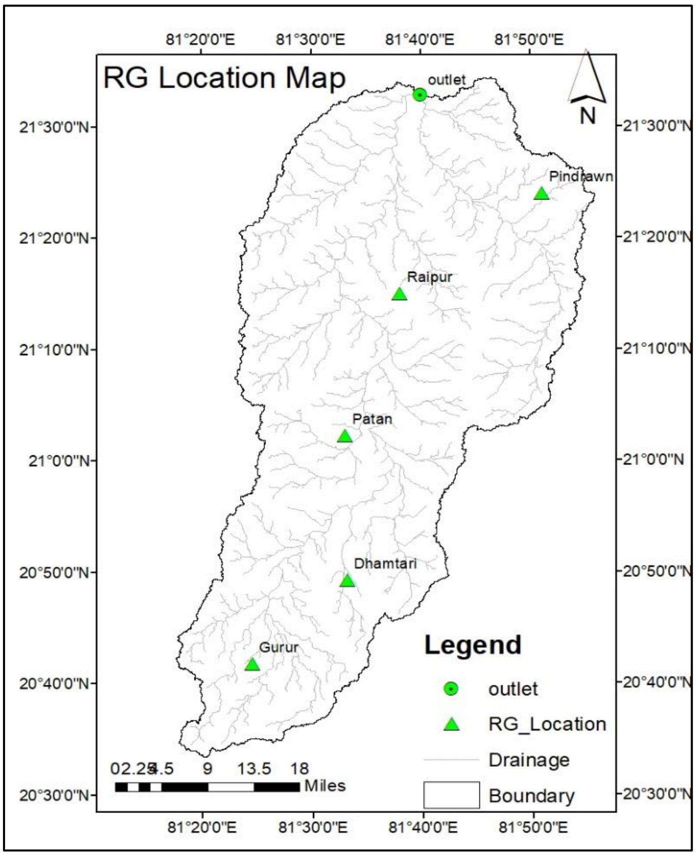

Fig 2: Location of various recording stations of Kharun watershed

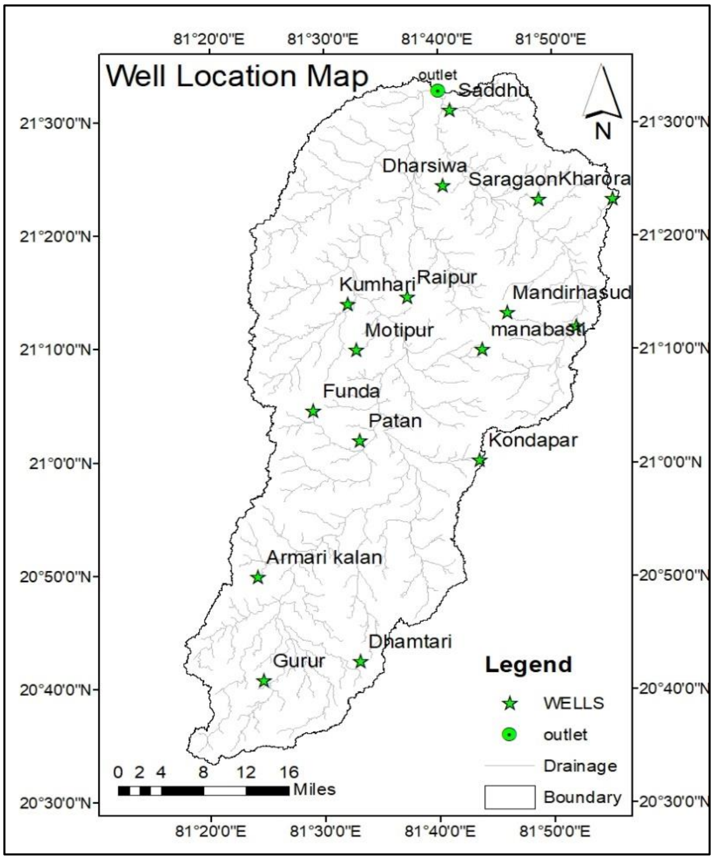

Fig 3: Location of various groundwater wells of Kharun watershed

Net groundwater availability

Net ground water availability = (Recharge from rainfall + Recharge from other sources) - natural discharge (10 % of recharge, as per groundwater estimation committee norm) …(2)

Groundwater behavior related to climate and census

For knowing the behavior of groundwater with census, rainfall and temperature graphs were prepared and analysied. For preparation of graphs rainfall and mean temperature with ground water level of different block of study area and census of 2001 and 2011 has to be taken. From analysis of graphs identify the behavior of groundwater.

Trend analysis

Trend analysis is method of time series data (information in sequence over time) analysis involving comparison of the same item (such as monthly rainfall data) over a significantly long period to detect general pattern of a relationship between associated factor or variables and project the future direction of this pattern. For analysing the trend of different parameters in different graphs Mann Kendall trend test was used.

The Mann Kendall Trend Test is used to analyse data collected over time for consistently increasing or decreasing trends in values. It is a nonparametric test. For the trend analysis of data Mann Kendall trend test was used in Microsoft Excel 2016.

Results and Discussion

Analysis of long term meteorological data

Monthly rainfall and temperature data

Result of data analysis of stations revealed that the average annual rainfall was 1252.47 mm. The graphs were plotted for 5-years on yearly basis for rainfall and mean temperature for Raipur station. Graphs of Raipur station of Dharsiwa block were shown in Fig. 4 (a to f). The amount of rainfall during the months of kharif season was found to be highest as compared to the others seasons but monthly highest rainfall was changed in each year within the season. The highest amount of rainfall received in June 2007 whereas lowest rainfall was recoded in December 1988. The receiving pattern of monthly rainfall of study area was found to be different for different years. It has been found that, the rainfall was varied in each month and this pattern followed in each year. In each year highest rainfall was received during the monsoon season which includes months of June, July, August and September. Similar study was also carried out by *Kwarteng et al*. 2009. The highest and lowest amount of rainfall received in the years 1988 and 2007 respectively.

