IJASRM International Journal of Advanced Scientific Research and Management, Volume 4 Issue 4, April 2019
www.ijasrm.com
ISSN 2455-6378

Impact of Climate Change on the Water Resources of North-Western Himalayas Region and Adjoining Punjab Plains

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Abstract

North Western Himalayan (NWH) Region has witnessed the pronounced impact of climatic variability during the course of 20th century. In this region and beyond over the past century both mean maximum and mean minimum temperature has considerably increased and precipitation has witnessed a significant decline. Present study reveals that discharge of the major rivers in the region, namely Ravi, Beas, Chenab and Sutlej have registered a study declining trend from (1960-2001) which has a negative impact on the irrigation facilities for agricultural operations in this fertile region of the country. Water table in Punjab and adjoining areas has gone down considerably. During the study it has been observed that in the year 1973 only 3.7% of the area of Punjab, water table was more than 10m deep. Under the influence of various climatic and agronomic factors in the area, water table has witnessed considerable recession across the region which is confirmed by the ground water data which indicates that in around 94% of the area of Punjab water table has sank below 10 metres by the year 2010. The multi-faceted impacts of climatic variability have been observed in the agricultural productivity which is either showing signs of stagnation or marginal decline across the region. Extensive land-use changes and shifts in cropping pattern in the last fifty years are putting extra pressure on water resources in this region. Moreover the frequency and intensity of extreme weather events such as floods, droughts and other hydro-meteorological hazards has increased; thereby putting life, property and long-term developments goals in the region at risk.

Keywords: *Fragile ecosystem, climatic variability, agricultural productivity, marginal decline, hydro-meteorological hazards.*

1. Introduction

North Western Himalaya (NWH) stretches between 72°–80°E longitude and 30°–37°N latitude covering Jammu & Kashmir, Himachal Pradesh and parts of Uttarakhand, India. North western Himalayan region has been marked by pronounced climatic variability in the 20th century. Generally a decrease in annual rainfall and increase in temperature has been registered in various parts of Jammu and Kashmir, Himachal Pradesh and Punjab. Volume of the major rivers has been affected and water table is receding across the region. Productivity of agriculture and horticulture has also got affected on account of climatic variability, which has been validated by various researches carried out at national and international level. The fragile landscapes of the Himalayan region are highly susceptible to natural hazards, leading to ongoing concern about current and future climate change impacts in the region (Cruz et al., 2007). Climate change concerns in the Himalayas are multifaceted encompassing floods, droughts, landslides, human health, biodiversity, agriculture livelihood, and food security (Barnett, Adam, and Lettenmaier, 2005).

A study carried out by (Kumar & Joshi. 2008) reveals that the mean annual temperature in the Alaknanda valley (western Himalaya) has increased by 0.15 ºC between 1960 and 2000. Satellite imagery suggests almost 67 % of the glaciers in the Himalaya have retreated. For example, in Nepal this process is as fast as 10 m/ year (Ageta & Kadota 1992). The average temperature of Kashmir valley has gone up by 1.05 ºC over the last two decades (Sinha, 2007).

Impact of changing climate is also perceptible on vegetation. In some parts of the high altitude, the biodiversity is being lost or endangered because of land degradation and the over use of resources; in 1995, about 10 % of the known species in the Himalaya were listed as `threatened' (IPCC, 2002). However, impact of Climate Change on biodiversity and vegetation in the region is yet to be carefully studied to establish such a relationship.

Climate change can influence the socio-economic setting in the Himalaya in a number of ways. It can influence the economy (e.g. agriculture, livestock, forestry, tourism, fishery, etc.) as well as

ISSN 2455-6378

human health. Specific knowledge and data on human wellbeing in the Himalaya is limited, but it is clear that the effects of Climate Change will be felt by people in their livelihoods, health, and natural resource security (Sharma et al., 2009). The consequences of bio-diversity loss from Climate change are likely to be the worst for the poor and marginalized people who depend almost exclusively on natural resources. Poverty, poor infrastructure (roads, electricity, water supply, education and health care services, communication, and irrigation), reliance on subsistence farming and forest products for livelihoods, sub-standard health indicators (high infant mortality rate and low life expectancy), and other indicators of development make the Himalaya more vulnerable to Climate change as the capacity to adapt is inadequate among the inhabitants.

