HYDROLOGICAL MODELING IN KABUL RIVER BASIN: A CASE STUDY OF AFGHANISTAN

A DISSERTATION

Submitted in partial fulfillment of the

requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

WATER RESOURCES DEVELOPMENT

By

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ROORKEE-247667 (INDIA)

May, 2018

Indian Institute of Technology Roorkee

CANDIDATE'S DECLARATION

I hereby declare that the work carried out in this thesis with the title of "***HYDROLOGICAL MODELING IN KABUL RIVER BASIN: A CASE STUDY OF AFGHANISTAN***" is presented on behalf of partial fulfillment of the requirement for the award of the Master of Technology degree with specialization in Water Resources Development and Management, submitted to the Department of ***Water Resources Development and Management***, ***Indian Institute of Technology, Roorkee***, India, under the supervision and guidance of ***Dr. Deepak Khare,*** Professor, WRDM, IIT Roorkee.

I have not submitted the matter embodied in this report for the award of any other degree or diploma.

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CERTIFICATION

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

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ACKNOWLEDGEMENT

I would like to express my genuine gratitude to my supervisor ***Prof. Dr. Deepak Khare*** for the continuous support of my M.Tech study and for his patience, motivation, and immense knowledge. His supervision helped me in all the time of research and writing report of this dissertation. Whenever I faced any problem or had a query about my thesis or writing his office was always open. I could not have imagined having a better supervisor and sponsor of my M.Tech study.

Besides my guide, I would like to acknowledge the rest faculty professors: ***Prof. M.L. Kansal, Prof. S.K. Mishra, Prof. Ashish Pandy and Prof. R.D. Singh*** for their perceptive clarifications and inspiration.

My truthful cheers also go to WRD&M drepartment members, who provided me an opportunity to contact the laboratory and research facilities. Without their valuable help, it would not be possible to conduct this research.

Very special thanks goes out to my family, who have provided me through moral and expressive support in my life. I am also thankful to my friends who have supported me along the way.

And finally, last but by no means least, also to everyone in M.Tech 2017 -19. It was great sharing classes with all of you during the last two years.

Thanks for all your help!

Taha Aawar

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Roorkee, India

May.2019

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ABSTRACT

River Basin has been considered as the ideal unit for comprehensive water resource issues. Climate, as well as land use/land cover change, have a direct influence on water resources and hydrological dynamics in a river basin. Climate change impact in a river basin differs from one area to another region, due to hydrologic systems and meteorological scenario. To evaluating the hydrological effects of climate change, several methods have been developed, which are divided into two main groups: time series analysis (statistical methods) and hydrological modeling. The statistical methods have used to analyze the trend of precipitation as well as temperature over the past two decades. One of the most powerful Non-parametric tests is Mann-Kendall (MK)test for Evaluates significant trends and Sen's slope estimator for finding the true slop in metrological weather series, without determining whether the trend is linear or non-linear. Precipitation and temperature are the two important factors which have more influence and role on climate change as well as hydrology cycle, therefore in this research, the fluctuating trends of rainfall and temperature of the Kabul River Basin, Afghanistan, through 8 different stations are analyzed. The annual and monthly data were used to detect the trends of precipitation, whereas for temperature trend the, maximum and minimum annual data were used. Precipitation data from 2000 to 2018 for eight different metrological stations of the Kabul river basin were analyzed to find the changes in rainfall trend, while for temperature data from the five available weather stations for a period from 2008 to 2018 were used. Precipitation and temperature variation regarding temporal were calculated on the monthly and annual intervals. Mann Kendall and Sen's Slope method are used for the trend analysis, which supports nonparametric statistical analysis. The trend of annual precipitation was calculated over the 18 years for all stations. After trend analysis of precipitation with Mann Kendall Test and Sen's slope, result shown the increasing precipitation trend of 4.88 to 30.42 mm/yr, as well as the minimum temperatures, have increased significantly at a different rate of 0.02 – 0.71 C°/yr. The outcome of the present study may be useful for the water managers to understand the impact of climate change in a sub-basin of Kabul river basin, Afghanistan. After climate change, LULC change has the most effect on a river basin, therefore the impact of LULC change was assessed from 1972, 1979, 1990, 2000, 2008 and 2018 by using the GIS and remote sensing. Kabul river is one of the most famous parts of the Kabul River Basin due to passing through the capital city of Afghanistan. This river adds an aesthetic view to the Kabul city, like the Seine river in Paris. In this research, the impact of land use land cover (LULC) changes on the Kabul river is analyzed by remote sensing and GIS technique. The multi-temporal satellite images are very useful tools for describing as well as exploring the LULC changes. Remote sensing and GIS technology is an easy way to carry out the impacts of LULC change in the study area. Arc GIS 10.4.1 and ERDAS Imagine 2018 are the software, which used to assess the LULC changes during 46 years in Kabul city from 1972 to 2018. Studies on LULC show, change in LULC has a direct effect on water resources. Kabul LULC maps disclose the grass and forest area are decreasing, while the urban and agricultural zones are increasing in the study area. However, drought and civil war are the main reason for deforestation, but LULC change shows the scarcity of water in the study area, which must consider it as a very serious issue. LULC map is an important parameter for hydrological modeling to carry out the impacts of LULC change in a river basin.

As hydrological models forecast are always unreliable, therefore further studies in water resources are needed to make more effective use of these models. Analyzing and executing of the watershed model to carry out the valid assessment of water resources is essential, individually in Kabul river sub-basin, where the modeling is a challengeable issue due to lack of data. In this research, the Soil and Water Assessment Tool (SWAT) model was used to assess the discharge prediction of the Kabul River sub-basin watershed at Estalif gauge station. The model calibrated with monthly discharge data for 2003 – 2010 and validated for 2010 to 2018. SWAT-CUP which recently has developed with the capacity of providing the decision making for using manual and automated calibration and incorporating sensitivity and uncertainty analysis through (SUFI2) Algorithm, was used for calibration and validation. Impact of climate change on the surface flow as well as LULC change and other different scenarios are evaluating by calibrated SWAT model for further investigation.

