INTEGRATED REMOTE SENSING AND GIS BASED CHARACTERIZATION OF KABUL RIVER WATERSHED

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ABSTRACT: *Although the Kabul River Catchment is located in a mountainous region with limited direct human intervention, it remains highly sensitive to the impacts of climate change and extreme hydrological events. This study focuses on the comprehensive analysis of catchment characteristics in the Kabul River basin using Digital Elevation Modal (DEM) of Kabul Catchment. The Arc Hydro tools are used to derive Watershed delineated, delineation of the Stream Network, Classification of the soil and land use classes, Estimation of Total Watershed area and Sub watersheds Areas, the estimation of Stream Characteristics, Climatic Characteristics, Slope, Aspect, Topography, Flood Peak and Water yield of Kabul catchment. The integration of these aspects is then used to develop a vector representation of catchments Characteristics. The utility of Arc Hydro tools enables to develop attributes that can be useful in hydrologic modeling. The findings of this study demonstrate the effectiveness of remote sensing and GIS techniques in producing accurate and detailed spatial results. This research highlights the potential of geospatial tools in watershed management, hydrology, agriculture, flood risk management, and sustainable water resource planning across the Kabul ba*sin.

Key words: Remote sensing, Geographical information system, watershed management, Climatic Characteristics

INTRODUCTION

To understand the laws of runoff processes within a catchment, hydrologists face many challenges, especially in respect of ungagged catchment where hydrological data are limited or entirely absent [1]. In such cases, hydrologists have relied on various empirical models to establish relationships between precipitation and runoff, though many of these models are crude approximations. To address these limitations many hydrologists and earth scientists quantify and relate geomorphological parameters of naturally shaped river basins to its hydrologic response characteristics [2]. Drainage basins are the fundamental units of the fluvial landscape, and, accordingly, a great amount of research has focused on their geometric characteristics, including the topology of the stream networks, and the quantitative description of drainage texture, pattern, shape, and relief. Because drainage basins are the physical entities used to measure the volume of water and sediment produced by runoff and erosion, the morphometric analysis of basin has been extended to include the interrelationships between network characteristics and the resulting water and sediment yields [3].In regions like the mountainous Kabul River catchment, where the vexed problem of non-availability or inadequacy of data for the river basins, particularly in mountainous areas [1]. DEMs are used to delineate watersheds, in this study, various physical characteristics i.e., Stream Network, Stream order, Drainage Density, Stream Density, Bifurcation ratio, stream Length, soil and Land use, Topography,(Max. and Min.) of rainfall and temperature, slope, aspect of Kabul catchment are evaluated . These attributes provide a foundational understanding of the catchment's hydrological behavior and serve as critical inputs for watershed modeling and resource planning [4].

OBJECTIVES OF THE STUDY

This study was based to estimate characterization of Kabul river basin using remote sensing and GIS [5].
The specific objectives were as follows:

1. To Delineate the Kabul River from DEM (Digital Elevation Modal).
2. To delineate the stream network of the Kabul River.
3. To Estimate the Slope and aspect of Kabul River.
4. To Estimate the Topography of Kabul River.
5. To Estimate the total watershed Area and sub-watersheds Area of Kabul River.
6. To determine the soil and land use classes of Kabul River confining in the Pakistan boundary.
7. To Estimate the Stream Order, Stream length, mean of Stream length, Stream Density, Bifurcation Ratio and Drainage Density of Kabul river Basin.
8. To estimate the Flood Peak of Kabul River.
9. To Estimate the water yield of Kabul River.
10. To Estimate the climatic characteristics of Kabul River basin.

UTILIZATION OF STUDY

The scope is not limited to the study of the Watershed Delineation, Area Estimation, Delineation of Stream network, Slop and Aspect Estimation, Soil and land use Classification Estimation of Topography, Estimation of Temperature and Rain fall (mean, Max. min.) as latest research was done in this regard so future steps and studies can be planned according to this Characterization [1]. This Calculations, Estimation and Analysis are very important for hydrology and watershed management, so that it is useful for hydropower plants and other managerial activities. In this regard the research done will provide new aspect in the field of hydrology and agriculture [6]. This study will focus to determine the water speed with slope and to calculate the total Catchment study area. Analysis will be carried out to examine the impact of these factors on the trend of river flows in Pakistan [7]. The results of this study will also be helpful for decision makers to

develop the strategies for planning and development of water resources under different climatic scenarios to overcome their adverse impact [8].

MATERIALS AND METHODS

STUDY AREA

This study carried out in the Kabul River. The Kabul watershed boundary was derived from Digital Elevation Model (DEM). Kabul River exist in eastern Afghanistan and northwestern Pakistan, 435 miles (700 km) long, of which 350 miles (560 km) are in Afghanistan [1]. It originates in the Sang lakh Range at the location of 34°33′ 30.71″N latitude and 68°51′4.51″E longitude covering 45miles (72 km) west of Kabul city.it flows east through past Kabul and Jalalabad, north of the Khyber Pass into Pakistan, and past Peshawar. It joins the Indus River near Attock Khurd at 33°53′58.54″ N latitude and 72°14′4.36″E longitude.

Figure: 1(Source: Google)

The river has four major tributaries—the Lowgar, the Panjshēr, the Konar (Kunar), and the Alīngār. Most of area of this catchment is lies in Afghanistan and Pakistan. Due to unavailability of data from Afghanistan, the study area was confined to the catchment falling within Pakistan boundary. The Kabul River, a major western flank tributary, joins with Indus near Attock.

Location map

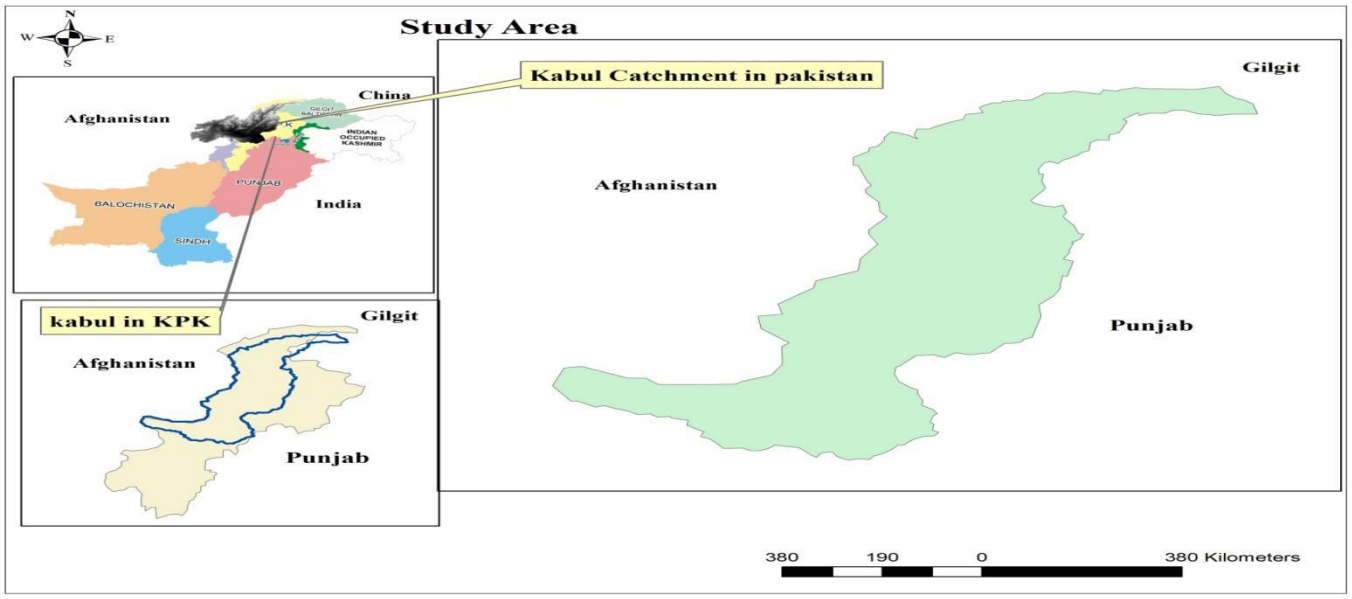


Figure: 2 (Location of study area)

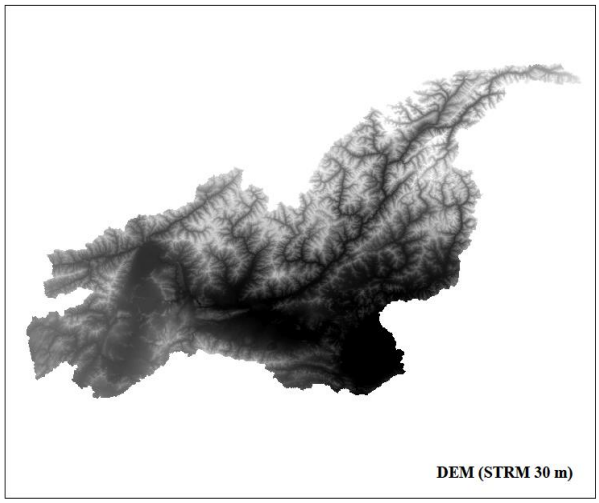


Figure: 3 DEM Data (Source: USGS)

Techniques and software are available for correcting errors in DEM. DEM used in the study is automatically corrected by SWAT model [4].

The SRTM (Shuttle Radar Topography Mission) 30 m resolution DEM was used in this study. SRTM is an international project headed by US National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA). The data are made freely available by the United States Geological Survey (USGS).

WATERSHED DELINEATION

This process consist in the delimitation of the topographic features, it means the geographic area in which every drop of water drains to the network stream evaluated. Not only does a watershed drain, it also captures precipitation, filters and stores water, and determines its release. The Automatic Watershed Delineation tool carries out advanced GIS functions to help in segmenting watershed into several hierologically connected sub-basins for use in watershed characterization and modeling [2, 3, 5]. The runoff efficiency (volume of runoff per unit of area) increases with the decreasing size of the basin, which means that the larger the size of the basin the larger the time of concentration and the smaller the runoff efficiency [9]. The conventional methods of watershed delineation require a topographic map. Currently, topographic information is becoming available in the form of Digital Elevation Models (DEM) [4]. These are a computer data file that gives land surface elevation at grid points. Although it is not an entirely straightforward exercise, it is possible to develop computer programs that can trace out water divides and stream networks by analysing the DEM. In the present study "Automatic Watershed Delineation tool" was used for completing the watershed delineation process which gives the sub basins, reaches and longest flow path [5]. The Kabul River Delineation and Climatic Stations Fall in Pakistan are given in Fig 4.

