ASSESSMENT OF PHYSIOGRAPHIC FEATURES AND CHANGING CLIMATE OF KABUL RIVER CATCHMENT AREA IN NORTHWESTERN PAKISTAN

S. Abbas[1], M.S. Hussain[2], S.A. Shirazi[3*] and M. Khurshid[3]

[1]Department of Geography, Konkuk University, Seoul, the Republic of Korea
[2]Department of Geography, Climate Research Institute, Konkuk University, Seoul, the Republic of Korea
[3]Department of Geography, University of the Punjab, Lahore, Pakistan
[*]Corresponding author's E.mail: shirazi.geog@pu.edu.pk

ABSTRACT: The purpose of this study was to estimate the catchment characteristics analysis on a Digital Elevation Modal of Kabul river catchment area spread between Pakistan and Afghanistan. For this purpose, the Arc Hydro tool has been used to delinate the features included; classification of land use classes, watershed, and sub-watershed areas, stream characteristics, climatic characteristics, topography, flood peak, and water yield. Results revealed that the relationship of geomorphological parameters with the hydrological features of the catchment provides a simple way to understand the hydrologic behavior of the different catchments. It is a fourth-order catchment, covering an area of 92,605 km^2. About 45% of the total catchment area fall in the Pakistan territory and rest 55% is a fall in Afghanistan. The outcome of the current investigation would be beneficial for the water resource development and can improved under various climatic stressed situations to overcome their adverse effects on the livelihood of population and agriculture in the study area.

Keywords: Kabul River catchment, Changing Climate, Physiographic features, DEM, northwestern, Pakistan.

(Received 15.02.2020 Accepted 21.04.2020)

INTRODUCTION

Kabul River Basin (KRB) is an important water resource in the Khyber Pakhtunkhwa province of Pakistan and a major contributor to Afghanistan's freshwater needs. Geographically the Kabul River is located in the northwestern region of Pakistan. For many decades; it has been providing water for multi-purpose uses such as power generation, irrigation, industries and for domestic usage (Tariq *et al.*, 2020). Due to increase in urbanization, bad governance, poverty, siltation in water reservoir across the province as well as numerous anthropogenic effects on the availability of fresh water in the region. The scarcity of water has also a negative impact on the agricultural sector in this region, which is more than 60% of the total water usage and consumption (Loucks and Beek, 2017). Keeping in view all physiographic characteristics of the KRB, the key features such as drainage network, temperature, precipitation, irrigation, population and surface land use patterns along with other indicators were analyzed in GIS environment. The aim was to suggest some implementable and developmental measures of water structures. The objective of this study was to estimate the characterization of the Kabul River Basin included its topography, stream network, catchment area, land use pattern, flood peaks, water yield and climate (temperature and rainfall).

In order to achieve this objective; delineation of KRB and some basic watershed properties like area, slope, stream network, flow length and density were calculated. This was generated with the help of Digital Elevation Models (DEM) with 30m interval using geo-spatial techniques. All these watershed properties can easily be extracted by using automated procedures in the GIS software (Celik *et al.,* 2020; Rasooli and Kang, 2015; Singh, 1997). Various studies have used the Arc Hydro tool to find out the physiographic features of the watershed areas while the methodology adopted in the previous studies was aimed at watershed delineation by using digital elevation models (DEM) 30m and automated watershed tools in Arc GIS (Celik *et al.,* 2020; Rasooli and Kang, 2015). This watershed tool was also used for a similar case study of a sum 38 sub-basins in Madhya Pradesh-India. The study identified that the application of SRTM DEM on hydrological evaluation to monitor watershed characteristics is better than other available techniques thus highlight the importance of geospatial techniques. The study concluded that this methodology can be used to generate potent results for the estimation of surface runoff, which were important for sustainable basin area planning (Singh *et al.,* 2014; Sreenivasulu and Bhaskar, 2010). Furthermore, the hydrology of Simly Dam watershed built on the Saon River basin near Islamabad-Pakistan was modeled by using the Soil and Water Assessment Tool (SWAT) which has proved its efficient utility in the semi-arid region to support government's water management policies (Celik *et al.*, 2020; Ghoraba, 2015; Gumindoga *et al.,* 2016; Singh *et al.,* 2014).

