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The longterm trend of temperature and precipitation of Kunduz River Basin, Afghanistan

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***Abstract*— This study aims to analyze the past temperature and precipitation of Kunduz river basin which is located in the northern part of Afghanistan. The annual and seasonal temperature and precipitation of five weather stations at the basin analyzed over period of 1961-2014. The Mann-Kendall and Sen's slope statistical tests were used to detect the positive or negative trend of the past maximum temperature (Tmax), minimum temperature (Tmin) as well as precipitation (Precip). The overall Tmax and Tmin showed warming over study period. The statistical results demonstrated a considerable increase of temperature at the fall and summer seasons. The Tmin indicated highest warming in autumn season at the rate of 0.02˚C/Year, 0.02˚C/Year and 0.03˚C/Year at Bamyan, Taloqan and Kunduz weather stations respectively over period of 1961-2014. However, the precipitation depicted declining at the majority weather stations. The upper catchment of basin represented decrease of precipitation. The most significant downtrend of annual precipitation obtained at the Bamyan and Taloqan meteorological stations. In contrary, Kunduz station indicated rise of annual precipitation pattern. The comparison of seasonal time series of precipitation demonstrated larger drop in summer months. The rate of decline 0.07 mm/year, 0.026 mm/year and 0.8 mm/year at Baghlan, North Salang and Kunduz stations respectively. In addition, both increase of temperature and decrease of precipitation is considerable concern regarding to irrigation water at summer time.**

***Keywords*— Tmax, Tmin, Statistical test, trend analysis, Kunduz River Basin.**

I. INTRODUCTION

The climate change is explained by using statistically in the mean or the variability climate parameters over a period [1]. In generally, the variation of observed atmospheric parameters such air temperature, precipitation and extreme climate events are referring as climate change. In addition, the recent report AR5 of Intergovernmental Panel on Climate Change (IPCC) conclude; the global mean surface temperature has increased since the late 19th century [1,2]. Each of the past three decades has been successively warmer at the earth's surface than any the previous decades in the instrumental record, and the decade of the 2000's has been the warmest. The globally averaged combined land and ocean temperature data, shows a warming of 0.85°C, over the period 1880–2012[2]. The main cause of this change in manmade greenhouse gas production since industrial development. The extensive production and concentration of to the atmosphere leading the greenhouse effect on the earth surface [3].

In general, climate of Afghanistan is varying from arid to semi-arid, which is completely defined by geographical location. The high altitudes represent lower temperature and higher snowfall and precipitation. The low land temperature is warm but receiving less precipitation within the year. The climate change is challenging issues and its implication will be very complex at the country level as well as basin level. For example, the rises of temperature will lead earlier and more rapid spring snow melt, consequently creating flash flooding risks which large area of country covers with snow ice. The snow fall occurs during the winter on top of Hindu Kush mountains of course, the precipitation occurs between November and April with peaks in February, March. On the hand, the low precipitation is making water resources scarcer. Subsequently, lead droughts which directly effects on natural resources as well as agricultural products and food security. Accordingly, about 80 percent of population of Afghanistan rely on that [4]. The overall objective of this study was to analyze the past climate of Kunduz sub basin of Amu River Basin of Afghanistan which host around 3 million people that highly dependent to natural resources.

Still, there no comprehensive research carried out about the past climate of the basin. The most important aims of this paper are to examine the longterm trend of past climate parameters such as maximum temperature (Tmax), minimum temperature (Tmin) and precipitation of Kunduz River Basin by using Mann-Kendell test and Sen's Slope statistical tests which is widely used for trend detection of past climate and, to investigate the annual and seasonal changes in climate parameters such as Tmax, Tmin and precipitation during the period of 1961-2014. The analyzing of past climate may lead to understand the variation of Tmax, Tmin and precipitation at the basin level. the study outcomes could be used at policy and planning levels such as water management, agriculture and environmental changes issues for better decision making at the future development projects.

II. MATERIAL AND METHODS

A. Study area

The Kunduz River Basin located in the northern part of Afghanistan. The total area of river basin about 35000 km2. the geographical location the river basin lies approximately between 66.70-70.30E longitude and 34.80- 37.20N latitude. The basin is one of major watershed tributary of Amu Darya

River Basin. Amu Darya is the longest international share river in Central Asia. From its headwaters at an altitude of 4,900 meter above the sea level on the Wakhan mountain's glacier in Afghanistan, it travels 2,540 km, of which 1,250 km are within the land of Afghanistan or along its border with the Tajikistan. However, after passing the frontier settlement of Khamaab area of Afghanistan, it flows to the Central Asian countries such as Uzbekistan and Turkmenistan and falls into an inland sea, called Aral Sea. Of course, it is the main source of irrigation and drinking water supply of riparian countries [5].