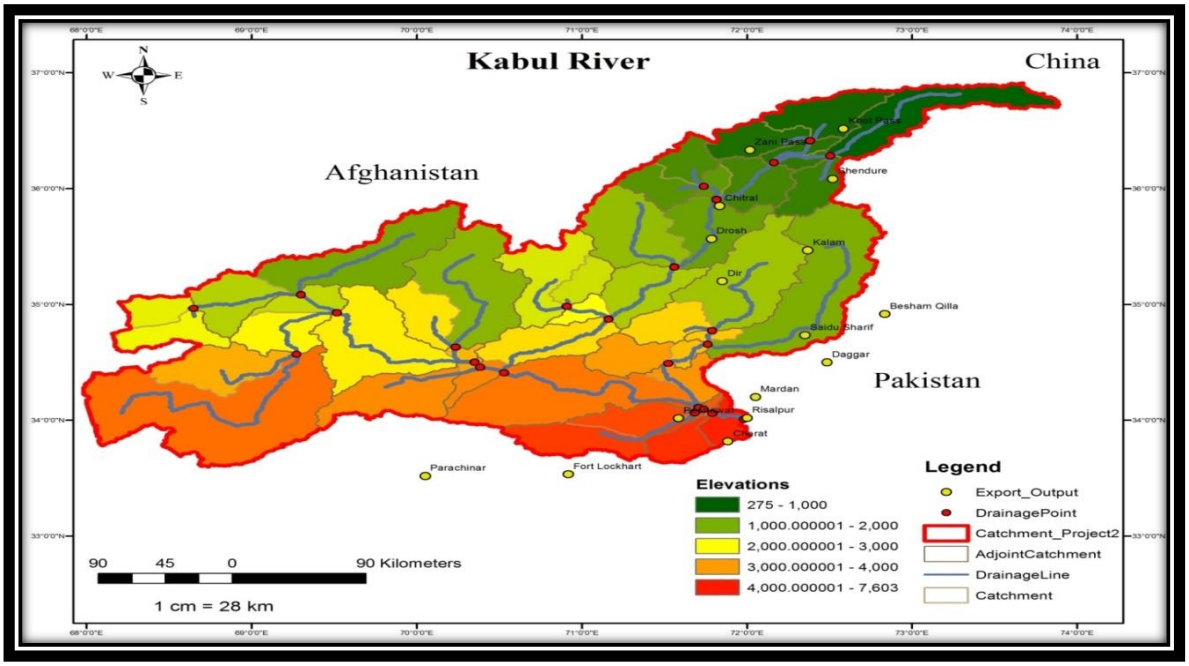


Figure: 4 Kabul River (Source: ArcGIS10.2.2)

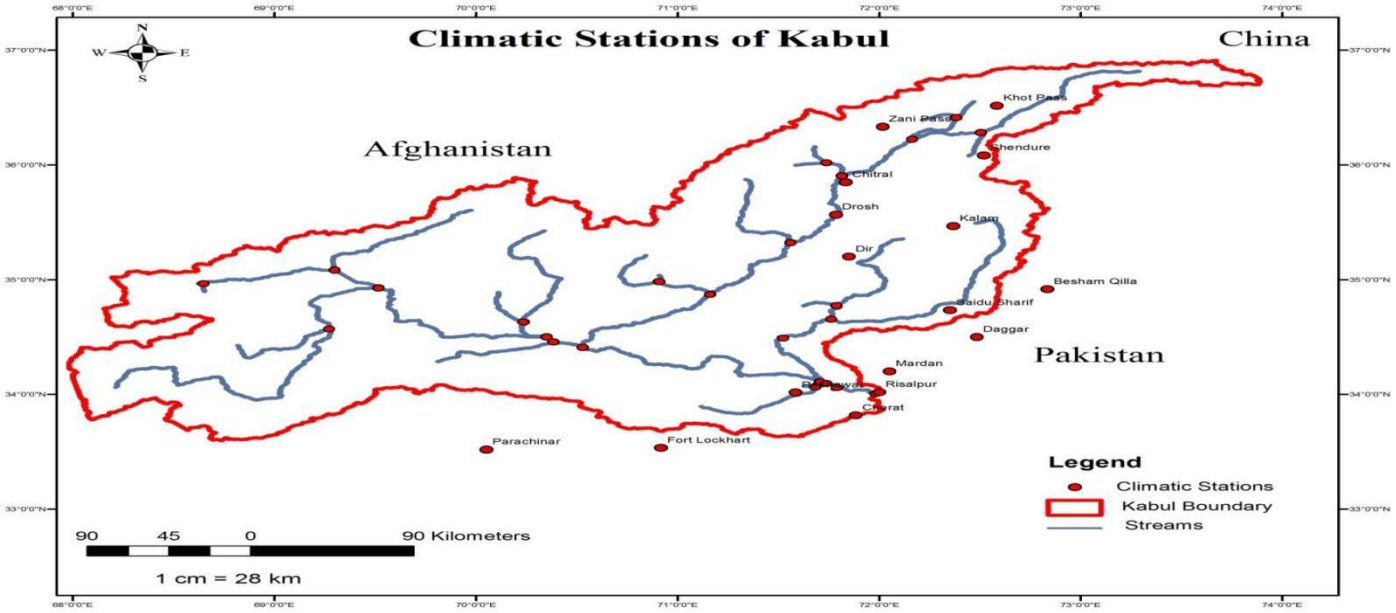


Figure: 5 (Climatic Stations)

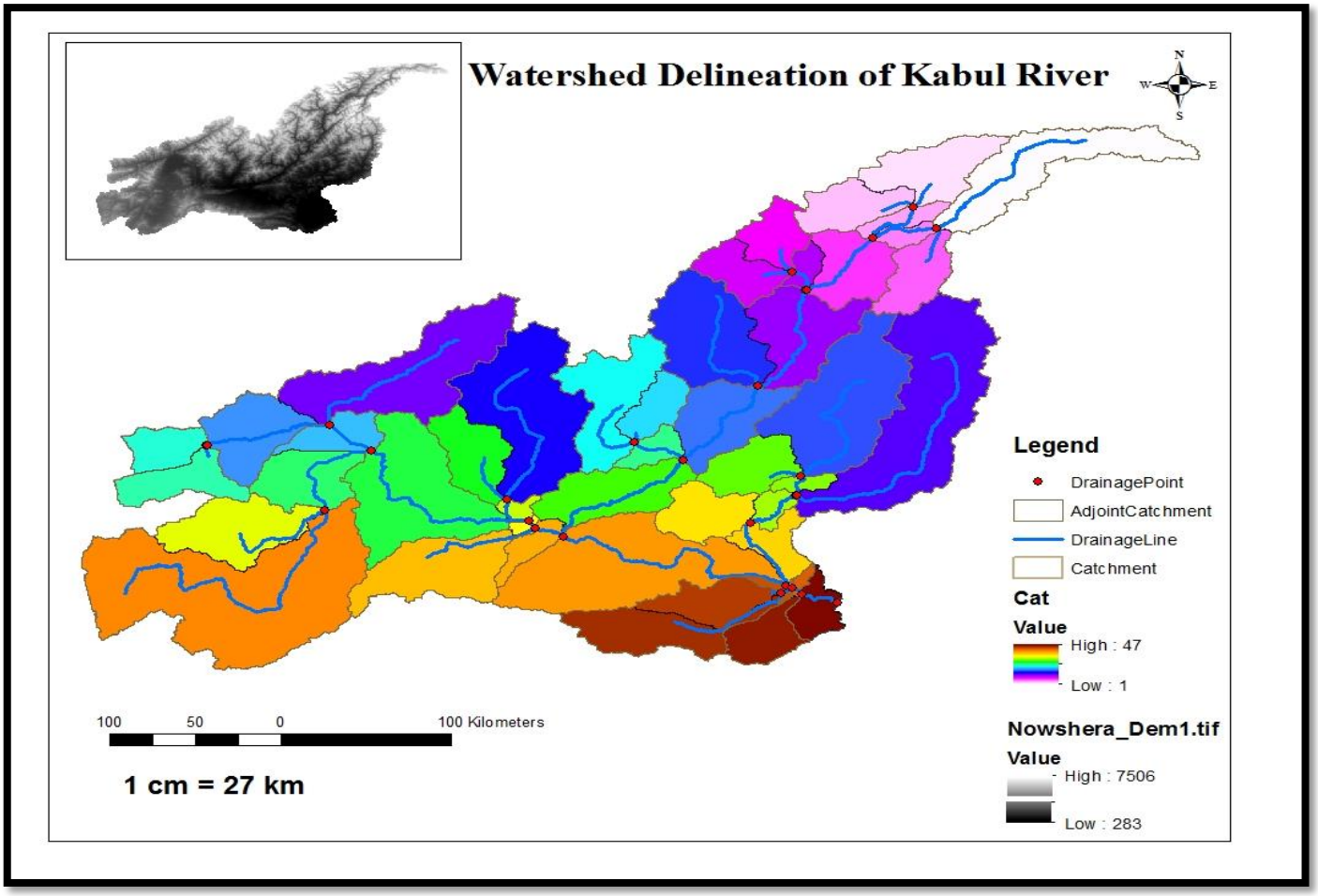


Figure: 6 (Kabul River Delineation)

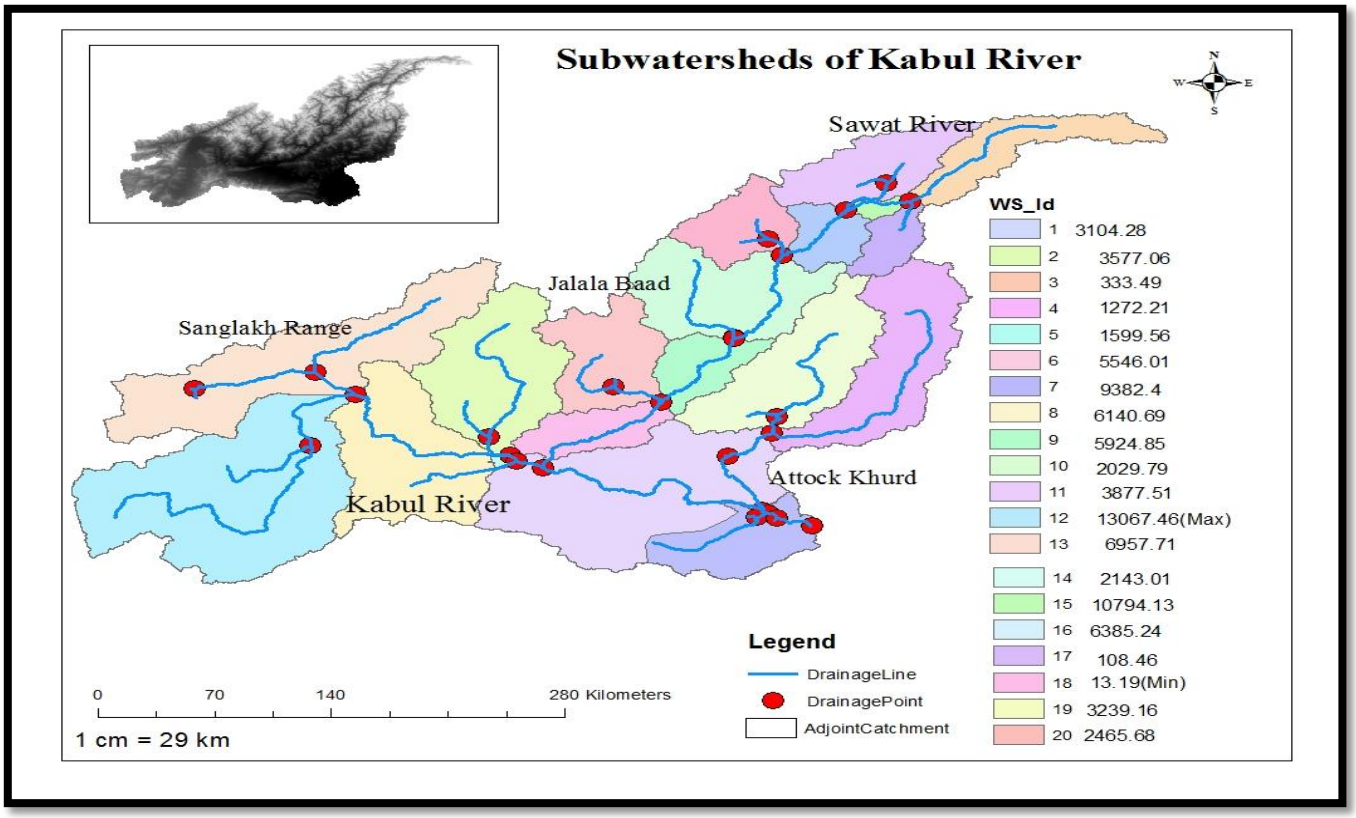
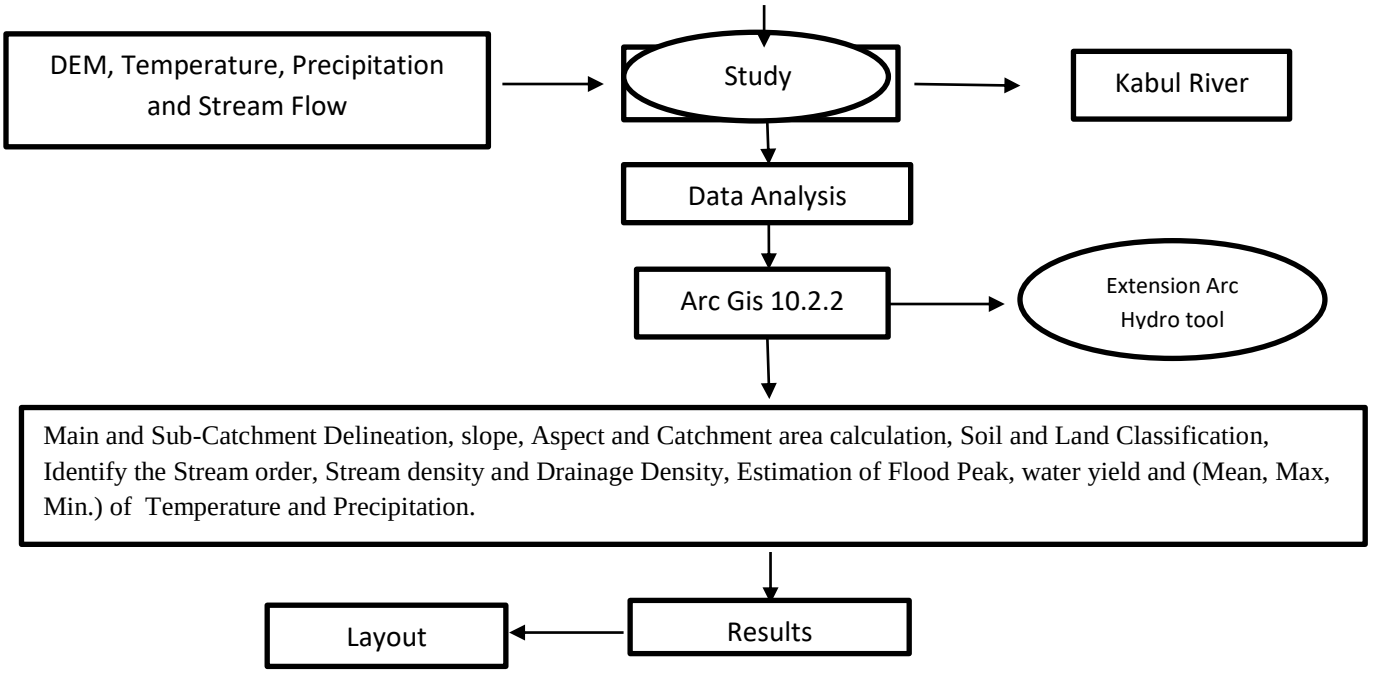