The management of surface water resources and physiographic traits of an area are important themselves for human beings and practicing agriculture. Keeping in view its importance in agriculture; watershed planning has been considered as a vital sector in irrigation planning by policy makers all over the world. The goal of achieving a sustainable irrigation network and its development in a region can also be accomplished by proper planning at the watershed areas of snow fed rivers (Mogaji and Sanlim, 2017).From the water conversation view point, hydrological implementation plans should be established in watershed regions according to local pedology and agronomic features which are major consumer of surface water (Ediriweera *et al*., 2016; Meraj *et al.,* 2015; Bao and Laituri, 2013). This is how water and land resources of a watershed can better be utilized in the watershed and basin management. As a result, watersheds of Kaddam watershed of the Godavari river basin were delineated much more accurately and with a consistent real-time response. In a similar way and with the usage of the DEM and Soil and Water Assessment Tool (SWAT), the delineation of Kadam River (India) watershed, streamlines, number of sub-basins and sub basin area was estimated by QSWAT (Ali *et al.,* 2017; Giridhar *et al*., 2015).

MATERIALS AND METHODS

The Kabul River flows in eastern Afghanistan and entered in northwestern Pakistan to water few areas of Peshawar valley. The length of this river is 430 miles (700 km) out of which about 350 miles (560 km) are in Afghanistan (Figure 1). The Kabul River is traversed in Kabul and Jalalabad city before entering Pakistan. It is originated from the Sanghlakh Range of Hindukush Mountain in Maidan Wardak province of Afghanistan. It is the located between 34°32'33.59 N latitude and 68°48'10.79 E longitude covering an area of 45 miles in the west direction to become part of the Kabul catchment area in Pakistan. The river passes near the cities of Peshawar, Charsadda and Nowshera in Khyber Pakhtunkhwa province. Finally, the Kabul River along its catchment area joined the Indus River near Attack Khurd with the geographic grids between 33°54″ N latitude and 72°36″E longitude. The whole catchment was covered by four important distributaries including Lowgar, Panjshēr, Konar (Kunar), and Alīngār. As stated earlier that the Kabul river catchment is spread over both Afghanistan and Pakistan in South Asia. However, the present study only deals with the catchment within the political boundaries of Pakistan.

In this study, the Kabul watershed boundary was derived from Digital Elevation Model (DEM) and a SWAT (Soil and Water Assessment Tool) and DEM (Digital Elevation model) with a 90m interval was used to perform watershed delineation.

In order to assess the physiographic features, a raster-based analysis was performed in Arc GIS software using the GIS-based hydro tool. The data set of the river catchment would be very essential for the representation of the drainage and catchment contour lines. The analysis was performed using hydro based techniques as well as through the utilization of methods like Digital Elevation Model extracted from the lines of contour and ultimately configured the catchment length and area (Rai *et al.,* 2018; Pujari *et al.,* 2015).