The mean temperature data of the study area varies from 5.03 ^{0}C to 51.77 ^{0}C. Mean minimum and mean maximum temperature was found to be 17.11 ^{0}C and 38.28 ^{0}C, respectively. Every year May month experiences maximum temperature whereas minimum temperature was recoded in month of January. Graph of mean temperature shows significant increasing trend. Jain *et al.* 2012 also analysed the meteorological data on monthly basis and found similar result in their study.

Weekly rainfall and temperature data

In the case of weekly plots, it was revealed that the highest rainfall was observed during the 26th week (26th SMW) of kharif season in the year 2007. Weekly highest rainfall was received in the month of June of Kharif season. In most of the graphs, it was seen that there were decreasing trend however, in some of the cases increasing trend of rainfall was visualized clearly. Overall trend of weekly data set of rainfall of Kharun watershed was said to be having decreasing trend. In weekly plots the mean minimum temperature was found to be 14.71 ^{0}C in second SMW of January 1992 (rabi season) and mean maximum temperature was 41.24 ^{0}C in 22nd SMW of the mont of May 2012 (zaid season). Weekly graphs of mean temperature were also showed increasing trend for gauging station of Kharun watershed. Weekly rainfall and mean temperature data were plotted for five year interval as shown in Fig. 5 (a to f) Raipur, gauging station.

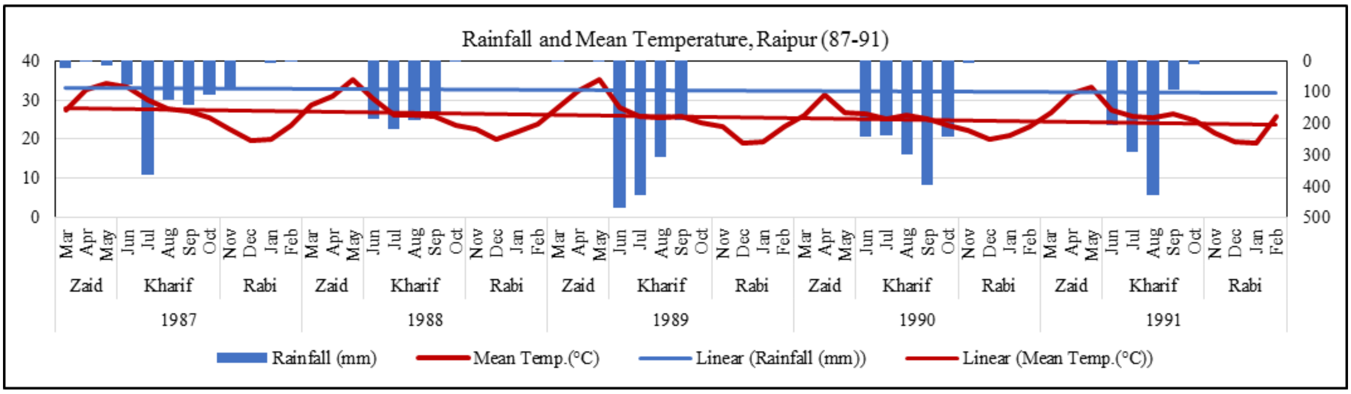

Fig 4 (a): Seasonal comparison of rainfall and mean temperature of Raipur station for five years (87-91) monthly basis

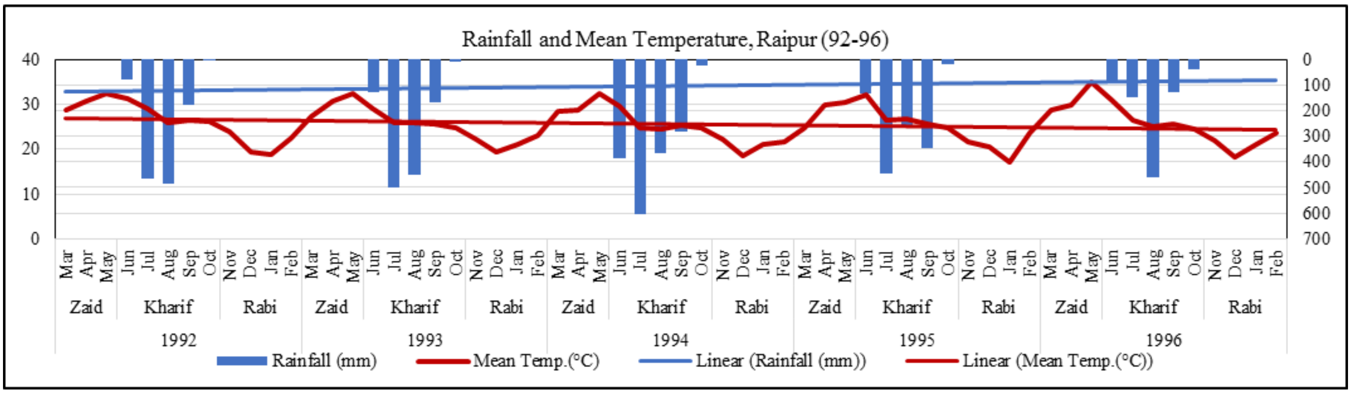

Fig 4 (b): Seasonal comparison of rainfall and mean temperature of Raipur station for five years (92-96) monthly basis