Figure: 7 (Sub watersheds Area)

DATA SOURCES

Data collection from primary source is USGS SRTM (Shuttle Radar Topography Mission) DEM 30m. In Arc GIS 10.2.2 the dispensation is occurring figure. After the Delineation of Basin by GIS 10.2.2(Arc Hydro tool) the catchment, Network stream, order and the catchment is produced [5]. After this work the slope and aspects of the catchment is calculated.

Data flow diagram



DATA REQUIREMENTS, SOURCE AND AVAILABILITY

The collection of following data was considered in order to analyze the climate change and its impacts on the stream flows in Kabul River [10, 11, 12].

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

Data Type	Source	Resolution/ Scale	Description
Topography	USGS National Elevation Dataset	30 × 30 m	DEM (Elevation)
Land use data	European Space Agency (ESA) Global Land Cover http://ionia1.esrin.esa.int/	300 × 300 m	Classified land use such as forest, agriculture, crops, water etc.
Soil data	FAO– International Soil Reference and Information Centre (ISRIC)	1 km	Classified soil and physical properties as sand silt clay bulk density etc.
Climatic data	Pakistan Metrological Department (PMD), Water and Power Development Authority (WAPDA)	Daily	Precipitation, Temperature, Solar radiation, Wind Speed
Hydrological data	Water and Power Development Authority (WAPDA)	Daily	Stream flows

Stream flows measurement in Kabul was carried out by the Water and Power Development Authority—Surface Water Hydrology Project (WAPDA-SWHP) The stream flow gauges are installed in all the Kabul Basin [10] at different locations which are shown in Fig 4. The flow data of these sites will be collected from Surface water Hydrology Project (SWHP), WAPDA. Sixteen stations were selected for this study. The geographical distribution of these stations is shown in Fig 5. The daily precipitation and temperature (maximum and minimum) data will be collected from Surface Water Hydrology Project (SWP), WAPDA and Pakistan Meteorological Department (PMD) [11].

RESULTS AND DISCUSSION

Delineation of Kabul River

Watershed Delineation was performed on Kabul Watershed, After Fill Sink, Flow Direction, Flow Accumulation, Stream Definition, Stream Segmentation, Catchment Grid Delineation, founded that main Watershed have 47 Catchment polygon and 47 Drainage Lines, 23 Adjoint Catchments and 24 Drainage Points [13].

Estimation of Sub watersheds Area

Founded that the Kabul Watershed have 20 Sub-watersheds in which the WS ID#18 has the minimum Area (13.19 Sq km) and the WS ID#12 has the Maximum Area (13067.46 Sq km).Kabul River Originated From Sanglakh range and Merge with INDUS at Attock khurd . Sub watersheds Area are as shown in Fig 7.

ESTIMATION OF TOTAL CATCHMENT AREA

The total catchment area of Kabul River was found 87961Km^2 as shown in Fig 8: About 45% of total catchment area fall in the Pakistan territory and rest 55% is fall in the Afghanistan [1].

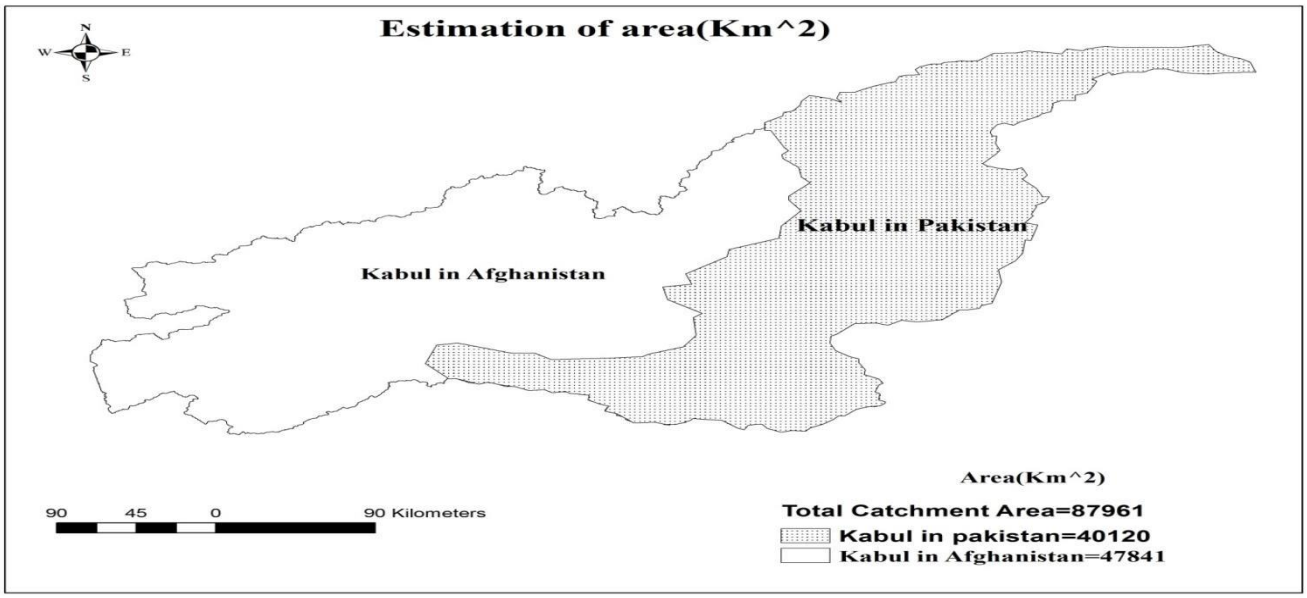


Figure: 8 Area Calculation of Kabul River

DELINEATION OF STREAM NETWORK

Stream Network was generated for the Estimation the Stream ordering, total Stream length, Drainage Density, Bifurcation Ration, Stream Density Shown in the fig 9and 10.

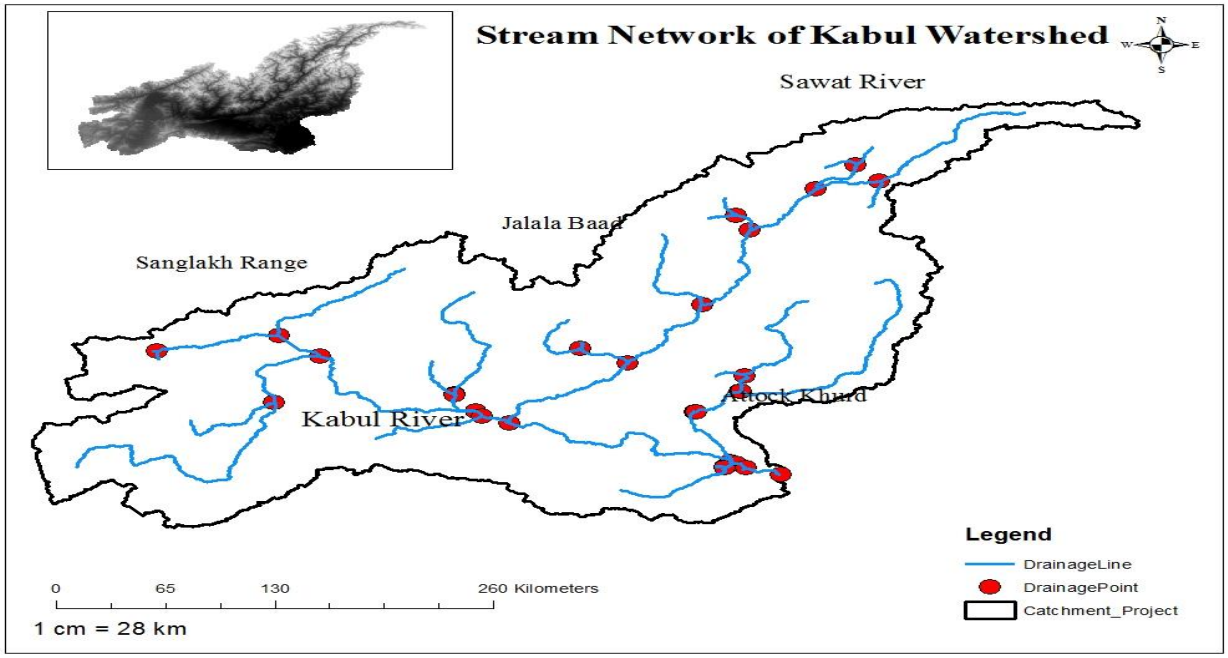


Figure: 9 (Stream Network of Kabul River)