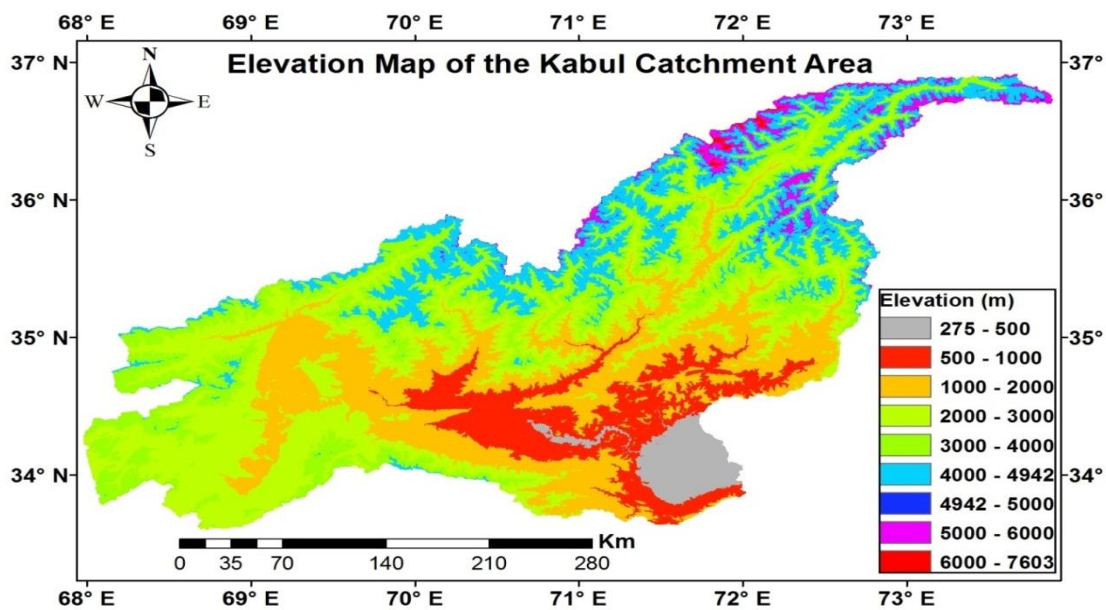

Figure-1: Topographical map of Kabul catchment in northwest of Pakistan.

The major source of data is USGS SRTM (Shuttle Radar Topography Mission) DEM 30m downloaded from the US Geological Survey website. For accomplishing the objective of this study; after the delineation of the basin in geo-spatial software ArcGIS 10.2.2 using Arc Hydro tool) the catchment, network stream, order, and the catchment are produced (Singh, 1995). This is essential while we were to analyze the impact of climate on the flow of various tributaries in the catchment of the Kabul River. For further analysis, the Arc hydro tool is used to estimate the physiographic features of the catchment area of the Kabul River. This was necessary to achieve the objectives of our research. The measurement of stream flows in the Kabul river catchment was collected from a government agency named Water and Power Development Authority—Surface Water Hydrology Project (WAPDA-SWHP). The rainfall and temperature (maximum and minimum) data have also been taken from WAPDA and Pakistan Meteorological Department (PMD).

Table-1: Type of data used in the present study and their source.

Data Type	Source	Scale	Description
Topography	USGS National Elevation Dataset	30 × 30 m	DEM (Elevation)
Land use data	European Space Agency (ESA) Global Land Cover http://due.esrin.esa.int/page_globcover.php /	300 × 300 m	Classified land use such as forest, agriculture, crops, water etc.
Climatic data	Pakistan Metrological Department (PMD), Water and Power Development Authority (WAPDA) (1985-2015)	Monthly	Precipitation, Temperature minumum and maximum

RESULTS AND DISCUSSION

The elevation of this study area is started with 275 meters and the highest elevation is observed 7603 meters. All the elevation classes have been generated from an interval of 1000 meters as shown in Table 2. Estimation of sub-watershed areas have been established by analyzing the Kabul watershed, which has 20 sub-watersheds in it.

For all this the calculated area has a minimum of 13.19 Km^2 to a maximum area of 13067.46 Km^2. Kabul River originated from the Sanglakh range and merges with the mighty Indus River near the city of Attock. The total catchment area of Kabul River was found 87961Km^2 as shown in Figure 3. About 45% of the total catchment area fall in the Pakistan territory and the rest of the 55% falls in Afghanistan.

Table 3 shows the total length of all the streams of the Kabul River basin (2543) divided by the total area (87961) of the drainage basin and the result of drainage density of the Kabul watershed is 0.028 Km^2**.** The total number of all the streams of the Kabul River basin (47) divided by the total area (87961) (Fig-3) of the drainage basin and the result of drainage density of the Kabul watershed is 0.00053 Km^2. The ratio between the number of streams of one order (see stream order) and those of the next-highest order in a drainage network in this study is described below. Figure 4 highlights the comparison of Gumbel & Log Pearson III distributions representing the flood the magnitude of flood frequency through calculating the Gumbel and Log Pearson-III.

Table-2: Elevation classes in the study area.