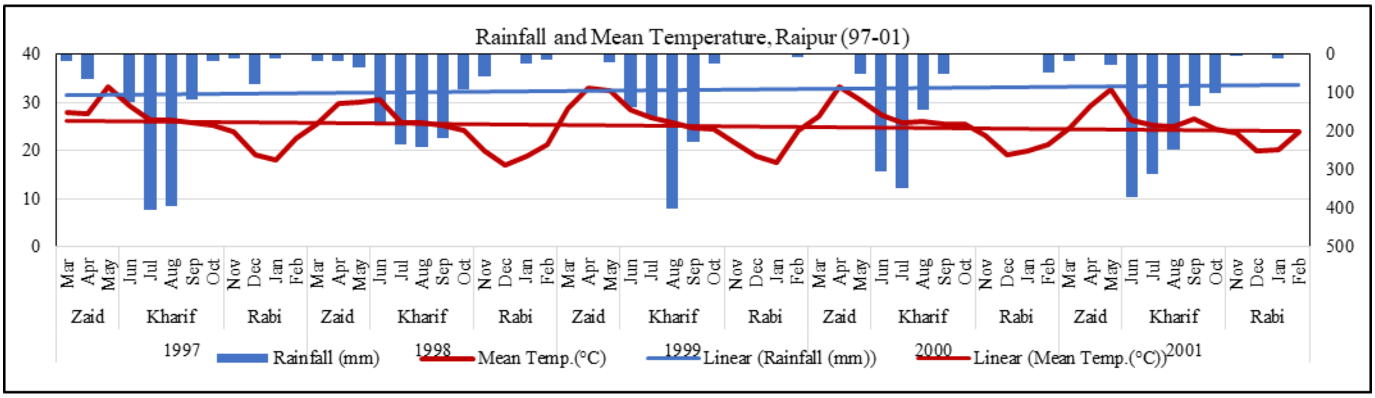

Fig 4 (c): Seasonal comparison of rainfall and mean temperature of Raipur station for five years (97-01) monthly basis

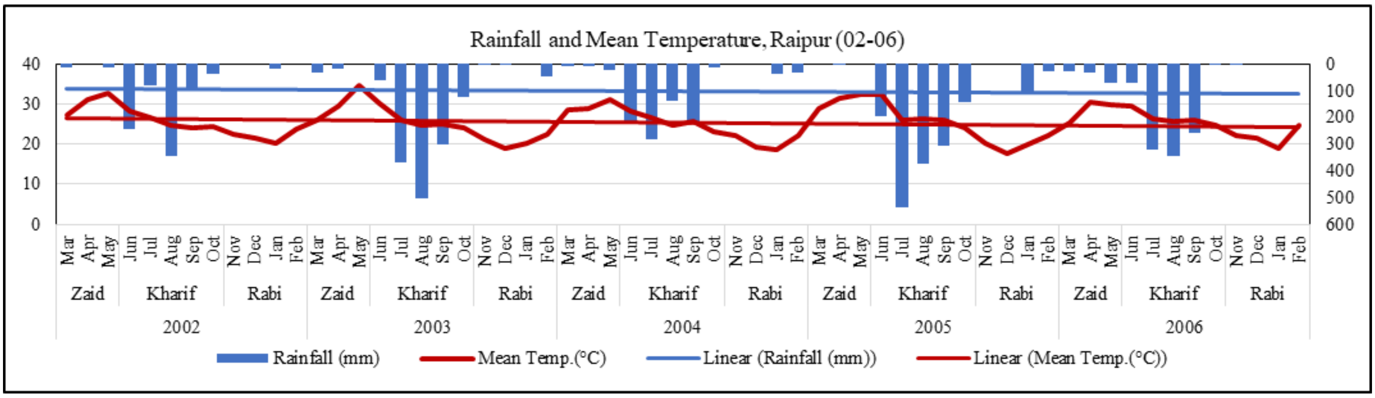

Fig 4 (d): Seasonal comparison of rainfall and mean temperature of Raipur station for five years (02-06) monthly basis

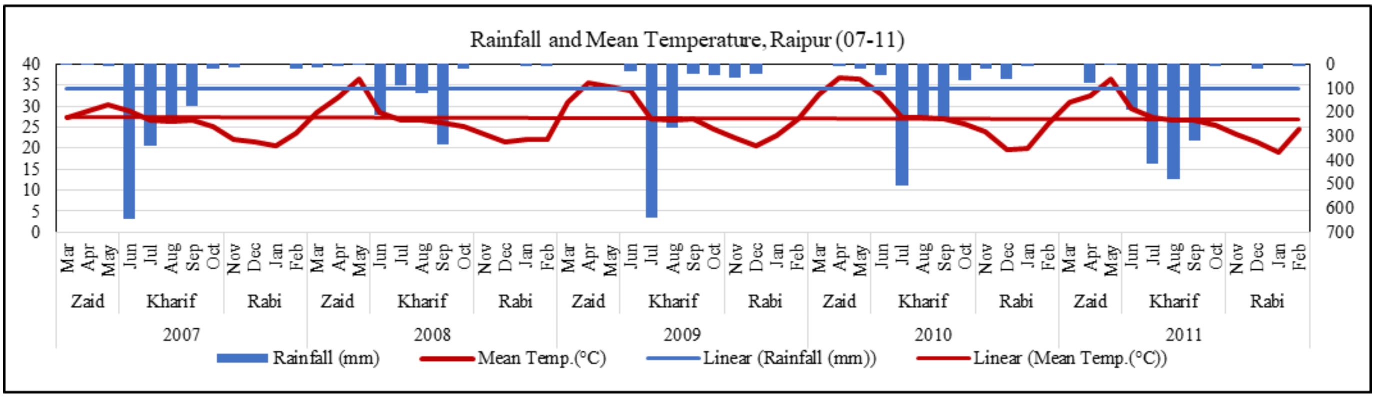

Fig 4 (e): Seasonal comparison of rainfall and mean temperature of Raipur station for five years (07-11) monthly basis

