Journal of Global Resources Volume 5 (01) January 2019 Page 83-89
ISSN: 2395-3160 (Print), 2455-2445 (Online)

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CLIMATE CHANGE: A TREND ANALYSIS OF WESTERN RAJASTHAN

Nidhi Kaushik
Department of Geography, University of Rajasthan, Jaipur (Rajasthan) India
Email: nidhikaushik07@yahoo.com

Abstract: *Being a state with varied climatic conditions, Rajasthan still needs lot of ground research to understand the climatic trends at local level. This inhibits the decision making and sustainable risk reduction strategies. The present paper intends to fill up some of the research gap. The paper shows the analysis of temporal variation in mean maximum and minimum temperature of the month of January and June and rainfall conditions with an assemblage of monthly data for a period of 40 years (1971-2010) in western Rajasthan. Regarding trends in temperature and rainfall the temperature series showed a rising trend while the rainfall does not show a clear trend but is clearly shows increase in extreme weather events which has clear implication on human life. The data used in trend analysis is assembled from Indian water portal and Indian Meteorology Department and Irrigation department of Rajasthan. This article also highlights the need of a network of baseline stations for climatic studies.*

Key words: Spatio-temporal trends, Climate change, Drought frequencies, Arid region

Introduction

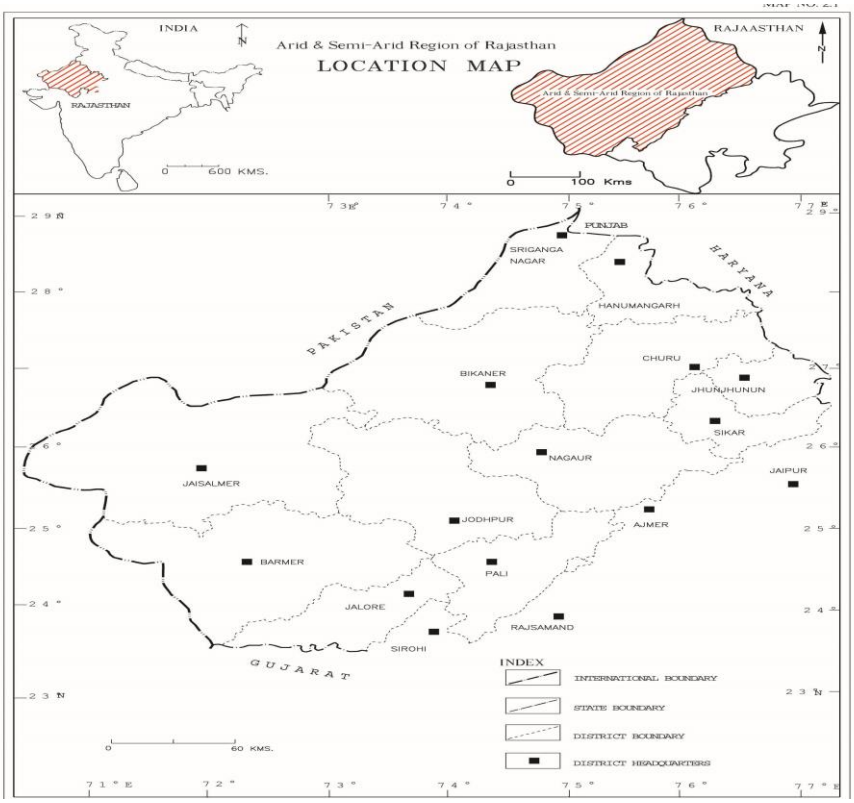
Since the beginning of industrial revolution human activities have led to unprecedented changes in the chemical composition of Earth's atmosphere. There is now credible evidence to show that such changes carry significant potential to influence earth's climate (Houghton et al., 2001). However, owing to complex interactions within the climate system it is difficult to differentiate the characteristics of climate change associated with natural and anthropogenic forcing. From a pre-industrial value of about 280 parts per million (ppm), the global atmospheric concentration of carbon dioxide (a greenhouse gas—GHG) has increased to 399 ppm in 2014. Similarly, concentrations of other potent GHGs like methane and nitrous oxide have also increased considerably on a global scale. According to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report of 2007, majority of the increase in the observed global average temperatures since the mid twentieth century is very likely linked to the observed increase in anthropogenic greenhouse gas concentrations. The report concludes that visible human influences have now extended to other aspects of climate including ocean warming, continental-average temperatures, temperature extremes and wind patterns. Projected scenarios also indicate rise in global mean temperatures in the range of 1.1 to 6.4^{o}C by 2100 (IPCC, 2007). The analysis from global instrumental records of over one and half century have revealed that the earth has warmed by 0.74 (0.56 to 0.92) ^{o} C during the last 100 years, with 12 out of the last 13 years being the warmest. According to IPCC Fourth Assessment Report, the rise in temperature by the end of the century with respect to 1980–1999 levels would range from 0.6^{o}C to 4.0^{o}C.