Sr. No	Elevation classes	Area (Km^2)	Catchment (%)
1	275-500	417.35	4.02
2	500-1000	746.65	7.02
3	1000-2000	1906.78	18.10
4	2000-3000	2327.49	22.09
5	3000-4000	1747.59	16.58
6	4000-5000	1227.85	11.65
7	5000-6000	1977.85	18.77
8	6000-7000	172.36	1.64
9	7000-7603	14.25	0.14

The investigated area of the Kabul Basin was fall within Pakistan (Figure 2). The land use data at a spatial resolution of 300 meters were obtained from the European Space Agency (ESA) database. The results revealed that all the investigated sub-basins are characterized into area up 1,000 Km^2, catchment area from (7,000-30,000 Km^2), sub-catchment (7,000-30,000 Km^2) and basin into the range of (30,000-95,000 Km^2). From a detailed investigation this study has identified two basins characterized into watershed, ten and eight into sub-catchments and catchments respectively. The total outflow from all of a drainage basin was observed either through surface channels or subsurface aquifers within a given time series. According to the findings, It is evident that the Nowshera has a large catchment area and but low water yield (Figure 3).

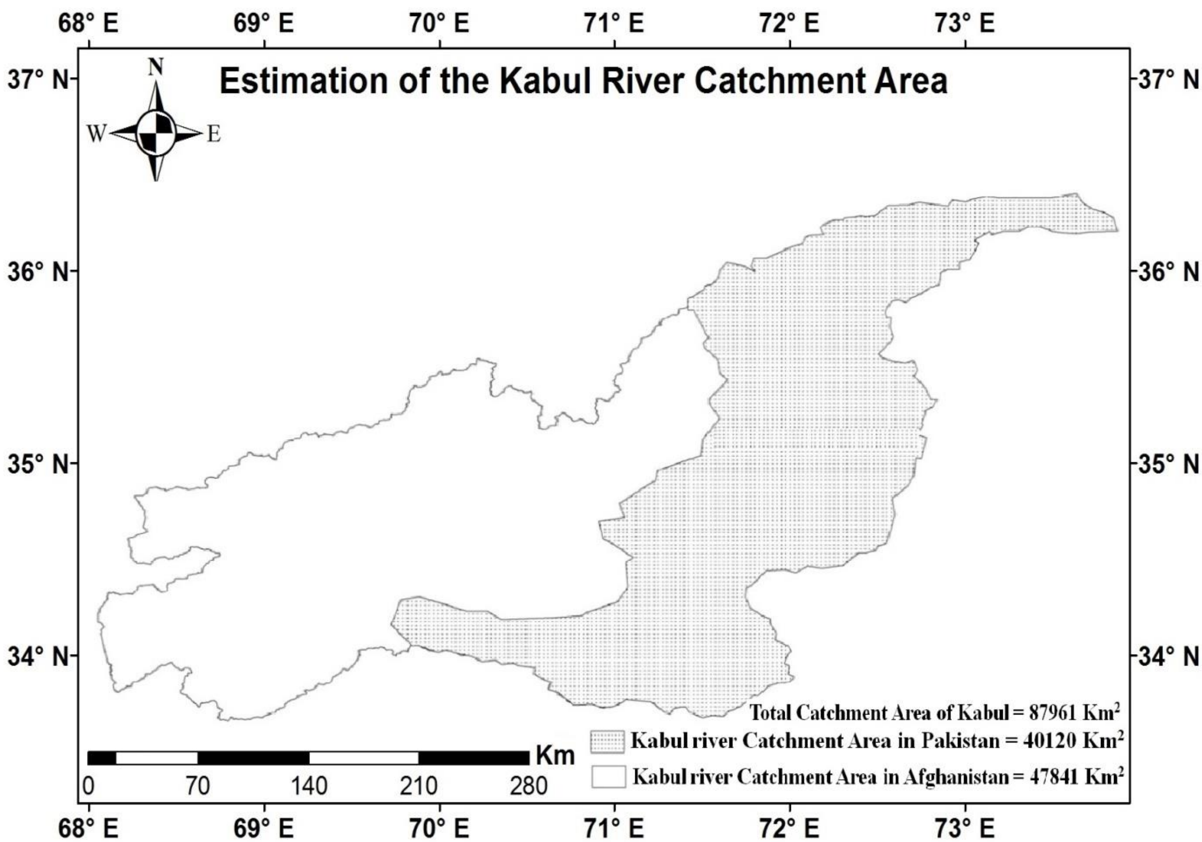

Figure-2: **Area calculation of Kabul River.**

Table-3: Stream characteristics of Kabul catchment.