Some of the documented impacts on mountain agriculture that are linked with Climate Change in the Himalayan region are: (i) Reduced availability of water for irrigation; (ii) Extreme drought events and shifts in the rainfall regime resulting into failure of crop germination and fruit set; (iii) Invasion of weeds in the croplands and those are regularly weeded out by the farmers; (iv) Increased frequency of insect-pest attacks; (v) Decline in crop yield (Negi & Palni, 2010).

Dash et al., (2007) reported that the western Indian Himalayas saw a 0.9°C rise over 102 years (1901-2003). They report that much of this observed trend is related to increases after 1972. Using winter (Dec-Feb) monthly temperature data from 1975-2006, Dimri and Dash (2011) also found a warming trend over the western Indian Himalayas, (1.1-2.5°C) with the greatest observed increase

Bhutiyani, Kale, and Pawar, (2007) in their study over the Northwest Indian Himalayan region, found 1.6°C warming (0.16°C /decade) in the last century. Singh et al., (2008) observed increasing trends in mean maximum temperature and seasonal average of daily maximum temperature for all seasons except Monsoon over the lower Indus basin in the Northwest Indian Himalaya.

In a recent study, Bhutiyani et al., (2010) observe a statistically significant downward trend (at 5% significance level) in Monsoon and average annual rainfall in the Northwest Indian Himalaya during 1866-2006. A similar trend was noted for 1960-2006 over the western Indian Himalaya region (Sontakke et al., 2009) but without any mention of statistical significance. The literature shows intra-regional differences in winter rainfall trends over Western Indian Himalaya. Dimri and Dash (2011) noted, significantly decreasing winter precipitation (Dec-Feb) in the region for 1975-2006 amid lack of spatially coherent phases among stations.

In a study carried by Shafi M. et al., (2015) in the Kashmir valley of North Western Himalaya, it was observed that core-winter temperature has registered a robust increase during the second half of twentieth century, while as winter precipitation has reduced significantly.

Several studies involving field based observations and satellite imagery have shown that a majority of Himalayan glaciers are retreating. A notable exception is the Karakorum region where some glaciers have shown advancement (Hewitt, 2005). Important climatic conditions that make Karakoram glaciers different from the rest of the Himalayas include, orographic conditions that enhance precipitation in the source area, an all-year accumulation regime, concentration and role of avalanche, and ablation buffering due to thick debris cover (Hewitt, 2011).

Precipitation analysis on all India level reveals that long term weighted average mean annual precipitation in India during 1901-2010 has been 1180mm. Trend analysis reveals that there is a marginal increase of 3 mm in the mean annual rainfall during the study period. However, the analysis of south-west Monsoon confirms the prevalence of slight declining trend with an overall decline of 17mm of rainfall during the period from 1901-2010 on all India level. The regional analysis of the south-west Monsoon indicates that rainfall has declined by 60 mm on annual basis in North-Western Region and 53 mm in North-Eastern Region (IMD Pune 2012).

Materials and Methods

The present study is based on secondary sources of data which have been obtained from (IMD) Indian meteorological Department Pune, Indus Treaty Commissioner-New Delhi, Himachal Pradesh Electricity Board (HPSEB); Bakhra Beas Management Board and Punjab Statistical Abstract. To draw the inferences and conclusions, regression analysis and Mann-Kendall Test and Time Series Analysis have been used to identify trends in the influential climatic variables and flow pattern of the major rivers in the region.