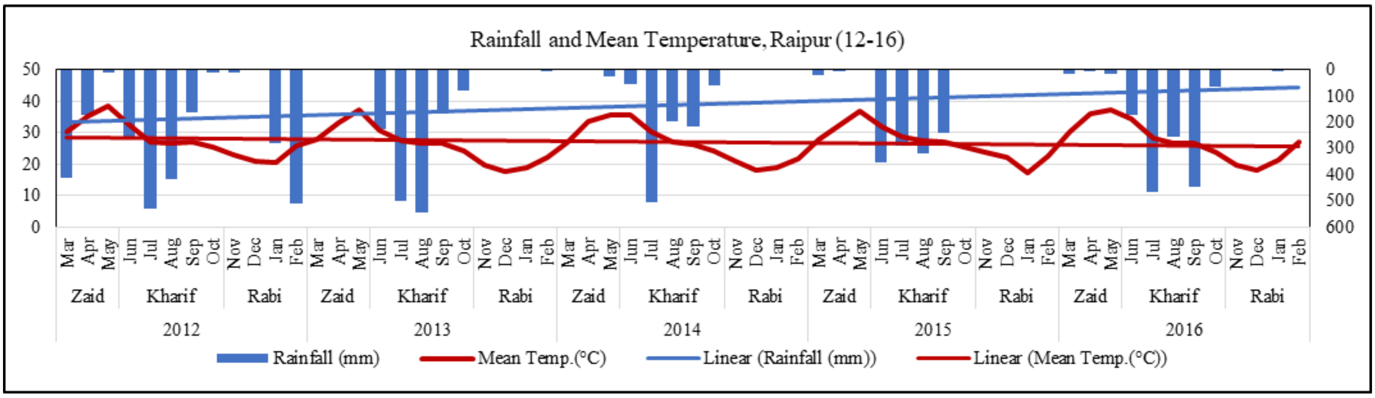

Fig 4 (f): Seasonal comparison of rainfall and mean temperature of Raipur station for five years (12-16) monthly basis

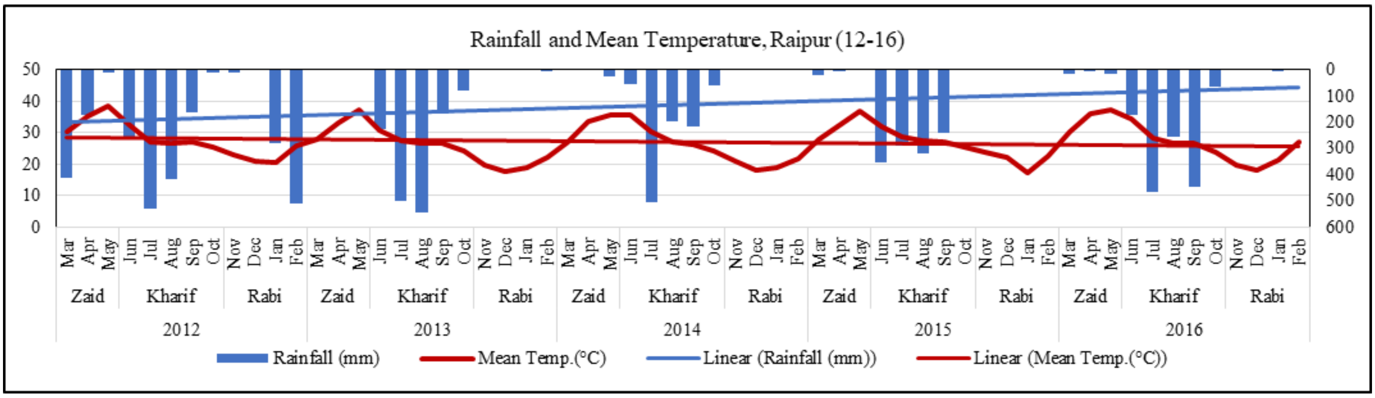

Fig 5 (a): Seasonal comparison of rainfall and mean temperature of Raipur station for five years (87-91) weekly basis

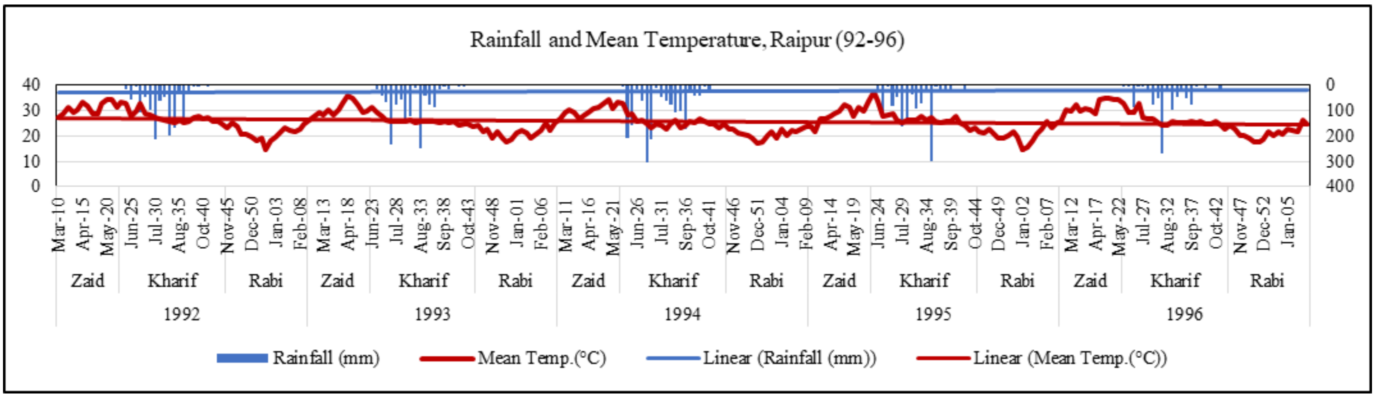

Fig 5 (b): Seasonal comparison of rainfall and mean temperature of Raipur station for five years (92-96) weekly basis

