DETECTION OF RIVER FLOW TRENDS AND VARIABILITY ANALYSIS OF UPPER INDUS BASIN, PAKISTAN

Khalida Khan[1], ♣Muhammad Yaseen[2], Yasir Latif [3] and Ghulam Nabi[4]

[1]*Centre for Integrated Mountain Research (CIMR), University of the Punjab, Lahore, Pakistan.* cimrpu87@gmail.com director.cimr@pu.edu.pk

[2]*, Centre for Integrated Mountain Research (CIMR), University of the Punjab, Lahore, Pakistan.* myaseen@cimr.edu.pk

[3]*, The institute of Tibetan Plateau Research, Chinese Academy Of Sciences (Beijing, P.R China). yasir8082@hotmail.com*

[4]*, Centre of Excellence in Water Resources Engineering, University of Engineering and Technology, Lahore, Pakistan. gnabi60@hotmail.com*

♣**Corresponding Author**: *Engr. Muhammad Yaseen, Centre for Integrated Mountain Research (CIMR), University of the Punjab, Lahore, Pakistan. E-mail: myaseen@cimr.edu.com, Contact No: 0092-333-8975891, Fax: (+92-42) 99230624*

ABSTRACT: *Pakistan being an agricultural country with heavy population growth, there is a great stress on water resources to meet the food and fiber requirement for the people. The elevation of Upper Indus Basin (UIB) ranges from 254 m to 8570 m above mean sea level. There are so many rivers which contribute water to main Indus River. This study examines the climate change and related hydrological impacts resulting from altitudinal variability. Trend analyses were performed by applying Mann-Kendall method while Sen's method was applied to estimate slope time series that indicates changes. The influence of serial correlation was eliminated from time series by applying the trend-free pre-whitening (TFPW) method prior to the trend analysis.*

The results of this study indicate that maximum and mean temperature have warming trends and have increased with increased in elevation while the minimum has the reverse situation. Annual precipitation has more decreasing rate in higher mountainous catchments. The impact of altitudinal variability under changing climate yields that Annual stream flows in River Indus (at Kharmong, Alam Br. and Khairabad), Sawat (at Kalam) and Kabul (at Nowshera) have decreased whereas in River Gilgit, Hunza, Chitral, Shoyk. Shigar and Astore have increased. The prevailing trends and variability, caused by climate change, have an effect on the flows that should be considered by the water managers for better water management in a water scarcity country like Pakistan. On the basis of collected real time data, an awareness regarding present Integrated Water Management (IWM) working with up-to-date techniques is recommended for effective water on-going reform process.

Keyword: Upper Indus Basin; climate change; trends; stream flows

1. INTRODUCTION

Documented by Intergovernmental Panel on Climate Change [1] Earth's over-all temperature has been intensified up to 0.89 C° over the time period 1901 to 2012. Research studies conducted by [2, 3 and 4] and reports published by *IPCC* [5] have identified significant warming up of the Earth's surface over the past 100-years period or so. Moreover, global circulation patterns are affected by warming up but directly affect local climatic settings with changes in distribution and characteristics of precipitation and temperature. Hydrological impacts by climate change may significant affect water resources availability and may cause changes in the hydrological cycle [6]. Changes vary in space and time domains as affected by local climatic and topographic settings. In *IPCC* [1] it is indicated that climate changes are accelerated and that impacts may become more extreme. This aspect of climate change has motivated this study where we aim to assess possible acceleration of climate changes and related hydrological impacts for Upper Indus Basin in Pakistan. This system is of high importance to sustainable water supply for large populations in the lower Indus in Pakistan. The climate in Pakistan has a large regional variation, categorized by hot summers and cold winters. The temperature difference between day and night is extremely important. During summer season the temperature in the southern part rises up to 45°C or even more. Lack of rain makes the dry and deserted place. Northern Pakistan is usually cold because of the snowcapped mountains, while the southern part is dry, with deserts around. Changing of climate greatly affecting the sources of water like Glaciers and Streams. Glaciers are melting rapidly because of the increasing temperature flows of stream are also affecting as well as pattern of rain fall has also change because of climate change.

Investigations of past shows that climate on Earth is continuous in changing process. The pace of change and the nature of the consequential nature resulting effects will fluctuate with time and throughout the country by impacting life on Earth. In an effort to reduce emissions of greenhouse, it is necessary to adapt to the effects of climate change. Learn what climate change will mean that Pakistan is the only one step in this direction. In most global climate models predict the magnitude of future climate change will lead to a significant impact on our water resources, and later affect the sustainability of the food supply, health, industry, transport and ecosystems. Problem because of the stress is exacerbated by the change in the supply and demand due to climate change , it takes a load on resources , is most likely to occur in already the southern part of the country . Pakistan's economy is based on agriculture that "is highly dependent on Indus Basin Irrigation system" [7] Stated by *Archer,* [8], "the irrigation system assists an area of 22.2 million hectares and irrigated land for 85% of all crop/food production". Pakistan has three major reservoirs (Tarbela, Mangla and Chasma), which have original storage capacity of 19.43 BM^3. Future assessment of water resources in Pakistan under climate change is a prerequisite for the planning and operation of hydraulic equipment [9]. Seasonal flow forecasting in relation to climate change would have been an effective tool to water resource management authority in an timely warning to an excess or deficit in power generation [10], further it will be helpful for planners [11] As seen in some recent studies, due to wide variation in topographic and meteorological parameters, different trends has been observed in different climatic regions of the country [12, 13 and 14]. The elevation of UIB ranges from 254 m to 8570 m above mean sea level. There are so many rivers which contribute water to main Indus River. The main sub basins like Chitral, Swat, Kabul, Hunza, Gilgit, Astore, Shigar, Shyok are lying at different elevation raging in "three hydrological regimes: a nival regime depends on the melting of the winter snow, a glacial regime and the precipitation regime depends on simultaneous rainfall [15 and 16] studied long-term precipitation and temperature series (1895 to 1999) from 17 stations in the UIB described that records exhibit a complex season-dependent spatial correlation structure. Results, as such, indicate large differences in climate change as affected by local climatic and topographic settings. Keeping in view, hydro-climatic variability and related hydrological impacts resulting from altitudinal variability under changing climate was analyzed in this study. The results of this study will also be helpful for decision makers to develop the strategies for planning and development of water resources under different climatic scenarios to overcome their adverse impact. Sections 2 and 3 describe the study area and all data available for this study. Section 4 describes the methodology and statistical analysis performed. Results and discussions are made in Section 5 while conclusions are finished in Section 6.