Estimation of Stream Order, Stream Length, Mean Stream length

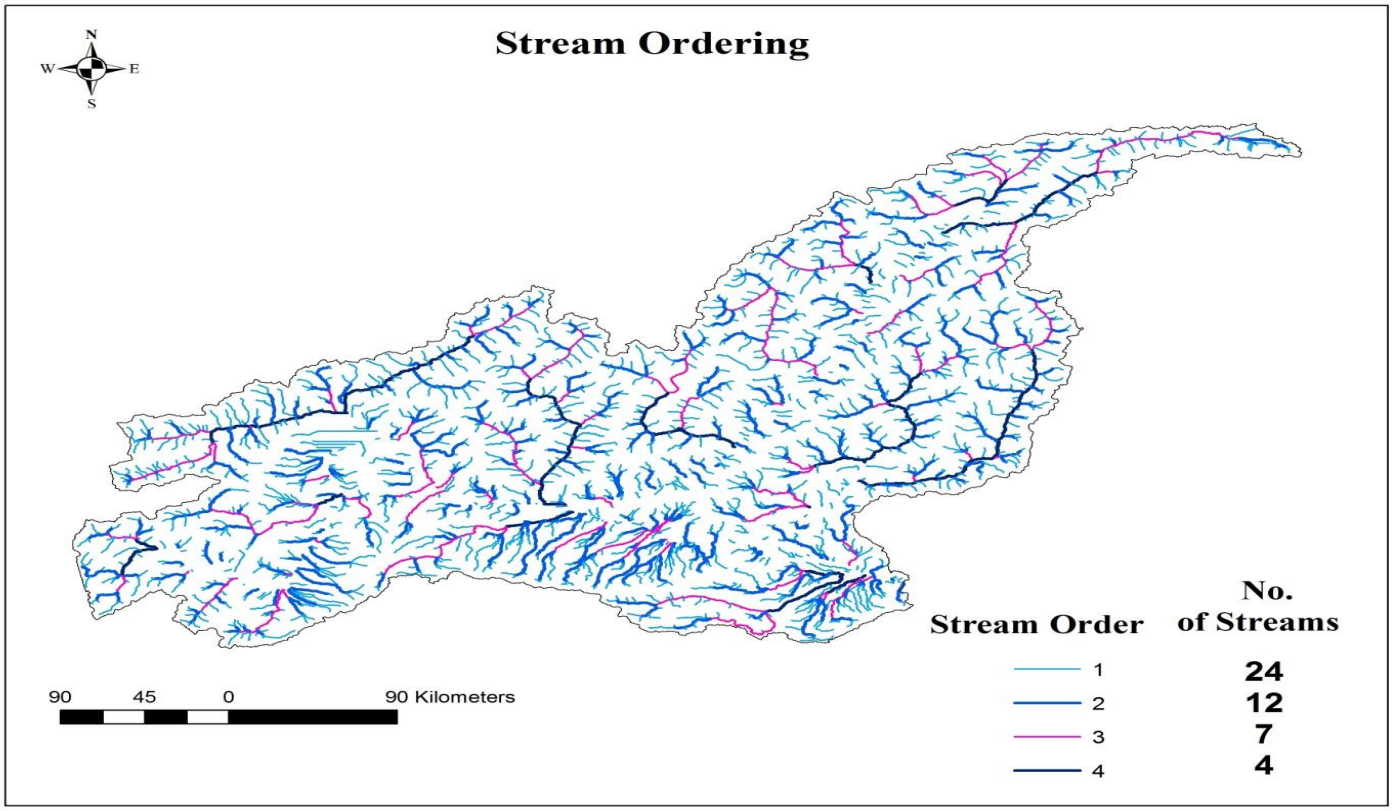


Figure: 10 (Streams Ordering of Kabul River)

Table: 2 Stream Characteristics

Sr. no	Stream Order	Stream Length Km)	No. of Streams	Mean Length (Km)
1	1st	1400	24	58.3
2	2nd	449	12	37.4
3	3rd	489	7	69.9
4	4th	205	4	51.3
Gross total	**4**	**2543**	**47**	**216.9**

Estimation of Bifurcation Ratio

The ratio between the number of streams of one order (see stream order) and those of the next-higher order in a drainage network in this study is Described below [14].

Table: 3 Bifurcation ratios

Bifurcation Ratio	(Nu/Nu+1)
N1/N2	2
N2/N3	1.7
N3/N4	1.7
Mean	1.8

Estimation of Drainage Density

The total length of all the streams of Kabul River basin (2544) divided by the total area (87961) of the drainage basin and the result of Drainage Density of the Kabul watershed is 0.028 $Km^{2.}$

Estimation of Stream Density

The total Number of all the streams of Kabul River basin (47) divided by the total area (87961) of the drainage basin [5] and the result of Drainage Density of the Kabul watershed is 0.00053 $Km^{2.}$

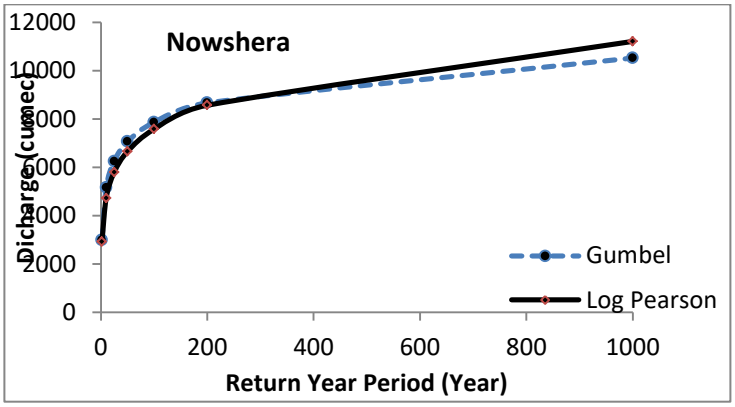
Estimation of Flood Peak

Comparison Graph of Gumbel & Log Pearson III Distribution Figure representing the flood magnitude on different return periods by applying Gumbel and Log Pearson-III at Nowshera Sub-catchment [14].

Table: 4 Flood Peak

Graph of flood magnitude at Nowshera by using

Graph No: 1 Flood Peak



Return Year	Gumbel	Log Pearson
2	2986	2912
10	5156	4726
25	6248	5789
50	7058	6651
100	7863	7574
200	8664	8567
1000	10520	11209

Gumbel & LogPearson-III method

Table provides the information of flood magnitudes of different return periods by applying Gumbel and Log Pearson-III distribution on historical record of flow at Nowshera. Gumbel distribution has shown lower value then Log Pearson-III. Suggesting that Gumbel distribution can be preferably used for estimation of flood of different return periods at Nowshera sub-catchment[9].

Estimation of Water Yield

Water yield was estimated from the water flow data of Nowshera dam is given below.

Table: 5 Water flow data of Nowshra watershed.(Units?)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
265.3	276.7	436.6	969.7	1459.2	1910.2	1917.8	1384.6	625.4	307.0	248.2	238.5	836.6

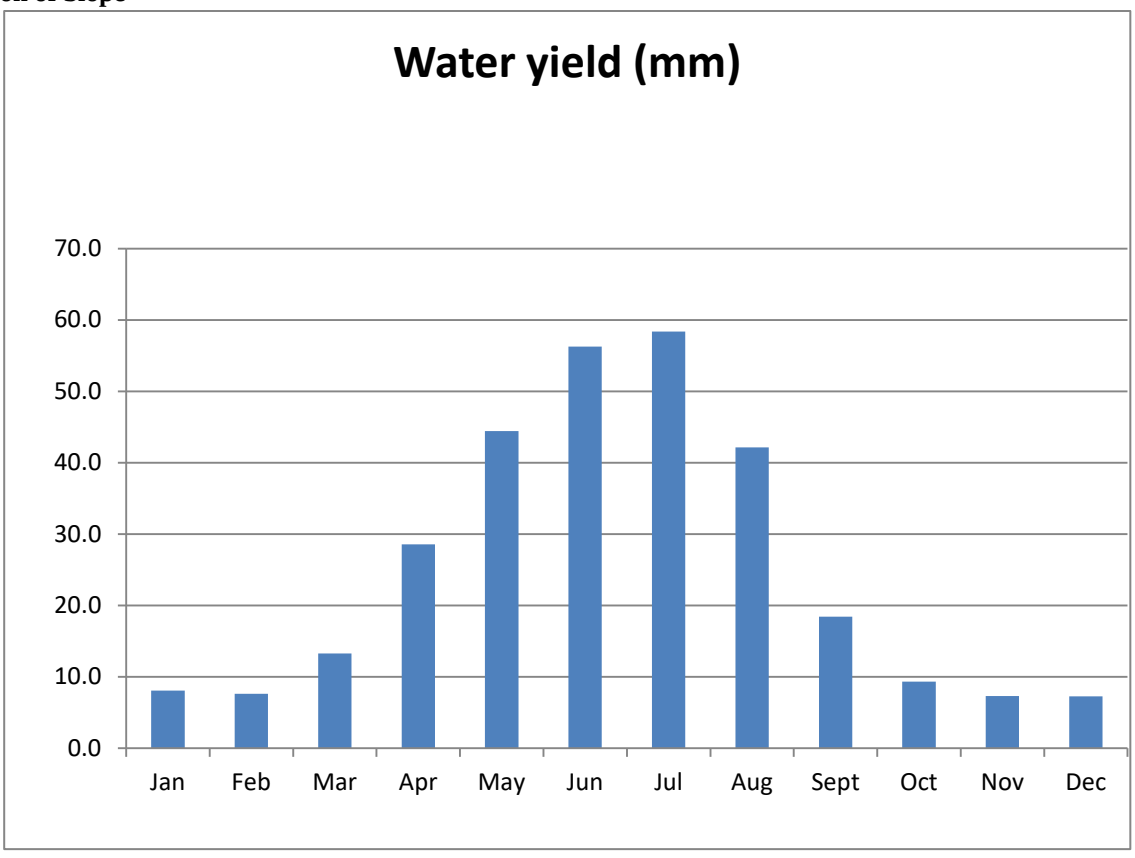
Table: 6 Water Yield

Month	Water Flow (m^3/Sec)	Days	Water yield (mm)
Jan	265.3	31	8.1
Feb	276.7	28	7.6
Mar	436.6	31	13.3
Apr	969.7	30	28.6
May	1459.2	31	44.4
Jun	1910.2	30	56.3
Jul	1917.8	31	58.4
Aug	1384.6	31	42.2
Sept	625.4	30	18.4
Oct	307	31	9.3
Nov	248.2	30	7.3
Dec	238.5	31	7.3
Annual Mean	836.6		301.2

The total outflow from all or part of a drainage basin through either surface channels or subsurface aquifers within a given time so that the results show that the nowshera has a large catchment area and low water yield.

Graph: 2 Water yield

Estimation of Slope



The results founded the values of the Slope from the Arc Hydro tool.