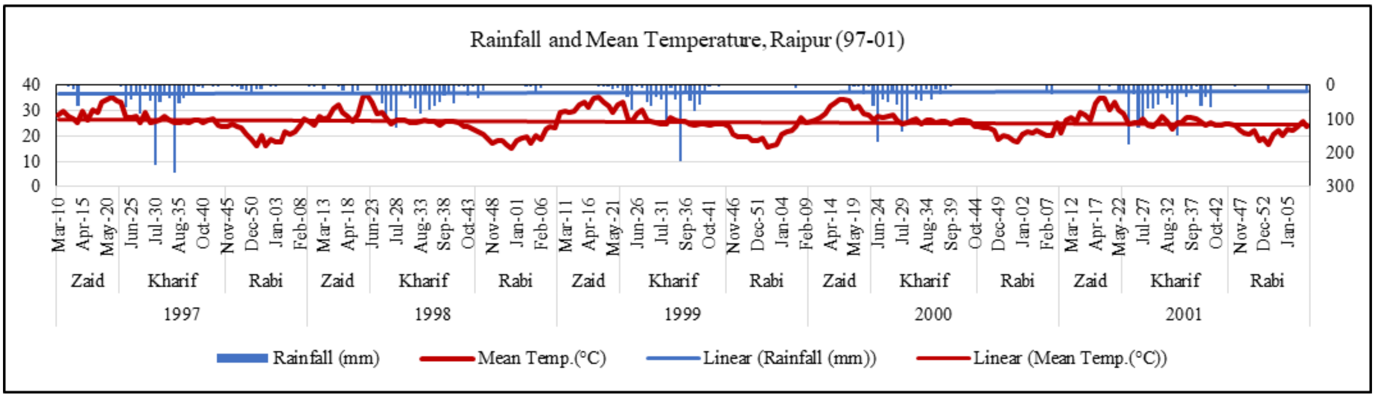

Fig 5 (c): Seasonal comparison of rainfall and mean temperature of Raipur station for five years (97-01) weekly basis

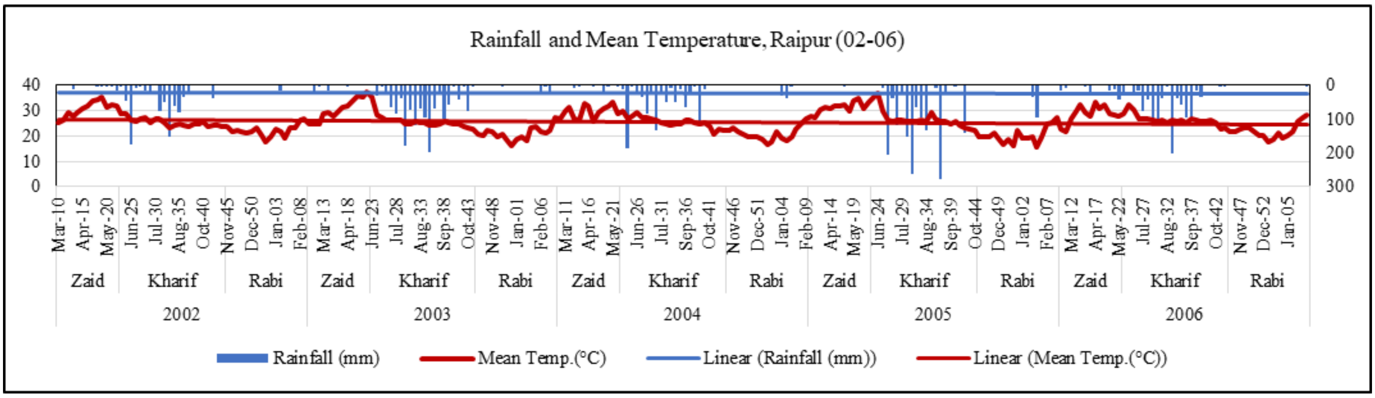

Fig 5 (d): Seasonal comparison of rainfall and mean temperature of Raipur station for five years (02-06) weekly basis

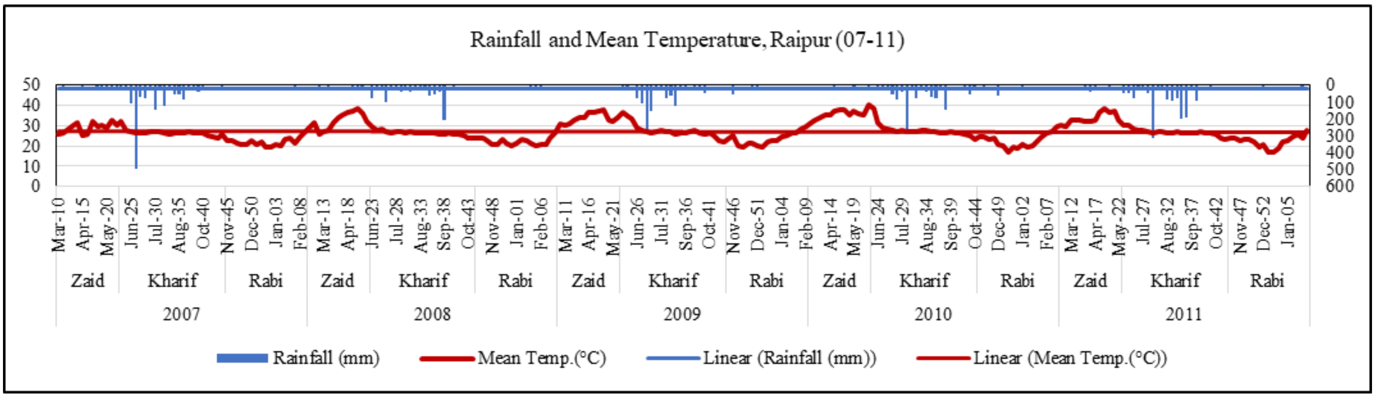

Fig 5 (e): Seasonal comparison of rainfall and mean temperature of Raipur station for five years (07-11) weekly basis