Sr. no	Stream Order	Stream Length (Km)	No. of Streams	Mean Length (Km)
1	1st	1400	24	48.3
2	2nd	449	11	47.4
3	3rd	479	7	69.3
4	4th	105	3	31.3
5	5th	110	2	21.3
Total	5	2543	47	216.9

The results of table-4 showed that 12 different types of land cover were detected. The research was conducted on terrain evidence for identifying the causes of natural hazards such as debris flows, debris floods and flash floods. This basic consequence of this study was to initiate the corrective measures for reducing the risk of life and property. The watershed characteristics like, size, slope, shape, drainage density, land use/land cover, geology features, soils and vegetation cover were assessed to reduce the hazard vulnerability.

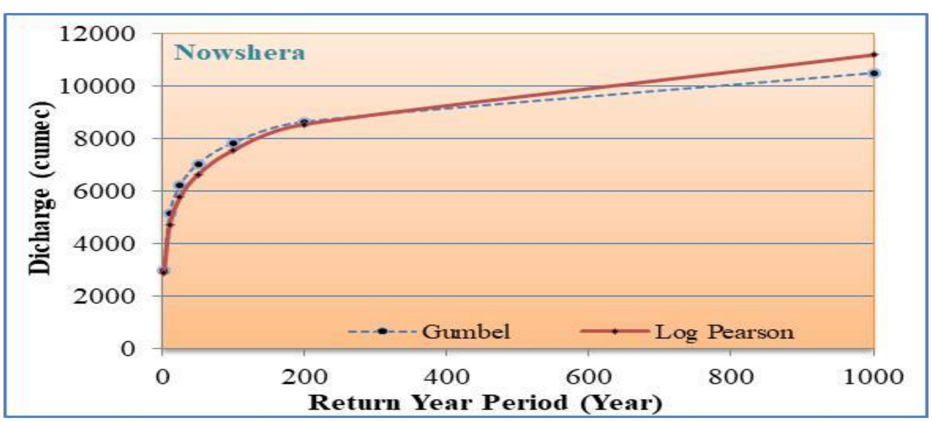

Figure-3: Flood magnitude at Nowshera by using Gumbel and Log Pearson-III method.

Table -4: Land use type and categories in the study area.

Sr. No	Land type	Area (Km^2)	Catchment (%)
1	Area of Irrigated cropland	3553.48	9.66
2	Area of Rain fed cropland	5223.68	14.89
3	Area of mosaic cropland (50-70%)/vegetation (Grassland, Shrub land, Forest)(20-50%)	2538.33	7.94
4	Area of mosaic vegetation (grassland, shrub land, forest)(50-70%)/cropland(20-50%)	2670.96	6.63
5	Ara of needle leaved evergreen forest(>5m)	789.4	3.45
6	Area of mixed broadleaved and needle leaved forest (>5m)	426.87	1.19
7	Area of mosaic forest/shrub land (50-70%)/grassland (20-50%)	181.31	0.89
8	Area of Grassland and shrub	9349.81	26.66
9	Artificial related area (urban areas >5%)	211.41	0.59
10	Bare areas	6672.69	18.67
11	water bodies	27.09	0.08
12	Permanent snow and ice	4099.86	11.47

Source: European Space Agency, 2016

The analysis incorporated that this study was a comparative study of two watersheds of the Jhelum basin (Rather *et al.,* 2017). The results revealed that the watershed area of the Lidder was display less than the Rembiara catchment area during a storm condition. This area was more population density as compared to other regions and therefore is generally vulnerable to flooding than Rembieria. However, it might be helpful for the determining of flood mitigation strategies in the HKH (Hindu Kush Himalayan) territory (Singh, 1992).

Water yield was estimated from the water flow data of Nowshera dam, which is shown in table 5. The water balance components were correctly estimated and Simly Dam inflow was successfully reproduced with a coefficient of determination (R^2) of 0.75. The results indicated that drainage, hydro-planning, soil and crop management, management of siltation are measured the basic ways that was creating the hurdle in the adaptation and policy formulation regarding the water quality.

Table -5: Water Yield of Kabul catchment area-northwestern (1985-2015).