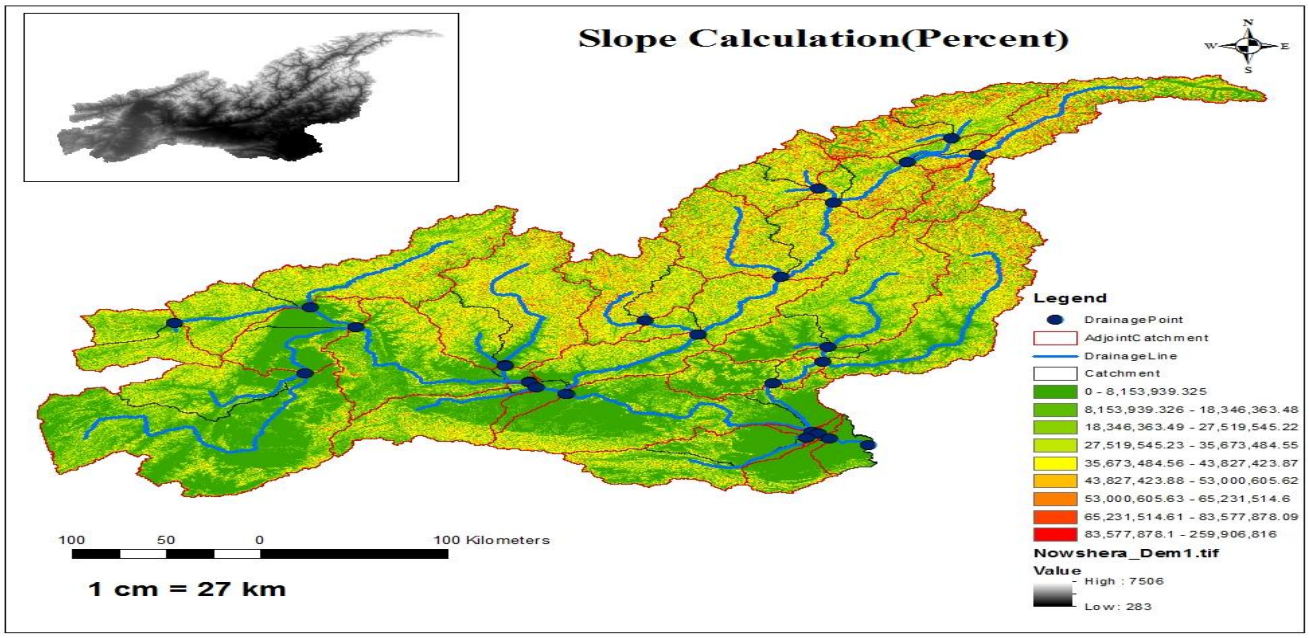


Figure: 11 (Slope Calculations (Percent) of Kabul River)

Estimation of Aspect

The results founded the values of the Aspects from the Arc Hydro tool.

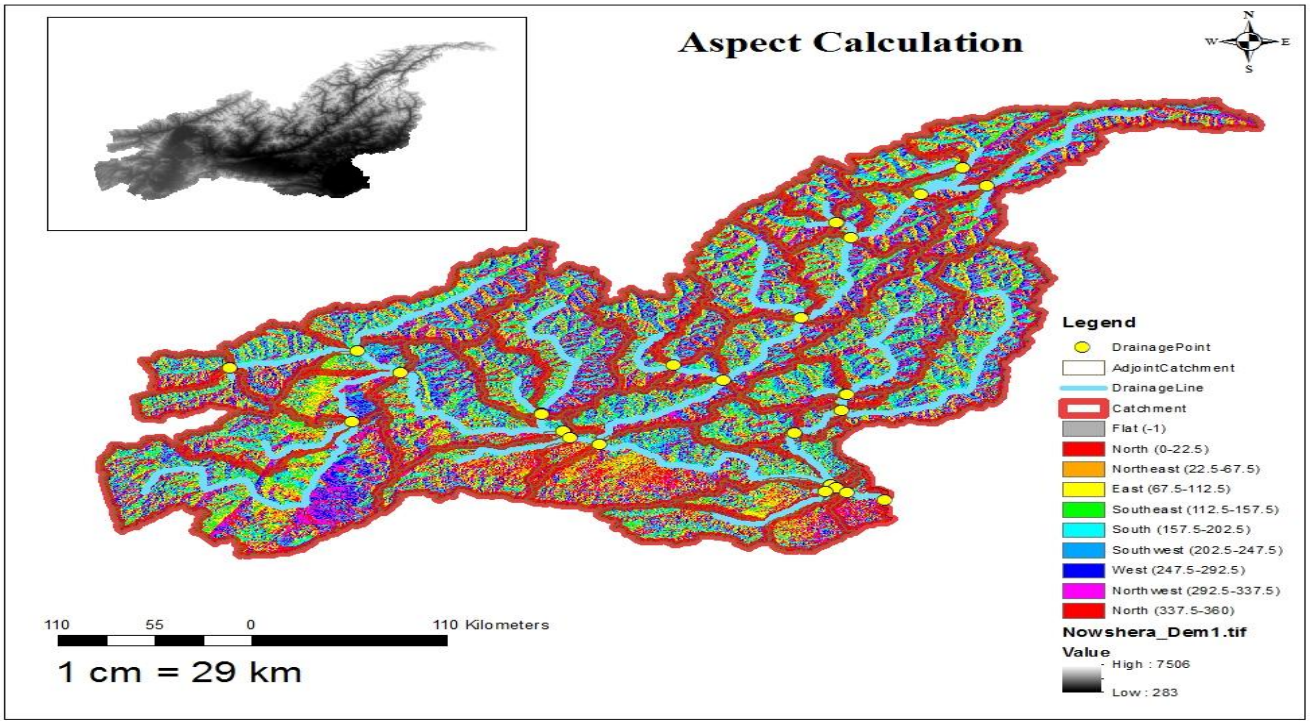


Figure: 12 (Aspects Calculation of Kabul River)

Estimation of Soil Classes

The global IPCC soil classes from United Nation Food and Agriculture Organization (FAO) regional scale soil database were downloaded to build user soil file consisting of 6 soil classes for SWAT modeling in the selected watershed. The following map (Figure) illustrates the distribution of soil type's classification in the Kabul catchment [15]. This catchment is mountainous and characterized by winter high precipitation as snow which has formed weathering soil types in that area. Additional information about soil texture was obtained from literature and reports [12].

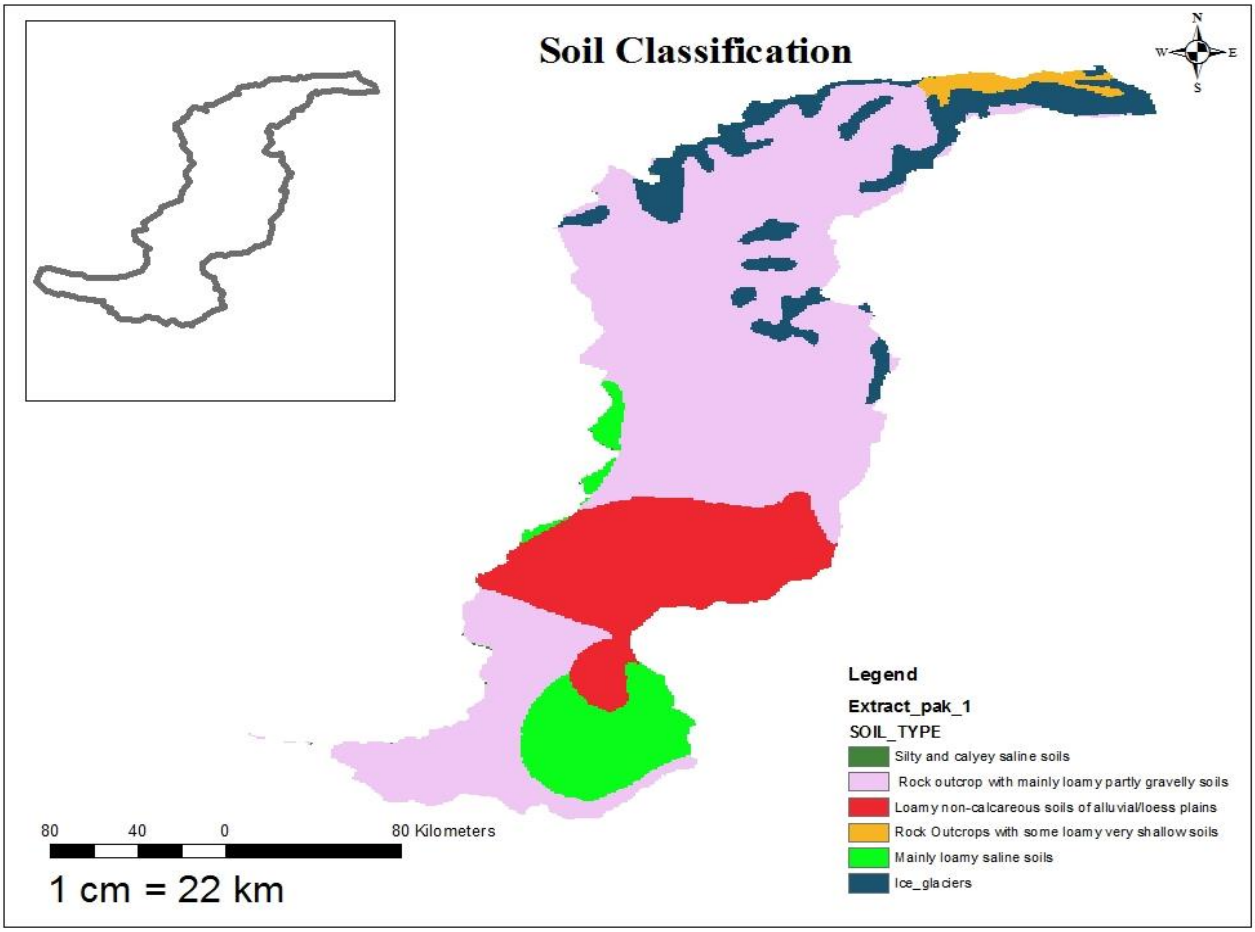


Figure: 13 (Soil Classifications)

Table: 7 Soil classifications in Kabul basin.

Sr. No	Soil Type	Area (Km^2)	% in catchment
1	Silty and Clayey Saline Soil	21.06	0.06
2	Rock outcrop with mainly loamy partly gravelly soil	21332.16	60.64
3	Loamy non-calcareous soil of alluvial/loess plains	6499.44	18.48
4	Rock outcrops with some loamy very shallow soil	623.7	1.77
5	Mainly loamy saline soils	3180.87	9.04
6	Ice-Glaciers	3521.07	10.01

Estimation of Land cover/Land use classes

Land use data at a spatial resolution of 300 meters were obtained from European Space Agency (ESA) database [16].

The land use map for this study and the percentage of watershed area for each cover is given in Figure 14 and Table 8. The map shows 16 different types of land cover.

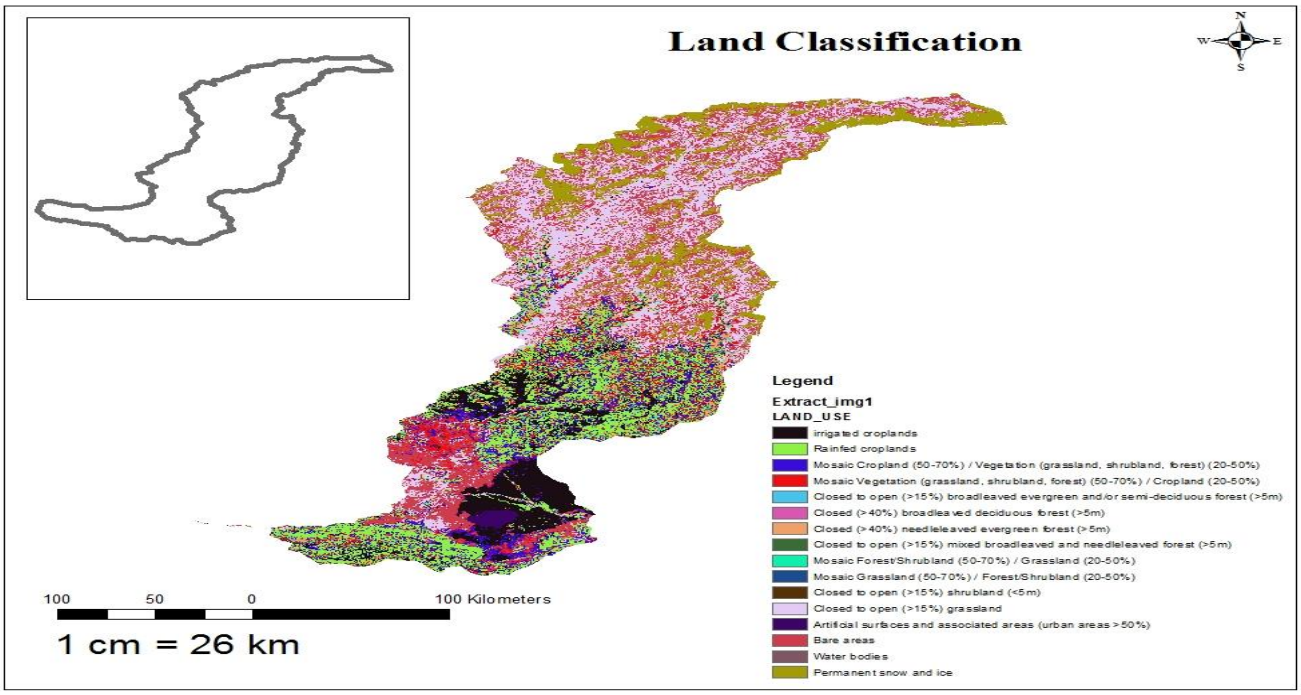


Figure: 14 Land Classifications

Table: 8 Land use type coverage in the study area.