The sensitive parameter is required to improve the calibration efficiency, therefore in this model the coefficient of determination (R^2), Nash Sutcliffe efficiency (NSE) and Present bias (PBIAS) parameters considered as the main parameter.

CHAPTER 1:
INTRODUCTION

1.1 Importance of water:

In fact, water is considered as a very ordinary substance in our life, but water is the most remarkable element. We are using water for washing, swimming, cooking, and drinking might be not at the same time. Two – thirds of our body are water and we need water to be alive. Although drought and floods are the cause of death as well as disease, therefore water is the most important studies and it is clear the importance of water. R.B. Martin., (2001).

For storing the water large number of reservoirs as well as dams have been constructed. At the same time, water is one of the most important sources of irrigation which this water need is increasing day per day as the population has been growth Wada, et al., (2011).

The results of various studies have shown the importance of temperature and rainfall. With detecting possible climate trends and changes across the world, recently, most of the researchers have been focused on changes in temperature and precipitation Gocic and Trajkovic, (2013).

1.2 Sources of water:

Out of total volume of water in the world, 97.5 percent belongs to the seas and oceans water which is not drinkable, while 2.5 percent rest is surface water and groundwater Zoga, et al., (2019).

The total quantity of water is shown in Fig.1.1 and Table1.1 from a variety of water sources.

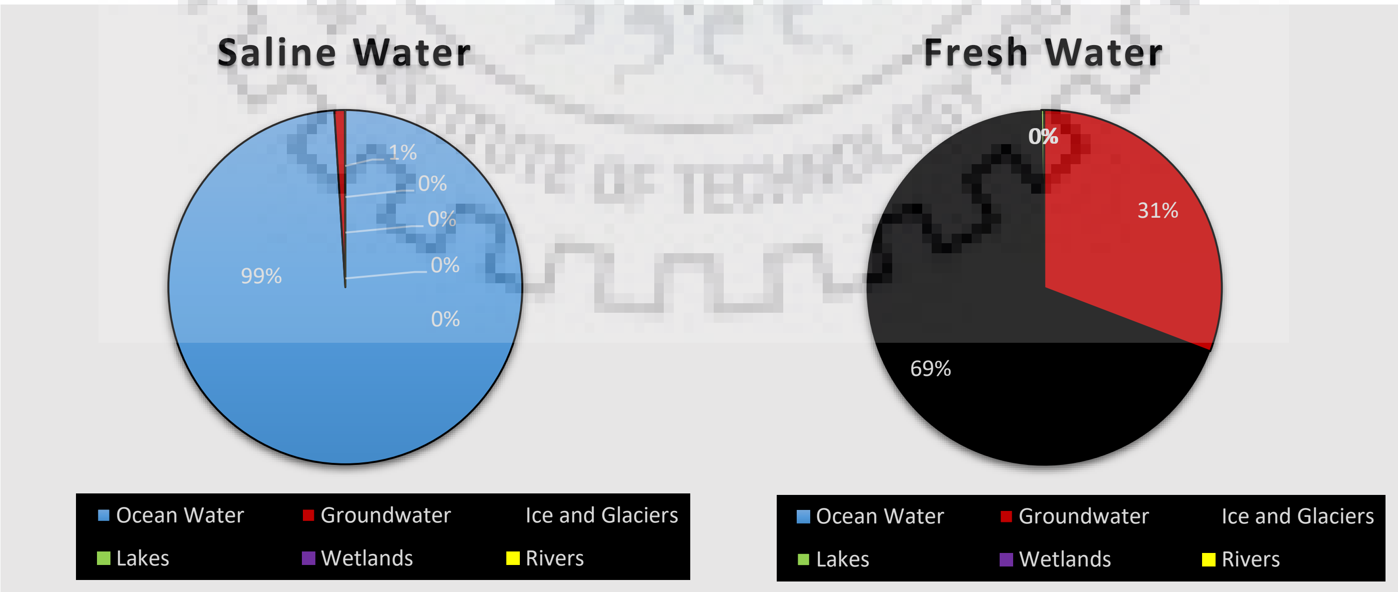

Figure 1.1 Water Resource in the world

Table 1.1 Percentage of world water Sources

Source	Fresh Water %	Saline Water %
Ocean Water	0	96.5
Groundwater	0.76	0.93
Ice and Glaciers	1.7	0.025
Lakes	0.007	0.006
Wetlands	0	0.008
Rivers	0.0002	0.0011
Total	**2.5**	**97.5**

1.3 **Hydrologic Water cycle:**

"water occurs on the earth in all its three states, viz. liquid, solid and gaseous, and in various degrees of motion. Evaporation of water from water bodies such as oceans and lakes, formation and movement of clouds, rain and snowfall, streamflow and groundwater movement are some example of the dynamic aspects of water. The various aspects of water related to the earth can be explained in terms of a cycle known as the hydrologic cycle" which shown in Fig 1.2. K. Subramanya., (2016).