2. STUDY AREA

The Upper Indus Basin was selected to investigate study. The catchment of this basin falls in range 33º, 40′to 37º, 12′ N latitude and 70º, 30′ to 77º, 30′ E, longitude. The Upper Indus watershed boundary was derived from Digital Elevation Model (DEM) at confluence point of Kabul River and Indus River just upstream of Khairabad in Attock as shown in Fig. 1. The catchment area at Khairabad point is 312818 km^2. Most of area of this catchment is lies in China and India. Due to unavailability of data in China and India, so study area was confined in catchment carrying in Pakistan boundary as shown in Fig.3.2. The elevation varies from 254 m to 8570 m above mean sea level. There are so many rivers which contribute water to main Indus River. The main sub basin are Chitral, Swat, Kabul, Hunza, Gilgit, Astore, Shigar, Shyok, Kunhar, Neelum, Kanshi, Poonch, Soan, Siran, Sil, Haro etc. Indus River originates from the north side of the Himalayas at Kaillas Parbat in Tibet having altitude of 18000 feet. Traversing about 500 miles in NW direction, it is joined by Shyok River near Skardu (elevation 9000 feet).

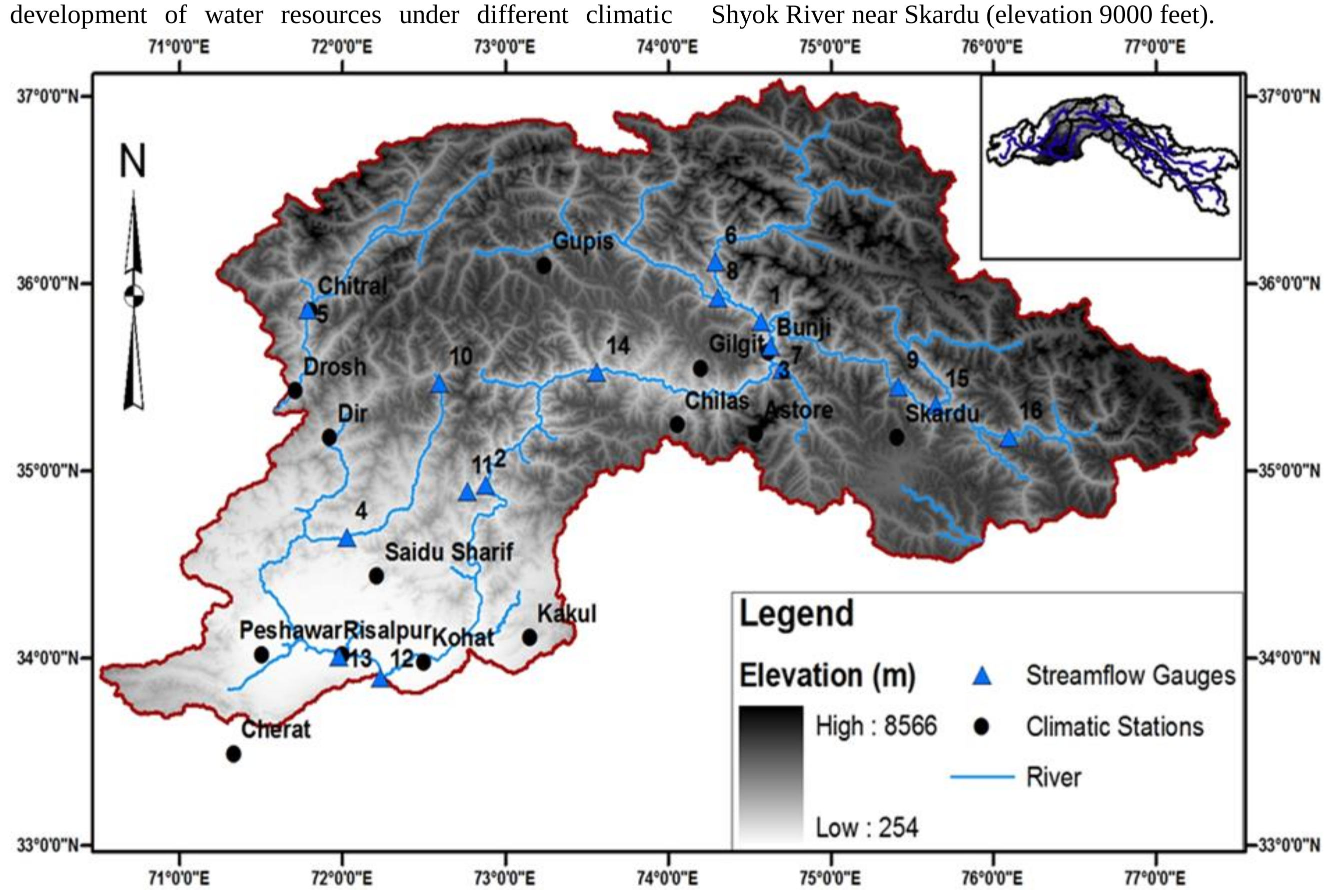

Figure 1: Digital elevation model of Upper Indus Basin showing major rivers, climatic stations (Table 1) and stream flow gauges (Table 2).

After traveling about 100 miles in the same direction, it reaches Nanga Parbat and joined by the Gilgit River at an elevation of 5000 feet. Flowing about 200 miles further in SW (South West) direction, the river enters into the plains of the Punjab province at Kalabagh (800 feet). The Kabul River, a major western flank tributary, joins with Indus near Attock. The Kunar which is also called Chitral River joins Indus below Warsak. About five miles below Attock, another stream Haro River drains into the Indus River. About seven miles upstream of Jinnah Barrage, another stream called Soan River joins with Indus. The tributaries of Indus Rivers are detailed in Figure 1.

3. DATA SET

Designated sixteen climatic stations (CS) and physiognomy are in shown in Table 1 and CS location is given in Fig. 3.3. The data of these stations were composed from Pakistan Water and Power Development Authority (WAPDA), Surface water Hydrology Project (SWHP) and Pakistan Meteorological Department (PMD) for period (1960 to 2011). The mean monthly maxi- and mini- were calculated for each year of the daily maximum daily minimum and daily average temperatures. Mean daily temperatures are based on the "arithmetic mean of daily maximum and minimum temperatures" [17]. The data is also missing replaced via mean linking the earlier year's data with subsequent years. Stream-flow measurement in UIB is of the WAPDA-SWHP project conceded starting in 1960 with original records. The stream flow gauges are installed in all sub-basins of UIB at different locations which are shown in Fig.1. The stream gauges have a wide range of drainage area from 262 km^2 to 286,000 km^2. Sixteen flow gauges stations were selected as installed in all sub-basins of UIB. The characteristics/information of selected flow sites are given in Table 3.5. The data of these sites were for period 1961 to 2011.

