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IMPACT ASSESSMENT OF RAINFALL ON STREAMFLOW SENSITIVITY: A CASE STUDY OF KUNHAR RIVER BASIN, PAKISTAN

Zahoor Khan [1], Fayaz Ahmad Khan[2], Afed Ullah Khan[3]

[1]*Lecturer, Department of Civil Engineering, University of Engineering and Technology Peshawar, Bannu Campus*
[2]*Assistant Professor, National Institute of Urban Infrastructure Planning, University of Engineering and Technology Peshawar*
[3]*Lecturer, Department of Civil Engineering, University of Engineering and Technology Peshawar, Bannu Campus.*

Abstract —*Accurate and reliable estimates of streamflow sensitivity to climate drivers are needed to integrate the effects of worldwide climate change as a result of global warming in future water supply planning. In this case, we used the elasticity model to assess the sensitivity of the streamflow to rainfall for Kunhar River basin considering three stream flow gauging stations including Kunhar River at Naran, Kunhar River at Talhata bridge, and Kunhar River at Garhi Habib Ullah for the study period of 1963-2007. The precipitation elasticity of streamflow 'εp', is represented by a ratio of the proportional change occurring in streamflow divided by the proportional change occurring in mean annual precipitation.*

The results of the study present the sensitivity of the Kunhar River basin at the three gauging points i.e. at Naran, Talhata bridge, and Garhi Habibullah stations as 0.3, 0.5 and 0.8 respectively. This means that a. deviation of 1% from the long duration mean rainfall will bring 0.3%, 0.5% and 0.8% change in annual discharge at the afore mentioned gaging sites of the Kunhar river respectively. This study findings can be used to guide the use of elasticity techniques to quantify hydrological reactions to climate change that inform the region's policies for long-term water management.

Keywords- *Climate change, Streamflow, Rainfall, Sensitivity, water management*

I. INTRODUCTION

Rising temperature at global scale is accountable for intensifying the hydrological cycle which causes more frequent and intense drought and flood occurrences. Pakistan is highlighted among the top 10 water stress countries that is directly affected by climate change and is ranked on 8th position in the list of countries most affected by extreme weather events according to Global Climate Risk Index report released by the public policy group Germanwatch [1]. The existing studies alarms that global warming will interfere with and intensify the global hydrological cycle [2], [3]. Majority of research relevant to climate change emphasized on temperature, precipitation and evaporation as they are regarded to be the key iconic variables of climate change and variability in a river basin [4]. Outputs from a general circulation model (GCM) which are numerical-based and the most sophisticated paired climate models have been fed into a hydrological model over the past two decades to identify the evolving impacts of weather on a watershed's water resource in the future. In Pakistan, water assets of the region has been studied by employing well-known hydrological models, i.e. Arc SWAT, GCMs or RCMs models to study the potential impacts of changing climate [2], [3], [5] but analytical models are rarely utilized for climate change studies.

The goal of this research study is to investigate the climate sensitivity using elasticity technique in water resources which is basically an economics term. This study utilized the nonparametric estimator which provides the ability to measure the sensitivity of streamflow to precipitation straight from the readily replicable and "defensible" historical data [6]. Streamflow rainfall elasticity is here described as the proportional change in mean annual streamflow divided by the proportional change in mean annual rainfall [6], [7]. As an example, if elasticity value came out to be 3.0 from an analytical model it will suggest that 1% change in long duration mean precipitation will cause 3.0% change in discharge.