Study Area

The study area is located in the north-western part of India between 24°31′ to 30°12′ north latitudes and 69°15′ to 76°42′ east longitudes (Ma). Total geographical area 2,08,751 km^2. It is surrounded by Punjab in north, Gujarat in south, Pakistan in west and Aravalli in east. Its length

is 690 km from north to south and width is 300 km from east to west. The western arid region includes 12 districts i.e. Ganganagar, Hanumangarh, Churu, Sikar, Jhunjhunu, Nagaur, Bikaner, Jodhpur, Barmer, Jalor, Pali and Jaisalmer (Fig.1). The study area can be divided into two main physical regions viz. i) Arid Region and ii) Semi-Arid Region.

Figure 1: Key Map



Objective and Methodology

Climate change studies in Rajasthan have been very few thus inhibiting decision making and sustainable risk reduction strategies. This section intends to analyze and explore the findings from the trend study done for the variability in temperature and rainfall data of last 40 years (1971-2010) in the above said regions and also a compilation of so far studies done by various researchers in the same region. The work is based on the data obtained from the India Meteorology Department and Indian water portal. The main objective is to find out the pattern/trend of variation in temperature and rainfall in last four decades. The analysis was done for the months of June and January which reflects the peak summer and peak winters in the study regions. Graphs were prepared by plotting climate data of 12 meteorological stations situated at headquarter of each district to understand the general pattern using various aspects of the data. The temperature pattern is analyzed on the basis of its three forms i.e. mean annual temperature, maximum mean temperature, and minimum mean temperature.

RESULTS AND DISCUSSION

Average Temperature Variation:

In the Western Rajasthan during last 40 years (1971-2010) the annual mean temperature has shown significant change and it has risen by 2.4^{o}C for the month of June and 1.4^{o}C increase for the month of January. For better understanding 4 graphs (fig 2) consisting 3 districts in each