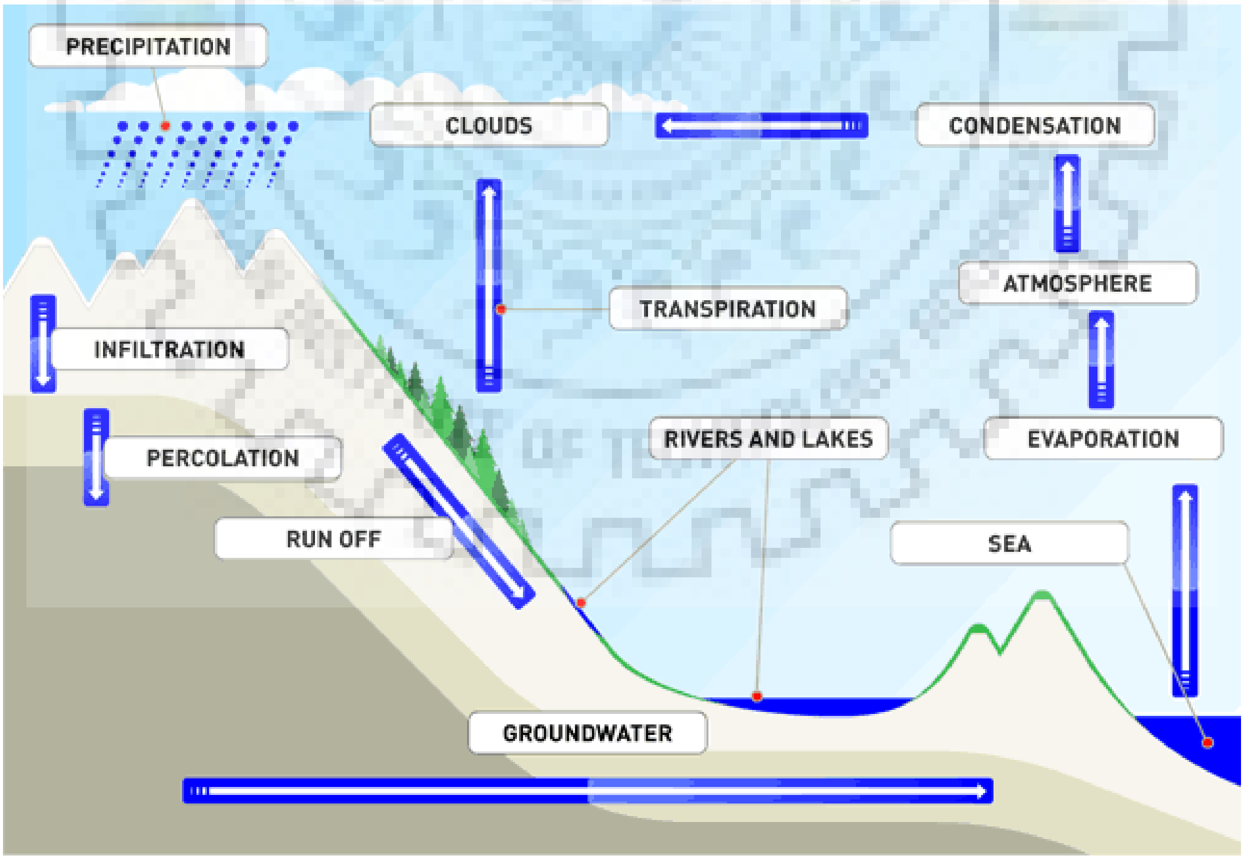

Figure 1.2 Hydrologic Cycle

1.4 **Hydrological Modelling:**

The purpose of hydrological modeling is the planning and management of water resources, therefore for better management and planning of water resources, the identification of factors which has direct effect in water resources is required. The most important factors which have a direct impact on water resource are as below:

- Climate change impacts
- Land use land cover changes
- SWAT Model

Climate change has the most important role in water resources as well as the hydrological cycle. Climate change has a direct impact on the water resources, due to change of climate factors such as rainfall, temperature Yang, et al., (2011).

Land cover is used to indicate all physical features on the earth surface, whereas the changing on the earth by a human is called land use such as agricultural land. Kaul, et al. (2014). Climate and LULC changes are the two important components which have a significant role in water resources planning and management. Mango, et al. (2011). Hydrological Model

Discharge is one of the most important parameters in water resources, which plays a key role in the planning and management of the catchment area. To estimate the discharge value a model is needed that can realistically simulate the runoff. Runoff is characteristic of resolution for hydrologic modeling. Duvvuri., (2018). Impact of climate change, as well as land use in river hydrology and surface water availability, can be directly related to the discharge as well as rainfall-runoff model application. Stehr et al., (2008). Two important components which have a significant role in water resources planning and management are climate and land use/land cover. Setegn,et al., (2008).

1.5 **Problem Statement:**

Due to the geographical strategic location of Afghanistan, it doesn't access any sea water, therefore water is a very serious and important threat for this country. Afghanistan is a mountainous country regarding geological characteristic, so it has a potential source of water. Water resource management is one of the necessary issues to be considered in Afghanistan. Due to more than three-decade civil war in the country as well as a natural disease like drought, most of the hydraulic and irrigation structures destroyed and most of the green area is changed. With consideration of all situation, the following research gaps are identified;

- The impact of the climate change on Kabul river basin has been not considered by researcher since a long time.
- land use and land cover change has been not considered in Kabul river basin.
- To access the best water resource management required investigation of the hydrological models but these has been not studied any hydrological modeling in Kabul river basin.

1.6 **Objectives:**

The purpose of hydrological modeling at river basin is primarily to support decision making for water resources management, and their sufficiency or otherwise must be evaluated in that context. The objectives of the present study area are;

1. To conduct the trend analysis of temperature and precipitation
2. To study LULC changes in the study area
3. Carry out hydrological modeling of the study area

CHAPTER 2:
LITERATURE REVIEW

2.1 **General:**

Climate change is the change of climate state which analyzing by changing mean or change in variability of its properties in a long period of time, usually a decade or more. changes in climate as well as temperature are due to the internal processes and/or external forces, for example, solar radiation is an internal effect which occurs naturally, and automatically is the case of natural changes in the ecosystem. The composition of the atmosphere which start from the Industrial is the result of human activity as an external change. Climate change is a big global challenge in the long term with its unique features and it involves complex interactions between environmental, climate, economic, political, institutional, social and technological processes. Climate change has a direct effect on the society through the change in patterns like change in distribution, intensity as well as the magnitude of precipitation, change in temperature and due to increasing the heat change in evaporation. (Singh, et al., 1997; Boils, et al., 2003). Change in the hydrological process such as evapotranspiration, soil moisture, surface flow and base flow are due to potential effect of climate change, therefore; evaluating changes in the rainfall and temperature at a regional and local levels are essential for assessing climate change, as these two has a direct effect on all processes of human life and society. A river basin is an ideal unit for a comprehensive solution to water resource issues. The impact of climate change in the river basin is different from hydrologic systems based on the region and between the weather scenarios.