Results and Discussion

North western Himalayan region has been marked by pronounced climatic variability in the 20th century. Generally a decrease in annual rainfall and increase in temperature has been registered in various parts of Himachal Pradesh, Uttarakhand and Jammu & Kashmir. The analysis of temperature data reveals that entire north-western Himalayas has experienced severe warming trend during the course of 20th century. The temperature data of Dehradun Shimla and Srinagar clearly indicates a robust warming across the region. Mann-kendall test confirms the prevalence of a statistically significant warming trend in the mean maximum temperature with 95% confidence level in the entire north western Himalayan region. It also confirms a statistically significant warming trend in annual mean maximum temperature at Dehradun, Shimla and Srinagar. Simultaneously mean maximum winter temperature in all the three station has shown an abnormal increase during the course of 20th century. The findings of this study are in conformity with the studies carried out by (Ageta & Kadota 1992) which reveal that Satellite imagery suggests almost 67 % of the glaciers in the

Himalaya have retreated. For example, in Nepal this process is as fast as 10 m/ year. The average temperature of Kashmir valley has gone up by 1.05 ºC over the last two decades (Sinha, 2007). The abnormal increase in temperature has induced glacial recession in the Himalayas which in turn has negatively affected the discharge regimes of the major rivers of north western Himalayan Region which is evident from (table 1.1).

Table-1.1:Observed Increase and Trends in Air Temperature in (NWH)

Observatory / Station	Period	Annual Max (oC)	Mean Max Winter(oC)	Mann-Kendal Test
Northwest Himalayas	(1901 - 2010)	1.5	1.7	(+)*
Shimla HP	(1901 - 2010)	1.7	2.6	(+)*
Dehradun Uttarakahand	(1901 - 2010)	0.8	1.5	(+)*
Srinagar J&K	(1901 - 2010)	0.6	1.1	(+)*

(=95%confidencelevel)*

Analysis of precipitation data also reveals that entire North-Western Himalaya has witnessed a drastic decline during 20th century with the exception of Jammu and Kashmir. However in J&K despite a marginal increase in the mean annual rainfall, winter precipitation has registered a declining trend. Man-Kendall Test and linear regression analysis confirms a decreasing trend in annual precipitation across North-western Himalayas, Shimla and Dehradun with a confidence level of 95%. However Srinagar shows a slight increasing trend without any statistical significance. Winter precipitation across the region shows a robust and statistically significant declining trend which is evident from (table 1.2). This abnormal increase in temperature and decrease in precipitation has adversely affected the flow of major rivers in the region, which has got long- term socio-economic and ecological implications in the adjoining Punjab Plains which depend on the water resources originating from North-western Himalayas.

Table-1.2: Trend Analysis of Annual & Winter Monsoon Precipitation

Observatory/ Station	Data/Period	Trend Analysis	
		Mann-Kendall's	Linear Regression
Annual Precipitation North West Himalaya	1866-2010	(-)*	(-)*
Winter Precipitation North-West Himalaya	1866-2010	(-)*	(-)*
Annual Precipitation Shimla HP	1866-2010	(-)*	(-)*
Winter Precipitation Shimla HP	1866-2010	(-)*	(-)*
Annual precipitation Srinagar J&K	1901-2010	(+)	(+)
Winter Precipitation Srinagar J&K	1901-2010	(-)*	(-)*
Annual precipitation Dehradun Uttarakhand	1901-2010	(-)*	(-)*

(+)Increasing,(-)Decreasing trend

(=95%confidencelevel)*

To analyze the impact of climatic variability on the flow of measure Rivers in the North- Western Himalayas seasonal and annual trends have been worked out. The results of trend analyses of discharge in the winter, spring and monsoon seasons along with average annual discharge from (1961–2004) are depicted in figure (1.1). The data indicates that in the last four decades, monsoon discharge in the Beas River has shown a statistically significant decrease. Moreover statistically insignificant variation in discharge is observed in other basins during all the three seasons, indicating episodic fluctuations. These may have been caused because of the variations in the precipitation and temperature.

Furthermore long-term analysis of discharge data (1922–2004) of Sutlej River shows a slightly increasing but statistically insignificant trend in the discharge during winter and spring months, despite rising temperatures. It is also interesting to note a statistically significant decreasing trend in discharge during monsoon months in the Sutlej River.

By and large it has been observed that that there is a steady decline in the discharge of rivers in Punjab which is evident from table (1.3). Moreover Mann Kendall test and linear regression confirms a statistically significant declining trend in the annual discharge of Beas River. The decline in the flow of rivers may be attributed to the rising temperature, glacial recession and significant decline in precipitation in the NWH region.