II. STUDY AREA DATA COLLECTION AND METHODOLOGY

1.1. Study area.

The location of Kunhar River is situated in the north part of Pakistan and extends from 34.2 ° –35.1 ° N to 73.3 ° –74.1 ° E which is demonstrated in Figure 1. It flows within the territory of Khyber Pakhtunkhwa (KPK) province of Pakistan. It comes from the Lulusar Lake of KPK's Kaghan Valley. It runs through Jalkhand, Bata Kundi, Naran, Kaghan, Kawai, Balakot, and Garhi Habibullah and eventually meets the Rara Jhelum River The Kunhar's water is rich in algal flora, which gives rise to a marvelous diversity of aquatic life. The water of the Kunhar is rich in algal flora, giving rise to a wonderful diversity of the aquatic life it harbors [8]. It has a drainage region of 2535 km^2 whereas the elevation of the basin varies from 736 to 5092 m (Figure 1). The Kunhar is among the Jhelum River basin's largest tributaries. It's the only major river that is fully located in Pakistan's land and is therefore of excellent significance from the view of Pakistan's WAPDA hydrological monitoring. The Kunhar adds to the Mangla Reservoir built in the Jhelum River basin about 11 percent of the complete flow. The reservoir of Mangla is the country's second largest water storage site. The water collected here is mainly used by the irrigation and hydropower generation of 6 million hectares of territory in the country. The existing hydropower capacity at Mangle reservoir is 1000 MW [9], [10].

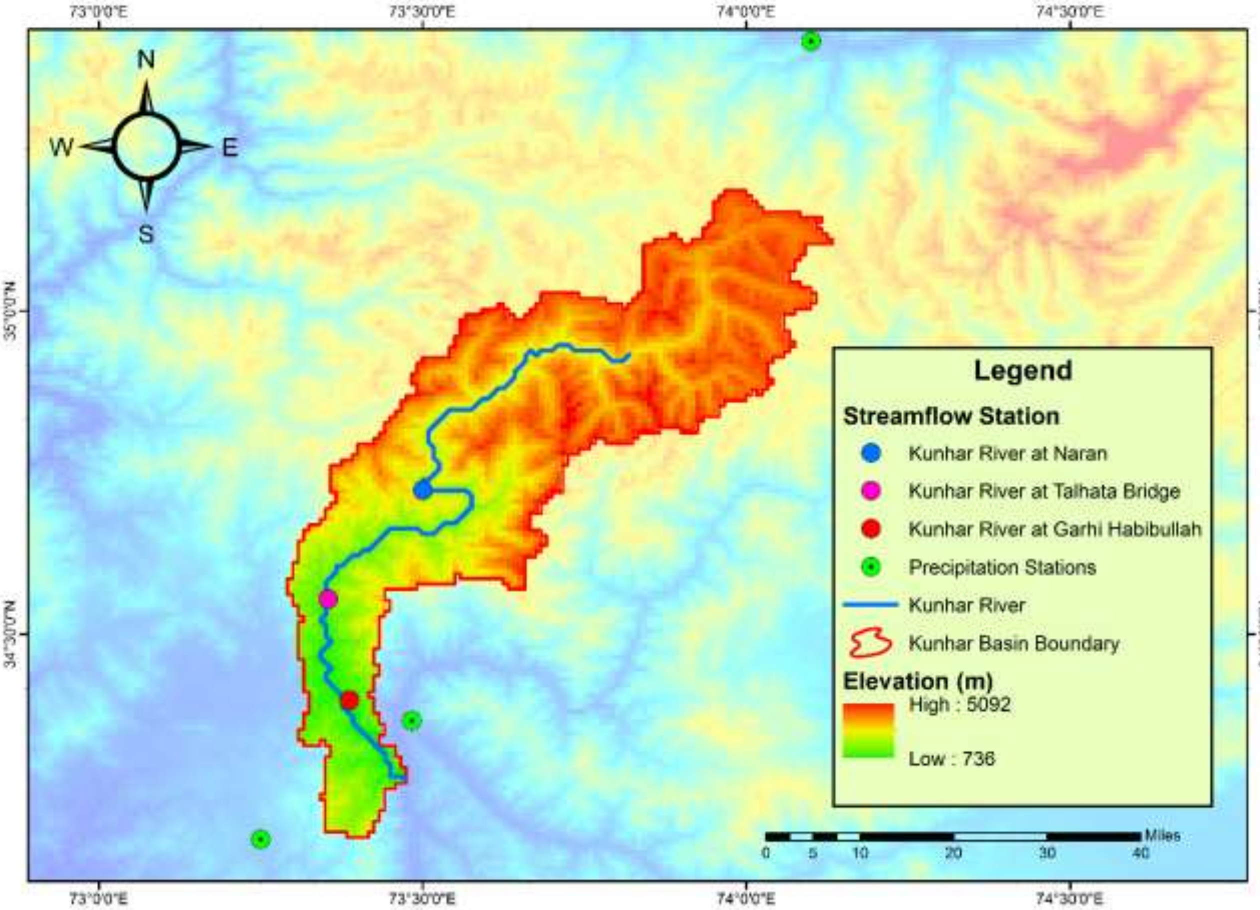

Figure 1 Map showing details of Kunhar River basin and location of hydro-climatic stations