Meanwhile, Kunduz rivers is sourcing from the high-altitude part of Hindu Kush mountain and Baba mountain in the central part of Afghanistan. The river is running as usable water resources for household, agriculture use and environmental flow in most part of the basin. Kunduz River itself has two major tributaries such as Taloqan (Khanabad river) and upper Kunduz (Bamyan river) rivers which is originating from Hindu-Kush and Baba mountains respectively. The Bamyan river which is upper Kunduz river originate from Baba and Hindukush mountain with tributaries such as Bamyan and Kohmard rivers which joins at the Doab Bamyan and then flowing through Baghlan province. At the Dushi area of Baghlan province another stream tributary by the name of Shirin Tagab river joins to this river. Subsequently, passing the center of Baghlan province the river flows to along the lower part of Baghlan and parts of Kunduz province. Finally, at the downstream the two rivers such as Baghlan river (upper Kunduz river) and Khanabad river joining and establishing the Kunduz river. after passing some low land of Kunduz province the river drains to Amu Darya River Bain.

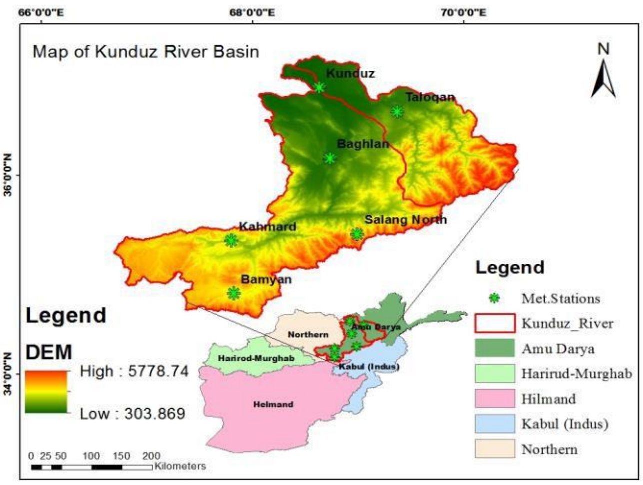

Figure (1) location map of the study area and weather stations.

Digital elevation model (DEM) map represent the elevation of study area was downloaded from USGS public geoportal database with 90-meter resolution. The DEM map of the study area clipped by ArcGIS 10.1 Clipping tool. DEM map shows the upstream with high elevation and downstream with lowlands. The given basin elevations between 5778.7 to 307.6 meters above the mean sea level [6].

B. Data collection

The observed monthly maximum temperature (Tmax), minimum temperature (Tmin) and precipitation data set of 5 meteorological stations were collected from Afghanistan Meteorological Authority and one rain gauge station from ministry agriculture and irrigation and livestock(MAIL). The detail information about the weather station are listed in the table of (1) and the geographic location of stations mentioned.

The climate data set were collected from Afghanistan meteorological authority had gaps in term of records.as for solving the gaps of observed the supplementary climate data set is used. The supplementary data for filing the gaps were downloaded from Climate Research Unit (CRU) at the University of East Anglia. The climate research unit constructed high spatial resolution at the 0.5˚x0.5˚ grids degree for the globe with time span of Jan. 1901 - Dec. 2012 without the future scenarios [7], [8]. Afterwards, the data format visualized by using ArcGIS10.1, the gridded data of (x,y) coordinates must matches with each location weather stations. Lastly, the CRU climate variables such as maximum, minimum temperature and precipitation were used for filling the gaps of ground recorded data set.