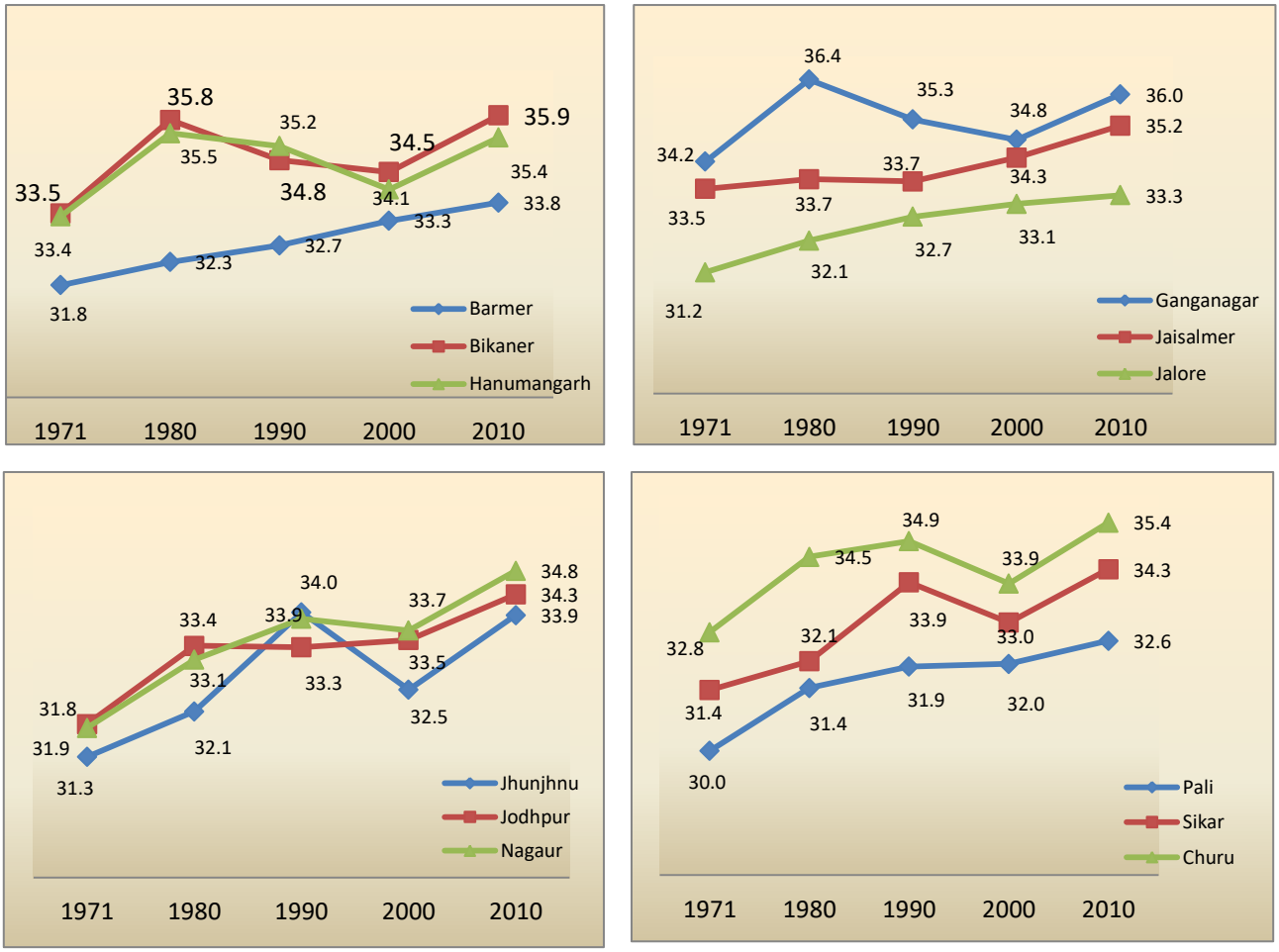


Figure 2: District Wise Average temperature (^{0}C) variation

graph is plotted for 12 districts to depict the scenario. Comparing the averages of periods 1971-1980 and 2000-2010 it has been observed that the temperature rose from average temperature of 32.2^o C in 1971 to 34.6^o C in 2010. Though the temperature seems to be constant in between 1990 to 2000 there is a significant increase of almost 1^{0}C in the 2001-2010 time periods. On the other hand, when the temperature variation for the month of January was analyzed, it was observed that maximum variation was in the decade of 1980-1990 (2.2^{0}C). Afterwards, the temperature for January month is constantly declining and in 2010 it was recorded 16^{0}C only.

Among the districts, maximum variation for the month of June was recorded for Nagaur and Sikar (3^{0}C and 2.9^{0}C) and lowest variation was observed for Jaisalmer and Ganganagar (1.7^{0}C and 1.8^{0}C) as depicted in figure 2. Similarly, figure 3 suggests that the variation for the month of January was highest in Jaisalmer and Barmer (2.4^{0}C and 2.1^{0}C) and lowest was witnessed in Pali and Nagaur (0.9^{0}C and 1.0^{0}C). Based on the available information we can say that the Average Temperature variation is relatively high in the month of June for almost all the districts of Arid Region as compared to the variation in the month of January. Also, we can say that the region witnessed a common trend of increasing temperature in the region for all the districts and for both winter and summer seasons. In the coming pages further analysis of Maximum Average Temperature and Minimum Average Temperature for June and January month will help us to in understanding the fluctuations/variations for the Arid Region.

