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ASSESSMENT OF CLIMATE CHANGE AND VARIABILITY IN TEMPERATURE, PRECIPITATION AND FLOWS IN UPPER INDUS BASIN

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ABSTRACT:

Population of Pakistan increasing day by day but the storage of water is not enough to fulfill the any drought. 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. All the minor and major river of Pakistan falls into Indus River at different locations. This study examines the climate change and related hydrological impacts resulting from altitudinal variability. Variability analysis in annual temperature, precipitation and stream flow has been made by and climate change has been predicted. The results of this study indicate that maximum and mean temperature have warming trends and have increased with increased in elevation whereas 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 Br. Khairabad and Kharmong, Alam), and Kabul (at Nowshera) Swat (at Kalam) have decreased whereas in River Hunza, Shigar, Astore Chitral, Shoyk. and Gilgit 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 analysis, an awareness regarding present Integrated Water Management (IWM) and steps should be taken to adopt Integrated Watershed Management up-to-date techniques for effective water on-going reform process.

Keyword: Upper Indus Basin; Variability in trends, Climate change; Stream flows, Statistical test, Time series analysis, Annual Temperature, Annual Rainfall

1. INTRODUCTION

A per 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] and reports published by IPCC [3] 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 [4]. Changes vary in space and time domains as affected by local climatic and topographic settings. IPCC [1] reported that 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 precipitation made 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

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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" [5] Stated by Archer, [6], "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 BM3. Future assessment of water resources in Pakistan under climate change is a prerequisite for the planning and operation of hydraulic equipment [7]. 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 [8], further it will be helpful for planners As per previous studies, due to wide variation in topographic and meteorological parameters, different trends has been observed in different climatic regions of the country [9]. 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 regime depends on the melting of the winter snow, a glacial regime and the precipitation regime depends on simultaneous rainfall [11] 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. Khalida et al (10) also analyzed the annual rainfall data of upper Indus basin.

2. STUDY AREA

The Upper Indus Basin is 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. Due to unavailability of data in China and India, so study area was confined in catchment carrying in Pakistan boundary and catchment of Indus basin with in and out of Pakistan boundary is shown in Figure 2-1. 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 Figure. 2. The catchment area at Khairabad point is 312818 km2. Most of area of this catchment is lies in China and India.. 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, Khan Khawar, 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). 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 4-1.

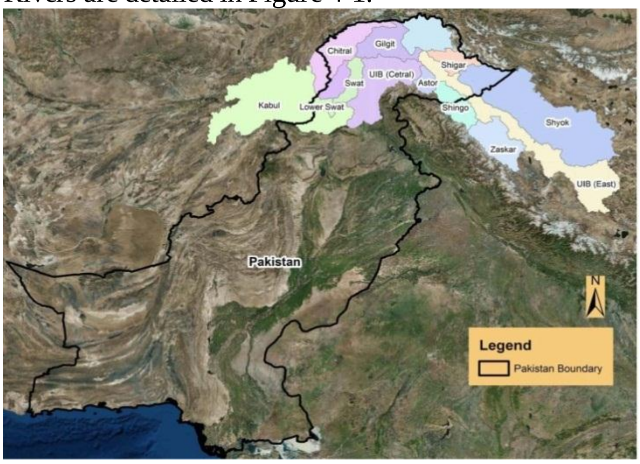

Figure 2-1: Map showing UIB (Study Area) with in and out of Pakistan Boundary

3. DATA COLLECTION

Sixteen climatic stations (CS) were selected for the analysis and the selected stations location, elevation and annual temperature is shown in Table 4-1 and climatic stations location is given in Figure 4-1. The data of these stations were collected from Pakistan Surface water Hydrology Project (SWHP), Water and Power Development Authority (WAPDA), and Pakistan Meteorological Department (PMD) for period (1960 to 2013). The mean monthly maximum and minimum were calculated for each year of the daily maximum daily minimum and daily average temperatures. The data is also missing replaced via mean linking the earlier year data with subsequent years. Stream-flow measurement in UIB is of the WAPDA-SWHP project conceded starting in 1960 with original records. Stream flow data of selected sixteen climate stations is shown in Table 4-2. The stream flow gauges are installed in all sub-basins of UIB at different locations which are shown in Figure 4-1. The stream gauges have a wide range of drainage area from 262 km2 to 286,000 km2. 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 4-2. The data of these sites were for period 1961 to 2013.

