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Analysis of Spatial Pattern of Streamflow Trends in the Chenab Basin Over 40 Years

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Abstract: Hydrologic regime of any river basin system is governed by various basin characteristics and meteorological variables mainly precipitation. The spatial and temporal changes in the patterns of precipitation and streamflow have direct and indirect impacts on water resources. Inception of global warming due to rising emissions of green house gases (GHGs) has resulted to the phenomenon known as climate change, subsequently, altering the spatial and temporal pattern of precipitation and river flows. In the view of changing climate, increased water scarcity and frequent occurrence of extreme hydrologic events, it is very important to analyze long-term spatial pattern of streamflow trends. The present study aims to determine trends in annual and seasonal streamflow patterns of the Chenab basin of Western Himalayan region. To understand and track these trends of streamflow over a long time span (1967-2007) in the Chenab basin, nine discharge gauging stations, namely Akhnoor, Dhamkund, Premnagar, Benzwar, Sirshi, Udaipur, Miyar Nallah, Ghousal and Tandi were analyzed. Discharge data analysis for three distinct seasons namely, Spring (March to May), Monsoon (June to October) and Winter (November to February) and annual series were performed to get the insight of pattern of changes. Linear trend analysis and Mann-Kendall non-parametric tests were employed for detection of trends and the magnitudes of the trends were determined using Sen's Slope estimator test in this study.

The study showed for the study period that there was a significantly increasing streamflow trends in Winter season (8 out of 9 stations with 95% significance level), Spring season (6 out of 9 stations with 95% significance level) and Monsoon season (4 out of 9 stations with 95% significance level). In case of annual time series, 3 out of 9 stations having positive trend with 95% significance level. As a whole, Chenab basin was showing an increasing trend of streamflows with a magnitude of 1.24 cumec / annum for the period of 1967-2007. The Chenab river has a large number of glaciers in its basin, which have played a regularity role in contributing its discharge. As the smaller glaciers recedes at relatively faster rate than the larger ones, this may ultimately lead to their desertion in the near future and increased river discharge.

Key Words: Streamflow, Trend Analysis, Chenab Basin, Mann-Kendall Test

1. Introduction:

Growing global demand of water due to increasing population, urbanization and industrialization have put on the water resources under tremendous pressure. Assessment of water availability in river basins at present and in future has become the prime priority for sustaining life. For this it's important to understand the behavior of the hydrologic regime of river which mainly governs by the precipitation and streamflow. Excessive emission of GHGs has raised the rate of green house effect resulted into global warming. Changing climate due to rising GHGs concentration and subsequently global warming is altering the spatial and temporal pattern of

streamflows. Various studies from different parts of the world including Himalaya in the past has resulted in establishing the discharge as possible indicator of climate change [1, 2, 3, 4, 5, 6, 7, 8, 9]. However, no detailed study on streamflow trends for the Chenab basin has been reported in the literature. The present study is undertaken with the objective to determine the trends of streamflow over a long time span (1967-2007) in the Chenab basin on seasonal and annual time scale using Linear Trend Analysis, Mann-Kendall Test and Sen's slope estimator Test.

2. Materials and Methods:

2.1 Study Area

The Chenab River or Asikin, as it was known in Vedic times, is formed by two important tributaries, the Chandra and the Bhaga, which join near Keylong in Himachal Pradesh to form Chandra-Bhaga or the Chenab River in Himachal Pradesh. The tributaries Chandra and Bhaga originate at about 5412 m and 4891 m from the north and south faces of Baralacha pass respectively in Lahaul Spiti Valley. The Chenab River is one of the most important tributaries of the great Indus River System. River Chenab is a trans-boundary river with the major part of upper catchment lying in India; its lower reach including the confluence with the Indus River is in Pakistan. In India, the Chenab basin is located in the Western Himalayas between latitudes 30° to 34° N and longitudes 74° to 78° E. The Chenab basin in India is spread over the two states, Himachal Pradesh and Jammu and Kashmir. Headwater catchment lies in Lahaul and Spiti area. The last discharge monitoring station in Indian border is Akhnoor. The total catchment area of the basin up to Akhnoor is about 22,770 km² and Chenab travels around 486 km of length from its origin to Akhnoor. On an average, about 70% of the total drainage area is covered by snow in the month of March/April and about 25% remains under permanent snow cover [10]. Chenab is a glacierized basin particularly south-eastern part of the basin is heavily covered with glaciers and permanent snow. Usually there are three components of discharge in a glacierized basin; snow-melt run-off, glacier melt and run-off due to monsoon rainfall [1]. The Chenab valley is a structural trough formed by the Great Himalayan and Pir Panjal ranges. The elevation of Chenab basin upto Akhnoor ranges from 300m to 7000m asl. The location of Chenab basin in India and the map of Chenab basin are shown in Fig 1.