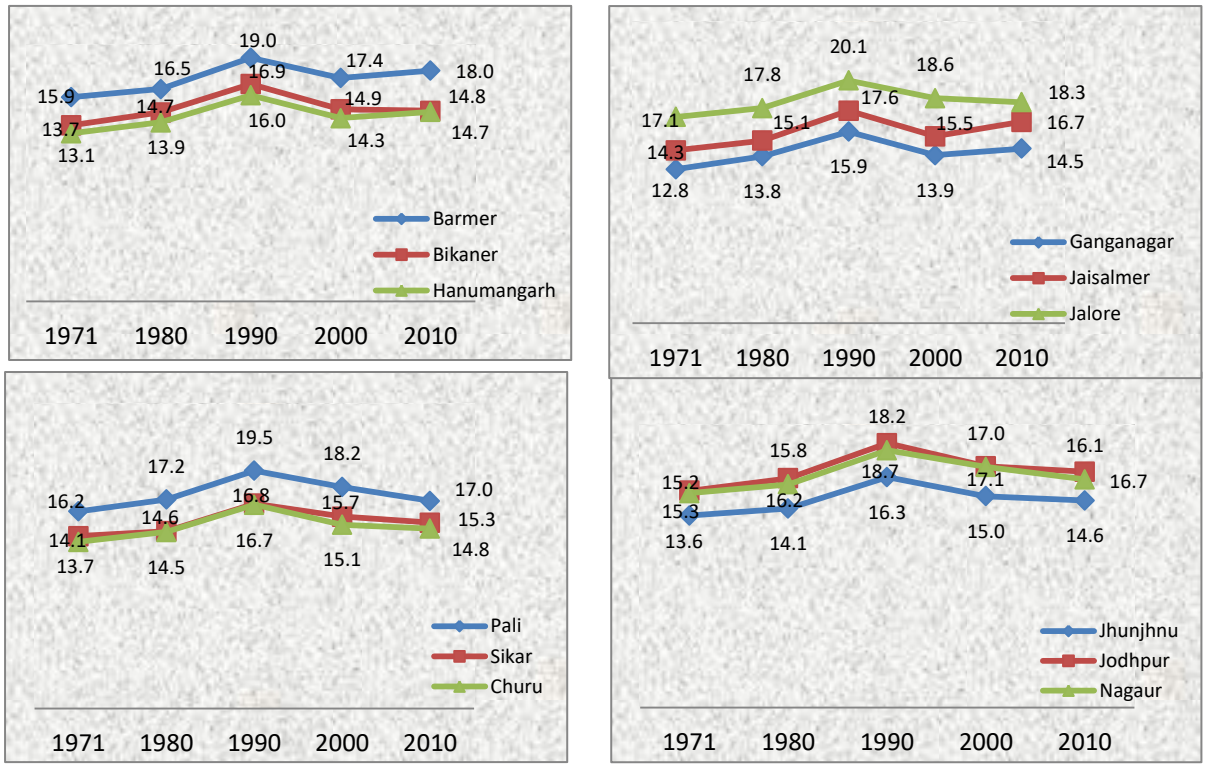


Figure 3: District Wise Average temperature (^{0}C) variation for January month

Maximum Average Temperature:

For Arid Region the Maximum Average Temperature was also analyzed for the month of June and January and for the same period of 1971-2010. The Data shows that Maximum Average Temperature has increased considerably for June and January in last four decades. The Maximum Average Temperature for June has increased from 38.6^{0}C in 1971 to 40.8^{0}C in 2010, an increase of 2.3^{0}C in the given period. Similarly, for the month of January the Maximum Average Temperature has risen from 23.5^{0}C in 1971 to 24.5^{0}C in 2010. A close look on district wise pattern suggests that the variation ranges from 2.9^{0}C to 1.6^{0}C with 8 districts out of 12 districts recorded an increase of more than 2^{0}C. Among all the districts Nagaur and Sikar had the highest increase of 2.9^{0}C in the years of 1971-2010, while the lowest Maximum Average Temperature was recorded for the month of June in Jaisalmer and Ganganagar (1.6^{0}C and 1.8^{0}C). This increase indicates towards the days with maximum temperature have increased and is responsible for the high evapotranspiration and will lead to the drier climate, depleted ground water level and decrease in soil moisture etc.