2.2 **Climate change:**

Recently studied result has shown that climate change will have an effect on water resources availability and management throughout the world Abebe, et al., (2017).

One of the primary concern for societies is climate change and associated effects on water resources. Future forecasting of climate and hydrological conditions are very complicated because of unknown future evaluation of climate. Calanca, et al., (2004).

Researchers found that the change of precipitation and temperature have a significant impact on climate change as well as global warming, thus the Precipitation and Temperatures are the most important factors of the hydrological cycle and climate change (Pandey and Khare, 2018; Adarsh and Janga Reddy, 2015; Kundu *et al.*, 2015; He & Zhang., 2005). The climate has been changed due to the increase of greenhouse gases, and this has been crucially influenced to the ecosystem as well as water balance, therefore the precipitation, temperature, and evapotranspiration rates are changed Coulibaly *et al.*, (2018). Changes or fluctuations of rainfall, temperature, evaporation, evapotranspiration, and runoff in the hydrological cycle has a direct effect on the availability and quantity of fresh water. It is clear that fresh water is one of the significant environmental and vital issue in the 21st century Pal, et al., (2011). Due to impacts of climate change on the river basin, water scarcity, melting of glaciers and flows decreasing in rivers, it needs very urgent attention to the climate change and its impact on a hydrological cycle. (Intergovernmental Panel on Climate Change IPCC, 2007; Jain et al., 2013). Streamflow and peak flow have been varied due to variation and changes in the frequency and intensity of extreme rainfall Shao, et al., (2018). With the change of frequency and intensity of extreme climate events, it has been significant consequences for human and natural systems. The changes in mean variables are only the case of increasing degree temperature, drought, and flooding events in the rest of this century, and it is expected to have any adverse effects over and above the ecosystem as well as environmental society Hayelom et al., (2017).

He & Zhang (2005) analyzed the temperature and precipitation in a time interval of 1960–2000 through 19 different stations along the Lancang River in China. With reference to the result which was used an archival data of monthly air temperature and precipitation series, they found increases in air temperature and a decrease in rainfall. ElNesr et al., (2010) after analyzing the trend of evapotranspiration with the maximum, minimum and average temperatures in 29 years data set, in the Kingdom of Saudi Arabia, the result of analysis shown that the cooling trend was only in winter months of November to January while the warming trend was in the entire year except winter. In another case study which analyzed the statistical status of the northern part of Alaska by Stafford et al., (2000) result showed the annual air temperature is increased in all stations during 50 years from (1949 – 1998) and inversely rainfall was found decreasing. In central India, the Betwa Basin has analyzed by Trend analyses with to the historic past climatic changes. The result of the annual and seasonal long-term trend analysis of rainfall in different stations showed a decreasing trend. That is why in the Betwa Basin the seasonal and annual rainy days are decreased. Out of twelve metrological stations, five stations showed decrease significant trends of the maximum temperature during the monsoon season while in the winter all other rest stations were increasing trends. There was no maximum temperature trend in the summer for all stations and regarding the minimum temperature only two stations showed decreasing during the monsoon season and rest stations result was increasing trend in the winter as well as in the summer Suryavanshi *et al.*, (2014). In another research Karaburun et al., (2011) used Mann-Kendall test and Sen's method for identification of temperature trends in a time interval from 1975 up to 2006 with the annual, seasonal, monthly mean, minimum and maximum temperatures data in Istanbul. The results showed the importance of rainfall and temperature. In Jharkhand, India, through analyzing the trend of annual, seasonal rainfall and temperature by using non-parametric tests Jainet al., (2013) found no significant trend maximum and minimum temperature in the monsoon and summer season, but annual rainfall trend showed a significant decreasing of 2.04 mm/year during the monsoon season. Sonali et al., (2013) analyzed the trend of max, min temperature of annuals, monthly, pre-monsoon, monsoon and post-monsoon in three different time intervals from 1901–2003, 1948–2003 and 1970–2003, in seven major states of India. They found the impact of serial correlation, trend detection analysis during running the Mann Kendall test and Sen's slope estimator methods. Many scientists and researchers from different communities using different methods for trend analysis of rainfall and temperature (Jain et al., 2013; Almazroui *et al.*, 2012; Camici *et al.*, 2014; Fennessy, 1994; Ficklin *et al.*, 2009; Holman, 2006). In 2017 Pandey et al, (2018) by using Mann Kendall test and Discrete Wavelet Transform (DWT) investigated the trend of annual, seasonal and monthly rainfall over the seven different regions in India. The trend result showed both, positive and negative significant variation for the different regions. The precipitation trend for southern India was examined by Adarsh et al., (2015), they applied Sequential Mann Kendall and wavelet transforms method. Sequential Mann Kendall test was used for identification of the sequential changes in the annual and seasonal trend.

2.3 **Land use land cover changes:**

Changes in LULC and climate are expected to have a significant impact on river flow and water resources. For example, water flow in low seasonal periods decreases in many areas due to high evaporation; this is why rainfall changed, it can increase or decrease due to increased evaporation, Therefore, integrated water management requires the intergovernmental and interdisciplinary participation of relevant actors, a decision-making process defined by all stakeholders, and legitimacy through political support, public participation and financing. McKenzie., (1996). Global warming is a very hot issue in this century due to the increase in average temperature of the earth over time. Increasing the greenhouse gases has a direct effect on global warming, which is the case of changing in and precipitation in some parts of the world. Matondo, et al (2001).

The land is one of the most important parts of ecosystems, which all-natural sources such as soil, water, plant included, therefore for better planning and management of activities, LULC is one of the fundamental elements of earth feature. (Al Mamun., 2013; East n.d.; Lillesand, et al. 2000). The change detection of land use land cover is an important factor for management and monitoring natural resources through remote sensing and GIS technique. (Abdulwahab, et al. 2019; Islam *et al*., 2018). Due to the development of technology, satellite data is easily accessible as well as available. Geographic Information System (GIS) is one of the famous integrated computer programs which has the abilities to capture, analyzing, storing and displaying spatial information to investigate the decision making as well as better management purposes. (Marinopoulos, et al. 2017; Alqurashi, et al. 2013).