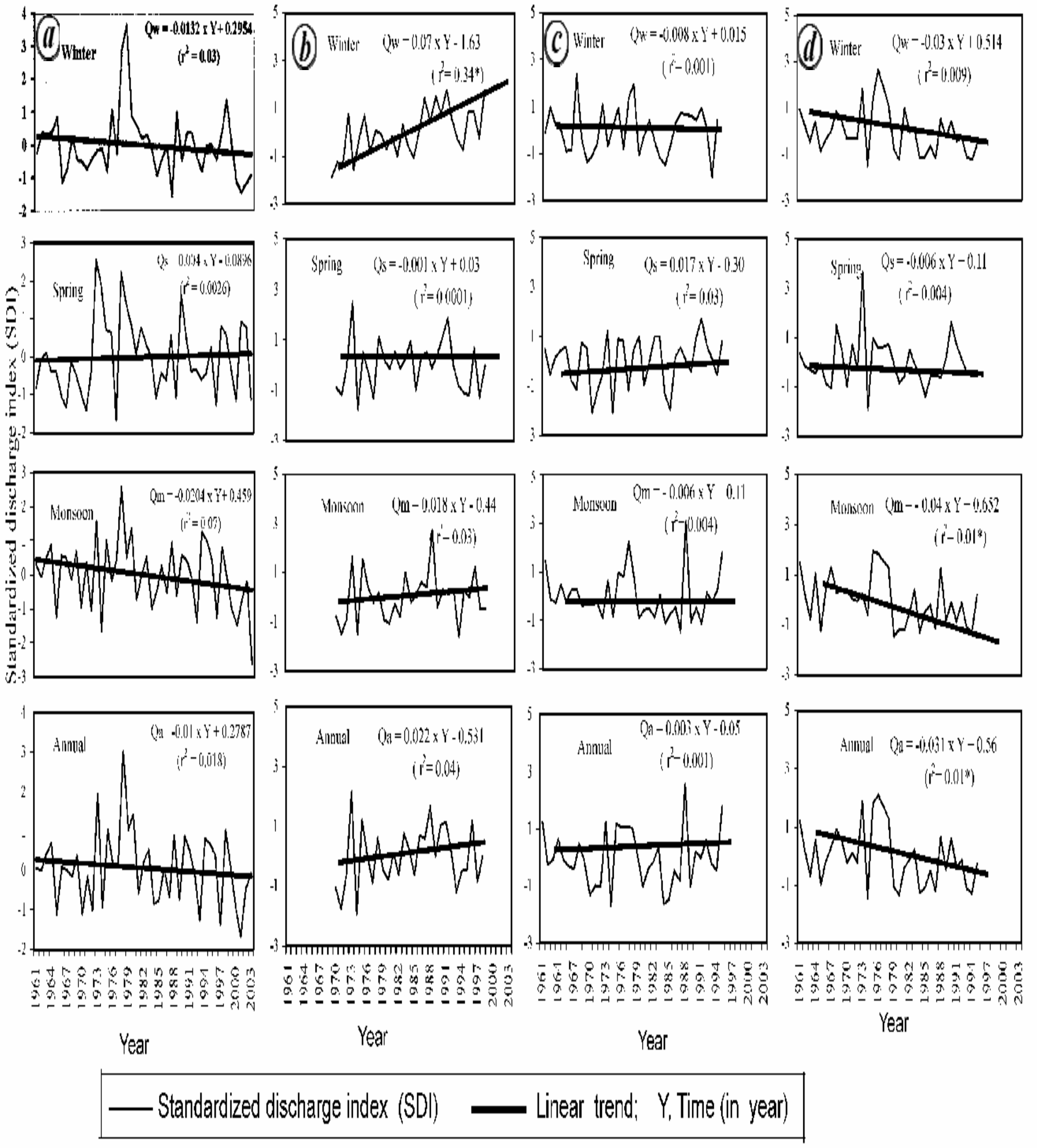

Figure 1.1 Temporal variation and linear trends in average discharge in winter (*Qw*), spring (*Qs*), monsoon (*Qm*) and annual (*Qa*) in the rivers of the NWH.*a*,Satluj(1961–2004);*b*,Chenab(1970–98);*c*,Ravi(1961–95)and*d*,Beas(1961–95).*Significantat95%confidencelevel.