Sr. No	Land Type	Area (Km^2)	% in catchment
1	Irrigated Cropland	3453.48	9.66
2	Rain fed cropland	5323.68	14.89
3	Mosaic cropland (50-70%)/Vegetation (Grassland, Shrub land, Forest)(20-50%)	2838.33	7.94
4	Mosaic Vegetation (grassland, shrub land, forest)(50-70%)/cropland(20-50%)	2370.96	6.63
5	closed to open(>15%)broadleaved evergreen and/or semi-deciduous forest(>5m)	46.44	0.13
6	Closed(40%) broadleaved deciduous forest(>5m)	27.27	0.08
7	Closed(>40)needle leaved evergreen forest(>5m)	716.4	2
8	Closed to open(>5%)mixed broadleaved and needle leaved forest(>5m)	426.87	1.19
9	Mosaic forest/shrub land (50-70%)/grassland (20-50%)	104.31	0.29
10	Mosaic grassland (50-70%)/forest/shrub land (20-50%)	77.04	0.22
11	Closed to open(>15%)shrub land(<5m)	178.11	0.5
12	Closed to open(>15%)Grassland	9171.81	25.66
13	Artificial surface and associated area (urban areas >5%)	211.41	0.59
14	Bare areas	6672.69	18.67
15	water bodies	27.09	0.08
16	Permanent snow and ice	4099.86	11.47

Estimation of Topography: Elevation of this study area start with 275 meters and the highest elevation is 7603 meters .all the Elevation class generated from the interval of 1000 meters as Shown in Figure 15.

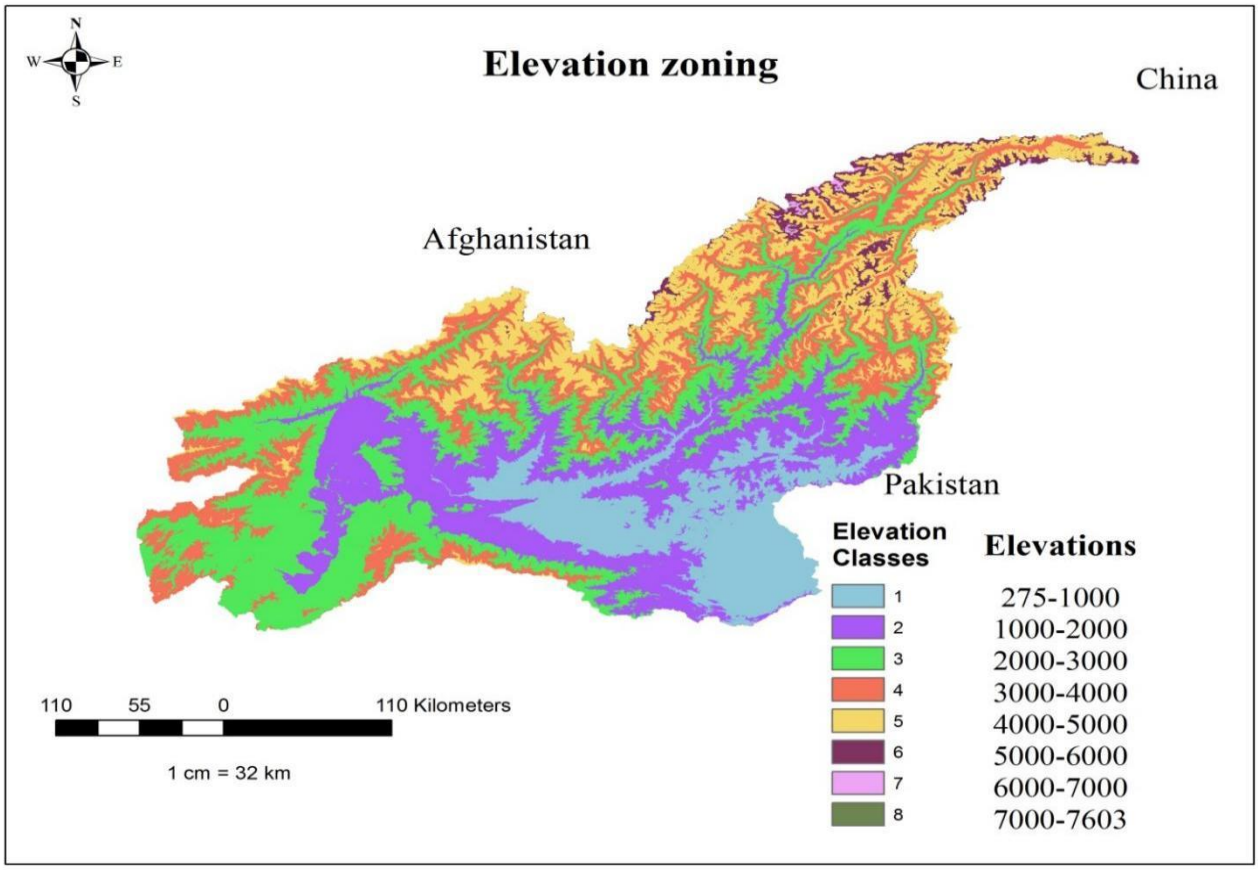


Figure: 15 (Elevation Zoning)

Table: 9 Elevation classes in the study area.

Sr. No	Elevation classes	Area (Km^2)	% in catchment
1	275-1000	1163.35	11.04
2	1000-2000	1906.78	18.10
3	2000-3000	2327.49	22.09
4	3000-4000	1747.59	16.58
5	4000-5000	1227.85	11.65
6	5000-6000	1977.85	18.77
7	6000-7000	172.36	1.64
8	7000-7603	14.25	0.14

Estimation of the monthly and annually Rainfall and monthly and annually Temperature max. And min. of Kabul River

Table: 10 Climatic stations in Kabul Watershed.

Sr. No.	Stations	Lat	Long	Elevation (m)	Precipitation (mm)	Max. Temp.(°C)	Min Temp.
1	Chitral	35.9	71.8	1500	472	23.3	8.6
2	Zani Pass	36.3	72.0	3895	595	4.1	-1.8
3	Khot Pass	36.5	72.6	3505	443	7.1	-4.0
4	Shendure	36.1	72.5	3719	169	5.7	-4.0
5	Drosh	35.6	71.8	1465	593	24.1	16.1
6	Kalam	35.5	72.4	2225	669	15.7	3.0
7	Dir	35.2	71.9	1370	1357	22.9	8.0
8	Saidu Sharif	34.7	72.4	962	1060	26.1	12.0
9	Peshawar	34.0	71.6	360	451	37.6	16.1
10	Cherat	33.8	71.9	1302	605	21.5	14.3
11	Risalpur	34.0	72.0	1200	576	29.7	14.5
12	Fort Lockhart	33.5	70.9	1982	2171	18.5	10.2
13	Parachinar	33.5	70.1	1729	859	21.2	8.0
14	Mardan	34.2	72.1	305	644	22.7	8.1
15	Daggar	34.5	72.5	732	966	25.6	11.3
16	Besham Qilla	34.9	72.8	480	1076	27.5	16.4

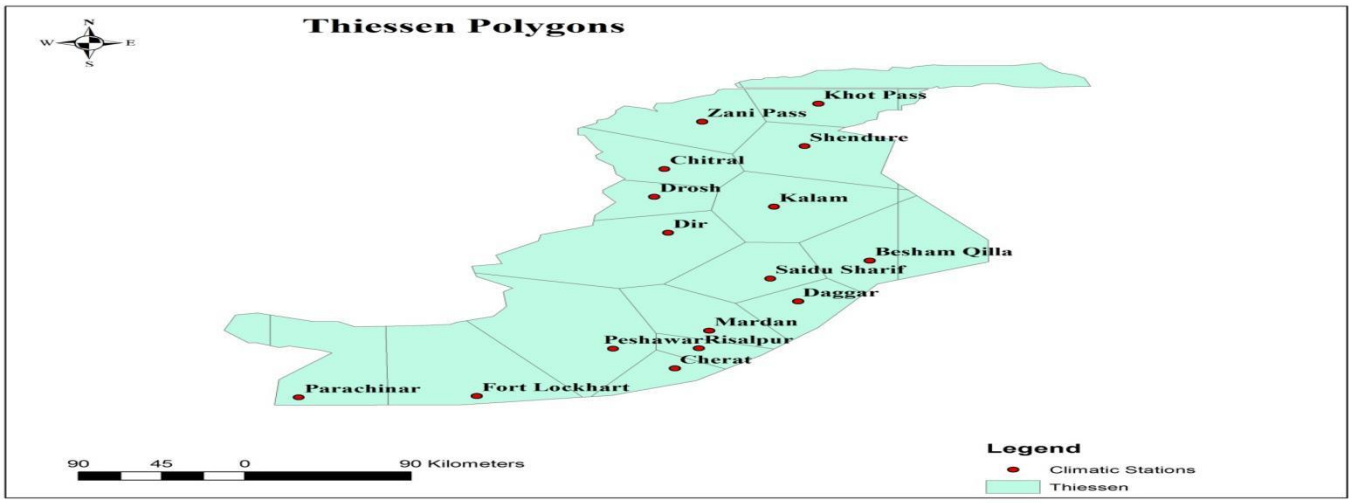
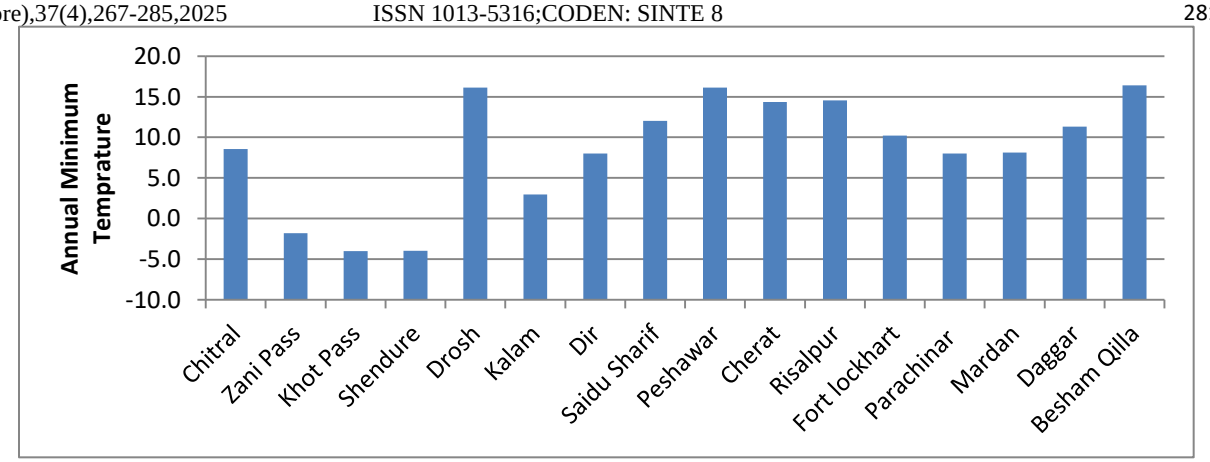