Table (1) the detail of data set used in this study

Observed data set from Afghanistan Meteorological Authority (AMA)						
Station	**Lat (D)**	**Long(D)**	**Alt (M)**	**Past period**	**New record**	**source**
Bamyan	34.81	67.82	2550	-	2003-2014	AMA
Baghlan	36.17	68.73	550	1961-1972	-	
Salang North	33.41	68.99	3365	1961-1977	-	
Taloqan	33.64	69.37	804	1968-1978	2004-2014	
Kunduz	37.01	69.1	460	-	2005-2014	
Kohmard	35.34	67.80	1890		2005-2014	MAIL
Global data set						
Name	**Grid resolution**		**Source institute**		**source link**	
	Lat (D)	**Long(D)**				
CRU data	0.5	0.5	University of East Anglia		http://www.cgiar-csi.org/data	

C. Climate of the basin

According the recorded meteorological data at the station level, the reality climate of Kunduz river basin is defined by geographical location. The temperature variable of study area dominated of elevation, stations are located at higher altitudes areas shows colder weather than the lowland of areas of the basin. For example, North Salang with elevation of 3366 meters above the mean sea level shows the warmest weather (+14.29˚C) at July and Kunduz station with elevation of 460 meters above mean sea level shows hottest temperature of (+39.73˚C) at the same month of July. However, minimum temperature follows the maximum temperature patterns entire the basin. For instance, Tmin at North Salng station recorded (-14˚C) at the month of January and (-0.5˚C) recoded at Kunduz station from more detail figure (2 a,b). Analysis of monthly temperature depicted that July is warmest month and January is coldest month entire the year, in order of seasonal perspective, the summer months are warmest season and winter months are coldest time at the whole basin.

In this study, climate of Afghanistan divided in four seasons while these seasons represents as Spring (March, April, May), summer (June, July, August), Autumn (September, October, November) and Winter (December, February, March) months which is commonly using in yearly calendar of country [4,9].

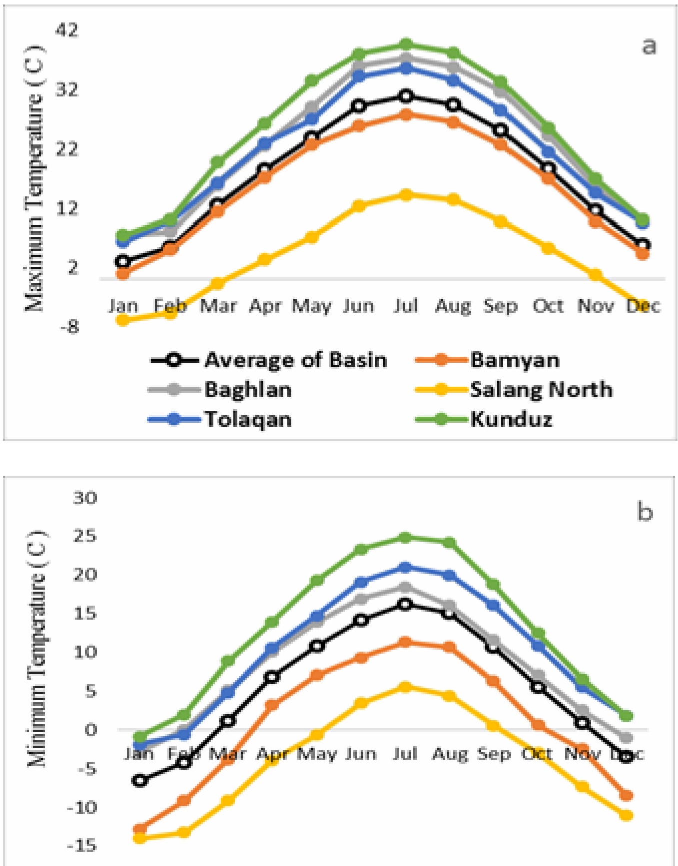

Figure (2a,b) Distribution of average temperature (a,Tmax b,Tmin) from all meteorological stations in the Kunduz river basin.

In addition, distribution of precipitation at the Kunduz basin is totally complicated. The North Salang station with higher elevation receives more precipitation than all stations in the basin. For example, during the spring month's highest values (194.85mm) of rainfall and summer season lowest values (5.46mm) of rainfall recorded at this station figure (3). However, the average monthly statistic of precipitation shows highest values at the spring months and lowest values at summer months.