4. METHODOLOGY

The rationale of the documentation trend is to determine whether the value of the random variable usually decreasing / increasing over a certain time [12]. Parametric or nonparametric statistical tests have been used to solve, whether the trend is statistically significant [13]. The analysis was carried out for the time series mean values; these steps include essentially: (i) the Analyze of serial correlation effect; (ii) Identification "of trends by using the Mann - Kendall test" [14] Spearman test and linear trend methods; (iii) Estimation of 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" [15]. In particular, [16] 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 [16] explained 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, [17] 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, [18] have also 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 Tabari, [19]. We have integrated the recommendations in this study and accordingly prospective statistically considerable trends in temperature examination (x1, x2. . . xn) [16] 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

$$Y_i = x_i - (\beta - \mathrm{i})r^2 \qquad 1$$

Compute the lag-1 serial correlation coefficient (designated by r1)" [16]. Should the designed r1 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; [21] analyzed "If the calculated r1 is significant, prior to application tests, then the „pre-whitened‟ time series could be obtained" [22]:

$$Y_i = Y_i - rY_{1-i} + (\beta * \mathrm{i}) \qquad 2$$

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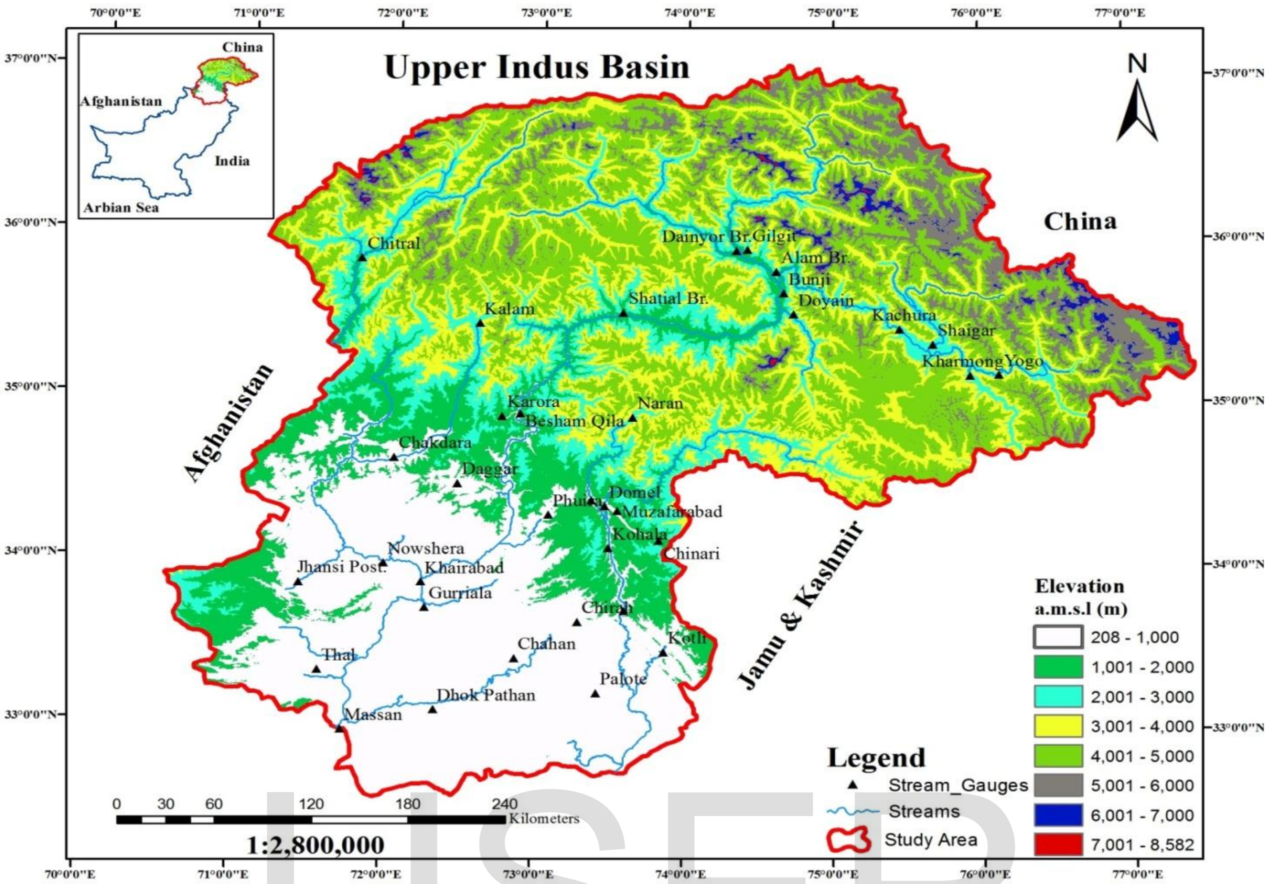