Human has used the unheard global environment in term of temporal as well as spatial which is called LULC. The most important change in LULC is the decreasing of forest and increasing cultivation area respectively. Turner, et al, (2009).

Remote sensing and GIS technology have made this opportunity to analyze and study LULC changes in very less time as well as low cost with more accuracy. Prakasam., (2010). The way to understand the current status of a specific area is analyzing the land use and land cover changes in case of temporal as well as spatial Raj, et al. (2010). The LULC change is directly relevant to the global environmental change issues, which nowadays it's a very important topic in the world, therefore study of LULC is a way to better understanding the global environmental change. Sun, et al. (2016). Recently the LULC change impacts on the sustainability of the ecosystem have considered as an important issue in the global changes research. Human activities in the earth are the case of changing in the surface status. (Islam, et al. 2018; Haque and Basak, 2017; Rawat, et al., 2013) One of the most important usages of remote sensing and GIS technology are preparation the excellent view of geographical and revenue regarding land use as well as city growth. LULC change is a function of human needs as per particulars purpose. Patil, et al. (2019). Mostly many problems and challenges presented by natural environmental issues, therefore the planning and utilizing of the natural resources change due to LULC change is an important issue which cannot figure out without using new technology like remote sensing and GIS. Marinopoulos, et al. (2017). Satellite images have used for measurement of the quality and quantity of LULC changes. The change of LULC is crucial knowledge for better understanding of the status of land in the past as well as in the future. (C et al., 2014; Yuan *et al.*, 2005). LULC change has a direct effect on water quality as well as quantity, for example, due to change of LULC patterns, the surface runoff is increasing while the groundwater recharge is decreasing. Butt et al., (2015). Since mid of the 1970s, remote sensing has used for documentation of the net change of LULC on local as well as global scales. Mengistu and Salami, (2007). The aim of this research is to assess the impact of LULC change on Kabul river by using remote sensing and GIS.

2.4 **Impact of climate change in the Hydrology cycle:**

Climate Studies showing which water is a major part of climate components. Impact of climate change on discharge and groundwater recharge different regarding the places and climate scenarios. (Manoj. J., et al.2006, Ma. Xing., et.al.2009). Flooding and increase of groundwater recharge, as well as surface runoff, is due to change in precipitation intensity and quantity as an impact of climate change in precipitation. Land use could have a direct effect on climate change while the land cover has directly impact on annual surface runoff. (Changnon.S.A., 1996; Wang. et.al., 2007). Great evaporation is the case of decreasing surface flow during the season, as a change of precipitation had an effect on evaporation. Adamowski et.al., (2003). Due to human activities, increasing global population, and climate change as well as land use, the water shortage has become a major crisis in the world as a key resource of sustainable economic and environmental development. Vilaysane et al., (2015). As surface water is the case of erosion; therefore, by increasing the surface runoff landslide and erosion increasing in a catchment area and this has a direct effect on agricultural production. Nursugi, et al., (2016). Due to integrated management and adequate allocation of water under climate change and LULC change, many societies faced to challenges; therefore, for analysis the impacts of this two major factors on water resources as well as river hydrology, the model application is necessary. Stehr et al., (2008). Study of water resource management would be very useful when it uses the methods and technologies for combining the parameters that have a direct impact on water resources like topography, climate change. Moreover, the management of water resources required method and technology which be powerful to analysis the impact of the human being as well as global change on it. Semlali et al., (2017). Due to the utilization of water, it is expected to appear the shortages of freshwater almost over all the world, which this issue would be a very concern point in the future. Abseno., (2013). Most of the Hydrological and ecological models need daily weather data, which is not easily accessible. In the world, around 40,000 stations of weather data are available, which data are quickly distributed as uneven from the few stations over all the world. moreover, another important issue is the quality of these data, which often large scales of these data are missing, therefore using a model like SWAT is useful. (Schuol, et al., (2007). water and land are the two important parts of ecology which have a direct effect on the persistence and decadence of a watershed. The SWAT model is used for a different purpose, like evaluating the water quality, flood warning due to the simulation of flow and assess the effect of climate change to the water resource. Studied has shown the efficiency and potential of the SWAT model for simulation of hydrology in a watershed. (Quyen, et al., (2014). SWAT model has used in several case study to find out the impact of climate change in water resource. (Fohrer, 1999; Setegn, et al., 2008; GITHUI, et al, 2009; Easton et al., 2010; Kushwaha et al., 2013; Quyen, et al., 2014; Duvvuri, 2018; Gashaw et al., 2018; Singh1,et al., 2018).

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CHAPTER 3:
DESCRIPTION OF STUDY AREA

3.1 Location of study area:

Afghanistan is located in the center of Asia. This country is a land lock country which has the same border with Iran, Turkmenistan, Uzbekistan, Tajikistan, China, and Pakistan in the west, North, East, and South respectively. Afghanistan with 650000 square kilometer area, is a mountainous country characterized by a dry continental climate. The temperature variation interval is from -10 °C in winter to 40 °C in summer. Pul., (2011).

Afghanistan is one of the richest countries in case of water resources, which these resources springing from rainfall in its mountains. More than 80 percent of the country's water comes from the melting of snow in the Hindu Kush. Total annually renewable water resource recently estimated 75 billion cubic meters, which out of these 18 billion cubic meters are referred to groundwater and 57 billion cubic meters are surface water. Irrigation water in Afghanistan is estimated at around 20 billion cubic meters annually which is mostly drowning from surface water Ahmad, et al, (2004). Table 3.1 shown the water resource in Afghanistan.