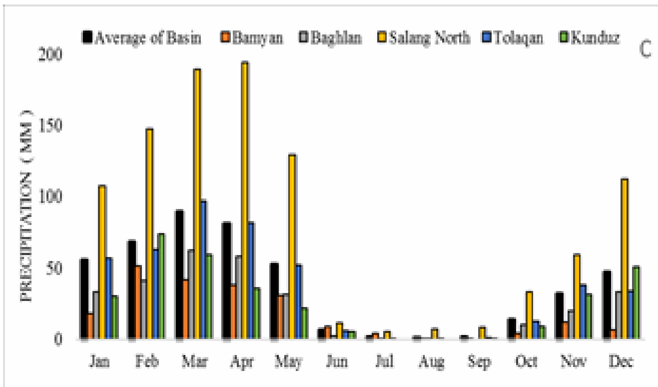

Figure (3) Distribution of average precipitation from all meteorological stations in the Kunduz river basin.

D. Bias Correction method

After extracted Climate Research Unit (CRU) data set for maximum, minimum temperatures and precipitation. The agreement between ground and supplementary obtained data cheeked by statistical parameter such as correlation coefficient and the standard deviation measures. The CRU data was shown biasness; the simple multiplicative shift method was used to correct the biasness of the CRU monthly data [10]. The equation (1 and 2) applied for correction of precipitation and temperature.

$$X'i = Xi\,\frac{\bar{X}_{obs}}{\bar{X}_{CRU}} \qquad (1)$$

$$X't = Xt + (ft) \qquad (2)$$

Where,

$$ft = (\bar{X}_{obs} - \bar{X}_{CRU}) \qquad (3)$$

Where, X'i, and Xi are the corrected and raw precipitation, , observed and CRU precipitation. Similarly, the X't and Xt are the corrected and raw temperature, the ft is correction factor for observed and CRU temperature. The bias correction method was applied in monthly basis for 5 weather stations from 1961-2014 time periods. The detail of statistical test standard deviation, correlation of co efficient and Root Mean Square Error shown in table(2).

E. Trend analysis technique

In this study, the Mann-Kendall (Mann 1945, Kendall 1975) test was used. The statistical test is widely used for analysis of trend in climate parameters. There are two advantages of using this test. First, is a non-parametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to the missing values [11] and [12]. In this test, the null hypothesis H0 is there is no trend the observation randomly ordered in time. The alternative hypothesis H1 where there increase or decrease of monotonic trend.

The test statistic S, is computed by Eq. (4)

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} Sgn\,(Xj - Xk) \qquad (4)$$

Where, *xj* and *xk* are the annual values in years' j and *k*, *j* > *k*, respectively, and

$$Sgn(Xj - Xk) = \begin{bmatrix} 1 & if\,(Xj - Xk) > 0 \\ 0 & if\,(Xj - Xk) = 0 \\ -1 & if\,(Xj - Xk) < 0 \end{bmatrix} \qquad (5)$$

The variance of *S* is computed by the following equation which consider that ties may be present:

$$Var(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} tp(tp-1)(2tp+5)\right] \quad (6)$$

Where, q is the number of tied groups and t_p is the number of data values in the p^{th} group.

The values of S and VAR(S) are used to calculate the Z value. In cases where the sample size n > 10, the standard normal variable Z is compute by using given equation.

$$Zmk = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if\ S < 0 \end{cases} \quad (7)$$

A positive or negative value of Zmk indicates an upward or downward trend. In Mann-Kendal test the two-tailed test is used for four different significance levels as □: 0.1, 0.05, 0.01 and 0.001[8].

F. Sen's Slope estimator

To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method was used. The Sen's method can be used in cases where the trend can be assumed to be linear [11], [12] and [13].

$$Qi = median\left(\frac{xj - xk}{j-k}\right)\ \forall K < j \quad (8)$$

Where xj and xk are data values at times j and k (j > k), respectively.

III. RESULTS AND DISCUSSION

The statistical tests performance of Tmax, Tmin and precipitation raw CRU, Corrected CRU and observed climate data set for all stations cheeked in term statistical controlling parameter for making sure the internal correlation of observed and supplementary gathered data set. the standard deviation (STD), correlation coefficient (R) and Root Mean Square Error (RMSE) are applied. The following table shows the statistical performance of CRU data set before and after bias correction for Tmax, Tmin and precipitation at Kunduz Rivers basin.

Table (2) summary of statistical test observed and CRU of Tmax, Tmin and precipitation of study area 1961-2014.