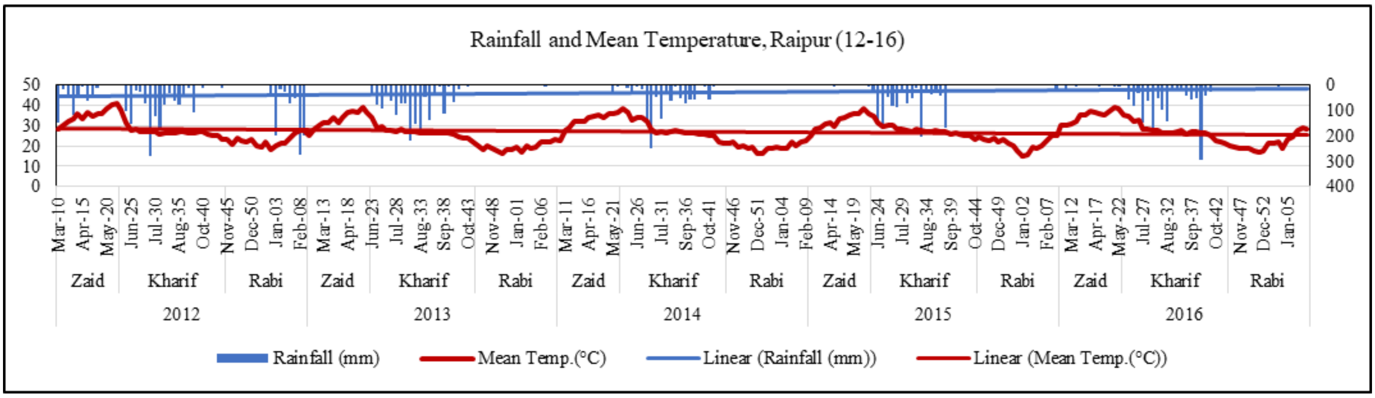

Fig 5 (f): Seasonal comparison of rainfall and mean temperature of Raipur station for five years (12-16) weekly basis

With the combination of other station, the scenario for the Kharun watershed showed that the trend of rainfall and temperature both shows significant increasing trend. Previous study is also reported that rainfall and temperature were having significant increasing trend (Kumar *et al.* 2017) [9].

Assessment of Groundwater Availability of Kharun Watershed

Ground water level fluctuation of observation wells of Kharun watershed

With the use of pre and post monsoon data groundwater fluctuation was calculated and further used for availability of groundwater assessment. Ground water fluctuation graph were prepared by using pre and post monsoon data for better presentation of groundwater. Henceforth the plots of groundwater fluctuation was prepared stations which is existing within the watershed.

In Dharsiwa station maximum groundwater depth was found to be 8.59 m in the pre monsoon in the year of 2006 whereas in post monsoon season maximum depth was found to be 6.56 in the year of 2000. Fluctuation was 7.05 m which is highest for this station in the year 2006. The results of analysis of groundwater data of Dharsiwa station was revealed that there was decreasing trend in both pre and post monsoon data which means that depth of groundwater is decreasing but there were large difference between the depth of water level in last 10 years (2007-2016) and the groundwater fluctuation was also found to be in increasing trend.

In case of Raipur station there is maximum groundwater depth was found to be 8.35 m in the year 2008 and maximum depth in post monsoon groundwater level was 3.89 m in the year 2015. The fluctuation of ground water was uneven for the year 2015. The result showed that the depth of post monsoon water level was greater than the pre monsoon water level. The analysis of groundwater data of this station was revealed that there was increasing trend in both pre and post monsoon data which means that the groundwater depth below ground level was in increasing trend and water level was in decreasing trend.

Maximum pre monsoon groundwater depth was 7.53 m in 1997 at Saragaon station. The post monsoon season maximum depth below ground level is 4.44 in the year of 1998. In 2015 the depth of water level was reduced to 1.35 m but in 2016 depth was increased to 4.15 m. Fluctuation was found to be high from 2000 to 2006. Here also some of the year has negative fluctuation which means depth of post monsoon water level was greater than the depth of pre monsoon water level like 2015. In case of 2015 the pre monsoon groundwater level was 1.35 m and in post monsoon it was increased but the depth was decreased and reached upto 1.68 m. The analysis of groundwater data of this station was revealed that there was decreasing trend in both pre and post monsoon data which means that groundwater depth below ground level was decreasing and resulting increasing water level.

Mandirhasaud station has very high depths in pre-monsoon seasons as compared to other station in Dharsiwa block but in post monsoon season depth was reduced up to 1.12 m. In this station maximum pre-monsoon groundwater depth was found to be 14.89 m in 1993 however in post monsoon season maximum depth was recoded to be 12.57 in the year of 2015 and maximum fluctuation was 13.54 in the year of 1993. Only year 2015 has negative fluctuation which means depth of post monsoon water level was greater than the pre-monsoon water level. In the 2015 the pre-monsoon level was 5.59 m and post monsoon it has to be decreased but the depth was increased and reached upto 12.57 m. This may be because of having pre-monsoon rains. The analysis of groundwater data of this station was revealed that there was decreasing trend in pre-monsoon and increasing trend in post monsoon it means that groundwater level was in increasing trend in pre-monsoon season but having decreasing trend in post monsoon. There was large difference between the depths of water level in last 30 years (1993-16). The groundwater fluctuation was also found to be in increasing trend.

