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THE ANALYSIS OF TEMPORAL VARIABILITY, TREND OF PRECIPITATION AND RIVER DISCHARGE OF KUNDUZ RIVER BASIN, AFGHANISTAN

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Abstract:

The aim of this study is to analyze the trend and variability of precipitation and streamflow in Kunduz River Basin which is located to north-eastern part of Afghanistan. The Mann Kendall and Sen's Slope statistical test were applied to understand the precipitation variability for 1961-2010 and about one-decade recorded streamflow respectively. However, the monthly precipitation illustrated significant downward trend in spring months and upward trend in summer season, the calculated annual precipitation represented decreasing trend in the river basin. The statistical analysis of monthly and annual river flow depicted dropping values of stream discharge as well which prove the correlation of both important variables. Therefore, the calculated time series of both hydro-climate elements showed decreasing, the basin experienced drying, the decisionmakers must consider proper water resource management project to reduce the negative implication of the change and boost the temporal water resource governance as well.

Keywords: *Trend; Statistical Test; Precipitation; Streamflow; Kunduz River Basin.*

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1. Introduction

Afghanistan has predominantly dry continental climatic condition, entire the country about 80 percent of precipitation occurs as snow during winter months in areas where elevation is greater than 2,500 m above the mean sea level. The Hindukush range which is the western extension of the Himalaya mountain range, divides the country from east to west in two parts as southern and northern, from the mentioned mountain major rivers flow to north, west, south and east, creating fertile valleys along which most agricultural, food production, irrigation development, small hydropower dams and other socio-economic development issues [1-2]. Hence, the natural resource services depend on river flow, the river water is major driver of food production in the northern

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part of the country, the understanding of hydrological regime, spatial and temporal variability of water is important for infrastructural projects, temporally change of rainfall and river flow are concern for food production. For example, shortage of water in summer directly impacts on agricultural farmland [3-4]. On the other hand, occurring of floods and drought are major natural disaster which is make vulnerable the livelihoods of people which these events often occur in northern part of Afghanistan. For instance, the recent heavy rainfall late April 2014 caused flash flood, destroyed house, water related infrastructures, hectares of agriculture land, 10 people killed and thousands house destroyed. Later in June, another heavy rainfall caused flash flood in Baghlan province, killed over 81 people, 35 people injured, about 400 houses damaged, this flood affected irrigation infrastructures and road network in this area [5].

In past study several studies conducted to detect the trend of rivers discharges, hydrological trend and variability of river flow [6-7], the trend of rainfall and river discharge at the watershed level [8] and, the change in the streamflow and sediment discharge associated with human intervention [9]. However, The Mann Kendall and Sen's Slope statistical test widely to obtain the variability or upward or downward trend climate elements such rainfall, streamflow, river discharge sediments, the test has two advantages; first, is a non-parametric test and does not require the data to be normally distributed and, second, the test has low sensitivity to the missing values [10-11].

The Kunduz River Basin located in northern part of Hindukush mountain as well as country, majority of rivers feeding from snow covers of upper catchments, any shortfall or increase of precipitation linked to streamflow and water resource of the basin. Hence, understanding of river flow and precipitation trend values are important for planning and development issues. The main objective of this paper is to examine the trendof precipitation and river flow regime over past period and; evaluated the variability of precipitation stream flow over Kunduz River Basin of Afghanistan.

2. Study Area, Materials and Methodology

2.1. Study Area

Afghanistan has five river basins such Amu Darya, Northern, Harirod-Murghab, Helmand and Kabul (Indus). The physical geography Amu Darya divided this basin different watersheds such as Wakhan, Kokcha and Kunduz watersheds [1]. However, this focused on Kunduz River Basin which is located at66.70-70.30E longitude and 34.80-37.20N latitude, the basin altitude varies from 5778.74m to 303.87m above msl at upstream and downstream watershed respectively**Fig.1**.