Figure 4-1: The Upper Indus Basin confined in Pakistan boundary showing rivers, stream gauges and elevation.

Table 4-1: List of climatic stations in the study

Sr. #	Station	Lat	Long	Elevation	Annual Temperature (°C)		
				(m)	Max.	Min	Mean
1	Astore	35.2	74.5	2168	15.6	4.1	10.5
2	Bunji	35.6	74.6	1372	23.8	11.4	13
3	Cherat	33.5	71.3	1372	21.5	13.2	17.6
4	Chilas	35.3	74.1	1250	26.4	14.1	16
5	Chitral	35.9	71.8	1497.8	23.3	8.6	16.7
6	Dir	35.2	71.9	1375	22.9	8	13.7
7	Drosh	35.4	71.7	1463.9	24.1	11.3	17.2
8	Gilgit	35.6	74.2	1460	23.9	7.6	11.3
9	Gupis	36.1	73.2	2156	18.7	6.7	15.6
10	Kakul	34.1	73.2	1308	22.8	10.9	10.8
11	Kohat	34.0	72.5	1440	29.3	16.9	5.5
12	Parachinar	33.5	70.1	1725	21.3	8	73.7
13	Peshawar	34.0	71.5	320	29.5	16.1	23.9
14	Risalpur	34.0	72	575	29.6	14.5	22.3
15	Saidu Sharif	34.4	72.2	961	26	12	19.4
16	Skardu	35.2	75.4	2317	18.6	4.9	11.6

Table 4-2: List of stream flow gauges used in the study area and their characteristics

Sr.No.	Stream flow Gauge	Lat. (dd)	Lon. (dd)	River	Catchment Area (km2)	Elevation (a.m.s.l) (m)	Mean Annual Stream
1	Alam Br.	35.8	74.6	Gilgit	27193	1280	638
2	Besham	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	Gorban	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

4.2 Mann Kendall test

Zhang, [23] pointed that Mann initially performed MK test, Kendall [24] are then derived the distribution of the test statistic. Extensively used Mann Kendall test is manipulated for investigate trends within climatological studies by [25],. Yi et al; [26] analyzed that there are two advantages to using this test. Wang, et al; [25] submitted, "It is a non - parametric test and does not require the data to be normally distributed". Hossein, [27] 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 [23]. According to Yu [28] "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:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} Sgn(x_i - x_k) \qquad 3$$