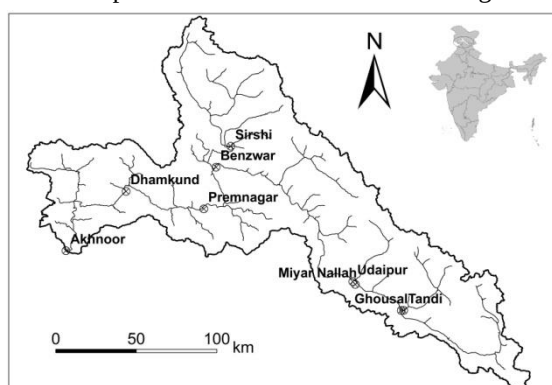


Fig 1: Discharge gauging stations in Chenab basin

2.2 Data

Central Water Commission (CWC) has initiated the gauging of streamflows in view of exploring the opportunities of potential hydro-power projects in the basin long back in 1960s. Chenab basin is one of

the best monitored basins in the Western Himalayan region with 24 precipitation and 9 discharge gauging stations of Central Water Commission (CWC) distributed in various altitudinal parts of the basin. The daily streamflow data for the years 1967-2007 has been acquired from CWC to carry out the study. Locations of these stations are shown in Fig 1.

3. Methodology

Daily time series of streamflow data was first converted in to discharge flux and aggregated into seasonal and annual time series then these discharge flux were standardized arithmetically in order to bring uniformity and facilitate comparison between the hydrological responses of these stations. Based on the yearly, daily discharge values from 1967-2007 of nine discharge stations the following can be identified to estimate the contributions by various components [2]:

- (a) Winter discharge (largely base flow from sub-glacial melting and groundwater storage): November– February.
- (b) Spring discharge (base flow + seasonal snow-melt): March–May.
- (c) Monsoon discharge (base flow + monsoon rainfall + glacier melt): June–October.

Seasonal as well as annual Standardized Discharge Index (SDI) series were computed by subtracting the mean and dividing by the standard deviation of the streamflow data series [11, 12] for all the 9 gauging stations of the period of 1967 to 2007. The SDI data series were then tested for detection of trends by two established statistical techniques: standard parametric technique i.e. linear trend analysis [13] and non-parametric test i.e. Mann-Kendall test [14]. The magnitude of the trends in form of slope values at all 9 discharge gauging stations has also been determined with Sen's Slope estimator method [15].

4. Results and Discussion:

The results of linear trend analysis, Mann-Kendall test and Sen's Slope Estimator of SDI series of annual, Spring, Monsoon and Winter precipitation are presented in Table 1 to Table 3. The long term trends in SDI series were evaluated by using both standard parametric simple linear trend and non-parametric statistical technique i.e. the Mann-Kendall test. The plots between SDI verses the respective years of all 9 discharge gauging stations of Chenab are being presented in form of graphs in Fig 2 for annual series. The linear regression plots of SDI verses years are also depicted in the Figure 2. On analyzing the plots and tables it is evident that the winter time series supports the rising trends in river discharge as 8 out of 9 gauging stations are showing positive trend with 95% significance level.