Table 1: List of climatic stations in the current study and their physiognomies

Sr. No.	Station	Lat. (dd)	Lon. (dd)	Elevation (m)	Mean Annual Temperature (^oC) Max.	Min	Mean
1	Astore	35.2	74.5	2168.0	15.6	4.1	40.5
2	Bunji	35.6	74.6	1372.0	23.8	11.4	13
3	Cherat	33.5	71.3	1372.0	21.5	13.2	50.6
4	Chilas	35.3	74.1	1250.0	26.4	14.1	16
5	Chitral	35.9	71.8	1497.8	23.3	8.6	39.7
6	Dir	35.2	71.9	1375.0	22.9	8	113.7
7	Drosh	35.4	71.7	1463.9	24.1	11.3	50
8	Gilgit	35.6	74.2	1460.0	23.9	7.6	11.3
9	Gupis	36.1	73.2	2156.0	18.7	6.7	15.6
10	Kakul	34.1	73.2	1308.0	22.8	10.9	108.3
11	Kohat	34.0	72.5	1440.0	29.3	16.9	45.5
12	Parachinar	33.5	70.1	1725.0	21.3	8	73.7
13	Peshawar	34.0	71.5	320.0	29.5	16.1	37.9
14	Risalpur	34.0	72.0	575.0	29.6	14.5	52.3
15	Saidu Sharif	34.4	72.2	961.0	26	12	89.4
16	Skardu	35.2	75.4	2317.0	18.6	4.9	18.6

Table 2: List of stream flow gauges used in the present study and their characteristics

Sr.No.	Stream flow Gauge	Lat. (dd)	Lon. (dd)	River	Catchment Area (km^2)	Elevation (a.m.s.l) (m)	Mean Annual Stream flow (cusec)
1	Alam Br.	35.8	74.6	Gilgit	27193	1280	638
2	Besham Qila	34.9	72.9	Indus	179515	580	2403
3	Bunji	35.7	74.6	Indus	160989		1790
4	Chakdara	34.6	72.0	Swat	5642	676	187
5	Chitral	35.9	71.8	Chitral	12333	1500	276
6	Dainyor Br.	35.9	74.4	Hunza	13712		327
7	Doyain	35.5	74.7	Astore	3919	1583	138
8	Gilgit	35.9	74.3	Gilgit	12650	1430	249
9	Kachura	35.5	75.4	Indus	155402	2341	1078
10	Kalam	35.5	72.6	Swat	2013	1921	86
11	Karora	34.9	72.8	Gorband	559	880	19
12	Khairabad	33.9	72.2	Indus	252525	634	3042
13	Nowshera	34.0	72.0	Kabul	85895	282	840
14	Shatial Br.	35.5	73.6	Indus	171148	1040	2069
15	Shigar	35.4	75.7	Shigar	6965	2438	209
16	Yogo	35.2	76.1	Shyok	33670	2469	359

4. METHODOLOGY

The rationale of the documentation trend is to determine whether the value of the random variable usually increasing/decreasing certain time statistically [18]. The rationale of the document trend, the value of the random variable, is to determine whether generally reduce the increase or statistically certain time.

Parametric or nonparametric statistical tests are used to solve, whether it be a statistically significant trend [19]. The analysis was carried out for the time series of local mean values; these steps include essentially: (i) the examination of serial correlation effect; (ii) identification "of trends by using the Mann - Kendall test" [20] spearman test and linear trend methods; (iii) Estimate the trend value by applying Sen's estimator.

4.1 Serial correlation effect

In time series analysis, it is essential to consider correlation "or serial correlation, defined as the correlation of a variable with itself over successive time intervals, before the test for trend" [21]. In particular, [22] stated, "if there is a positive serial correlation (persistence) in the time series, then the non- parametric test is a significant trend in a time series that is random more often than specified by the significance level" . To do this [22] advocated that "the time series should be 'pre-whitened' in order to eliminate the effect of serial correlation before applying the Mann- Kendall test" or any trend detection test.

Tabari, [23] has revealed the elimination of serial correlation of pre-whitening used to efficiently eliminate the "serial correlation" remove impact of its test series on MW test. *Tabari*, [24] have amended the process of pre-whiting where exist substantial serial correlation. "TFPW method has been applied in the most recent studies to detect trends in the hydrological and meteorological parameters" by Oguntunde; [25] and Tabari, [26]. We have integrated the recommendations in this study and accordingly prospective statistically considerable trends in temperature examination (x_1, x_2. . . x_n) [*22*] and scrutinized procedures as follows:-

For a given time series of interest, the slope of the trend (β) by the use of robust slope estimator is estimated method of Sen. Then the time series is de-trended, assuming a linear trend [*27*] as:

$$Y_i = x_i - (\beta \times i) \quad (1)$$

Compute the lag-1 serial correlation coefficient (designated by r_1)" [*22*]. Should the designed r_1 prove not to be meaningful at 5% level, statistical tests would then be employed to the primary data sets of the time series. *Ramadan, et al*; [28] analyzed "If the calculated r_1 is significant, prior to application tests, then the 'pre-whitened' time series could be obtained" [*29*]:

$$\bar{Y}_i = Y_i - rY_{1-i} + (\beta \times i) \quad (2)$$

4.2 Mann Kendall test

Zhang, [30] noted that Mann initially exercised MK test, Kendall [31] are then derived the distribution of the test statistic. Extensively used Mann Kendall test is manipulated for investigate trends within climatological studies by [*32, 33 and 34*], and in hydrologic time series [35 and 36]. *Yi et al;* [37] analyzed that there are two advantages to using this test. *Wang, et al*; [34] submitted, "It is a non - parametric test and does not require the data to be normally distributed". *Hossein*, [38] suggested, minimal sensitivity of the test to disruptions due to inhomogeneous time series. This test has been found as an excellent tool for the trends detection [*30*]. According to *Yu* [39] "the number of annual values of the data series is denoted by *n"*. To compute the Mann-Kendall statistics, difference in annual *x* value were determined; S was computed using equation 4:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \quad (3)$$

Where *sgn* $(x_j - x_k)$ is "an indicator function that takes on the values 1, 0 or -1 according to sign of difference (x_j - x_k), where $j > k$" *[40 and 41]*.

$$sgn(x_j - x_k) = \begin{cases} 1 & if\ x_j - x_k > 0 \\ 0 & if\ x_j - x_k = 0 \\ -1 & if\ x_j - x_k < 0 \end{cases} \quad (4)$$

Yan, [42] analyzed, the values "*xj* and x_k are the annual values in the year j and k" respectively

The variance *S* was computed by the following equation applied by *Ramadan, et al*; [28]:

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)\right] \quad (5)$$

q= the No. of tied groups and t_p is the No. of data in the group *p* [*42*].