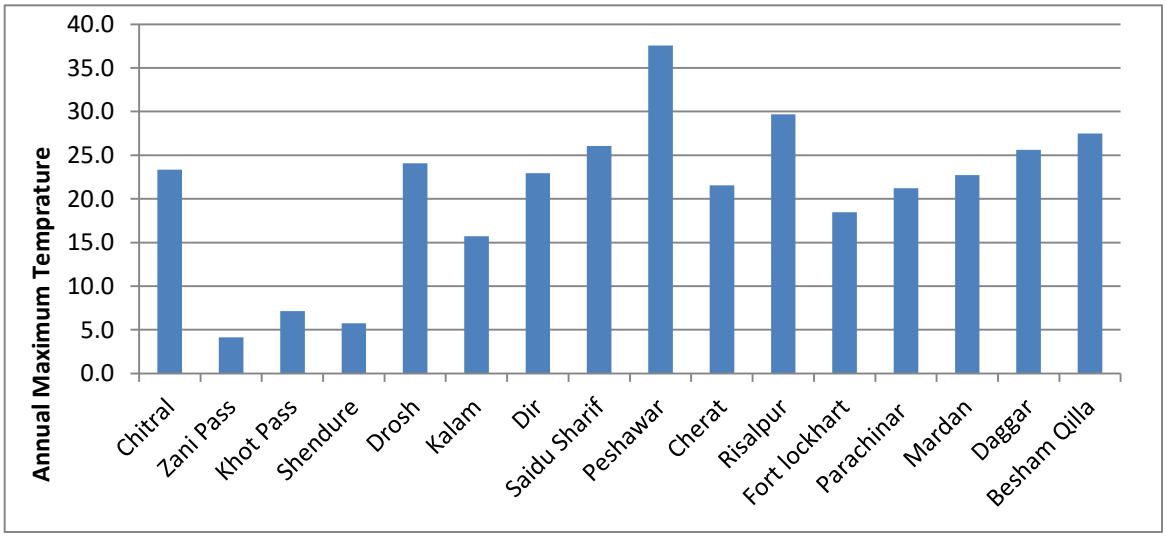
Figure: 16 (Thiessen Polygon of Kabul River)

Table: 11 Estimation of Climatic Stations areas

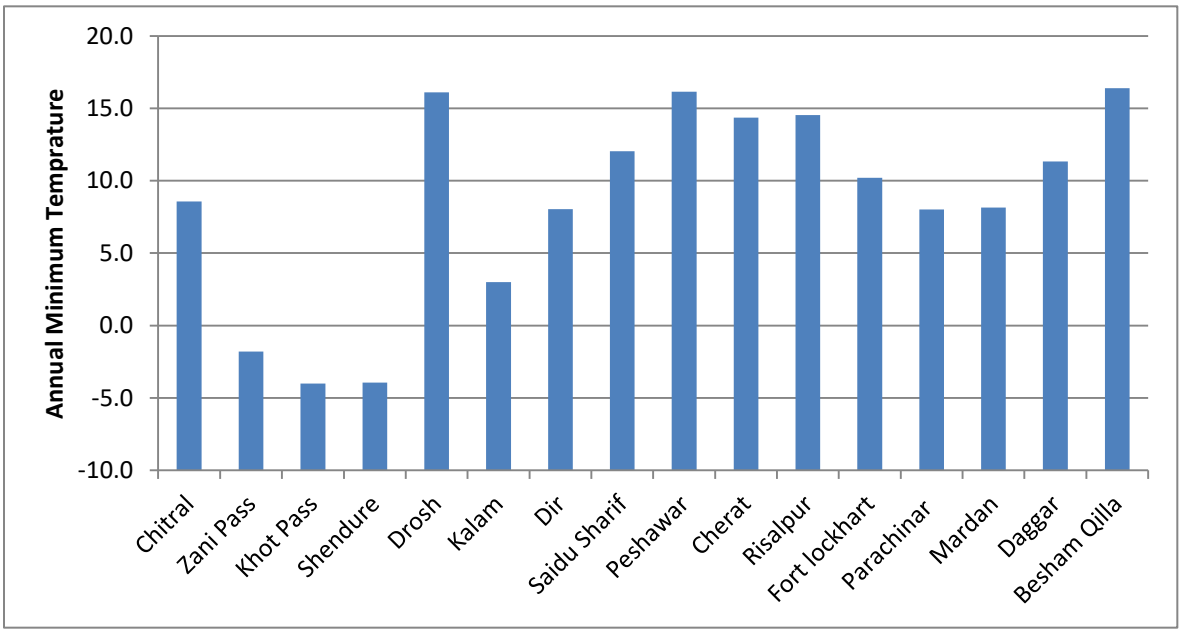
S.no	Station Name	Area (Km^2)	% Catchment Area
1	Chitral	2782	4.5
2	Zani Pass	3291.3	5.4
3	Khot Pass	5459.8	8.9
4	Shendure	3743.2	6.1
5	Drosh	1719.2	2.8
6	Kalam	4617.5	7.5
7	Dir	6465.1	10.5
8	Saidu Sharif	2983.9	4.9
9	Peshawar	6913.2	11.3
10	Cherat	1396.2	2.3
11	Risalpur	1111.5	1.8
12	Fort Lockhart	5785.1	9.4
13	Parachinar	2739.7	4.5
14	Mardan	2950.1	4.8
15	Daggar	4138.2	6.7
16	Besham Qilla	5326.8	8.7



Graph No: 3 Annual Rainfall Graph



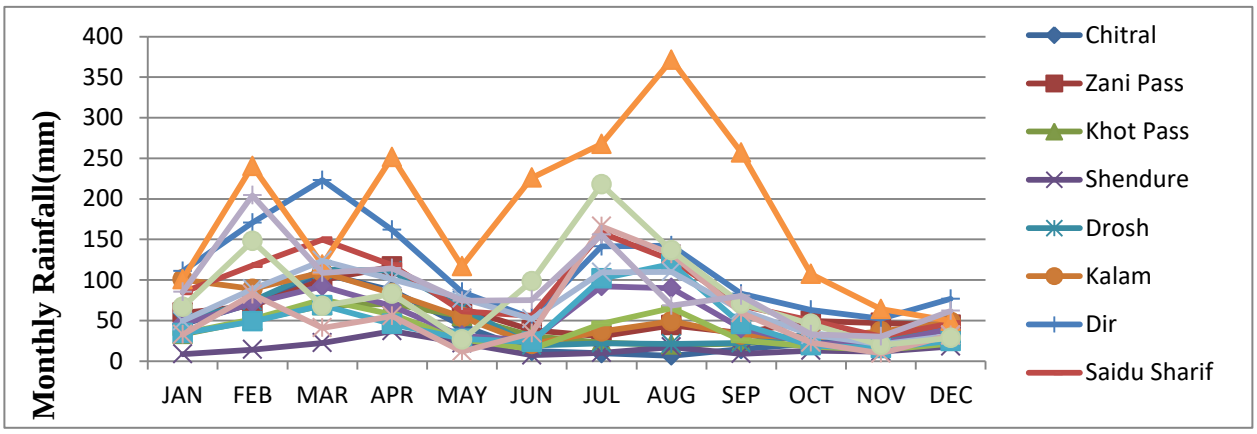
Graph No: 4 Annual Max. Temperature



Graph No: 5 Annual Min. Temperatures

Table: 12 Climatic stations Monthly Rainfall data of Kabul Watershed.

Sr.No.	Staion	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	**SEP**	**OCT**	NOV	DEC
1	Chitral	45.2	71.3	108.0	86.8	43.8	12.3	9.5	6.7	14.8	21.6	30.7	39.2
2	Zani Pass	59.5	68.0	100.2	116.5	64.9	38.1	30.7	44.1	34.5	49.6	46.9	44.5
3	Khot Pass	33.1	50.0	68.6	70.5	55.5	31.1	22.9	20.1	21.7	31.2	34.5	45.7
4	Shendure	8.7	14.1	22.5	37.1	22.3	7.3	10.2	17.4	9.1	12.9	11.8	18.1
5	Drosh	48.0	74.1	112.6	111.5	65.3	19.3	22.0	21.3	22.2	33.5	29.0	41.2
6	Kalam	100.5	88.8	109.6	83.6	54.2	21.0	36.5	49.1	32.4	28.8	36.6	48.2
	Dir	110.8	170.5	223.1	161.6	85.1	53.2	141.4	142.3	83.1	63.1	52.3	76.7
8	7	84.6	117.9	149.9	118.1	61.5	55.8	157.9	124.5	68.3	49.8	30.4	46.4
9	Peshawar	34.1	51.4	76.0	57.6	26.6	14.7	46.1	65.4	25.4	18.2	13.8	21.5
10	Cherat	46.2	71.2	92.3	67.6	31.2	25.7	92.3	89.9	40.5	21.5	21.5	39.7
11	Risalpur	34.3	48.9	68.8	45.8	27.4	23.7	101.6	119.7	45.5	19.3	15.9	24.7
12	Fort lockhart	100.8	240.3	119.0	251.5	116.8	226.1	267.5	371.3	257.0	107.2	64.1	49.5
13	Parachinar	49.4	88.7	123.9	100.7	77.4	52.1	109.5	110.1	62.7	32.5	20.7	31.5
14	Mardan	32.7	82.2	41.0	55.5	11.9	34.4	166.0	131.9	59.3	22.9	9.7	32.2
15	Daggar	66.6	147.8	68.0	82.8	26.4	98.4	217.6	136.4	70.7	45.6	19.7	28.6
16	Besham Qilla	85.1	204.3	108.8	114.4	74.3	75.3	155.7	68.5	80.4	32.8	30.3	61.9

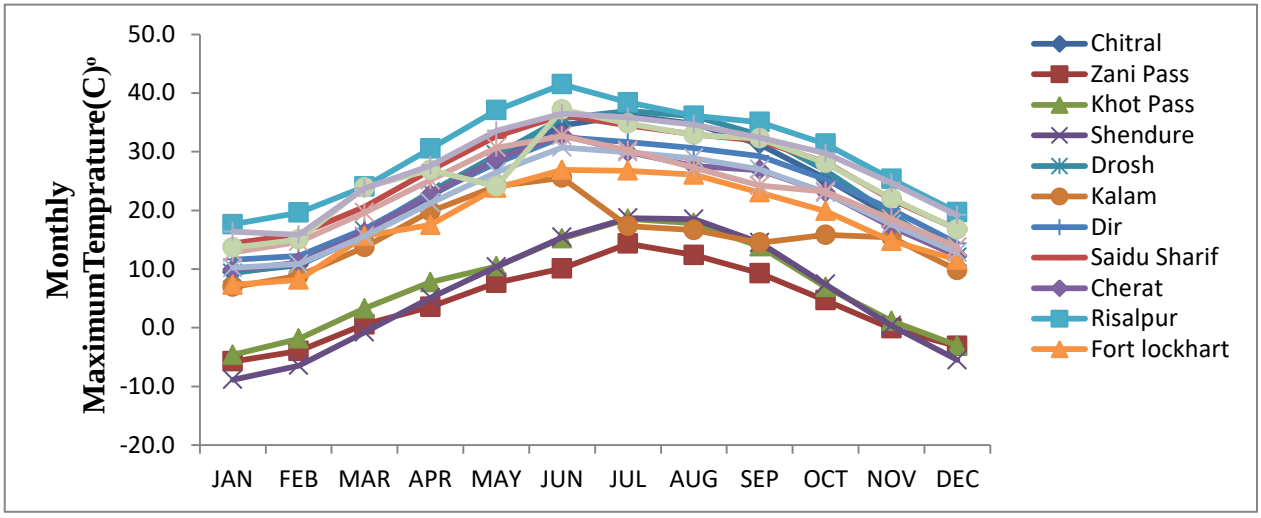


Graph No: 6 Monthly Rainfalls

Table: 13 Climatic stations Monthly Maximum Temperature data of Kabul Watershed.