Manabasti station was showed similar results as Mandirhasaud station and it has also same trend as Mandirhasaud station. In this station maximum groundwater depth below ground level was 12.20 m in 1993 during pre-monsoon season and in post monsoon season maximum depth below ground level was 7.33 m in the year 2013. Maximum fluctuation was recorded to be 9.7 in the year 1995. After 2006 in pre monsoon depth was suddenly reducing upto a depth of 4.36 m. Here only one station has negative fluctuation which means depth of post monsoon water level was greater than the pre monsoon water level in 2015 year due to having pre-monsoon rains. In 2015 the pre monsoon level was 1.29 m and in post monsoon it has to be decreased but the depth was increased and reached upto 4.42 m. The analysis of groundwater data of this station was revealed that there was increasing trend in post monsoon whereas groundwater depth below ground level was having increasing trend and water level was decreasing accordingly.

Overall in case of Dharsiwa block groundwater level was decreasing and depth was increasing with uneven fluctuation. Year 2015 was most critical because in this year all station and higher depth of groundwater below ground level may be because of withdrawal of groundwater during Kharif season for irrigation. Recharge from rainfall and net groundwater availability are important components for ground water assessment, therefore assessed in this study for knowing the groundwater behavior in relation to climatic scenario.

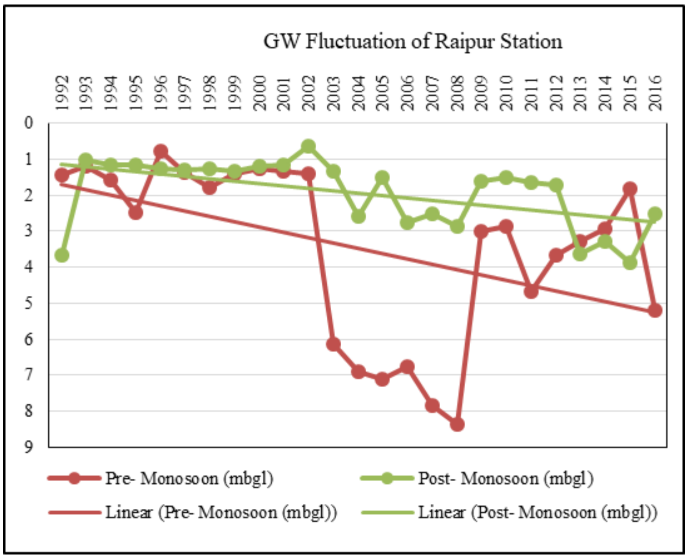

Fig 6(a): GW fluctuation of Raipur station

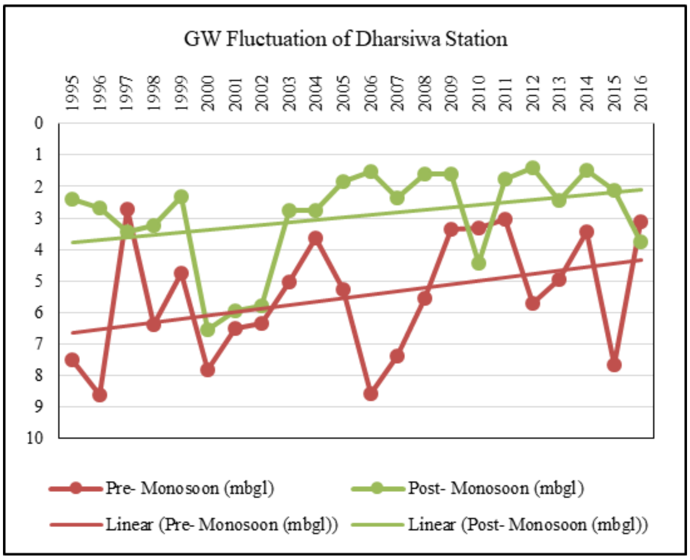

Fig 6(b): GW fluctuation of Dharsiwa stations

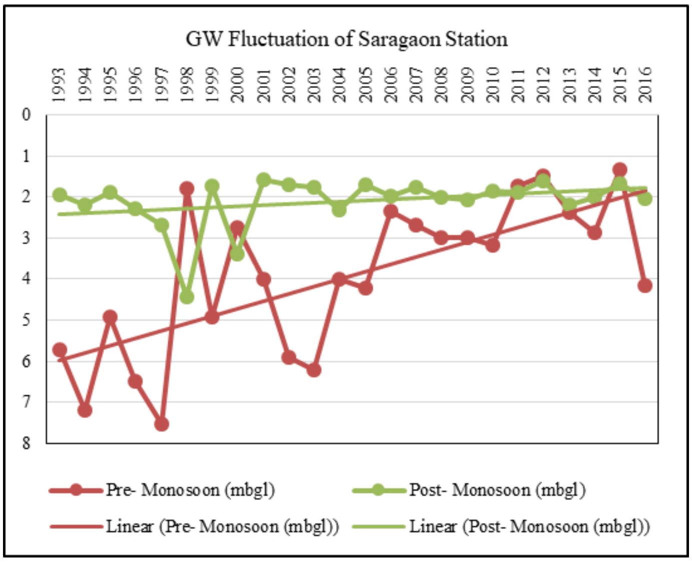

Fig 6(c): GW fluctuation of Saragaon stations

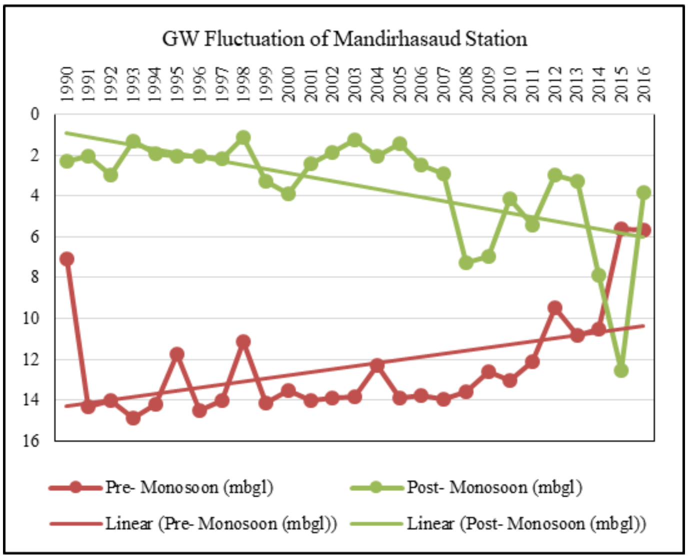

Fig 6(d): GW fluctuation of Mandirhasaud stations

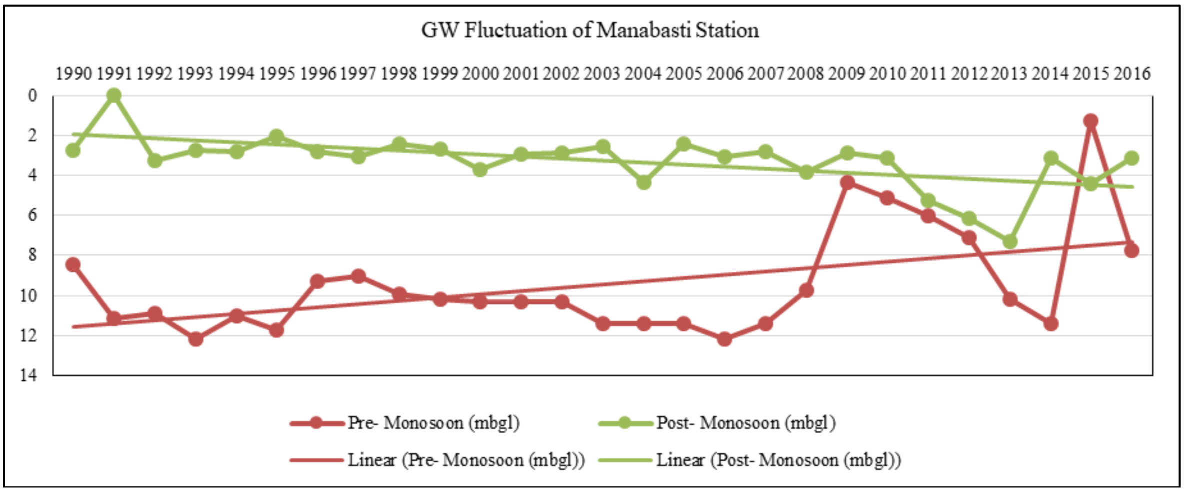

Fig 6(e): GW fluctuation of Manabasti stations

Assessment of groundwater availability using long term groundwater fluctuation data

Net groundwater availability

The net available ground water in the study watershed was found to be 0.4842 Bm^3.

Table 1: Net groundwater availability in Kharun watershed.

Basin Area (km^2)	Avg. Fluctuation (m)	Specific Yield	Groundwater reserve (BCM)	Net groundwater availability (BCM)
4118	4.36	0.03	0.5380	0.4842

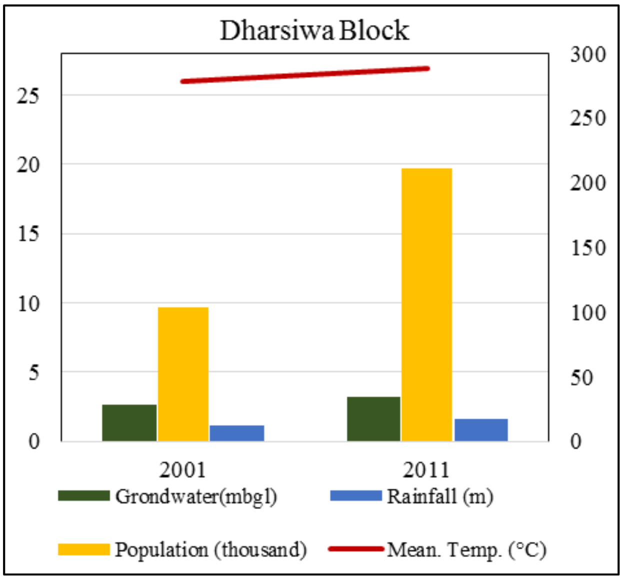