1.2. Data collection

The flow data was obtained from Surface Water Hydrology Project (SWHP) of Water and Power Development Authority (WAPDA) for the study period of 1963 to 2007 for all the three gauging sites of Kunhar River at Naran, Talhata bridge and Garhi Habibullah sites. Precipitation data were obtained from Pakistan Meteorological Department (PMD) for the same study period as of discharge i.e. 1963-2007. Similarly, spatial data i.e. digital elevation model (DEM) was downloaded from USGS website in 30m resolution.

1.3. Methodology

The concept of elasticity with its origin from economics, was introduced into water resources and environment for assessing the streamflow sensitivity against climate variable like precipitation, temperature, potential evapotranspiration etc. and water quality parameters respectively [11]–[13]. Here in this study nonparametric approach for measuring rainfall elasticity is utilized [6]. The nonparametric equation considers the median values in order to eliminate the errors induced by model calibration. The nonparametric equation can be given by Equation 1.

$$\varepsilon p = median(\frac{Qt - \overline{Q}}{Pt - \overline{P}} \frac{\overline{P}}{\overline{Q}}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

In Eq.1 the term Q_t and P_t represents the discharge and precipitation value at any time period 't' within the study period and the term $\overline{P}$ and $\overline{Q}$ represents the long term mean values of precipitation and streamflow in the study period.

The lumped average annual time series values of catchment's precipitation were obtained by interpolating precipitation values in ArcGIS 10.2 with precipitation stations at a distance of 100 km of the basin's boundary which adds to the Theisen weighting plotted around the basin's boundary.

III. RESULTS AND DISCUSSIONS

The elasticity values were obtained by using Eq. 1. The results and details of the catchment under study sites of the basin are given in Table 1. The result demonstrates a higher sensitivity having elasticity of 0.8 at Talhata bridge which means the site is more sensitive to rainfall events and is relatively more prone to floods as compared to Kunhar river at Naran and Garhi Habib Ullah sites where the elasticity came out as 0.3 and 0.5. These elasticity values mean that a 1% increase in rainfall as compared to the long term means rainfall of the basin will amplify the discharge by 0.3%, 0.8% and 0.5% for Kunhar River at Naran, Talhata bridge and Garhi Habibullah sites. The spatial distribution of rainfall streamflow sensitivity of the basin is shown in Figure 2.

Table 1 Details of monitoring stations and corresponding precipitation elasticity

S.N	Catchment name	X (DD)	Y (DD)	Catchment Area (Km^2)	Elev. (m)	Avail. Record	Study Period	Rainfall elasticity (ε_p)
1	Kunhar River at Naran	73.5	34.7	2508.0	1036.0	45	1963-2007	0.3
2	Kunhar River at Talhata Bridge	73.4	34.6	992.0	2354.0	45	1996-2007	0.8
3	Kunhar River at Garhi Habibullah	73.4	34.4	820.0	2382.8	45	1996-2007	0.5

The values obtained at all the three gauging stations were positive. It is to mentioned that negative elasticity is due possible which means that increasing rainfall will cause decrease in streamflow. Such condition may happen in case when the averaging period is short or existence of an intervening storage reservoir within the catchment boundaries.