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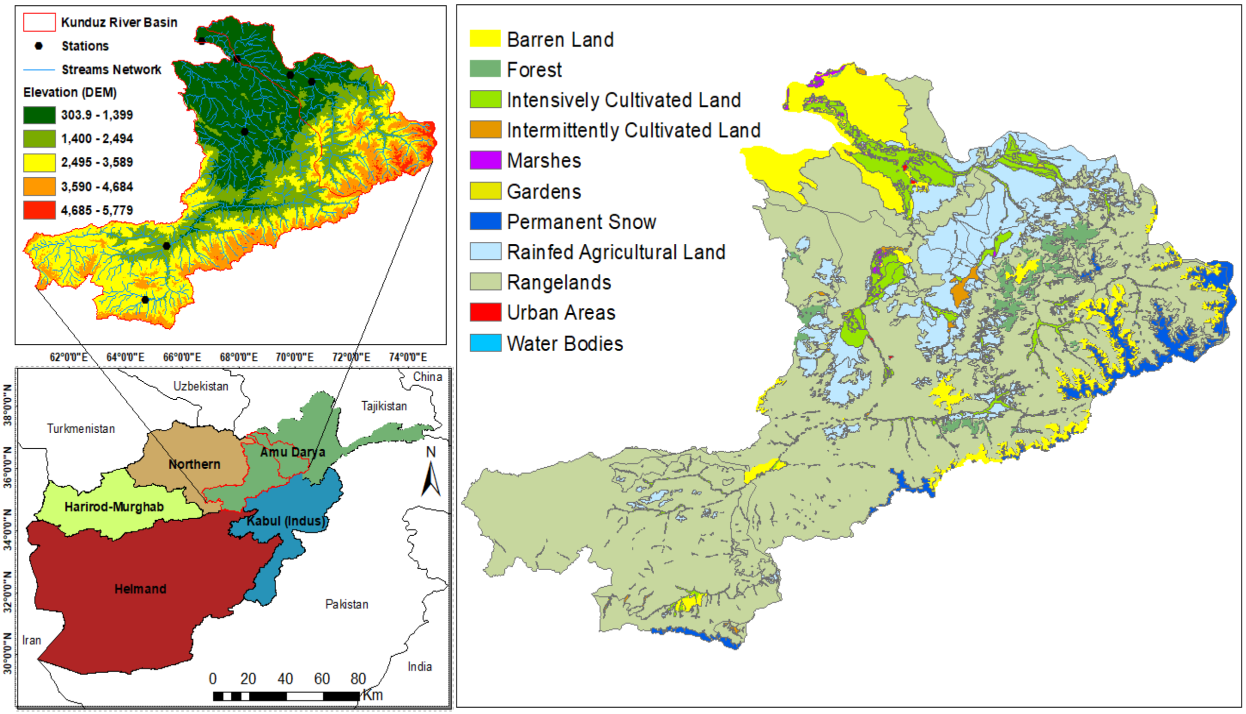

Figure 1: location map of Kunduz River Basin

The basin has about 35,000 skm drainage area which covers almost four provinces such as Bamyan, Baghlan, Takhar and Kunduz. This basin is host about million inhabitants (2,994,110) according to recent demographic estimates [12]. Kunduz River Basin itself has two major tributaries such as Khanabad and upper Kunduz (Bamyan river) rivers which is originating from Hindukush and Baba mountains respectively. The Bamyan river originate from the Baba and Hindukush mountain with tributaries such as Bamyan and Kohmard rivers which joins at the Doab Bamyan and then flowing through Baghlan province. In Dushi area of Baghlan province another stream tributary by the name of Shirin Tagab stream joins to the river. After passing the Baghlan province the river drains to Kunduz province. Finally, at the downstream watershed in Kunduz province, the two rivers such as upper Kunduz river and Taloqan rivers joining and establishing the Kunduz river. After passing some part of Kunduz province the river drains to Amu Darya in border of Afghanistan and Tajikistan.

2.2. The Precipitation and Streamflow Dataset

Evaluating and comprehensive statistical analysis of river flow regime is primary needs for initiating of water related development projects in context of Afghanistan, where the country face with insufficient water resources management unfortunately, lack of sufficient meteorological and river flow dataset in the country is a challenge for decision making and researchers, current meteorological stations and stream gauging stations has limited data records. However, in this study, the monthly time series of 4 stream gauging stations was collected from water resources department of Ministry of Energy and Water[13]. The recorded precipitation of 1961-1980 and 2003-2010gathered from Afghanistan Meteorological Agency(AMA) [14], the recorded gaps filled with Climate Research Unit (CRU) supplementary dataset as well [15-16].The detail

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information about station are listed in **Table.1**and, the current temperature and precipitation of climate condition and recorded streamflow of selected stations illustrated in **graph 2**.