Before computing *VAR(S)* the data was checked all the local groups and the data extent in each cluster are connected.

"S and *VAR(S*) were used to compute the test statistic Z" [*43*]:

$$Z = \begin{cases} \frac{S-1}{[VAR(S)]^{1/2}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{[VAR(S)]^{1/2}} & if\ S < 0 \end{cases} \quad (6)$$

The trend was evaluated using *Z* values.

Yue, and Wang, [36], has suggested "positive value of *Z* an upward (warming) trend while negative value downward trend (cooling trend)". Statistics "*Z* has a normal distribution" [*43*]. The insignificant assumption, Ho stands true if there is no trend and thus uses standard normal table to decide whether to reject H_o. For investigation whichever upward or downward trend ("a two-tailed test") inference identical H_o remains "rejected if the absolute value of *Z* is greater than $Z_{1-\alpha/2}$, where $Z_{1-\alpha/2}$, was obtained from standard normal" tables [*43*]. In this study existence and importance of trend was evaluated with α values that is $\alpha \leq 0.1$.

4.3 Sen's estimator slope

Tabari, [23] analyzed "if a linear trend is present in a time series, then the slope (change per unit time) can be estimated by using a simple nonparametric procedure". Slope values of pairs of data of N were initially calculated by *Tabari*, [23] as follows:

$$Q_i = \frac{x_j - x_k}{j - k} \qquad \text{If } j > k \quad (07)$$

"Where x_j and x_k are the annual values in the year j and k respectively" described by *Xuedong (2008)*

Suggested by Sujatha, [44], the "Sen's estimator of slope is the median of these N values of Q". *Yu*, [1993] noted, "median of the slope estimates (N) was obtained in the usual way". Documented by *Yan*, [42], "N values of Q_i were ranked from smallest to largest and the Sen's estimator" was computed as follow:

Sen's estimator = $Q_{[(N+1)/2]}$ if *N* was odd" and (08)

$\frac{1}{2}\left(Q_{N/2} + Q_{[(N+2)/2)]}\right)$ if *N* was even" (09)

Finally, by consulting *Tabari*, [45], Q_{med} was verified with double-sided test at 100 (1 - α) % confidence interval for testing and has been through non- parametric test of the true slope while data were processed using an Excel macro named MAKESENS.

5. RESULTS AND DISCUSSIONS

The trend analysis and changes in temperature, precipitation and streamflow in various climatic stations and stream gauges of UIB at different locations were found over the periods 1961-2010. The analysis was performed on annual time series. The percentage of stations with increasing and decreasing trends as well as significant trends is shown in Fig.2. To examine the spatial consistency of the observed trends, maps were created displaying with decreasing and increasing trends. The spatial distribution of trends and changes in temperature, precipitation and streamflow are shown in Figures 3, and 4 respectively. Distribution of trends of temperatures, precipitation and streamflows with elevation of stations is shown in Fig.5.

5.1 Temperature Trends

Annual maximum temperature analyses have indicated warming trends for the period of 1961 to 2011. All stations except Bunji, Cherat and Kakul showed the increasing (positive) trend in maximum temperature. The highest warming trend was observed at Skardu with rate of 0.49 °C per decade at 99.9% significant level. At Astore, Chitral, Dir, Drosh, Gilgit, Gupis and Skardu warming trend were also observed with highest significant level 99.9% the increasing trend with rate of 0.21, 0.28, 0.23, 0.23, 0.22 and 0.49 °C per decade. Kohat and Parachinar also showed warming trend with rate of 0.27 and 0.18 °C per decade with 99% significant level. Peshawar also showed warming trend at 95% significant level with the rate of 0.14 °C per decade. Chilas and Risalpur showed warming trend but statically insignificant. The annual maximum temperature decreased with the rate of 0.03, 0.38 and 0.18 °C per decade at Bunji, Cherat, and Kakul respectively as shown in Fig. 3 (a). The overall analysis of these sixteen meteorological stations applying Mann-Kendall test and Sen's showed, an increase of annual mean maximum temperature (13 out of 16, 11 significant) for period 1961 to 2011.

Figure 2: Percent number of stations with positive (upward) and negative (downward).