Station	Climatic parameter	Control	OBS	CRU Raw	CRU Corrected
Bamyan	Tmax	STD	9.24	8.67	8.49
		R		0.97	0.99
		RMSE		11.31	8.03
	Tmin	STD	8.05	7.57	7.42
		R		0.95	0.97
		RMSE		7.50	4.04
	Precipitation	STD	18.04	42.80	30.90
		R		0.21	0.74
		RMSE		57.99	28.83
Baghlan	Tmax	STD	10.79	10.55	10.41
		R		0.98	1.00
		RMSE		22.79	1.01
	Tmin	STD	7.07	8.58	8.45
		R		0.98	0.99
		RMSE		11.76	2.55
	Precipitation	STD	21.94	30.42	22.51
		R		0.79	0.96
		RMSE		36.35	7.51
Taloqan	Tmax	STD	10.18	10.23	10.10
		R		0.97	1.00
		RMSE		18.24	2.11
	Tmin	STD	7.93	8.13	8.02
		R		0.98	1.00
		RMSE		9.09	2.82
	Precipitation	STD	32.22	38.83	28.59
		R		0.46	0.98
		RMSE		57.69	6.64
Kunduz	Tmax	STD	11.39	10.59	10.43
		R		0.99	1.00
		RMSE		25.39	1.37
	Tmin	STD	8.88	8.28	8.14
		R		0.99	1.00
		RMSE		12.77	2.47
	Precipitation	STD	23.59	29.72	21.14
		R		0.81	0.89
		RMSE		38.85	10.66

A. Analysis of past temperature

In this study the analysis of historical Tmax and Tmin done by Mann-Kendall statistical tests to obtain upward or downward trends of the mentioned climate parameters.

Firstly, The Mann-Kendall and Sen's Slope statistical tests applied for detecting of seasonal and annual trends of Tmax over period of 1961–2014. Therefore, the seasonal results of the tests Tmax showed the increasing trend in all stations at spring, summer, autumn as well as annual except the winter season which is detected cooling but not significant. In addition, all stations indicated warming trend in the spring season, which is the spring warming leads early melting of snow covers within the Hindukush and Baba mountain which plays key role of water storage of Kunduz river basin as well as entire country. At the same time, at spring season rapid melting of snow ice associated with flooding. The flood is happening due to excess amount of heavy rainfall or snow cover melting of higher elevation of Hindu Kush and Baba mountain; the heavy rainfall consequence is flash flood which is make big risks such destruction of house, agricultural land at the sub basin. In addition, the snow ice melting starts from April until July which is the weather is getting warming at thin months. Any early melting of snow covers will be put impacts on water availability in the study area. Of course, summer season warming trend detected higher values than spring as well as than all seasons, the most significant trend in Kunduz station was detected at summer season at (+0.014˚C/Year) at the 95 % confidence level. While, in the autumn season increasing trend was not significant at all stations. Unlike to spring, summer and autumn the statistical test of Tmax at the winter season showed the cooling trend. Moreover, the annual Tmax indicated increasing trend too. The detailed results of the statistical analysis on the seasonal and annual maximum temperature time series were summarized in Table (3). In addition, the statistical test depicted warming trend in spring, summer, autumn seasons, which summer season experienced significant warming but the cooling trend in the winter time is not significant figure (4). On the other hand, the consequents of rising temperature at the spring and summer putting pressure on the melting of snow cover at the northeastern part of Hindu Kush and Baba mountain which is plays the water storage for Kunduz watershed. Thus, early melting and shrinking snow cover is big threat for natural ecosystem as well as for water resources and agricultural crops. Meanwhile, the early snow melting makes flooding at the spring season which is very destructive to infrastructures such as water canals, rangeland, vegetation covers as well as for local community economy which dependent to this resources.

Table (3) values of Zmk test, Sen's slope of seasonal, annual Tmax of basin (1961-2014).

	Spring		Summer		Autumn		Winter		Annual	
stations	Zmk	SS	Zmk	SS	Zmk	SS	Zmk	SS	Zmk	SS
Bamyan	0.93	0.01	1.49	0.01	1.90	0.02	-0.46	-0.01	1.47	0.01
Baghlan	0.24	0.01	0.86	0.01	1.04	0.01	0.32	0.01	0.82	0.01
Salang North	1.23	0.02	0.29	0.00	0.86	0.01	-0.92	-0.01	0.40	0.00
Taloqan	1.92	0.03	-0.10	0.00	1.57	0.02	-0.21	0.00	1.19	0.01
Kunduz	1.52	0.02	2.05	0.014*	1.17	0.01	-0.04	0.00	1.59	0.01

* Statistically significant at the 95 % of confidence levels.