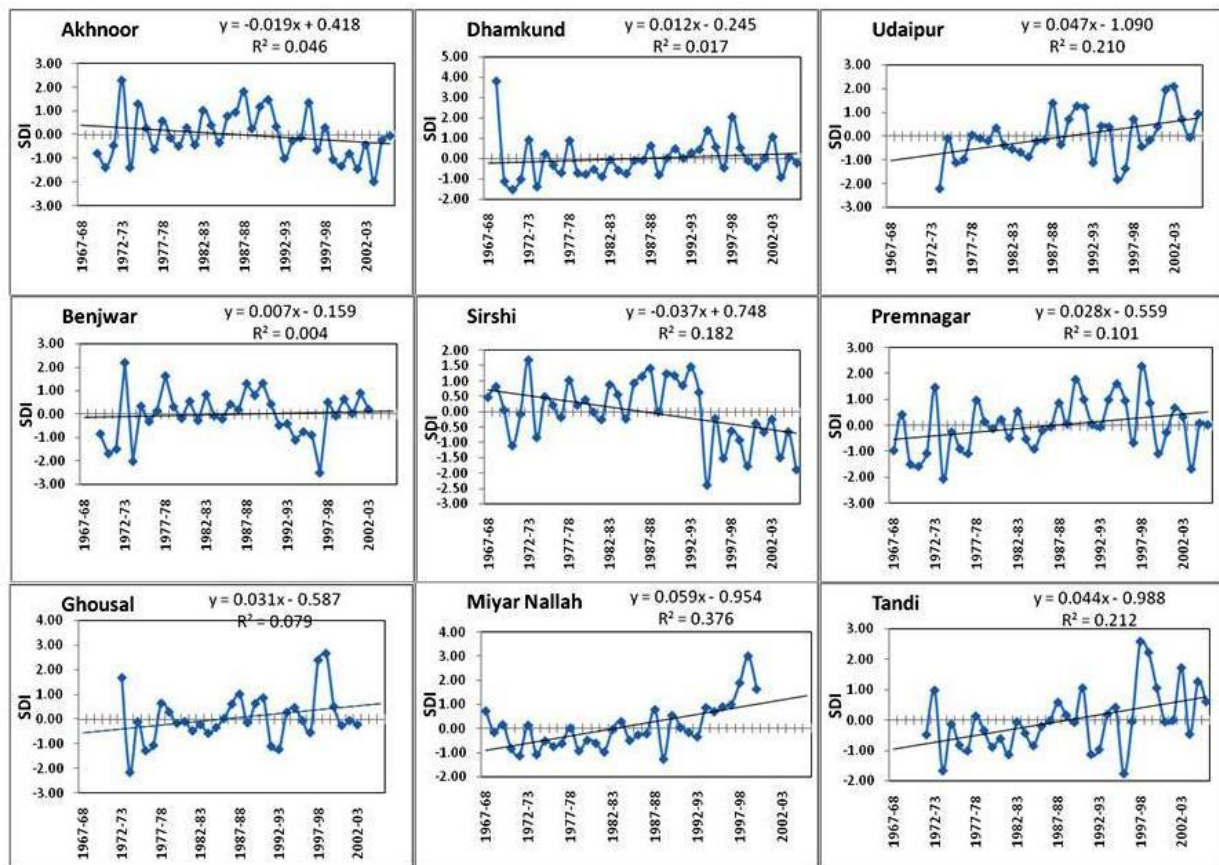


Fig 2: Annual Trends of Discharge Flux at different Gauging stations of Chenab Basin

The remaining two stations do not have any trend. Similarly, Spring season and Monsoon season also support the rise in the discharge at 6 and 4 numbers of gauging stations at 95% significance level. In case of annual time series, 3 out of 9 stations having positive trend with 95% significance level and other stations are not supporting any trend. The only one station namely Sirshi is showing declining trend in annual and Monsoon time series at 95% significance level.

Table 1: Results of SDI Linear trend analysis summary for annual, Spring, Monsoon and Winter seasons at various gauging stations in Chenab basin

Station	Elevation (m)	Season			
		Annual	Spring	Monsoon	Winter
Akhnoor	305	(-)	(-)	(-)	(+)
Dhamkund	600	(+)	(+)	(+)	(+)
Premnagar	896	(+)	(+)	(+)	(+)
Benzwar	1135	(+)	(+)	(-)	(+)
Sirshi	1675	(-)	(-)	(-)	(+)
Udaipur	2584	(+)	(+)	(+)	(+)
Miyar Nallah	2700	(+)	(+)	(+)	(+)
Ghousal	2850	(+)	(+)	(+)	(+)
Tandi	2850	(+)	(+)	(+)	(+)

(+) Rising Trend; (-) Falling Trend

Table 2: Summary of Results of Mann-Kendall Test for annual, Spring, Monsoon and Winter seasons discharge at various gauging stations in Chenab basin

Station	Elevation (m)	Z Value			
		Annual	Spring	Monsoon	Winter
Akhnoor	310	-1.36	-0.18	-1.53	1.73*
Dhamkund	600	1.48	2.29*	1.94*	3.17**
Premnagar	896	1.34	2.85**	1.38	2.62**
Benzwar	1135	0.59	2.00*	-0.55	5.22**
Sirshi	1680	-2.62**	-1.04	-2.23*	0.03
Miyar Nallah	1710	3.52**	2.60**	2.96**	4.86**
Udaipur	2584	1.96*	1.87*	2.25*	3.29**
Ghousal	2850	1.12	0.31	0.51	4.86**
Tandi	2850	2.27*	1.73*	1.86*	3.72**

** 99% Confidence Level; *95% Confidence Level

Table 3 represents the magnitude of the trends determined by Sen's Slope Method. Considering the stations with trend at 95% significance the maximum increasing trend with a magnitude of 6.96 cumec / annum was observed at Dhamkund in Spring season time series and maximum declining trend in streamflow at Sirshi at the rate of 2.16 cumec/ annum in Monsoon series. The magnitude of rising trends in annual streamflow series varied between 0.05 cumec / annum (at Ghousal) to 8.52 cumec / annum (at Premnagar). It is difficult to say about the

overall response of Chenab basin as a whole, but the average of nine stations was showing an increasing trend of streamflows with a magnitude of 1.24 cumec / annum for the period of 1967-2007.

