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Spatial Variation of Temperature and Rainfall Trends in Kabul River Basin

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***Abstract*—** Knowledge of temperature and rainfall periodicity is needed for urban and rural land-use and infrastructure planning, and their flood protection. In this study temperature and rainfall data from Climatic Research Unit Time Series version 4.03 (CRU TS4.03) was downloaded and inverse distance weighted (IDW) were made to analyze the temperature and precipitation variations in Kabul river basin (KRB). Interpolation maps were made using ArcMap 10.4.1. Analysis was done for period from 2004 to 2018. Annually for 15-year period, mean temperature variation can be noted as, upper part of the basin has minimum temperature of -1.2 °C while part of the study basin that lies in Pakistan has maximum temperature of 19 °C. Rainfall varies from 380 mm to 793 mm annually for 15-years. Due to increasing trend of both temperature and rainfall for KRB suitable methods should be applied for water management and flood risk reduction.

***Keywords*—** Temperature, Kabul River Basin, CRU, IDW, ArcMap 10.4.1

I. Introduction

Temperature and rainfall are key elements in hydrological cycle that plays an important role in water allocation. About one sixth (1/6th) of world's population depends upon water coming from frozen sources as their water resource [1]. This melting of water is influenced by temperature variations thus affecting the dependents. KRB is having its upper part covered with snow throughout the year. Thus, variation in temperature and rainfall analysis is necessary for the basin for better water distribution [2].

Higher temperature over a region is the feature of global warming. The global average temperature has increased by an average of 0.85 °C during 1800–2012 relative to 1961–1990 [3] and 0.74 °C (1906-2005) [4]. This increasing temperature ultimately rises the flow of water coming from frozen sources and results in changing the water distribution.

For the study climatic component of water balance approach was acquired from Climatic Research Unit Time Series version 4.03(CRU TS4.03), produced by University of East Anglia, England. It includes various variables like rainfall, cloud cover, temperature, potential evapotranspiration, vapor pressure, and frost day frequency on monthly basis from January 1901 to December 2018. Station anomalies are interpolated into 0.50 x 0.50 (latitude-longitude) grid cells covering entire land surface globally [5].

II. Data and Methodology

A. Study Area

The study is carried out on the Kabul river basin that lies between longitude 67040/ to 75042/ east and latitude 33033/ to 36002/ north [6]. Kabul river, 700 km long, has its origin from the Sanglakh Range of the Hindu Kush Mountains in Afghanistan, passes through Nowshera, Pakistan and ends in the Indus river near Attock [7]. Kabul river basin is in south-east of Afghanistan also is the portion of Indus river catchments. The catchment area of basin is 68040 km2 i.e. 78% area lies in Afghanistan while 22% area is in Pakistan boundaries, as depicted in Figure 1. The eastern portion of the basin that emerges from Pakistan has higher elevation and is covered by snow in most part of the year [8].

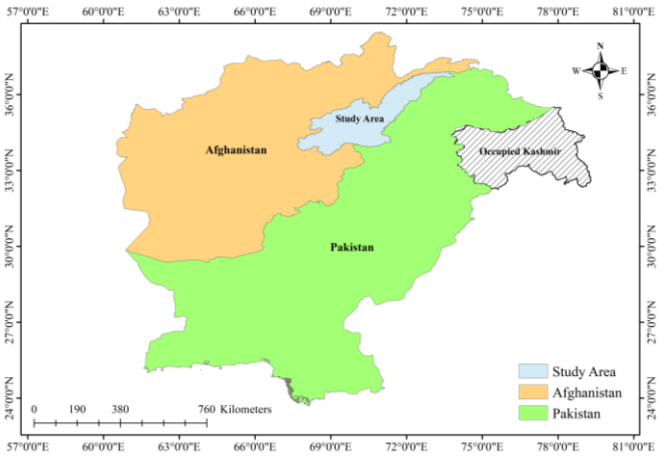

Figure 1. Study Area Map

B. *Temperature and Rainfall Data*

Monthly temperature and rainfall data of spatial resolution 0.50 was downloaded from CRU TS4.03 http://www.cru.uea.ac.uk/data from January 2004 to December 2018. Data was acquired for each grid made in study area and exported to excel spreadsheet. After that average of all grids were calculated to get temperature and rainfall data for entire basin.