Month	Water Flow (m^3/Sec)	Days	Water yield (mm)
Jan	275.3	31	7.1
Feb	286.7	29	8.6
Mar	416.6	31	12.3
Apr	989.7	30	26.6
May	1480.2	31	46.4
Jun	1889.2	30	56.3
Jul	1897.8	31	59.4
Aug	1404.6	31	43.2
Sept	605.4	30	19.4
Oct	327	31	9.3
Nov	248.2	30	8.3
Dec	238.5	31	6.3
Annual Mean	838.2		303.2

Source: Water and Power Development Authority (WAPDA) 2016

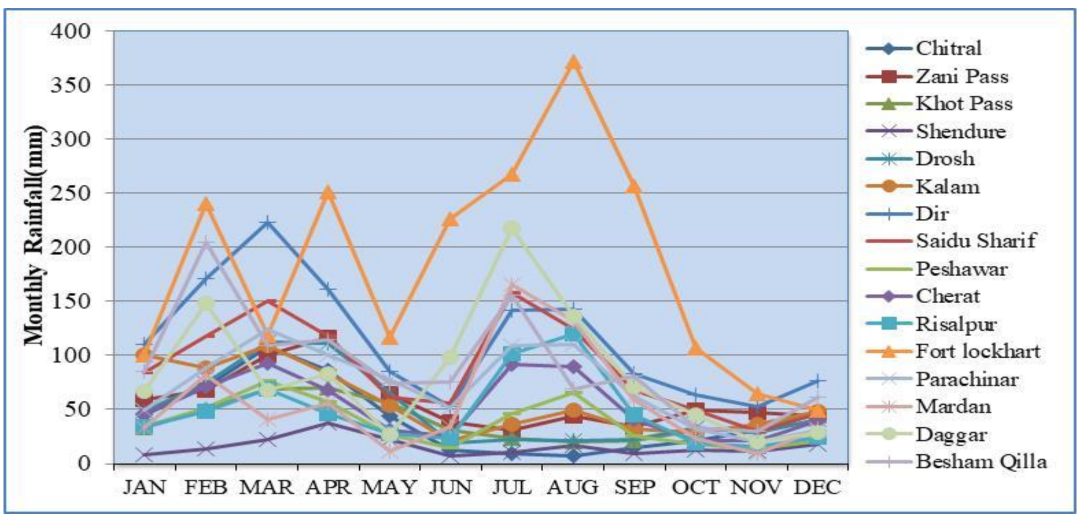

Figure- 4: Rainfall pattern of the Kabul catchment area (1985-2015).

Thirteen stations have been categorized into various ecological zones, based on the climate and types of forests in the Kabul catchment area in northwestern Pakistan. There were a total of 830 extreme weather events observed with an overall surplus of 5 mm rainfall, which has been used to access the relationship between various climatic parameters. The intensity of rainfall was not evidently found significant in any catchment area of the watershed. The peak flow (hrs.) was not significantly related to any watershed factors. The distribution of the forest cover was significant and noticed with two types of flow rate indices. These two independent forest parameters were connected with 20-30% of total variance with the correspondent water runoff. The size of the watershed was not found significant. The runoff indices were linked with the increase and decrease of surface runoff. Monthly rainfall pattern of the 13 meteorological stations was located in the

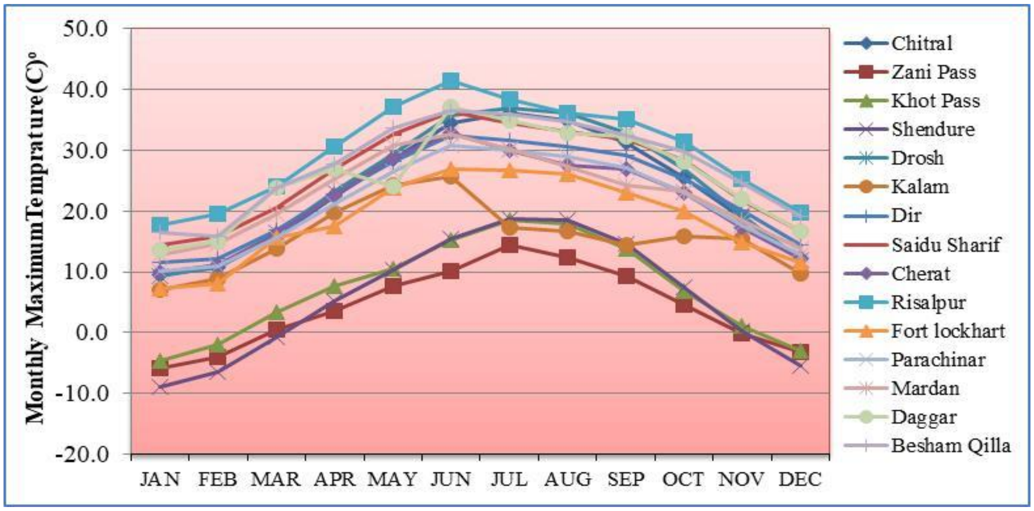

Figure-5: Maximum temperature of the Kabul catchment area (1985-2015).