Table 3.1 Water Resources in Afghanistan

Water Resources	Potential (BCM)	now		Potential Situation	
		Utilize	Unused	Future Use	Unused
Surface Water	57	17	40	30	27
Groundwater	18	3	15	5	13
Total	**75**	**20**	**55**	**35**	**40**

Afghanistan has five major river basin Rout., (2008), which is shown in Table 3.2.

Table 3.2 Afghanistan River Basin

River Basin in Afghanistan			
Name of River Basin	**Catchment area percentage**	**Water percentage**	**Rivers**
Amu Darya	14	57	Amu Darya, Panj, Wakhan, Kunduz, Kokcha
Hari Rod-Murghab	12	4	Hari Rod, Murghab, Koshk
Helmand	41	11	Helmand, Arghandab, Tarnak, Ghazni, Farah, Khash
Kabul (Indus)	11	26	Kabul, Konar, Panjshir, Ghorband, Alinigar, Logar
Northern	11	2	Balkh, Sar-i-Pul, Khulm
Non - drainage area	10		

Kabul River basin which is located in the southeastern part of Afghanistan, has 700 km long and start from Hindu Kush Mountains, Sanglakh range in Afghanistan and ends in the Indus River near Attock, Pakistan. The total catchment area of Kabul River Basin is 76908 square kilometers. Rasooli et al., (2015).

The Kabul River Basin lies in the southeast quarter of Afghanistan, between 67°40 - 71°42' (longitude) and 33°33 - 36°02' (latitude). Lashkaripour et al., (2008). Figs. 3.1 & 3.2.

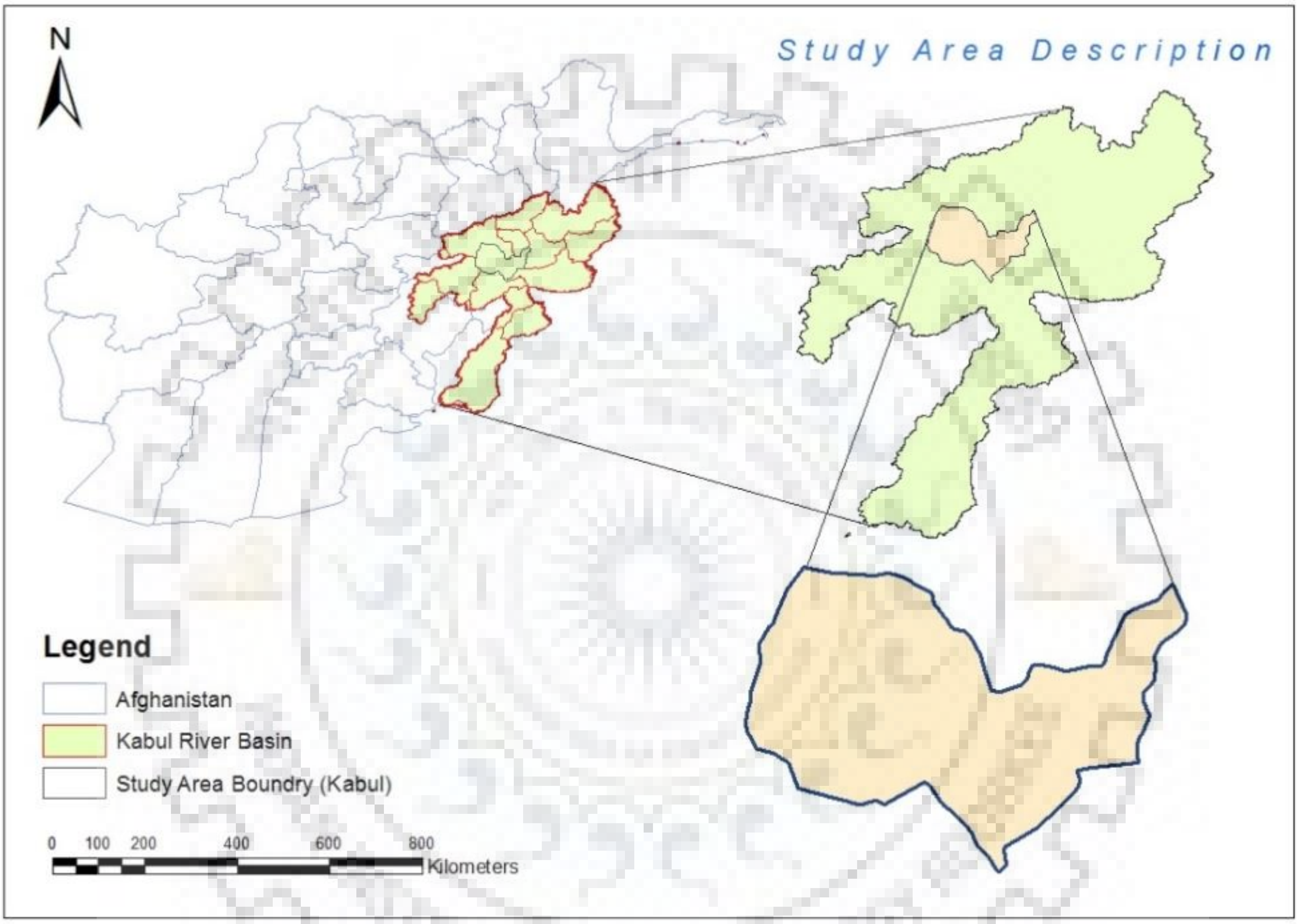


Figure 3.1 Study Area

3.2 Weather:

Precipitation and groundwater are the most two important source of irrigation water in Afghanistan, therefore with accordance to the precipitation and groundwater variation Afghanistan divided into 6 climate zone Qureshi., (2002). Table. 3.3 is shown the different climate zone based on precipitation.