Table 1: Information about the gauging stations in Kunduz River Basin of Afghanistan

Stations	Long (D)	Lat (D)	Altitude (M)	Precipitation	Discharge
Bamyan	67.82	34.81	2550	1961-2010	-
Doab Bamyan	68.01	35.26	1468	-	1968-1980
Baghlan	68.722	36.11	562	1961-2010	1968-1980
Taloqan	69.37	36.64	854	1961-2010	-
Pul-i-Chuga	69.16	36.70	823	-	1968-1980
Kunduz	69.10	37.01	460	1961-2010	-
KulukhTeapa Kunduz	68.34	36.98	460	-	1968-1980

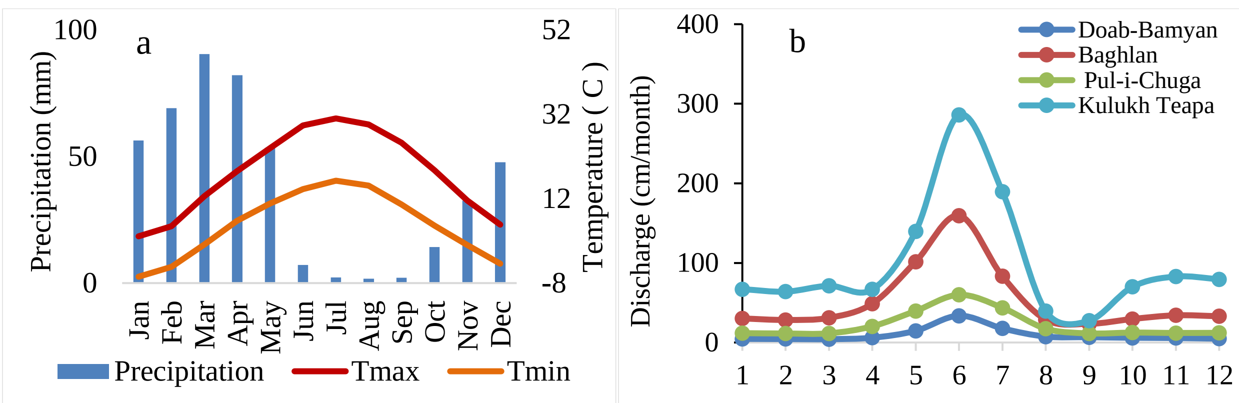

Figure 2: The monthly observed temperature, precipitation (a) and streamflow (b) in Kunduz River Basin.

2.3. Trend Analysis Technique

Mann Kendall (Mann 1945, Kendall 1975) test is a statistical test widely used for the 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 [17-20]. According to 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 statistic S, is computed by Eq1.

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

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

$$Sgn(Xj - Xk) = \begin{bmatrix} 1 & if\,(Xj - Xk) > 0 \\ 0 & if\,(Xj - Xk) = 0 \\ -1 & if\,(Xj - Xk) < 0 \end{bmatrix} \tag{2}$$

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

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$$Var(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} tp(tp-1)(2tp+5)\right] \quad (3)$$

Where, q is the number of tied groups and tp is the number of data values in the p 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.

$$Zmk = \begin{Bmatrix} \frac{S-1}{\sqrt{Var(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if\ S < 0 \end{Bmatrix} \quad (4)$$

The significant trend is evaluated using the Zmk value. A positive (negative) value of Zmk indicates an upward (downward) trend. To test for either an upward or downward monotone trend, the two-tailed test is used for four different significance levels as 100 (1-α) % weighted as $p < 0.001$ or 99.9% confidence level (***), $p < 0.01$ or 99.5% confidence level (**), and $p < 0.05$ or 95% confidence level (*), $p < 0.1$ or 10% confidence level[17].