Where sgn (xj - xk) is "an indicator function that takes on the values 1, 0 or -1 according to sign of difference (xj - xk), where j > k" [29 and 30].

$$Sgn(x_j - x_k) = \begin{bmatrix} 1 & if\ x_j - x_k > & 0 \\ 0 & if\ x_j - x_k = & 0 \\ -1 & if\ x_j - x_k < & 0 \end{bmatrix} \qquad 4$$

Yan, [31] analyzed, the values "xj and xk 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; [21]:

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

q= the No. of tied groups and tp is the No. of data in the group p [31]. 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" [32]:

$$Z = \begin{bmatrix} \frac{s-1}{VAR(s^{0.5})} & if\ S > & 0 \\ 0 & if\ s = & 0 \\ \frac{S+1}{VAR(S^{0.5})} & if\ < & 0 \end{bmatrix} \qquad 6$$

The trend was evaluated using Z values. positive value of Z an upward (warming) trend while negative value downward trend (cooling trend)". Statistics "Z has a normal distribution" [32]. The insignificant assumption, Ho stands true if there is no trend and thus uses standard normal table to decide whether to reject Ho. For investigation whichever upward or downward trend ("a two-tailed test") inference identical Ho remains "rejected if the absolute value of Z is greater than Z 1-a/2, where Z 1-a/2, was obtained from standard normal" tables [32]. In this study existence and importance of trend was evaluated with α values that is $\alpha \leq 0.1$.

3.1. 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, [17] as follows:

$$Q = \frac{x_j - x_k}{j-k} \qquad If\ J > k \quad 7$$

"Where xj and xk are the annual values in the year j and k respectively" described by Xuedong (2008) Suggested by Sujatha, [33], 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". Yan, [31], "N values of Qi were ranked from smallest to largest and the Sen"s estimator" was computed as follow:

$$Sen,s\ Estimator = Q_{[(N+1)/2]} \quad if\ N\ is\ odd\ and \frac{1}{2}(Q_{\frac{N}{2}} + Q_{[\frac{N+2}{2}]} \quad if\ N\ was\ even$$

Finally, by consulting Tabari, [34], Qmed 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 precipitation, temperature and stream flow in the climatic stations and stream gauges of UIB at different locations were found over the periods 1961-2013. The analysis has been carried out on annual time series. The percentage of stations with decreasing and increasing trends as well as significant trends is shown in Figure 5-1. To examine the spatial consistency of the observed trends, maps have been created displaying with increasing and decreasing trends. The spatial distribution of trends and changes in precipitation, temperature and stream flow are discussed in preceding sections.

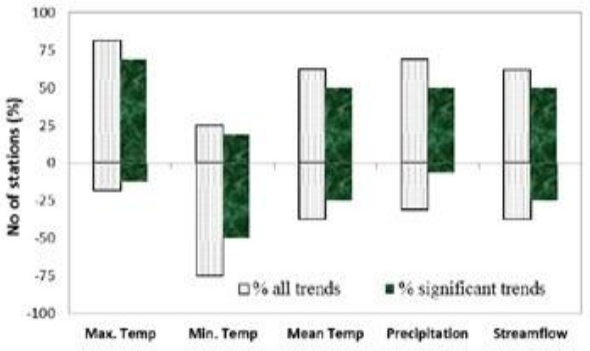

Figure 5-1: Percent number of stations with negative (downward)and positive (upward)