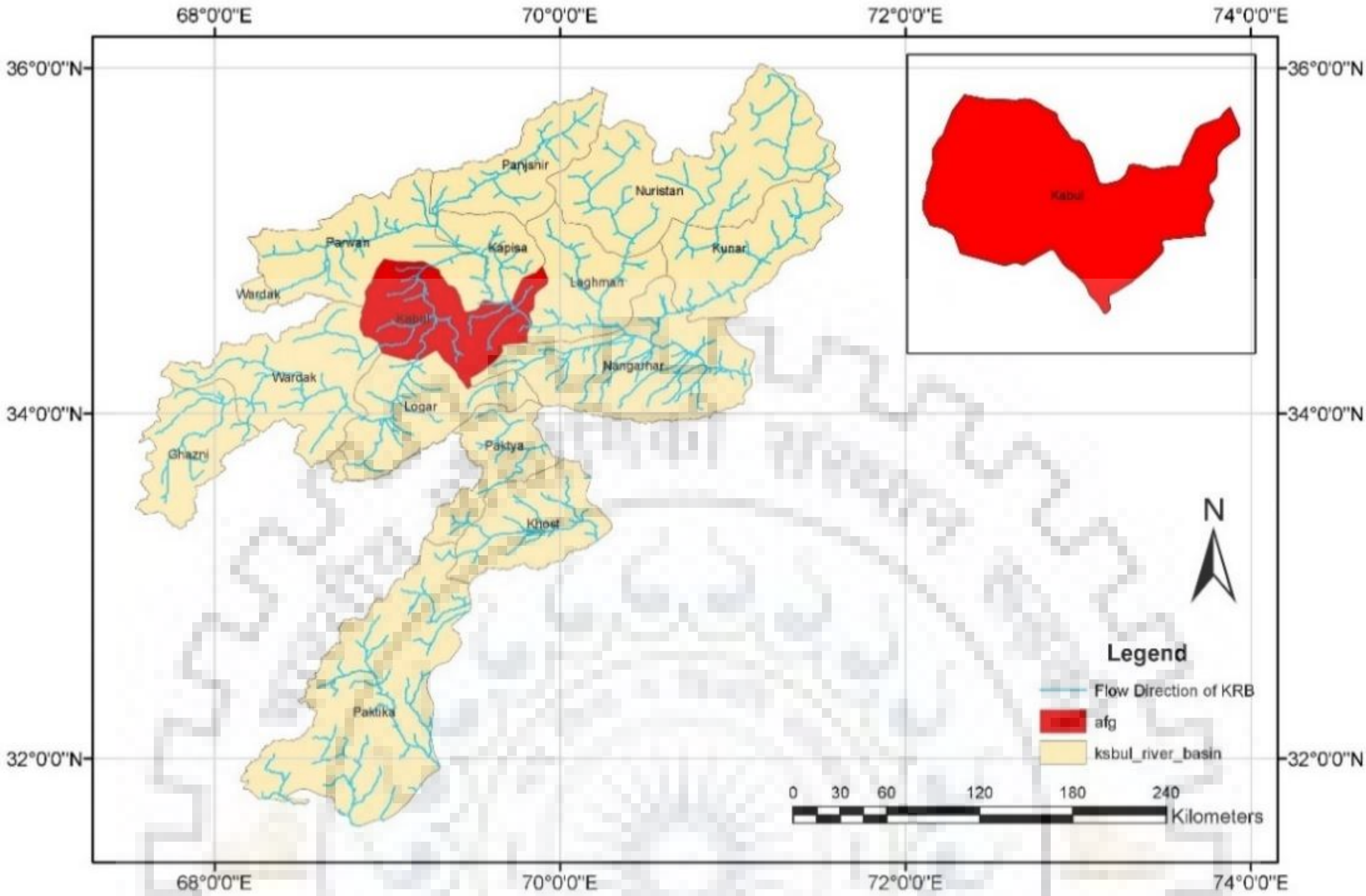


Figure 3.2 Kabul River Basin Location

Table 3.3 Afghanistan climate Zone

zone	Name	Precip. (mm)	Dry Months	Frost Months
1	Badakhshan (without Wakhan)	300 - 800	2-6	1-9
2	Central and Northern mountains	200 - 600	2-9	0-8
3	Eastern and Southern mountains	100 - 700	2-9	0-10
4	Wakhan corridor and Pamir	<100 - 500	2-5	5-12
5	Turkestan plains	<100 - 400	5-8	0-2
6	Western + South-western Lowlands	<100 - 300	6-12	0-3

Result of 12 years annual recorded precipitation, temperature and evapotranspiration from 19 metrological stations which is located in 18 different provinces, shown the 100 – 300 mm, precipitation is in half area of Afghanistan and half rest part of Afghanistan has 300 – 800 mm amount of precipitation Qureshi., (2002). As shown in Table 3.4.

Table 3.4 Annual Recorded Rainfall, Temp, Evapotranspiration in 18 sites

Location	Altitude [m asl]	Precipitation [mm/yr]	Temperature [°C]		Annual ETP [mm/yr]	Daily ETP [mm/day]
			Min	Max		
Shiberghan	360	214	-2	38	1,420	8
Mazar-i Sharif	378	190	-2	39	1,530	9
Kunduz	433	349	-2	39	1,390	8
Baghlan	510	271	-2	37	1,100	6
Jalalabad	580	171	3	41	1,350	7
Farah	660	77	0	42	1,610	8
Lashkargah	780	89	0	42	1,720	8
Maimana	815	372	-2	35	1,310	7
Herat	964	241	-3	36	1,720	10
Qandahar	1,010	158	0	40	1,790	8
Khost	1,146	448	-1	35	1,390	6
Faizabad	1,200	521	-5	35	1,020	6
Qadis	1,280	323	-3	30	1,240	6
Jabul-Saraj	1,630	499	0	31	1,610	9
Kabul	1,791	303	-7	32	1,280	7
Karizimir	1,905	433	-7	31	1,100	6
Ghalmin	2,070	222	-8	29	1,100	6
Ghazni	2,183	292	-11	31	1,420	7
Lal - Sarjangal	2,800	282	-21	25	950	5

Most of the agricultural (cultivable) lands in Afghanistan feeding water through rivers. due to low temperature in the northwestern part of Afghanistan cultivable lands are irrigated with rainfall. with accordance the forested area in the eastern part of Afghanistan the irrigation lands are fertile. Because of the long growing season in the south part of Afghanistan, double crops are sowing. The dessert area is located mostly in the north and south zone of Afghanistan, therefore due to lack of water resource its vegetation is less. Ahmad, et al, (2004).