2.4. Sen's Slope Estimator

To estimate the true slope of an existing trend (as change per year or decade) 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

$$f(t) = Qt + B \quad (5)$$

$$Qi = \left(\frac{Xj - Xk}{j-k}\right) \quad (6)$$

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

The median of N values of Qi is the Sen's slope. If N is odd or even, then slope is computed by eq 7 or 8 respectively.

$$Q = Q(N+1)/2 \text{ if N is odd} \quad (7)$$

$$Q = \frac{1}{2}\left(Q_{\left[\frac{N}{2}\right]} + Q_{\left[\frac{N+2}{2}\right]}\right) \quad \text{if N is even} \quad (8)$$

At the end, a true slope can be estimated by the non-parametric technique. Positive value of Q indicates upward trend and a negative gives a downwardor decreasing trend [22-23].

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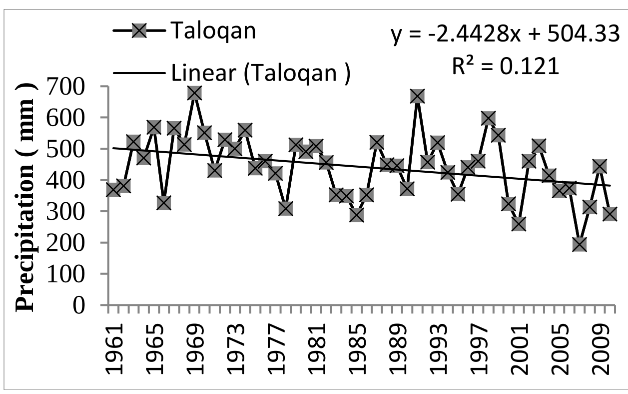
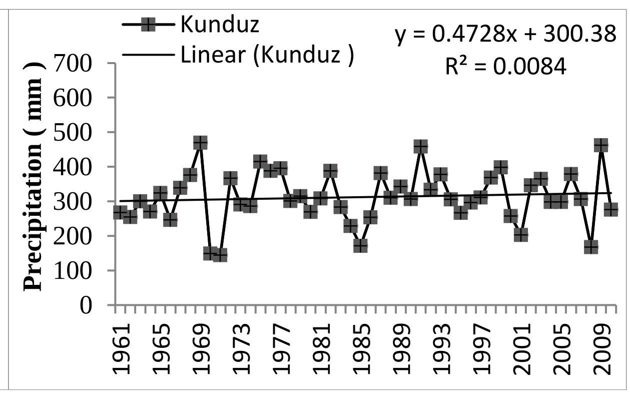
3. Results and Discussion

The historical trend of monthly and annual precipitation and streamflow of Kunduz River Basin of Afghanistan have been evaluated. However, the nonparametric Mann-Kendall test was used, the slope of upward or downward trend modified by Sen's Slope estimator which is represent the increase or decrease in calculated values. The four major stations have been selected for assessment of precipitation and river flow fluctuation in the study area.

3.1. Precipitation Time Series

Precipitation is main source of water budget and water balance in the study area. Therefore, decreasing in precipitation may be put considerable impacts on streamflow. To understand the precipitation variation, the Mann-Kendall and Sen's Slope statistical have been used. The results of statistical analysis of precipitation represent both negative and positive trend in spring and summer months respectively over the past decades, majority of stations illustrated downward trend in annual time scale. According to Mann-Kendalland Sen's Slope seasonal statistical outputs, the spring months illustrated decreasing trend since 1961. The most significant downward of precipitation was detected in Bamyan and Taloqan stations (-1.01mm/Year) and (-2.00mm/Year) respectively. In contrast, the summer months rainfall illustrated increasing values of (+0.09mm/Year), (+0.12mm/Year) in Baghlan and Kunduz stations respectively with 95 percent of significant level. In addition, the annual time scale of precipitation showed declining values in Kunduz River Basin, the significant decreases calculated in Taloqan (-2.83mm/y). Meanwhile, the linear representation of annual precipitation figures out decreasing values of(-1.43 mm/y, -0.11mm/y, and-2.44mm/y) for Bamyan, Baghlan and Taloqan respectively, which is experienced drying over the study period**Fig.3**. Finally, the analysis of historical precipitation illustrated seasonal fluctuations with the overall decreasing values, the policy makers must consider this leaning seasonality in decision making process for compensation of temporal water shortage with proper water management.