5.1 Variablity in Temperature Trends

Analysis on the on the Annual maximum temperature have indicated overall trend of the region is shifting towards warming trends for the period of 1961 to 2013 which is a major sign of climate change. Out of sixteen climate stations Cherat, bunji and Cherat shows decreasing (negative)tends in annual maximum temperature. At the Skerdu station the highest warm in trend has been observed i.e with rate of 0.49 0C per decade at 99.9% significant level which is alarming because it's a very important zone of UIB. The warming trend is observed in the stations Gupis, Drosh, Chitral, Astore, Dir per decade temperature is increasing 0.22, 0.23, 0.28, 0.21 0C respectively with maximum significant level of 99.9%. Parachinar and Kohat stations are shifting towards warming trend with rate of 0.18and 0.27 0C per decade with 99% significant level. Annual maximum temperature of Peshawar also moving warming trend with the rate of 0.14 0C per decade at 95% significant level. s Risalpur and Chilas showed warming trend but statically not significant. The annual maximum temperature decreased with the rate of 0.03, 0.38 and 0.18 0C per decade at Bunji, Cherat, and Kakul respectively as shown in Figure 5-2. The analysis of minimum and mean temperature at sixteen climatic stations using Mann-Kandal test and Sen,s is shown in the Figure 5-3 and Figure 5-4 respectively. Upward and downward arrows shows per decade increase and decease in temperature. 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 2013. The analysis of maximum, minimum and mean temperature for the selected stations is shown in Figure 5-2, Figure 5-3 and below respectively. The upward and downward arrows show per decade increasing and deceasing trends.

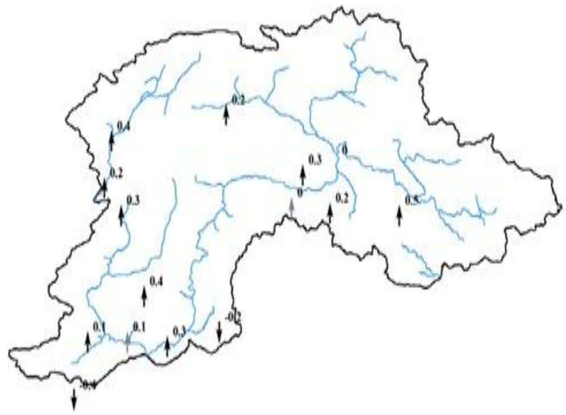

Figure 5-2: Spatial distribution of maximum temperature trends detected by Mann-Kendal and trend values estimated by Sen's method showing change in °C per decade (Down and up arrow shows negative and positive trends

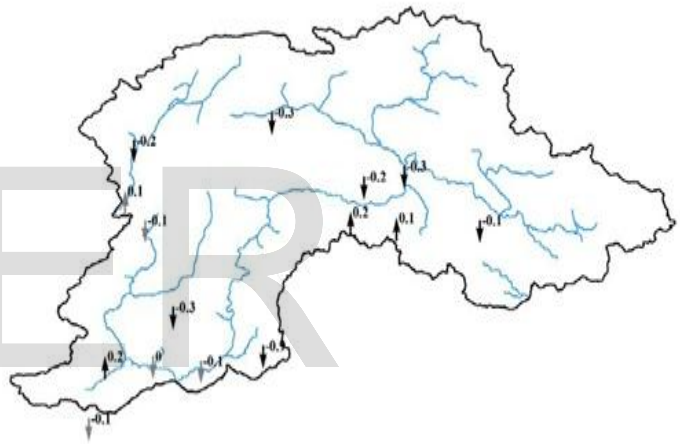

Figure 5-3: Spatial distribution of minimum temperature trends detected by Mann-Kendal and trend values estimated by Sen's method showing change in °C per decade (Down and up arrow shows negative and positive trends

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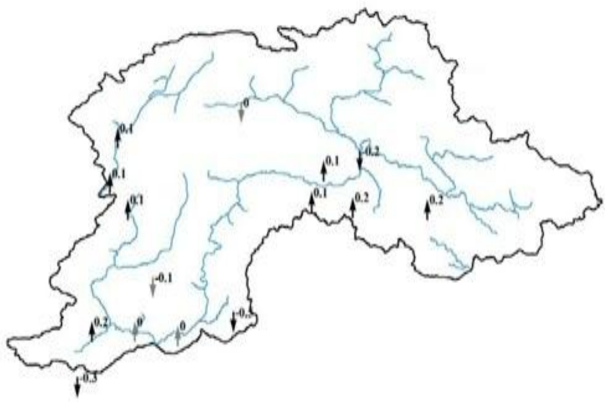