For the month of January as stated above the Maximum Average Temperature has increased by 1.0^{0}C during the period of 1971 to 2010 in the Arid Region comprises of twelve districts. In one of the interesting findings Ganganagar is the only district in the region in any of the months having recorded a decline in temperature. In the January of 1971 the temperature of Ganganagar was recorded 25.3^{0}C and only in 1980 it went up to 26.6^{0}C and afterwards there is either a decline or status-quo in the Maximum Average Temperature and in 2010 it was 24.7^{0}C, thus a -0.6^{0}C decline in the time span of four decades. Among the districts Jaisalmer and Barmer had a high variation of 2.2^{0}C and 2.0^{0}C in the given period while the temperature of Pali increased by only 0.7^{0}C. Though not much change was recorded in the January month for most of the district, where out of twelve districts six districts had a variation of less than 1.0^{0}C and one district had a negative growth of -0.6^{0}C.

The Minimum Mean Temperature

The Minimum Average Temperature of the study regions for the month of June and January for the same period of 1970-2010, is also depicted district wise and for Arid Region also. The both scenarios show an increasing trend in this section as well. The district wise map of June shows the increment by 3.0^0C to 1.8^0C in different district. The overall minimum temperature of the region is also showing an increased trend in the month of June and January. Comparison of 1971 and 2010 shows that the temperature of the month of June has rose from 25.9^0C to 28.3^0C. Among the districts Nagaur (3.0^0C) and Sikar (2.8^0C) recorded highest change in terms of variation recorded for June month, while Jaisalmer (1.9^0C), Ganganagar (1.8^0C) and Hanumangarh (1.8^0C) recorded the least. This means that not only the summers are being more hot but the winters are also being hotter, which will directly impact on the Rabi crop pattern and reduce the crop yield as the seed maturing time will change. For the month of January, the Minimum Average Temperature the temperature has increased by 1.6^0C from 1971 to 2010. In 1971 the temperature was recorded 6.0^0C and in 2010 the temperature was 7.6^0C, at the same time Jaisalmer witnessed highest change of 2.4^0C and Pali 1.0^0C was lowest with respect to the change of temperature in the month of January.

The overall temperature scenario is showing an increasing trend in the arid region of Rajasthan both in summers and winters as well. This variability in the temperature is responsible for many related sectors change such as increase in surface temperature will lead to lacking soil moisture, depleted ground water, increased no. of hotter days, change in crop pattern and its yield. The increased temperature will directly increase the evaporation rate of the surface and the hydrological cycle of the western districts will be changed. The temperature rise for January is more consistent and the fluctuations are not so abrupt as compared to June. This rise in temperature is mainly attributed to global rise in GHG concentration but along with that the local factor influencing the temperature rise is increased cloud cover during winter months.

Rainfall Variability

Analysis of rainfall pattern and its variability is crucial for this region. Thus, a detailed analysis of the average rainfall trends for 12 districts of the study area for period of 40 years (1971-2010) explains the variability of the average seasonal precipitation pattern.

District wise average annual rainfall variability

The district wise rainfall pattern is shown as each graph reflecting three districts, this is done for better visibility and understanding of the district. The study explored rainfall pattern of five years spreading over in 40 years or four decades, the unit of measurement was millimeter (mm) for every district. It suggests that except in year 2000 Churu witnessed consistently increased rainfall and it has almost doubled in all these years from 298 millimeter in 1971 to 635 millimeter in 2010. On the other hand in 1990 Barmer district received extraordinary rainfall of 748 millimeter as compared to 89 millimeters only in the year of 1980. Though in Bikaner the trend was quite fluctuating in nature and rainfall has increased to 409 millimeters from 241 millimeters in all these years.