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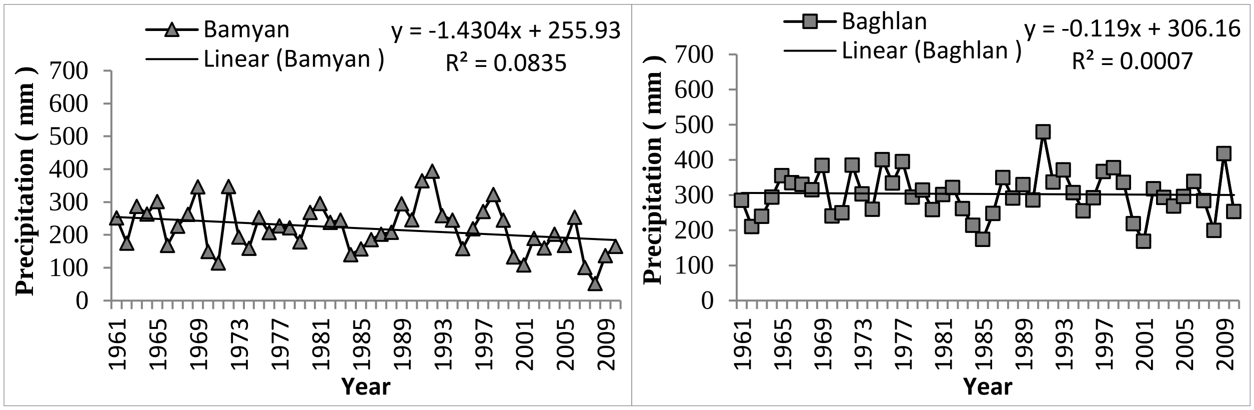

Figure 3: The graphical illustration of annual precipitation trend over the study period

Table 2: Values of statistics Zmk and Q Sen's Slop test for seasonal precipitation time series (1961-2010).

	Statistical control	**Spring**	**Summer**	**Fall**	**Winter**	**Annual**
Bamyan	Zmk	-2.24	1.18	0.28	-1.69	-1.81
	S slope	-1.01*	0.13	0.04	-0.62	-1.41
Baghlan	Zmk	-1.49	3.61	0.55	1.72	-0.17
	S slope	-1.00	0.09*	0.10	0.58	-0.12
Taloqan	Zmk	-2.61	1.60	-0.25	-1.25	-2.58
	S slope	-2.00**	0.10	-0.09	-0.63	-2.83**
Kunduz	Zmk	-0.85	2.12	0.50	1.32	0.62
	S slope	-0.52	0.12**	0.14	0.64	0.36

P value statistically significant (**=0.01,*=0.05 and 0.1) of confidence levels

3.2. The Bserved Stream Flow Trend

The available one-decade data of the river basin discharge has been analyzed to know variation of recorded dataset, the river flow statistical performance such as minimum, maximum, median, standard deviation (StD), summarized in **Table3**, these parameters indicated that Doab station at Bamyan with minimum discharge in upstream and Kulukh Teap gauge station with maximum water yield at the downstream of Kunduz River Basin respectively. The downstream flow gauge stations of the study area represent big variation in annual streamflow.

Table 3: Descriptive statistics of the annual river discharge time series of gauge stations (1968-1980)

Stations	**Min.**	**Max.**	**Median**	**StD**
Doab Bamyan	1.97	86.50	6.58	4.40
Baghlan	15.00	261.00	35.95	13.52
Pul-i- Chuga	7.50	113.00	14.00	5.15
Kulukh Tepa	4.43	618.00	74.20	27.85