The shape of the watershed was supported at a total of 27% variation with flow rate. The average slope (%) was not recorded significant with runoff variables at the level of 0.01. The average elevation difference (m) was noticed highly significant to the index of water flow rates (m^3 s^{-1}). Figure 4 depicts the rainfall pattern of investigating stations. In Kabul River catchment area, the highest rainfall was recorded in Fort Lockhart in July-August as compared to other weather observatories in northwestern Pakistan. The water stress of this catchment was mostly balanced by the summer monsoon rainfall season while an increase in temperature above normal has the negative effect on the rainfall pattern and river flow. This study investigates the trends of minimum and maximum temperature over the catchment area of the Kabul River in northwestern Pakistan. Figure 5 shows the trends of the maximum temperature monthly.

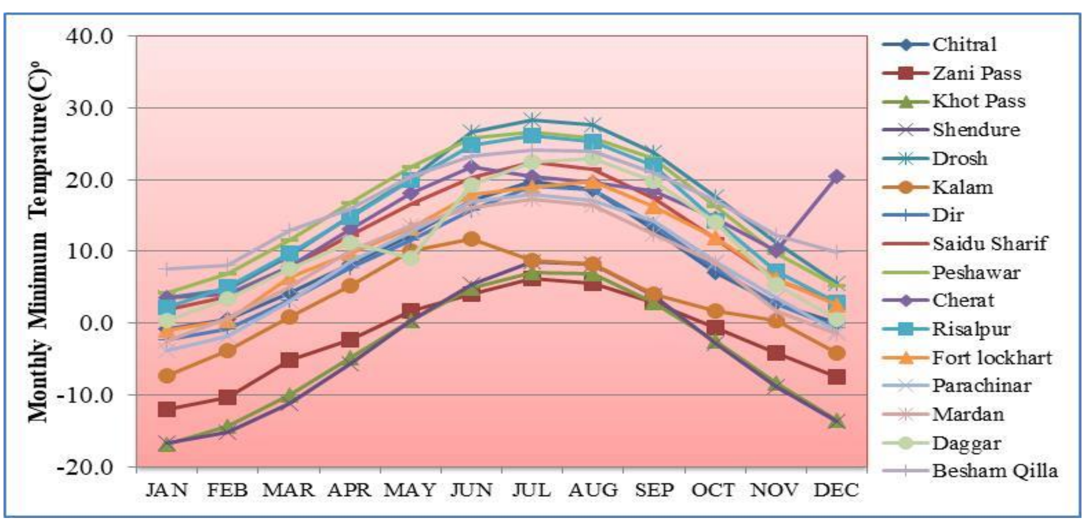

Figure-6: Minimum temperature of the Kabul catchment area (1985-2015).

Results have documented that Rasulpur station has highest maximum temperature above 40 °C in the June. The lowest maximum temperature observed in Shendure -10 °C in the January, whereas the minimum temperature was high observed above normal in Drosh 26 °C in the July and low in the Khot Pass in the January at -15 °C (Figure 6).

Conclusion: The physiography and geomorphometric features of the catchment area are useful to simulate the hydrological response of the catchment and the climate change scenario in the region. The result of this study is also effective for the management of a watershed, controlling erosion of the soil, minimizing damages from the runoff, increasing groundwater recharge, reduction in the sediment production and appropriate use of the land resources in the Kabul catchment region in particular and for Pakistan in general.

REFERENCES

Ali, K., R.M. Bajracharya, B.K. Sitaula, N. Raut and H.L. Koirala (2017). Morphometric analysis of the Gilgit River basin in mountainous region of Gilgit-Baltistan province, northern Pakistan. J. Geo. Sci. Env. Pro. 5 (7): 70-88.