There is a threefold increase in Ganganagar i.e. from 121 mm in 1971 to 366 in 2010 and similar trends were recorded in the adjacent district of Hanumangarh where rainfall has risen from 121 mm in 1971to 547 in 2010, a sharp increase of almost five times. While Jaisalmer received 108 mm in 1971, slightly increased by 143 mm in 1980, and dropped by 88 in 1990 and again rose by 149 and 309 in 2000 and 2010 respectively. The trend for this Arid region suggests that in the year 1990 most of the district's received more than average rainfall,

as also seen in the case of Jalore and Jodhpur where rainfall was 1047 and 815 millimeter in 1990 as compared 173 and 269 millimeter in 1980 and 311 and 273 millimeters only in the year 2000. Though the rainfall for all the three districts has seen considerable increase as it has increased from 368, 535 and 269 millimeter in 1971 to 535, 828 and 511 millimeter in 2010 for Jalore, Jhunjhunu and Jodhpur respectively.

In Nagaur district 467 mm rainfall received in 1971, which goes down to 228 mm and again rose by 461 in 1990, and received 431 mm in 2010. While Pali in 1971 surprisingly did not received any rainfall in the whole year, and suddenly rose up by 1022 mm in 1990 and 465 mm in 2010. In Sikar district 575 mm rainfall received in 1971, which dropped by 198 mm in 2000 and again rose by 896 mm in 2010.The analysis suggests that the rainfall pattern in the arid region received extraordinary rainfall in the year of 1990 across all the twelve districts, but at the same time average rainfall for all the district has doubled in the past four decades.

A preliminary glance on the data suggests that the average annual rainfall in the region has increased but when analyzed closely we can say that the in-spite of the increased rainfall the distribution is not evenly spread because of many reasons. Western Rajasthan is likely to face increased extreme events and the analysis also showed a delayed onset of monsoon resulting in increase in post monsoon rainfall. In one of the studies, Dr. Roy analyzed the rainfall variability over arid Rajasthan and found that the pre-monsoon rainfall ranges between 2-9 mm, the districts of Hanumangarh, Churu, Ganganagar, Jhunjhunu and Sikar received the highest rainfall during the season. The cumulative variation varies from 62 percent to 125 percent, which illustrates that the temporal variability of rainfall is very high during this season. The variability is highest towards the districts of Jalore, Sirohi, Barmer, Jaisalmer, Jodhpur, Udaipur, Dungarpur and Banswara while it declines towards north, north eastern and eastern districts. To the west of the Aravalli ranges in the rain shadow districts of Bikaner, Barmer, Jaisalmer, Jodhpur and Nagaur the rainfall ranges within 60-40 mm. As the rainfall amount spatially decreases the temporal variability and unpredictability of rainfall amount increases. The cumulative variation in the western side of the Aravalli Mountains is a little above 20 percent but it increases to around 52 percent in the desert districts further west. At the same time the post monsoon season receives an average rainfall ranging between 2 mm to 30 mm. The IPCC also reported increases in precipitation at a global level, however, in the present study, precipitation was found to increase in some urban centers and decrease in other centers. This may be due to changing land use/land cover, and several other anthropogenic activities at a local scale (Gowda et al., 2008).

Conclusion

The climate over Western Rajasthan is showing definite signs of change with uneven and fluctuating rainfall pattern and increase in temperature and aridity. The arid climate belt has shifted eastward intensifying the process of land degradation and causing desertification. The water resources are scarce, adding to vulnerability of region towards climate change. The overall temperature scenario in the arid region is showing an increasing trend both in summers and winters as well. This variability in the temperature is responsible for many related sectors change such as increase in surface temperature will lead to lacking soil moisture, depleted ground water, increased no. of hotter days, change in crop pattern and its yield. The increased temperature will directly increase the evaporation rate of the surface and the hydrological cycle of the western districts will be changed. The temperature rise for January is more consistent and the fluctuations are not so abrupt as compared to June. This rise in temperature is mainly attributed to global rise in GHG concentration but along with that the local factor influencing the temperature rise is increased cloud cover during winter months. Though the average annual

rainfall is not showing any significant trend over the region and are erratic but overall scenario and various climate model studies showing a decreasing trend over the region. The high variability in onset of monsoon rains have resulted in rising rainfall trends in most of the districts in the non-monsoon period.

Acknowledgement

The author is extremely thankful to Prof. (Retd) R.N. Mishra, Dept. of Geography, University of Rajasthan for his guidance and valuable remarks throughout the research work. I would also like to show my gratitude towards the eminent researchers whose work helped me to understand the various aspects of the issue.

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