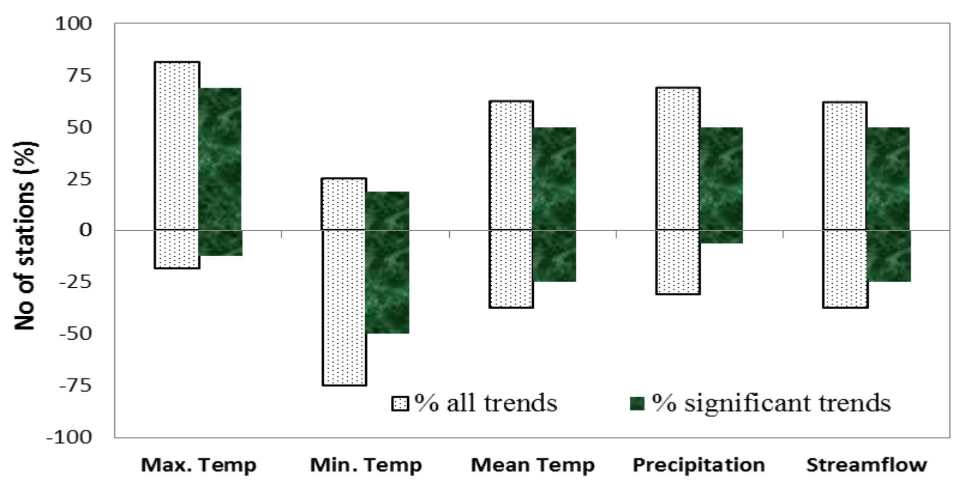

Figure 2 showed the results of the trends in the annual average minimum temperature for the period of 1961 to 2011. This analysis clearly showed that annual mean temperature has decreased in most of UIB regions. Twelve sites showed the cooling trend in mean minimum temperature. Only at Astore, Chilas, Drosh and Peshawar showed the upward trend with rate of 0.1, 0.21, 0.1 and 0.15 ^{o}C per decade respectively at 90% significance level as shown in Fig. 4.14 (C). Descending trend at Bunji, Cherat, Chitral, Dir, Gilgit, Gupis, Kakul, Kohat, Parachinar, Risalpur, Saidu Sharif and Skardu was observed with rate of 0.26, 0.06, 0.19, 0.11, 0.17, 0.29, 0.92, 0.05, 0.74, 0.04, 0.33 and 0.13 ^{o}C per decade respectively. Significant warming in annual mean temperature at Astore, Chilas, Chitral, Dir, Drosh, Gilgit, Peshawar and Skardu was observed with increasing rate of 0.15,0.11, .09, 0.12, 0.14, 0.1, 0.18 and 0.19°C decade $^{-1}$ respectively. Gupis, Kohat, Peshawar and Risalpur have not any inclination (zero slopes). Bunji, Cherat, Kakul and Parachinar showed significant cooling trend with decrease of 0.17, 0.31 and 0.53 and justify the findings of *Fowler and Archer*, [16], 0.37 °C decade $^{-1}$ respectively at 99.9% significant level.

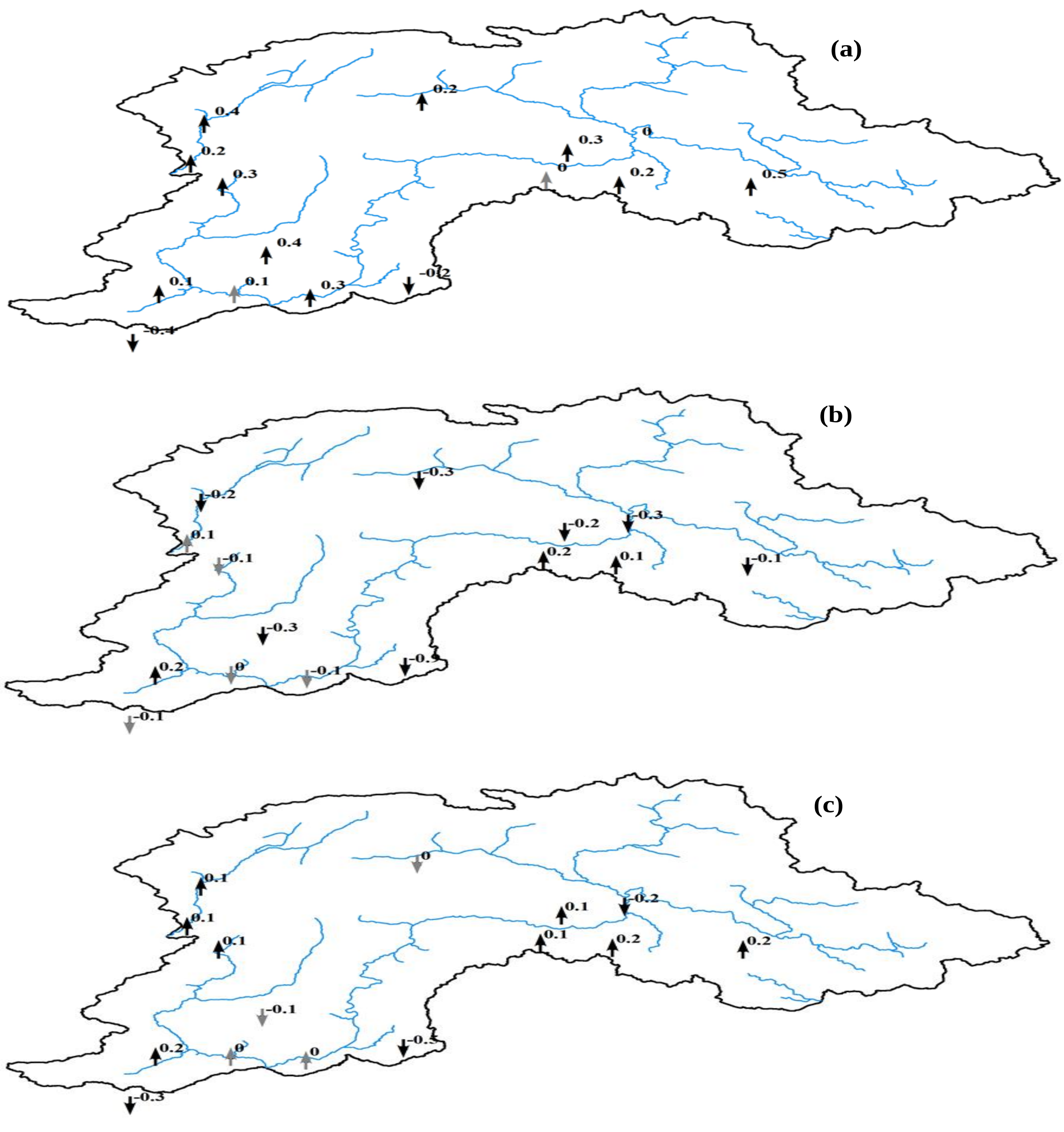

Figure 3: Spatial distribution of trends detected by Mann-Kendal and trend values estimated by Sen's method showing change in °C decade^{-1} in: (a) maxi- temperature, (b) mini- temperature and (c) *m* temperature (Upward and downward arrow shows positive and negative trends respectively, bold arrow shows significant trends at α=0.1).

5.2 Trends in Precipitation

The results of analysis by applying Mann-Kendall besides Sen slope estimation methods; annual rainfall were summarized in Fig . 2. At ten stations, the annual precipitation has increased for the period 1961 to 2011. Amplified precipitation with highest significance level (99.9%) was observed at Bunji, Chilas, Peshawar and Risalpur with the rate 9.41 (6%), 16.41 (9%), 40.33 (9%) and 40.24 (6%) mm per decade respectively. Increasing trend of annual precipitation was also observed with 99% significance level at Gilgit, Gupis and Skardu with increased of 5.18 (4%), 3.72 (2%) and 16.81(8%) mm per decade respectively whereas Chitral showed swelling trend of rainfall at 95% significance level with rate of 22.65 (5%) mm per decade. The decreasing trend of annual precipitation at Astore, Cherat, Dir, Drosh, Kohat and Parachinar was observed with shrinkage of 7.27 (1%), 30 (5%), 41 (3%), 9 (1), 12.49 (2%) and 1.84 (1%) mm per decade respectively but all these were statistically inconsequential.