C. *Methodology*

Entire study basin was divided into grid cells of 0.50 x 0.50 resolution. Data from each grid cell was obtained and then mean value for the basin was calculated using the weighted mean technique.

$$\bar{x} = \frac{\sum_{i=1}^{n}(x_i \times w_i)}{\sum_{i=1}^{n} w_i}$$

where, w = weights,
x = value

Inverse distance weighted maps were made using commands of GIS software ArcMap 10.4.1. Downloaded climatic data was arranged in excel spreadsheets and opened in ArcMap. Then after interpolation of data, monthly IDW maps for temperature and rainfall from 2004 to 2018 were made.

III. Results and Discussion

A. *Spatial Analysis of Temperature and Rainfall*

Spatial analysis of temperature and rainfall data, that was downloaded from CRU was done on ArcMap. Monthly IDW maps were made to inspect temperature and rainfall variations in KRB. Annually it can be noted that temperature ranges from -1.2 °C to 18.9 °C, as shown in figure 4 (a). the upper part of the basin was having negative temperature thus covered with snow throughout the year and serves as source of frozen waters. While lower part that lies in Pakistan boundary has maximum temperature of 18.9 °C i.e. plain area. Monthly maps shown in Figure 2 depicts that in January temperature of the study basin falls to minimum of -13 °C that follows the rainfall in upper part as snow at this minimum temperature. In June, the temperature rises maximum to 28 °C that results in snow melting and causes the stream flow to reach its peak rate.

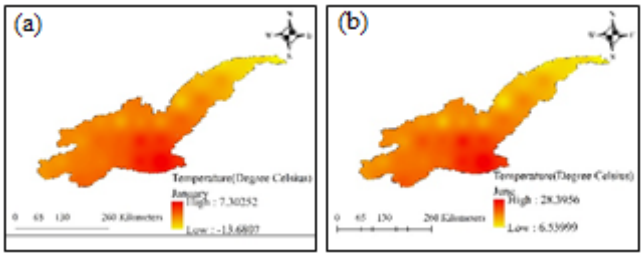

Figure 2. Spatial Analysis of Temperature over KRB (a) January and (b) June

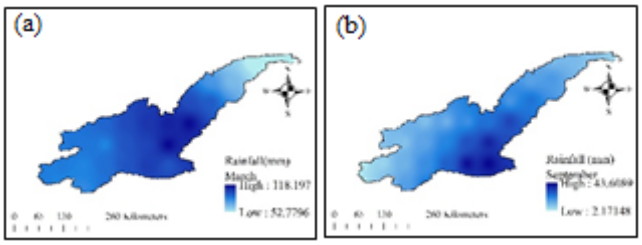

Figure 3. Spatial Analysis of Rainfall over KRB (a) March and (b) September

Rainfall map divides the entire basin into two zones, semi-arid and sub-humid. Semi- arid is the zone with annual rainfall of 300 to 600 mm, 70% of area lies in it. While other 30% lies in sub-humid zone with 600 to 1000 mm annual rainfall shown in figure 4 (b). Rainfall spatial analysis shows the minimum rainfall of 380 mm to maximum of 793 mm. the upper part of basin is having rain falling as snow. March is having maximum rainfall of 118 mm over the basin while in September has minimum rainfall of 2 mm (figure 3).