Table (4) values of Zmk, Sen's slope test of seasonal and annual Tmin of basin (1961-2014).

	Spring		Summer		Autumn		Winter		Annual	
Stations	Zmk	SS	Zmk	SS	Zmk	SS	Zmk	SS	Zmk	SS
Bamyan	0.30	0.00	2.53	0.02*	2.22	0.02*	0.38	0.01	1.93	0.02+
Baghlan	0.35	0.00	-0.51	0.00	1.46	0.01	0.12	0.00	0.78	0.01
Salang North	0.27	0.00	-0.20	0.00	1.17	0.01	-0.66	-0.01	0.22	0.00
Taloqan	1.39	0.01	0.39	0.01	2.88	0.02**	1.05	0.01	2.48	0.02*
Kunduz	1.13	0.01	1.90	0.01+	3.80	0.03***	0.78	0.01	2.78	0.02**

***, ** and * Statistically significant at the 99.9%, 99.5% and 95 % of confidence levels.

Furthermore, at the regional level of study area the statistical analysis results concluded; Bamyan, Baghlan, North Salang and Kunduz provinces experienced warming at the spring, summer and autumn seasons as well as annual scales. In the contrast, at the winter season months the station of North Salang and Kunduz illustrated cooling trend. However, another study done by Fiddes.J; the upstream of Kunduz river basin is Hindu Kush and Baba mountains and some parts hosts for snow covers experienced a longterm rise in temperature of 1.32˚C during the 20th Century [14].

Secondly, the MK test and Sen's Slope estimator test applied for detecting trend of seasonal and annual time series of Tmin over period of 1961–2014. The analysis of Tmin at this basin represented complicated results. Based on seasonal results, the spring season not showed significant trend over study period. In the summer time Bamyan and Kunduz stations experienced warming trend of (+0.02˚C/Year) at the 95% confidence level. In autumn season, all stations experienced significant warming, the rate of rising Tmin at the Bamyan, Taloqan and Kunduz weather stations was (+0.02˚C/Year), (+0.02˚C/Year) and (+0.03˚C/Year) respectively with 95% confidence level. In winter season, both increase and decrease of Tmin founded. In North Salang demonstrated cooling trend vis other station showed positive trend.

Finally, at the annual time series results of Tmin at all stations illustrated increasing trend. for example, at the Taloqan and Kunduz province the rate of warming detected (+0.02˚C/Year) at the 95% confidence level table (4) and figure (5).

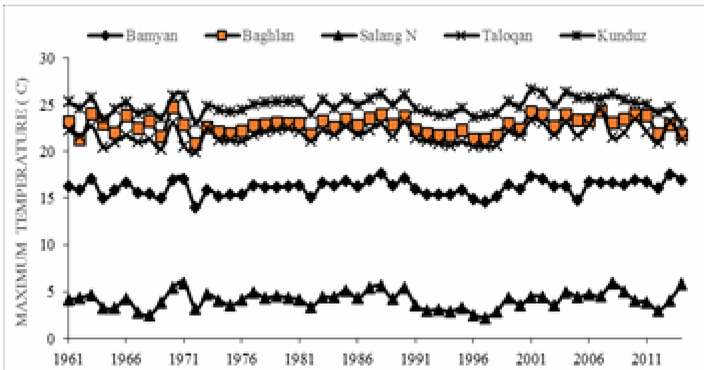

Figure (4) Graph of annual Tmax of all stations of the Basin.

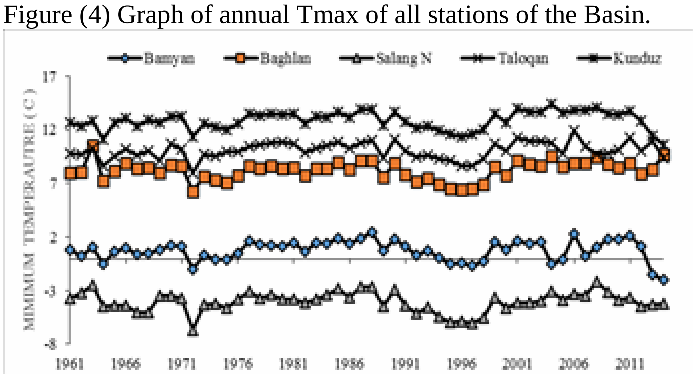

Figure (5) Graph of annual Tmin of all station of the river basin.