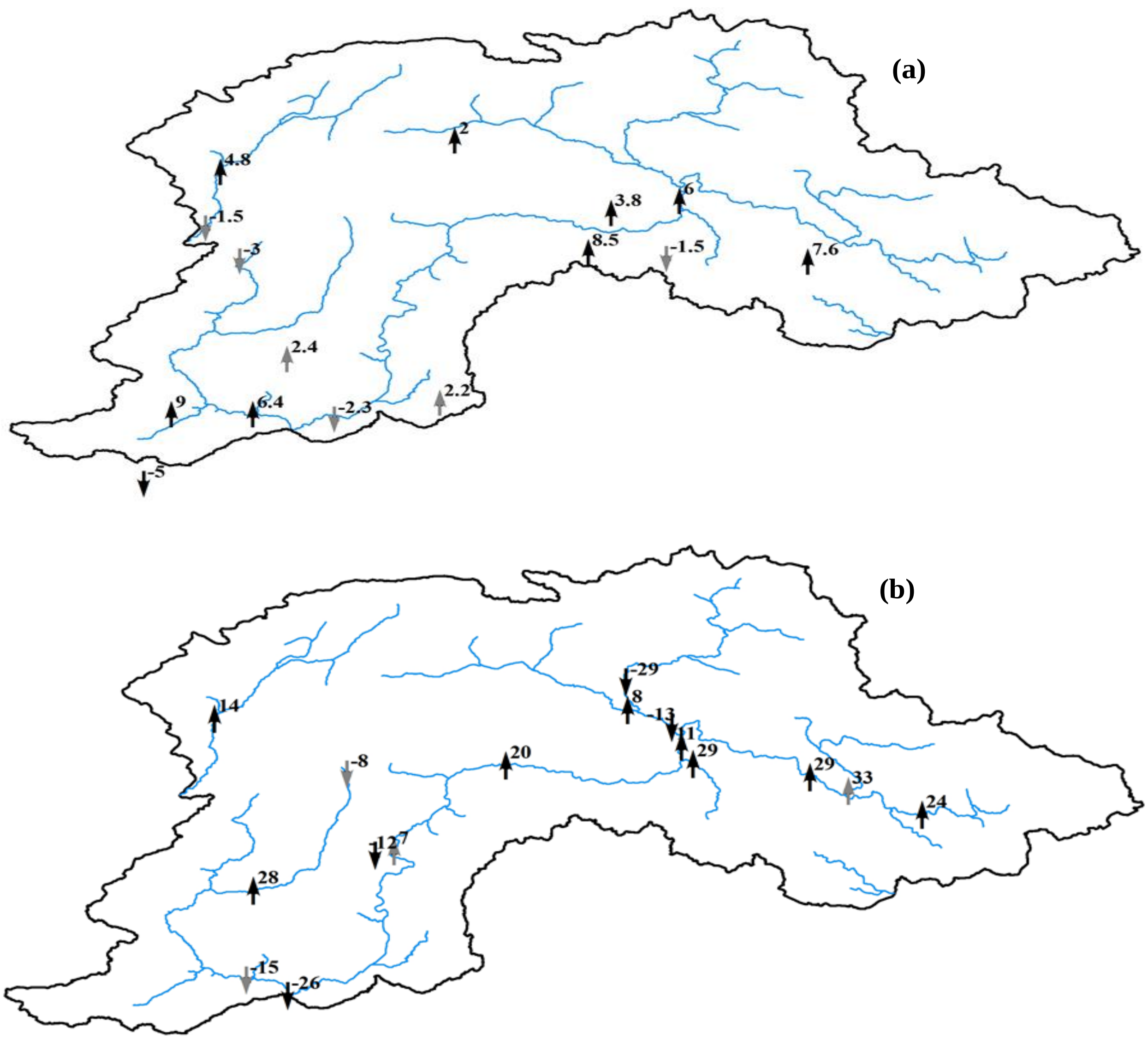

Figure 4: Spatial distribution of trends detected by Mann-Kendal and trend values estimated by Sen's method showing change in % decade^{-1} in: (a) precipitation and (b) stream flows (Upward and downward arrow shows positive and negative trends respectively, bold arrow shows significant trends at α=0.1).

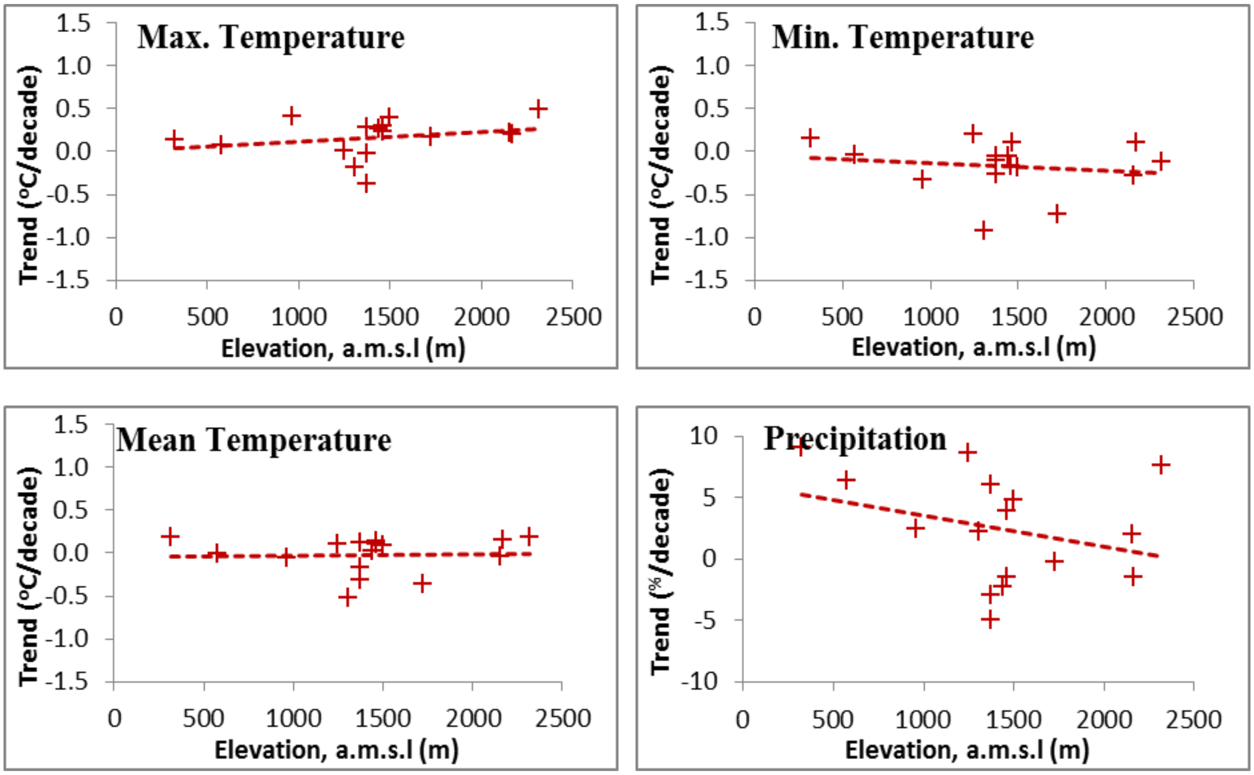

Figure 5: Distribution of trends of temperatures, precipitation and stream flows with elevation of stations.