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However, the Mann-Kendall and Sen's Slope test result presented in **Table4**. The obtained results from the monthly streamflow trend analysis, clarify downward values in annual and seasonal time scales, none of stations showed rising values which affirm the Kunduz River Basin water balance decreasing in annual as well as monthly level with the p value significant of 10 percent (0.1). The decadal image of streamflow indicated decreasing values of water resource in spring and summer time which is may impacts on various water dependent income and rural people livelihoods as well. As the rural community rely on stream flow, geographically the water resource storage and distribution infrastructure system are limited, still large scale infrastructural project not yet implemented to manage the temporal and spatial variation of water resource for affordable allocation and redistribution of water within the basin. In addition, the monthly precipitation and streamflow have temporal variation in maximum and minimum values. For example, the maximum and minimum precipitation occurs in spring and summer (February and August) respectively. However, the maximum and minimum streamflow occurs in summer and fall seasons (June and September) respectively. However, in the study area the precipitation occurs in form of snowfall in winter months while, this time the weather is cold and, precipitation accumulate as snow cover in upper mountainous parts of the watershed. Subsequently, during the spring and summer it gets melting and feeding the rivers discharge **Fig.2.** Therefore, considering to the temporal and spatial variation of both precipitation and streamflow, the comprehensive water resource strategy required to meet various sectors such as agriculture, domestic demand and environmental flow requirement accordingly, the infrastructural projects must be considered for storing and redistribution of the resource to meet physical water scarcity in the basin. The individual and sectorial use efficiency is essential for protecting the water capital and minimizing the waste as well.

Table 4: Values of statistics ZmkQ Sen's Slope test for monthly streamflow time series (1968-1980).

Stations	**Test**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Doab. Bamyan	Z mk	-0.89	-1.79	-1.58	-0.89	-0.07	-0.34	-1.17	-1.03	-1.03	-1.17	-0.89	-0.48	-1.17
	S S	-0.12	-0.17	-0.11	-0.18	-0.04	-1.04	-1.01	-0.34	-0.37	-0.19	-0.14	-0.04	-0.15
Baghlan	Z mk	-1.92	-1.85	-1.85	0.00	0.14	0.07	-0.07	-0.41	-0.89	-1.10	-0.07	-0.34	0.00
	S S	-0.60	-0.63	-0.60	-0.15	0.16	1.19	-0.09	-0.75	-0.70	-0.58	-0.16	-0.18	0.04
Pul-i-Chuga	Z mk	-0.50	-0.63	-1.40	1.13	0.00	-0.81	-0.45	-1.58	-1.53	-0.54	-1.08	-0.68	-0.32
	S S	-0.05	-0.09	-0.29	0.55	0.02	-1.58	-0.66	-0.58	-0.17	-0.12	-0.17	-0.07	-0.03
KulukhTeapa	Z mk	-1.14	-0.74	-0.59	-1.39	-0.25	-0.40	0.00	-1.09	-1.58	-0.49	-0.59	-0.20	-0.49
	S S	-0.56	-0.28	-0.25	-2.11	-0.88	-4.00	-1.45	-2.91	-1.30	-0.65	-0.44	-0.23	-0.75

P value statistically significant (0.1 or 10 percent) of confidence levels.

4. Conclusion and Recommendation

This study examined trend and variation of the past precipitation and streamflow of Kunduz River Basin of Afghanistan which the country has arid climate condition. the Mann-Kendall and Sen's Slope test have been applied for detecting the trend of monthly, seasonal and annual time series of precipitation and streamflow. The precipitation represents severe seasonal fluctuation as dropdown in spring and increase in summer time, the reduction magnitude is bigger in spring and annual time scale. Also, the monthly and annual streamflow trend illustrated declining as well.

The basin face with rapid population growth, due to population rise, the water demand for municipal, irrigation and industrial use increasing. The Kunduz River Basin water management,

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and governance is big deal to meet various demand interest. Agriculture is main source of rural people income. However, food production and agriculture sector face with water shortage in summer months, the current aggressive water use associated with transmission loss, unproperly allocation and unregulated water use. Therefore, the highly top-down institutional decision-making process must be transformed to the basin wide management organization with full coordination in all levels from central ministry to water users or farmers in one decision platform, to eradicate decision bias and heard all stakeholders interest, well-functioning of agencies planning and implementing of large scale project for boosting the sectorial water accessibility such domestic and irrigation well as environmental flow as well. Besides, the water use efficiencies must be considered for conservation of limited freshwater in the basin, the irrigation facilities and infrastructure should be improved and building new dam, canals as well. The improving farm level water practices or introducing new water use friendly technologies could be useful for reducing small scale water loss and boosting the productivity as well.

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