Moreover, over all outputs of meteorological stations at the Kunduz river basin illustrated warming. the statistical results conclude; Bamyan and Kunduz provinces experienced warming at seasonal and annual time series. However, Baghlan and Taloqan provinces tended cooling trend at summer and warming at autumn, winter months as well as annual scale. Unlike, the North Salang showed no any trend in spring months. However, a positive and negative trend at autumn and winter time series respectively with no significant consideration.

B. Analysis of pastprecipitation

The MK and Sen's Slope test applied in order to understand the seasonal and annual time series trends of precipitation over past of 1961–2014. According to seasonal statistical outputs, the spring season illustrated decreasing trend over study period. The most significant downward of precipitation was detected in Bamyan and Taloqan stations (-0.96mm/Year) and (-2.43mm/Year) respectively at the 95% confidence level. In contrast, at the summer season, all stations illustrated increasing values of precipitation. For example, the increasing values obtained at stations of Baghlan, North Salang and Kunduz provinces (+0.07mm/Year), (+0.26mm/Year) and (+0.08mm/Year) respectively with 95 percent of confidence level. However, based on recent evidence at the heavy rainfall of 24 and 25 April of 2014 caused flash flooding in northern part of country, and destroyed houses, roads, water related infrastructures and hectares of agriculture lands. At this risky disaster 10 people killed and more than thousands of people affected. Later, another heavy rainfall in June caused a flash flood in Baghlan province, killed over 81 people, 35 people injured and nearly 400 houses extensive damaged, irrigation infrastructure, and road networks affected too [15]. On the other hand, the Kunduz river basin is vulnerable to natural hazards disasters such as heavy rainfall and flooding. During the April, May, June and July months the region faces with frequencies of flooding which consequence of heavy rainfall and early rapid snow melting from the upper catchment of the river basin. The economic loss of flooding is big socio economic challenge for local and rural communities. The proper management mechanism and policies required to reduces risks of such natural hazards specially flooding at the Kunduz river basin of Afghanistan. In autumn season majority of stations indicated increasing of precipitation except Taloqan stations shown decrease in value precipitation. In winter season, the output of statistical analysis illustrated both negative and increasing values of precipitation. For instance, at Bamyan province the rate of decreasing obtained (-0.89mm/Year). However, Kunduz station depicted increasing of precipitation at the rate (+0.87mm/Year) at the 95% confidence level. The detail of statistical outputs of precipitation values summarized in table (5). Another study done by Immerzeel at 2009 about the snow covers and river runoff simulation of h Himalayan river basin. That research also concludes; at the Himalayan mountainous region, there is a significant decreasing trend of snow cover at the upper catchments of Indus basin during the winter months [16].

Table (5) values of Zmk, Sen's slope of seasonal and annual precipitation of basin 1961-2014.

	Spring		Summer		Autumn		Winter		Annual	
Stations	Zmk	SS	Zmk	SS	Zmk	SS	Zmk	SS	Zmk	SS
Bamyan	-2.24	-0.96*	0.94	0.09	0.57	0.06	-2.42	-0.89*	-2.06	-0.46*
Baghlan	-1.28	-0.70	3.85	0.07***	1.25	0.22	1.06	0.35	-0.19	-0.14
Salang North	-1.25	-2.56	2.09	0.26*	0.20	0.17	1.11	1.34	-0.06	-0.10
Taloqan	-3.24	-2.43**	0.37	0.01	0.33	0.08	-1.21	-0.57	-2.78	-2.8**
Kunduz	-0.24	-0.14	2.61	0.08**	1.04	0.25	2.03	0.87*	1.49	0.95
Kohmard	-1.17	-1.65	0.45	0.60	1.17	1.80	-1.07	-2.43	-0.54	-1.78

***, ** and * Statistically significant at the 99.9%, 99.5% and 95 % of confidence levels.

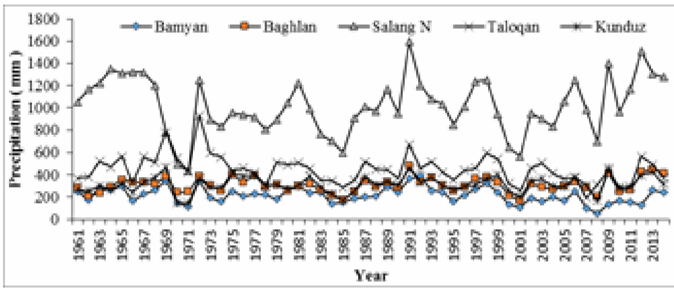

Figure (6) Graph of annual precipitation of all stations at the basin.