5.3 Trends in Stream flows

The annual flow in Indus Basin at Besham Qila illustrated trivial increasing trend with the rate of 6%. *Sharif, et al;* [46] also found the positive trend at Besham Qila for the period 1969 to 1995. The flow at Dainyor has decreased significantly (p=.006) upto 29% for the record length (1966 to 2010) and has also found decreasing trend for period 1966 to 1995 [*46*]. The trend in Rivers Shyok at Yogo and Indus at Kharmong, Kachura and Bunji has the same tendency as detected by *Sharif, et al;* [46] with changes up to 24%, 13%, 29% and 11% respectively. The annual mean flow in Kabul basin at Nowshera has decreased with p value 0.15 upto 15%. The River Swat at Kalam has subsiding trend whereas Swat River at Chakdara and River Chitral at Chitral showed cumulative tendency.

5.4 Altitudinal Impact on Climate Change

Analysis on the relation between elevation and maximum and mean temperature indicate increasing trends with higher temperatures whereas decreasing trend for the minimum temperature. The maximum and mean temperature has higher trends in high mountainous region. The low elevated region (<1300 m) of UIB has the positive trends ranging from 2% to 9% in annual precipitation whereas the high mountainous region (>1300 m) has the cooling trends. The most of sub-basins of UIB have the increasing trends. The Hunza and Kalam basins have the decreasing trends.

5. CONCLUSION

Trend identification is an important task in hydrological series analysis, on the basis of such trends the following suppositions have been strained from the upshots of this revision:

1. Inclusive investigation of sixteen climatic stations of Upper Indus Basin with Mann-Kendall test and Sen's method indicated that there is an upsurge of annual maximum & mean temperature for period 1961 to 2011.
2. The mean minimum annual temperature has declined in most of the region of Upper Indus Basin for the period (1961 to 2011).
3. The annual precipitation augmented in twelve stations of Upper Indus basin.
4. Maximum and mean temperature has increased with increased in elevation while the minimum temperature and precipitation has more decreasing rate in higher mountainous catchments.
5. The annual runoff showed an upwelling trend for rivers Shoyk (at Yogu), Shigar (at Shigar) Indus (at Kachura) up to 9%, 7% and 5 % respectively due to warming trend of annual temperature upto 5% (1 ^{o}C) whereas the annual and summer (JJA) stream flow in river Kabul at Nowshera has come to a diminution up to 22% and 11% by increasing 4% and 1% (0.96 & 0.22^{o}C) temperature.

ACKNOWLEDGEMENTS

The authors gratefully acknowledged to Higher Education Commission of Pakistan for affording financial support to this research, Furthermore, the PMD and the Pakistan, WAPDA for providing the time series of data for this study. We appreciate greatly the perceptive remarks of the anonymous reviewers, technical observations and revises by reviewers who facilitated us strong and meritorious in improvisation of the manuscript.