Table 1.3: Results of trend analyses of discharge in the Northwestern Himalayan Rivers

Station/site	Period	Season	Mann-Kendall test	Linear Regression
Beas/Thalot	1961-2000	Spring	(-)	(-)
		Monsoon	(-)*	(-)*
		Winter	(-)	(-)
		Average	(-)*	(-)*
Ravi/Madhopur	1962-2000	Spring	(+)	(+)
		Monsoon	(-)	(-)
		Winter	(-)	(-)
		Average	(+)	(+)
Satluj/Barra	1962-2000	Spring	(+)	(+)
		Monsoon	(-)	(-)
		Winter	(-)	(-)
		Average	(-)	(-)

*Significant at 95% confidence level. (+), Increasing; (–), Decreasing Trend

The effect of climatic variability (reduced rainfall, increased temperature, glacial recession, and reduced flow of the major rivers) has led to the over-exploitation of Ground Water Resources in Punjab plains. Over-exploitation of ground water resources can also be attributed to the increase in Gross Cropped Area under water intensive crops. Table (1.4) shows the water table depth in central Punjab over time and highlights that the share of area in which the water table is greater than 10 meters rose from just 3% in 1973 to almost 94% in 2010. The exploitation of groundwater resources has gone up to such an extent that water demand (more than 39.75 MAF) has exceeded the ground water availability (29.64 MAF). Compounding this has been a reduction in state rainfall by nearly 25 percent from 1980 to year 2000.

Table 1.4: Area under critical water-table depth(% wise) in Central Punjab, 1973 to 2004

Year	% area >10m	%area >15 m	%area > 20 m
1973	3.7	0.56	0.39
1980	5.7	0.57	0.38
1990	26.7	2.95	0.38
2000	53.2	14.11	0.12
2001	65.7	21.73	1.22
2002	72.7	26.15	4.26
2003	79.9	32.73	5.73
2004	84.6	36.57	12.47
2010	94.0	48.0	21.0

Source: Punjab Statistical Abstract, Various Years

Therefore the implications of climate change in the form of increasing temperature, declining rainfall, receding ground water table, and reduced flow of the major rivers in the north-western Himalayas has got far-reaching socio-economic and ecological ramifications for the region and beyond . It has got the potential to threaten the food security of the country as most of the buffer stock of major food grain come from Punjab Plains and adjoining areas which are heavily dependent of the water resources of North western Himalaya. Therefore to combat the negative effects of climate change on agriculture and livelihoods in the region proper adaptation and mitigation strategies should be implemented in the field of water conservation, efficient irrigation, and promotion of drought resilient agriculture.

Conclusion

The present study acknowledges the prevalence of significant warming trend across North Western Himalayan region. There is significant increase in mean maximum and mean minimum temperatures especially in the mountainous belt. Winter temperatures are steeply rising across the region. Along with the increase in average temperature annual rainfall and snowfall has witnessed a significant decline in Himachal Pradesh, and Uttarakhand which is reflected in the steady decline in the discharge of most of rivers in the region. The water table in Punjab has significantly receded during the last forty years. Mean maximum and mean minimum temperature in Jammu and Kashmir is also sharply rising thereby enhancing glacial recession. Although precipitation has shown a marginal increase in Jammu and Kashmir; winter precipitation is declining at an alarming rate.

The implications of climatic variability are felt across the region. Productivity of Rabi crops is stagnating or marginally declining in Punjab. On account of declining water table and erratic rainfall cost of production has gone up in the region. Rising winter temperature, which reduces the required chilling hours during December and January has adversely affected the productivity of horticulture in Himachal Pradesh. Therefore proper adaptation and mitigation strategies should be put in place to combat the fallout of climate change in North Western Himalaya. It includes conservation of water resources through innovative methods of irrigation (drip and sprinkle irrigation) and discouraging the expansion of water intensive crops like paddy and sugarcane which are responsible for the depletion of water table in Punjab. Furthermore fruit verities which are resistant to moisture and temperature stress should be promoted.

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