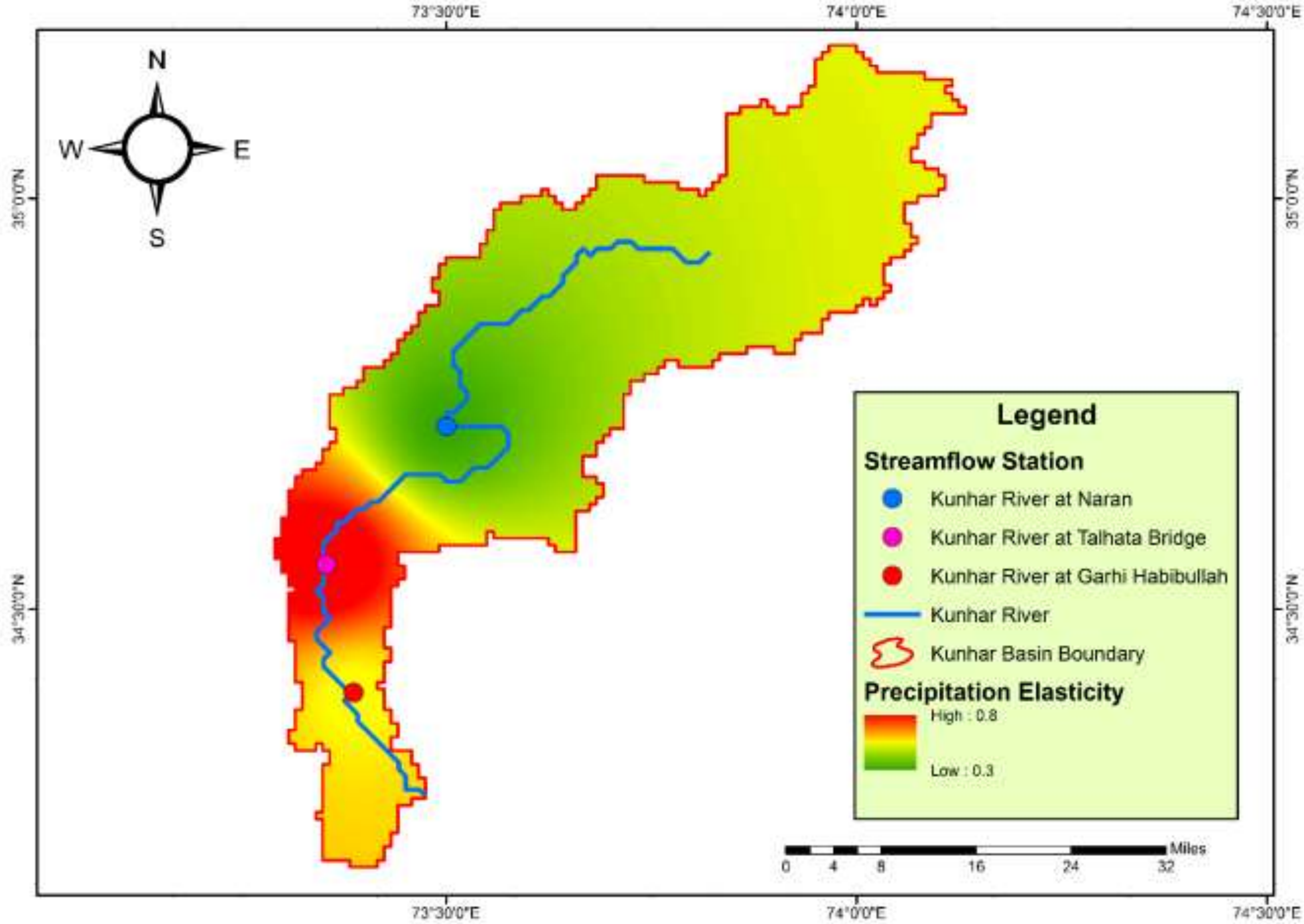

Figure 2 Map showing spatial distribution of precipitation elasticity of Kunhar River basin

Figure 2 clearly shows that higher elasticity or sensitive zone lies surrounding the Talhata bridge at Kunhar river which needs to be considered in future infrastructure project and coping climate change impacts.

IV. CONCLUSIONS

The study results suggest that rainfall elasticity values of the Kunhar River at Naran, Talhata bridge and Garhi Habibullah sites are 0.3, 0.5 and 0.8 respectively. This means that 1% raise in historic mean precipitation will increase the streamflow at the above stated site by 0.3%, 0.5% and 0.8% respectively. The areas having high rainfall elasticity values are relatively more sensitive and at higher risk of floods. The water management strategies must be framed taking into account the existing sensitivity of rivers in the locality so that sustainable projects may be executed to save economy and safeguard the marine and human live.

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