Sr.No.	Staion	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Chitral	9.4	10.6	15.8	22.5	28.5	34.5	36.2	34.8	31.3	25.4	18.9	12.2
2	Zani Pass	-5.8	-4.0	0.6	3.5	7.7	10.1	14.3	12.4	9.3	4.7	-0.1	-3.1
3	Khot Pass	-4.6	-1.9	3.3	7.7	10.4	15.2	18.5	17.8	13.9	6.9	1.2	-3.0
4	Shendure	-8.8	-6.5	-0.8	5.1	10.4	15.4	18.7	18.5	14.5	7.4	0.4	-5.5
5	Drosh	9.3	11.0	16.5	23.1	29.4	35.7	37.0	36.1	32.9	26.8	19.3	12.0
6	Kalam	7.0	8.9	13.7	19.8	24.1	25.6	17.3	16.6	14.5	15.8	15.4	9.8
7	Dir	11.6	12.2	16.8	22.8	28.1	32.4	31.7	30.6	29.2	25.2	20.2	14.3

8	Saidu Sharif	14.4	15.9	20.6	26.8	32.6	36.2	34.5	33.0	31.9	28.2	21.8	16.8
9	Peshawar	34.1	51.4	76.0	57.6	26.6	14.7	46.1	65.4	25.4	18.2	13.8	21.5
10	Cherat	9.9	11.1	16.2	22.7	28.7	32.9	30.0	27.6	26.9	23.1	17.2	12.2
11	Risalpur	17.6	19.6	24.0	30.5	37.1	41.5	38.4	36.1	35.0	31.3	25.4	19.7
12	Fort lockhart	7.3	8.2	15.6	17.5	23.8	26.9	26.8	26.1	23.0	19.9	14.8	11.6
13	Parachinar	10.2	10.9	15.6	21.3	26.5	30.8	29.9	28.9	27.0	23.0	17.6	12.8
14	Mardan	12.8	14.7	19.6	25.2	30.7	32.7	30.2	27.3	24.2	23.2	18.5	13.8
15	Daggar	13.7	15.0	23.9	26.9	24.1	37.2	34.8	32.9	32.3	28.1	22.1	16.7
16	Besham Qilla	16.4	15.8	23.7	27.6	33.5	36.5	35.9	34.6	32.4	29.7	24.7	19.2



Graph No: 7 Maximum Monthly Temperature.

Table: 14 Climatic stations Monthly Minimum Temperature data of Kabul Watershed.

Sr.No.	Staions	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Chitral	-0.8	0.5	4.3	8.3	12.2	17.1	19.8	18.5	13.1	7.1	2.7	0.1
2	Zani Pass	-11.9	-10.3	-5.2	-2.2	1.7	4.0	6.2	5.5	2.9	-0.6	-4.1	-7.6
3	Khot Pass	-16.8	-14.3	-10.1	-4.7	0.4	5.0	7.0	6.8	2.9	-2.5	-8.4	-13.5
4	Shendure	-16.6	-15.1	-11.1	-5.7	0.3	5.3	8.6	8.2	3.9	-2.8	-8.8	-13.6
5	Drosh	3.5	4.7	9.3	14.9	20.1	26.7	28.4	27.6	23.7	17.6	11.2	5.6
6	Kalam	-7.3	-3.8	0.8	5.2	10.0	11.8	8.7	8.3	4.0	1.8	0.5	-4.1
7	Dir	-2.2	-0.7	3.2	7.7	11.6	15.7	19.1	18.5	13.8	7.5	2.7	-0.7
8	Saidu Sharif	1.8	3.8	7.8	12.3	16.5	20.2	22.4	21.5	17.4	11.7	6.1	2.8
9	Peshawar	4.2	6.8	11.6	16.7	21.7	25.7	26.7	25.9	22.9	16.3	9.8	5.3
10	Cherat	3.5	4.0	7.9	13.1	18.1	21.8	20.4	19.7	18.5	14.6	10.1	20.5
11	Risalpur	2.1	5.1	9.8	14.8	19.9	24.7	26.2	25.3	22.0	14.3	7.3	2.9
12	Fort lockhart	-1.0	0.4	6.4	9.8	13.3	18.0	18.9	19.7	16.2	11.9	6.2	2.6
13	Parachinar	-3.8	-1.8	3.1	8.5	12.8	16.9	18.0	17.1	14.3	8.5	3.5	-1.1
14	Mardan	-2.4	0.7	5.0	10.1	13.5	16.1	17.2	16.4	12.5	8.3	1.8	-1.5
15	Daggar	0.4	3.3	7.6	11.3	9.0	19.3	22.4	22.9	19.8	14.1	5.4	0.5

16	Besham Qilla	7.6	8.1	12.9	15.9	20.4	23.3	24.1	24.0	21.0	17.1	12.2	9.9

Graph No: 8 Monthly Minimum Temperatures.

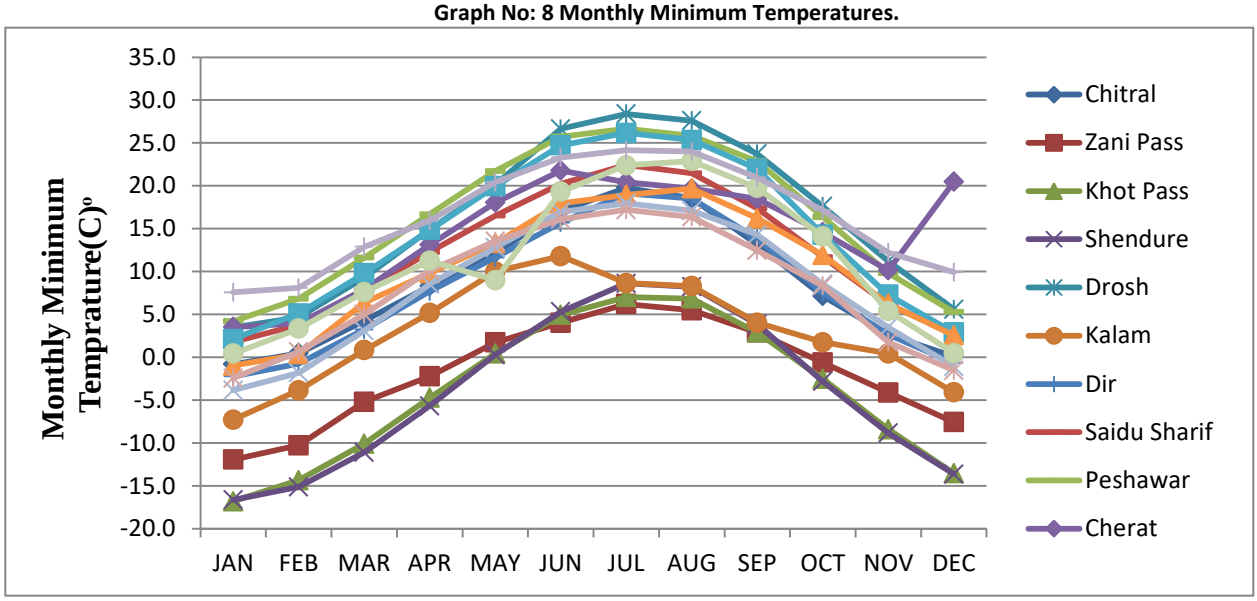
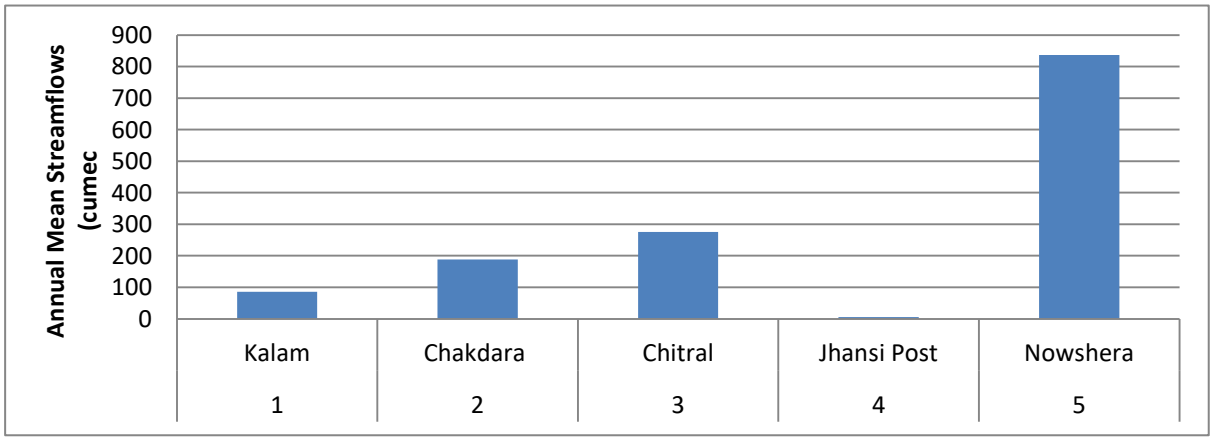


Table: 15 Stream Gauges data of Kabul Watershed.

Sr.No.	Station	Lon	Lat	River	Basin	Area	Annual Mean Streamflows (cumec)
1	Kalam	72.6	35.5	Swat	Kabul	2020	86
2	Chakdara	72.0	34.6	Swat	Kabul	5776	188
3	Chitral	71.8	35.9	Chitral	Kabul	11396	276
4	Jhansi Post	71.4	33.9	Bara	Kabul	1847	6
5	Nowshera	72.0	34.0	Kabul	Kabul	88578	837



Graph No: 9 Annual Stream flow of Kabul river

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

An integrated approach where remote sensing and GIS techniques have been utilized for evaluation of catchment characteristics such as Watershed delineated, delineation of the Stream Network, Classification of the soil and land use classes, Estimation of Total Watershed area and Sub watersheds Areas, the estimation of Stream Characteristics, Climatic Characteristics, Slope, Aspect, Topography, Flood Peak and Water yield of Kabul catchment. Quantitative analysis of geomorphological parameters of the Kabul catchment is carried out and various geomorphological parameters, which are important from the viewpoint of the hydrological Agricultural and geological studies, have been evaluated. The linking of the geomorphological parameters with the hydrological

characteristics of the catchment provides a simple way to understand the hydrologic behavior of the different catchments. Watershed has 47 Catchment polygon and 47 Drainage Lines, 23 Adjoint Catchments and 24 Drainage Points. It is a fourth order catchment, covering an area of 87961 km2. About 45% of total catchment area fall in the Pakistan territory and rest 55% is fall in the Afghanistan. Drainage Density of the watershed is (0.028 $Km^{2)}$ and the Stream Density is (0.00053 $Km^{2)}$. The estimated catchment characteristics and relationships may be useful to simulate hydrological response of the catchment.

5.2Recommendations

1. Adaptation of this study for whole Watersheds is very essential for better result.
2. Statistical tests can only indicate the significance of the observed test statistics and do not provide unequivocal findings. It is therefore important to clearly understand the interpretation of the results and to corroborate findings with physical evidence of the causes, such as land use changes or river stations influenced by human activities. Changes in stream flow, drought severity and frequency might occur as a result of changes in climate (mainly precipitation and temperature) and artificial influences in the catchment such as groundwater abstraction, irrigation and urbanization.
3. Some hydrology simulation models should be used to see contemporary impact.

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