Figure 5-4: Spatial distribution of mean temperature trends detected by Mann-Kendal and trend values estimated by Sen's method showing change in °C per decade (Down and up arrow shows negative and positive trends

5.2 Variablity in Precipitation Trends

The results of analysis by applying Mann-Kendall besides Sen slope estimation methods; annual rainfall were summarized in Figure 5-5. At ten (10) stations out of sixteen (16) stations, the annual n precipitation has been increased for the period 1961 to 2013.At the stations Risalpur, Bunji, Chilas, and Peshawar and Risalpur annual precipitation with highest significance level (99.9%) was observed with the rate 40.24 (6%) , 16.41 (9%), 40.33 (9%) and 9.41 (6%) mm per decade respectively. At the stations Skardu, Giligit and Gupis increasing trend of annual precipitation has been observed with 99% % significance level and per decade increase in annual rainfall is 16.81(8%), 5.18 (4%),and 3.72 (2%) respectively. Chitral station showed 95% significance level with rate of 22.65 (5%) mm per decade. There are also some stations where annul maximum rainfall is decreased for period 1960-2013. At the stations Parachinar, Drosh, Cherat, Dir, Kohat and Astore 1.84 (1%) 9 (1%),30 (5%),41 (3%), 12.49 (2%) and 7.27 (1%), mm per decade respectively but all these were statistically inconsequential. The spatial distribution of annual rainfall trends in shown in Figure 5-5. The upward and downward arrows shows perdecade increasing and deceasing trends.

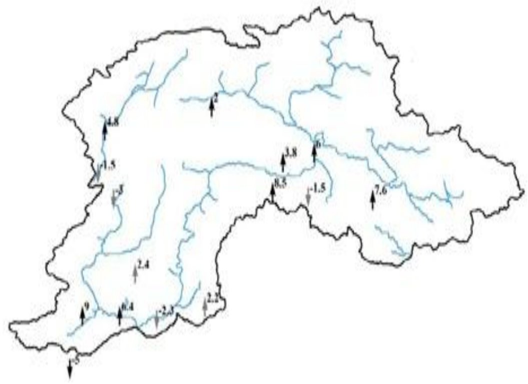

Figure 5-5: Spatial distribution of annual rainfall trends detected by Mann-Kendal and trend values estimated by Sen's method showing change in % per decade (Down and up arrow shows decrease and increase trends)

5.3 Altitudinal Impact on Climate Change Variation in Climate Change with Elevation

Analysis of maximum, minimum, mean temperature and annual rainfall has been made with elevation which is shown in Figure 5-6 below percent per decade in maximum temperature increase with increase in elevation whereas minimum temperature deceases with increase in elevation. Mean Temperature is also increasing with elevation. 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.