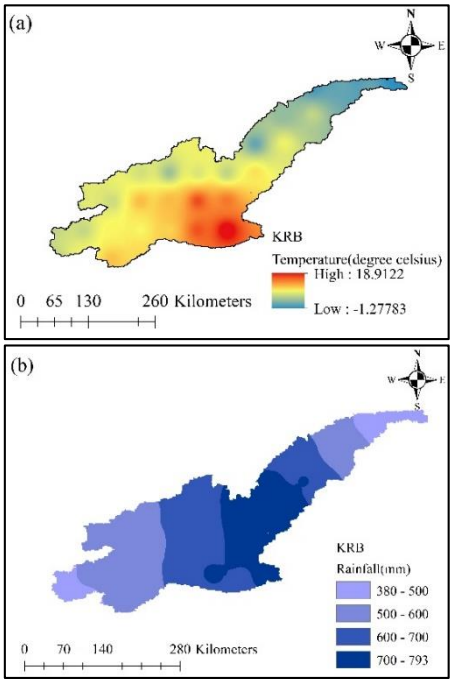

Figure 4. Annual Variation of (a) Temperature and (b) Rainfall in KRB

B. *Trend Analysis of Temperature and Rainfall*

Graphs were made to examine the trend for temperature and rainfall in KRB. Figure 5 gives the trendline for seasonal as well as annual temperature and rainfall. It can be observed that in summer temperature trendline is increasing. Same trend can be seen for annual temperature for 15-year i.e. from 2004 to 2018. This increasing temperature is affecting the snow budget as the basin comprise some of its part as snow. And this change influences the downstream water allocation.

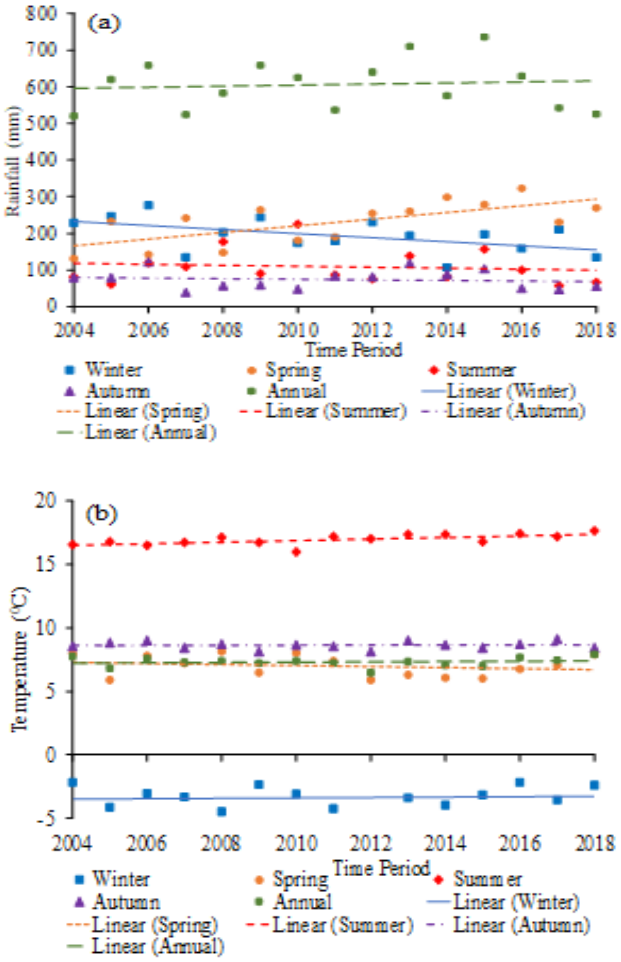

Figure 5. Trend Analysis for (a) Rainfall and (b) Temperature data for 15-Years.

Similarly, for rainfall trend estimation graph was developed and trendline was analyzed on seasonal and annual basis. Winter season is having decline in trendline for study period. That demands the proper management of water resources to be used by dependents. While annually, slight increasing trend line is observed.

CONCLUSIONS

The study concluded that the temperature has increasing trend for summer while on annual basis trend is also increasing slightly. The mean maximum annual temperature of the basin for 15-years was 19 °C and minimum was – 1.2 °C. Seasonally, temperature falls to -13 °C in January and rises to 28 °C in June. Rainfall range for the basin for 15-year period on annual base is 380 mm to 793 mm. Monthly analyses concluded that March has maximum rainfall of 118 mm and September has minimum 2 mm rainfall.

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