In general, the annual time series outputs of precipitation at all stations demonstrated both decreasing and increasing trend. For example, Bamyan and Taloqan provinces represented decreasing values of (-1.46mm/Year) and (-2.8mm/Year) respectively with confidence level of 95 percent. However, Kunduz showed increasing trend table (5) and figure (6).

In addition, at the region level the statistical results indeed Bamyan and Taloqan provinces experienced decreasing of precipitation at spring, winter time series but increase obtained at summer months. However, Baghlan, North Salang and Kunduz provinces illustrated increasing trend at the summer, autumn and winter seasons but the most significant increasing was demonstrated at summer season.

At the annual time series, majority of weather stations illustrated decline of precipitation. This downtrend obtained at Bamyan, Baghlan, North Salang, Taloqan and kohmard stations which is represented decreasing of precipitation at the basin level. In contrary, Kunduz station which is located in downstream and northern part of the basin demonstrated rise of precipitation. Hence, the longterm analysis of precipitation at the upper catchment of Kunduz river basin illustrated decreasing value at winter season as well as annual time scale which is the most snowfall occurs at winter time. Any downtrend of winter precipitation leads the negative impacts on river discharge as well as water resources of the river basin.

CONCLUSIONS

In conclusion, climate change may have considerable impacts on water resources as well as natural resources services of the Kunduz river basin. Therefore, in this study we analyzed the long term historical of both maximum and minimum temperatures and precipitation since 1961.

Firstly, past temperature demonstrated positive trend. Tamx showed small change over study time period. Tmin illustrated significant change over past period. For example, in case of Tmin Bamyan and Kunduz provinces experienced warming of

(+0.02˚C/Year) at the 95% confidence level the summer time. In autumn time, all provinces experienced warming, the rate of rising Tmin at the Bamyan, Taloqan and Kunduz station was obtained (+0.02˚C/Year), (+0.02˚C/Year) and (+0.03˚C/Year) respectively with 95 percent confidence level. In winter season, the North Salang station showed the cooling trend but the other stations demonstrated warming. Finally, at the annual level, the outputs of Tmin at all stations showed increasing trend. For example, Taloqan and Kunduz provinces experienced warming at the rate of (+0.02˚C/Year) at the 95% confidence level.

On the other hand, the historical precipitation pattern depicted decrease at seasonal as well as annual perspectives. At the seasonal time series spring season illustrated decreasing trend over study period. the most significant decrease of precipitation was detected at Bamyan and Taloqan stations (-0.96mm/Year) and (-2.43mm/Year) respectively at the 95 percent of confidence level. In contrast, at summer time, all provinces illustrated increasing trend of precipitation values. For example, rising precipitation values detected at Baghlan, North Salang and Kunduz weather stations (+0.07mm/Year), (+0.26mm/Year) and (+0.08mm/Year) respectively with 95 percent confidence level. In autumn time series, the majority of weather stations indicated increasing of precipitation values except Taloqan stations demonstrated decrease of precipitation value. In winter season, statistical analysis outputs illustrated both negative and positive trend of precipitation values. For instance, at Bamyan province rate of decreasing obtained (-0.89mm/Year). However, Kunduz station depicted increasing of Precipitation values at the rate (+0.87mm/Year) at the 95 percent confidence level. In addition, the annual precipitation illustrated decline at most provinces. For example, the rate of decreasing trend at the Bamyan and Taloqan provinces demonstrated larger values at the rage of (-1.46 mm/Year) and (-2.8mm/Year) respectively over the study time period of 1961-2014.

Finally, the statistical outputs of past temperature of Kunduz river basin demonstrated warming of both maximum and minimum temperatures entire of basin and declined precipitation values at the majority of weather stations except Kunduz station which is represented rise of precipitation at the annual time series. These change of climate parameters such as temperature and precipitation must be take into consideration during the decision and policy making for socio-economic development projects such water resources management, agriculture, food production and environmental challenges incorporation projects.

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