REFERENCES

1. IPCC, 2013, Climate Change The Physical Science Basis pp 1535
2. Parker, D.E., Horton, E.B., 1999. Global and regional climate in 1998. Weather 54, 173–184.
3. Jones, P.D., Moberg, A., 2003. Hemispheric and large-scale surface air temperature variations: an extensive revision and update to 2001. J. Climate 16 (2), 206–223
4. del Rio, S. (2005), Analysis of recent climatic variations in Castile and Leon (Spain), *Atmospheric Research* 73(1-2):69-85
5. IPCC, 2001. Climate change 2001: synthesis report. Contribution of Working Group I and III to the Third Assessment of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge.
6. Bates, B. C., Kundzewicz, Z. W., Wu, S. and Palutikof, J. (2008). Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva.
7. Tahir, A. A. (2011), Snow cover dynamics and hydrological regime of the Hunza River basin, Karakoram Range, Northern Pakistan, Hydrology and Earth System Sciences Discussions, 409(s 1–2):104–117.
8. Archer, D.R. H.J. Fowler (2008), Using meteorological data to forecast seasonal runoff on the River Jhelum, Journal of Hydrology 361, 10– 23
9. Akhtar, M. (2008), The impact of climate change on the water resources of Hindukush-Karakorum-Himalaya region under different glacier coverage scenarios, *Journal of Hydrology,* 355, 148–163
10. Fowler, H. J. and D. R. Archer. (2005). Hydro-climatological variability in the Upper Indus Basin and implications for water resources. Regional Hydrological Impacts of Climatic Change-Impact Assessment and Decision Making, T. Wagener et al., Eds., IAHS Publication, 295: 131–138.
11. Archer, D. R., and H. J. Fowler (2004), Spatial and temporal variations in precipitation in the Upper Indus Basin, global teleconnections and hydrological implications, Hydrol. Earth Sys. Sci., 8 (1), 47 to 61
12. Chaudhry, Q.Z. and Sheikh M. M., 2002: Climate Change and its Impact on the Water Resources of Mountain Regions of Pakistan, Pakistan Journal of Geography, Vol.11, & 12, No.172 June-December.
13. Chaudhry Q.Z. and G. Rasul, 2007: Global Warming and Expected snowline shift along Northern Mountains of Pakistan. Proceedings of 1st Asiaclic symposium, Yokohama, Japan.
14. Afza1, M., M. A. Haroon., Chaudhary, Q. Z. 2009: Interdecadal Oscillations and the Warming Trend in the Area-Weighted Annual Mean Temperature of Pakistan. Pakistan Journal of Meteorology, 6 (11), 13-19
15. Archer, D. R. N. Forsythe, H. J. Fowler, and S. M. Shah (2010), Sustainability of water resources management in the Indus Basin under changing climatic and socio economic conditions", Hydrology and Earth System Sciences, 14, 1669-1680,
16. Fowler, H. J., and D. R. Archer, (2006), Conflicting Signals of Climatic Change in the Upper Indus Basin, *Journal of Climate*, Volume 19, Issue 17
17. Richardson, A.D. (2004), Microclimatology of tree line spruce-fir forests in mountains of the northeastern United States, *Agricultural and Forest Meteorology*, *53–66*
18. Olofintoye, Oluwatosin, Josiah Adeyemo, and Fred Otieno, (2012), Impact of Regional Climate Change on Freshwater Resources and Operation of the Vanderkloof Dam System in South Africa, Global Warming-Impacts and Future Perspectives,
19. Thakur, G. S. (2011), Analysis of groundwater levels for detection of trend in Sagar district, Madhya Pradesh, Journal of the Geological Society of India, vol. 77, no. 4, pp. 303-308
20. Jhajharia, D., (2012), Identification of trends in rainfall, rainy days and 24h maximum rainfall over subtropical Assam in Northeast India, Comptes rendus - Geoscience, 344(8):396-405
21. Sinha, Tushar, and Keith A. Cherkauer, (2008), Time Series Analysis of Soil Freeze and Thaw Processes in Indiana", Journal of Hydrometeorology 11:2, 229-252.
22. Turgay Partal, (2006), Trend analysis in Turkish precipitation data, Hydrological Processes, Volume 20, Issue 9, pages 2011–2026
23. Tabari, H., Marofi, S., Aeini, A., Talaee, P.H., Mohammadi, K., 2011. Trend Analysis of Reference Evapotranspiration in the Western half of Iran. Agricultural and Forest Meteorology 51, 128 to 136.
24. Tabari, H (2012), Identification of Trend in Reference Evapotranspiration Series with Serial Dependence in Iran, Water Resources Management, DOI 10.1007/s11269-012-0011-7
25. Oguntunde, P. G., Abiodun, B. J., Lischeid, G., 2011. Rainfall trends in Nigeria, 1901 – 2000. J Hydrol. doi:10.1016/j.jhydrol.
26. Tabari, H (2011), Shift changes and monotonic rends in auto correlated temperature series over Iran, Theoretical and Applied Climatology, 109,. 95-108
27. Tommaso Caloiero, (2009), Trend detection of annual and seasonal rainfall in Calabria (Southern Italy, International Journal of Climatology, 31 (1), 44-56,
28. Ramadan, H. H., R. E. Beighley, and A. S. Ramamurthy, (2013), Temperature and Precipitation Trends in Lebanon’s Largest River: The Litani Basin, Journal of Water Resources Planning and Management 139:86-95.
29. Weiguang Wang, (2011), Spatial and temporal characteristics of changes in precipitation during 1957–2007 in the Haihe River basin, China, Stochastic Environmental Research and Risk Assessment, 25(7):881-895.
30. Zhang, W. (2009), Temporal and spatial variability of annual extreme water level in the Pearl River Delta

region, China, Global and Planetary Change, 69(1):35-47

31. Kendall, M.G., 1975. Rank correlation methods, 4th ed. Charles Griffin, London.

32. Shifteh Some'e, B., Azadeh Ezani, and Tabari, H (2012), Spatiotemporal trends and change point of precipitation in Iran, Atmospheric Research, Volume 113, Pages 1-146

33. Mavromatis T., Stathis D., 2011. Response of the Water Balance in Greece to Temperature and Precipitation Trends. Theoretical and Applied Climatology 104, 13 to 24,

34. Wang, H Y, Z Y Li, Z H Gao, J J Wu, B Sun, and C L Li, (2014), Assessment of land degradation using time series trend analysis of vegetation indictors in Otindag Sandy land, IOP Conference Series Earth and Environmental Science, Vol. 17 Issue 1, p012065-012070,

35. Bhutiyani, M.R., Kale, V.S., Pawar, N.J., 2007. Long-term trends in maximum, minimum and mean annual air temperatures across the northwestern Himalaya during the 20th century. Climatic Change, 85, 159–177.

36. Yue, S., and Wang, C., 2004. The Mann-Kendall Test Modified by Effective Sample Size to Detect Trend in Serially Correlated Hydrological Series. Water Resources Management 18, 201–218.

37. Yi, Yujun , Caihong Tang, Zhifeng Yang, and Xi Chen (2014), Influence of Manwan Reservoir on fish habitat in the middle reach of the Lancang River, Ecological Engineering, 69:106–117.

38. Hossein Ahani.(2012), An investigation of trends in precipitation volume for the last three decades in different regions of Fars province, Iran, *Theoretical and Applied Climatology*, Volume 109, Issue 3-4, pp

39. Yu, Y.S.. (1993) "Non-parametric trend analysis of water quality data of rivers in Kansas", Journal of Hydrology, 150 (1), 61-80, 1993.

40. Souvignet, Maxime, Patrick Laux, Jim Freer, Hannah Cloke, Dang Quang Thinh, Tran Thuc, Johannes Cullmann, Alexandra Nauditt, Wolfgang-Albert Flügel, Harald Kunstmann, and Lars Ribbe. (2013) "Recent climatic trends and linkages to river discharge in Central Vietnam : CLIMATE TRENDS IN CENTRAL VIETNAM" Hydrological Processes, 28:4, 1587-1601

41. Dogan, Mustafa, and Aysegul Ozgenc Aksoy, (2013), Investigation of the relation between meteorological parameters, North Atlantic Oscillation and groundwater levels in Torbali Region, Turkey : Trends of climate parameters and groundwater level, Water and Environment Journal, Volume 27, Issue 1, pages 138–145,

42. Yan Luo, (2008), Trends of precipitation in Beijiang River Basin, Guangdong Province, China, Hydrological Processes, Volume 22, Issue 13, pages 2377–2386

43. Heckl, Andreas, (2011), Impact of Climate Change on the Water Availability in the Near East and the Upper Jordan River Catchment, University of Augsburg, p. 194.GERMANY, OPUS,

44. Sujatha, K. V., and S. Meenakshi Sundaram, (2010), Stock index prediction using regression and neural network models under non normal conditions, INTERACT- .5706195

45. Tabari, H., Talaee, P. H., Ezani, A., Some'e, S. B., 2012. Shift changes and monotonic trends in autocorrelated temperature series over Iran. Theor Appl Climatol., 109, 95–108

46. Sharif, M., Archer, D. R., Fowler, H. J., and Forsythe, N. (2013): Trends in timing and magnitude of flow in the Upper Indus Basin. Hydrol. Earth Syst. Sci., 17, 1503–1516.