Bao, T.R. and M.J. Laituri (2013). The effects of watershed characteristics on storm runoff relationships in Vietnam. J. Env. Sci. Wat. Res. 2 (2): 40-52.

Celik, R. and V. Aslan, (2020). Evaluation of hydrological and hydrogeological characteristics affecting the groundwater potential of Harran Basin. Ara. J. Geo. Sci. 13 (4): 1-13.

Ediriweera, D.S., A. Kasturiratne, A. Pathmeswaran, N.K. Gunawardena, B.A. Wijayawickrama, S.F. Jayamanne, G.K. Isbister, A. Dawson, E. Giorgi, P.J. Diggle and D.G. Lalloo (2016). Mapping the risk of snakebite in Sri Lanka a national survey with geo spatial analysis. PLO. Neg. Tro. Dis. 10 (7): 1-14.

Ghoraba, S.M. (2015). Hydrological modeling of the simly dam watershed Pakistan using GIS and SWAT model. Ale. Eng. J. . 54 (3): 583-594.

Giridhar, M.V.S.S., R. Anirudh, G.S. Rao and P. Sowmya (2015). DEM Processing for watershed delineation using QSWAT. Int. J. Sci. Eng. Research. 6 (8):1670-1674.

Gumindoga, W., H. Makurira, M. Phiri and I. Nhapi (2016). Estimating runoff from ungauged catchments for reservoir water balance in the Lower Middle Zambezi Basin. Wat. SA. 42 (4): 641-649.

Loucks, D.P. and E.B. Van (2017). Water resource systems planning and management: An introduction to methods, models and applications. Springer. 567 p.

Meraj, G., S.A. Romshoo, A.R. Yousuf, S. Altaf and F. Altaf (2015). Assessing the influence of watershed characteristics of the flood vulnerability of Jhelum basin in Kashmir Himalaya. Nat. Haz. 77 (1): 153-175.

Mogaji, K.A. and H. San Lim, (2017). Application of a GIS-/remote sensing- based approach for predicting groundwater potential zones using a multi- criteria data mining methodology. Env. Mon. Ass. 189 (7): 1-26.

Pujari, S.S., S.S. Savairam and A.C. Ranveer (2015). Identification delineation and mapping of micro watershed of Kolhapur region. Int. J. Sci. Tec. 3(12): 1-7.

Rai, P.K., R.S. Chandel, V.N. Mishra and P. Singh (2018). Hydrological inferences through morphometric analysis of the lower Kosi river basin of India for water resource management based on remote sensing data. App. Wat. Sci. 8(1): 1-16.

Rasooli, A. and D. Kang (2015). Assessment of potential dam sites in the Kabul river basin using GIS. Int. J. Adv. Com. Sci. App. 6(2): 83-89.

Rather, M. A., J.S. Kumar, M. Farooq and H. Rashid (2017). Assessing the influence of watershed characteristics on the soil erosion susceptibility of Jhelum basin in the Kashmir Himalayas. Ara. J. Geo. Sci. 10 (3): 59-84.

Singh, P., A. Gupta and M. Singh (2014). Hydrological inferences from watershed analysis for water resource management using remote sensing and GIS techniques. Egy. J. Rem. Sen. Spa. Sci.17 (2): 111-121.

Singh, S (1992). Quantitative geomorphology of the drainage basin. In: Chouhan TS, Joshi KN Readings on remote sensing applications. Scientific Publishers; Jodhpur.

Singh, S (1995). Quantitative analysis of watershed Geomorphology using remote sensing techniques. Ann. Ari. Zon. 34 (4): 243-251.

Singh, S. and M.C. Singh (1997). Morphometric analysis of Kanhar river basin. Nat. Geo. J. lnd. 43 (1): 31-43.

Sinha, L., R. Rathore, and U. Jain (2015). Watershed delineation of narmada Basin-Indira sagar dam to maheshwar dam of Madhya Pradesh. Int. J. Eme Tec. Adv. Eng. 5(8): 307-312.

Tariq, M.A.U.R., N. Giesen, S. Janjua, M. L. U. R. Shahid and R. Farooq (2020). An Engineering Perspective of Water sharing issues in Pakistan. J. Wat. 12 (2): 1-14.