Table 3: Magnitude of the trends at various discharge gauging stations for Annual, Spring, Monsoon and Winter seasons of Chenab basin by Sen's slope estimator method

Station	Elevation (m)	Slope (Q) (Cumec / Annum)			
		Annual	Spring	Monsoon	Winter
Akhnoor	310	-3.82	-0.47	-5.71	1.05
Dhamkund	600	5.01	6.96	6.92	2.03
Premnagar	896	8.52	3.87	15.16	1.40
Benzwar	1135	0.35	1.79	-1.645	1.02
Sirshi	1680	-1.21	-0.26	-2.16	0.10
Miyar Nalah	1710	0.41	0.29	0.82	0.19
Udaipur	2584	1.46	1.29	2.95	0.88
Ghousal	2850	0.05	0.23	0.03	0.46
Tandi	2850	0.37	0.31	0.60	0.25

5. Conclusions:

The study indicates the most of the discharge gauging stations are experiencing the rising annual and seasonal streamflow trends over the last 40 years in Chenab basin. As, 7 out of 9 discharge gauging sites are supporting the increasing streamflow trend in basin on analysis of annual discharge flux data series. The monsoon trends are analogous to the annual trends for all the stations. There are 6 stations which are showing increasing trend in all the seasonal as well as annual basis viz. Dhanmund, Premnagar, Udaipur, Miyar Nallah, Ghousal, and Tandi. In these stations expect Dhamkund and Premnagar other four stations are located at higher altitude where snow-melt and glacier-melt is the major component of the stream flow and these are experiencing the increased discharge throughout the year. On the contra the outlet gauging station Akhnoor is showing no trend at 95% significance level. It is difficult to say about the overall hydrological response of Chenab basin as a whole. The hydrology of Chenab basin is very complex in nature as it is being governed by all three runoff components i.e. rainfall induced runoff, baseflow, snowmelt runoff and glacier melt runoff. However, large snow-capped mountainous areas and glaciated regions are not adequately represented by the present discharge monitoring network and may be forcing uncertainty of the basin response to the climate change. Therefore, it is highly recommended to study the trend of each component in detailed to known the basin response.

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References:

- [1] Singh, P. and Jain, S. K., Snow and glacier melt in the Satluj River at Bhakra Dam in the Himalayan Region, *Hydrol. Sci. J.*, 47, 93–106, 2002.
- [2] Bhutiyani, M. R., Kale V. S. and Pawar N. J., Changing streamflow patterns in the rivers of northwestern Himalaya: Implications of global warming in the 20th century, *Current Science*, 95 (5), 618-626, 2008.
- [3] Kuhnelt, I., McMohan, T. A., Finlayson, B. L., Haines, A., Whetton, P. H. and Gibson, T. T., Climatic influences on streamflow variability: A comparison between southeastern Australia and southern United States of America. *Water Resour. Res.*, 26, 2483–2496, 1990.
- [4] Burn, D. H. and Arnell, N. W., Synchronicity in global flood responses. *J. Hydrol.*, 44, 381–404, 2001.
- [5] Marengo, J. A., Variations and change in South American streamflow, *Climatic Change*, 31, 99–117, 1995.
- [6] Cigizoglu, H. K., Bayazit, M. and Önöz, B., Trends in the maximum, mean and low flows of Turkish rivers. *J. Hydrometeorol.*, 6, 281–290, 2005.
- [7] Mauget, S. A., Low frequency stream flow regimes over the Central United States: 1939–1998. *Climate Change*, 63, 121–141, 2004.
- [8] Pagano, T. and David, G., A recent increase in western US streamflow variability and persistence, *J. Hydrometeorol.*, 6, 173–179, 2005.
- [9] Kundzewicz, Z. W., Graczyk, D., Maurer, T., Piskwar, I., Radziejewski, M., Svensson, C. and Szwed, M., Trend detection in river flow series: 1. Annual maximum flow. *Hydrol. Sci. J.*, 50, 797–810, 2005.
- [10] Singh, P., Jain, S. K., and Kumar, N., Estimation of snow and glacier contribution to the Chenab River, Western Himalaya, *Mt. Res. Dev.*, 17(1), 49–55, 1997.
- [11] Shrestha AB, Wake CP, Dibb JE and Mayewski PA, Precipitation fluctuations in the Nepal Himalaya and its vicinity and relationship with some large-scale climatological parameters, *Int J Climatol.*, 20: 317-327, 2000.
- [12] Pant G B and Rupa Kumar K, Climates of South Asia: Behaviour Studies in Climatology, *John Wiley*, pp. 126-127, 1997.
- [13] Borgeonkar HP and Pant GB, Long-term climate variability over monsoon Asia as revealed by some proxy sources, *Mausam* 52: 9-22, 2001.
- [14] Kendall MG and Stuart A., The Advance Theory of Statistics: 2, Hafner Publishing Co, New York, 1961.

[15] Sen PK, Estimates of the regression coefficient based on Kendall's tau, Journal of the American Statistical Association, 63: 1379-1389, 1968.