Fig 7: Comparison of rainfall and mean temperature with groundwater level and population of Dharsiwa Block

Trend analysis

Rainfall and temperature with groundwater and census

Blocks of Kharun watershed was considered and results are compared and discussed in this section. Due to the increasing population demand and use of all resources was increased. Comparison between yearly rainfall, temperature with groundwater and census data are shown in Fig. 7 for Dharsiwa block. Results of different block revealed that the temperature was increased by about 0.6 ^{0}C from 2001-2011. In case of rainfall there was also found a slight increasing trend from between 2001 to 2011. Census was increasing drastically and it affects all parameters directly and indirectly. Due to population increase households are increasing and capture more land which causes land use/cover change. The analysis of graphs also revealed that there were decrease in groundwater level and increase in depth of groundwater and increase in population may be one of the reason for declined trend of groundwater level. The results of trend analysis for the rainfall temperature, groundwater and census data are supports the results. Mann Kendall Trend test was used for the trend analysis. For each graph with different parameters trend test was applied. The test was applied at 5% significance level.

Conclusions

Results of data analysis revealed that there were increase in monthly, seasonal and yearly rainfall amount among all the years (1987 to 2016) however weekly amount of rainfall decreased for all the years. Weekly monthly, seasonal and yearly mean temperature were showed increasing trend for all years (1987 to 2016). Remarkable change in rainfall pattern and its distribution was observed.

Groundwater availability of Kharun watershed was found to be 0.4842 BCM whereas highest availability was 0.6641 BCM in the year 1992. Analysis of groundwater data showed that there were decreasing trend for both pre and post monsoon water levels i.e. depth of groundwater below ground level is decreasing but there is large difference between the depth of water level in last 10 years (2007-16). The groundwater fluctuation was also found to be in increasing trend. Census was increased drastically in all the blocks of study area. Increase in population may be the reason for declined trend of groundwater level.

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