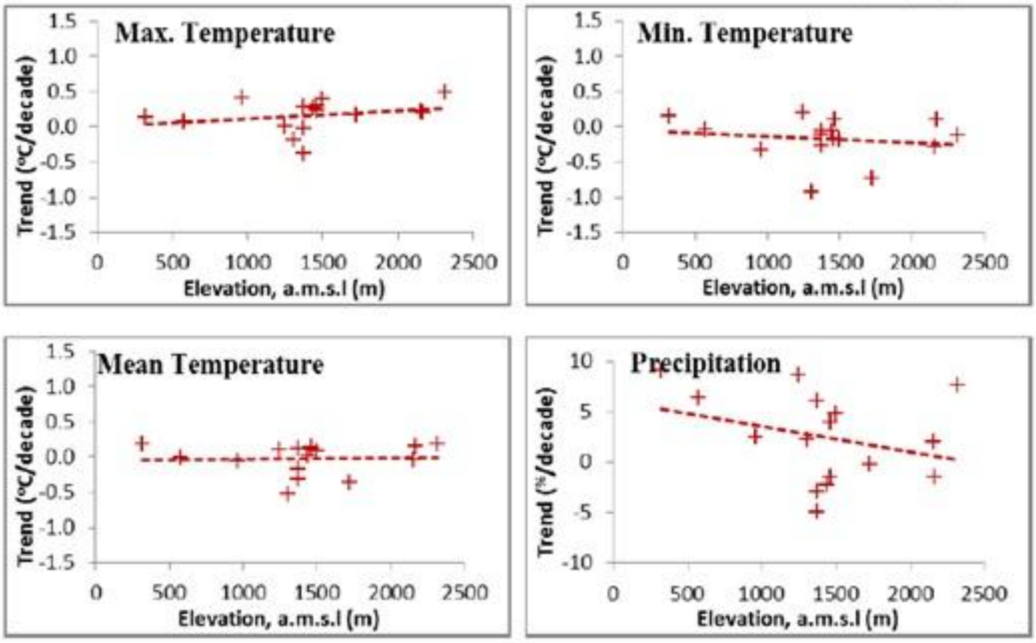

Figure 5-6: Distribution of trends of precipitation, mean, maximum and minimum temperature with elevation.

5.4 Variablity in Stream flow Trends

The annual discharges of Indus river at Besham Qila shows increasing trend with the rate of 6%. Sharif, et al; [35] also analyzed the Indus river flows at Bisham Qila for the period of 1969 to 1995 and found the increasing trend. On the other hand the flow at Dainyor has decreased significantly (p=.006) up to 29% for the record length (1966 to 2010) and has also found decreasing trend for period 1966 to 1995 [35]. The trend in Rivers Shyok at Yogo and Indus at Kharmong, Kachura and Bunji has the same tendency as detected by Sharif, et al; [35] 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 up to 15%. The River Swat at Kalam has subsiding trend whereas Swat River at Chakdara and River Chitral at Chitral showed cumulative tendency.

The average annual runoff showed increasing 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 up to 5% (1 0C) 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 ^{0}C) temperature.

6. CONCLUSIONS

On the basis of 53 (1960-2013) years' temperature, precipitation and stream flow data of sixteen stations, the following conclusion has been drawn.

1. Mann-Kendall test and Sen"s method has been applied on the data and After the analysis on the selected sixteen climate stations in Upper Indus basin that there is increase in annual mean and maximum temperature for the selected period.
2. There is a maximum increase in annul maximum temperature of 0.49 ^{0}C per decade at 99.9% significant level in the Gilgit station which is alarming because it's a very important zone of UIB because most of the region around the gilgit is covered with snow. As a result of increase in temperature glaciers are melting.
3. In lower region of UIB Cherat, bunji and Cherat of the regions of upper Indus basin mean annul temperature has been reduced. It is concluded that in upper region of UIB the annul maximum temperature is increasing whereas in lower region it is decreasing.
4. In high elevated areas the mean and maximum temperature is increasing where as in low elevated areas per decade

minimum temperature has decreasing trends

5. Out of the selected 16 sixteen climatic stations the annual precipitation in ten (10) stations has been increasing in upper Indus basin. Where as in highly elevated region percent per decade annual rainfall is decreasing and in low elevated area it is increasing.
6. As per annual flow analysis it is concluded that Indus river at kachura, Shoyk river at yogu and Shinger river at Shigar showing increase in flow up to 5%, 9% and 7% respectively. The flow is increasing due to the warming trends in Upper Indus Basin. Whereas average Annul flows of river Kabul at Nowshera has decreased with p value 0.15 upto 15%.
7. It is concluded from the analysis of temperature, precipitation and stream flow that the phenomenon of the climate change is occurring in the upper Indus basin, it is alarming for the planner and water experts to guide and adopt the Integrated Watershed Management to fulfill the fore coming food and water demands.
8.

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