Kabul River Basin with the accordance of hydrological, climate and physiographic characteristics, divided into eight sub-basins as below.

1) The Medium Kabul sub-basin
2) Logar Sub-basin
3) Ghorband Sub-basin
4) Panjshir Sub-basin
5) Laghman Sub-basin
6) Kunar Sub-basin
7) The lower Kabul sub-basin
8) Shamal and Khuram sub-basin

Kabul is the largest city located along the Kabul River in the south of the Hindu Kush mountain range. Kabul city has around 4.6 million residents and this city is one of the highest capitals in the world, with almost 1800 meters above the sea. Kabul City is one of the oldest cities with over 3,500 years ago since the Achaemenid Empire (https://en.wikipedia.org/wiki/Kabul).

Unai pass is the point which made separated Kabul River from the watershed of Helmand. This river is the one important branch of the Kabul river basin (Indus). There are several dams constructed on this river such as Naghlu, Surobi, and Darunta dams which are located in the Kabul and Nangarhar provinces of Afghanistan (https://en.wikipedia.org/wiki/Kabul).

3.3 Data Collection:

3.3.1 Metrological Data:

The three-decade civil war in Afghanistan from 1980 up to 2004 is the reason for no record keeping of the meteorological and hydrological data as well as losing the previous data. In the present paper, meteorological data including, daily, monthly maximum (T_{max}) and minimum (T_{min}) air temperatures, and precipitation (P) collected from the ministry of energy and water of Afghanistan with the period of 18 years from (2000 – 2018) for rainfall and 11 years from (2008-2018) for temperature through eight stations, the missed data was obtained from NASA power data access. (https://power.larc.nasa.gov/data-access-viewer/). The data stations and elevation maps are shown in Figs. 3.3 & 3.4, while the geographical details are given in Table 3.5.

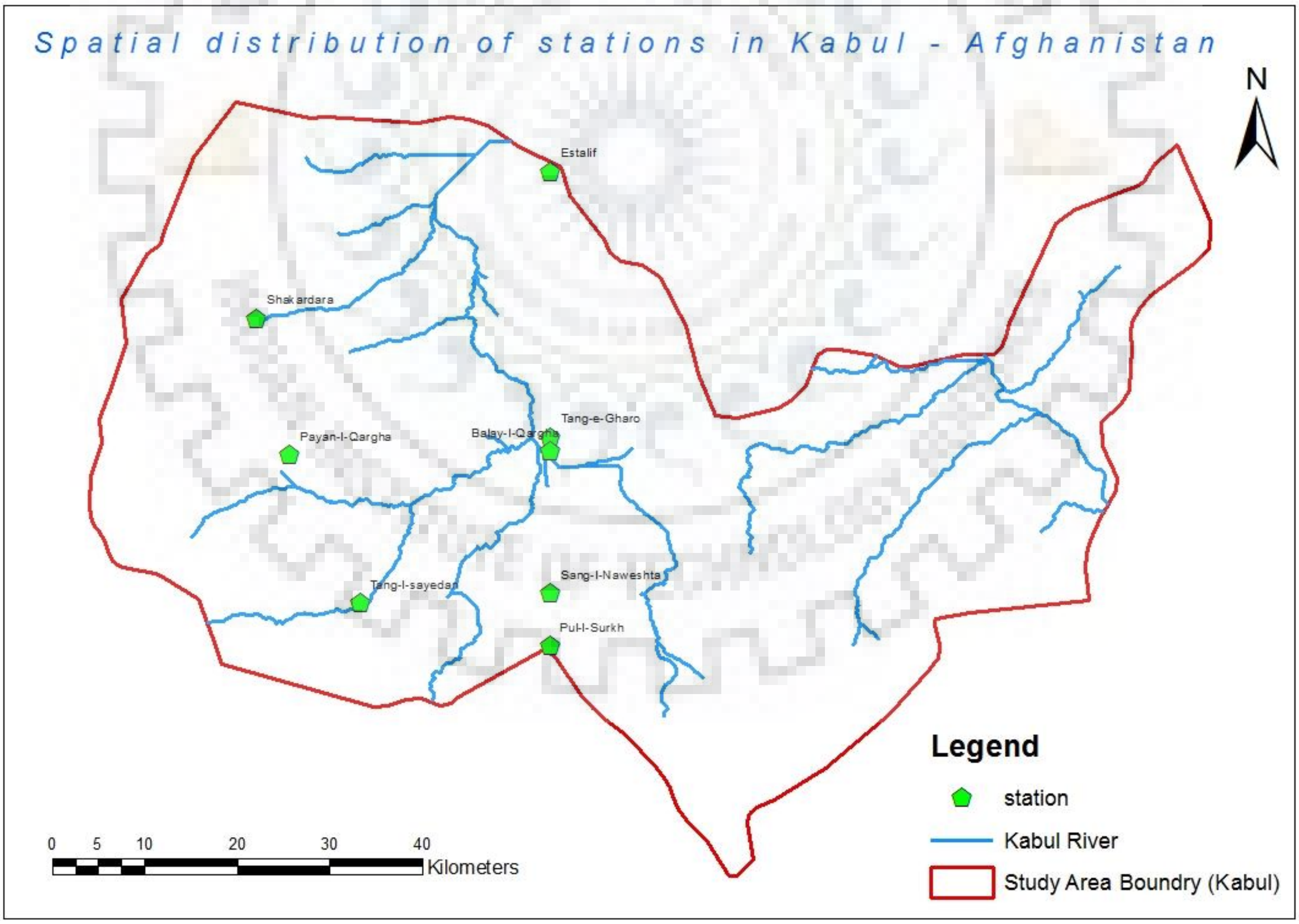


Figure 3.3 Spatial Distribution of Station in KRB

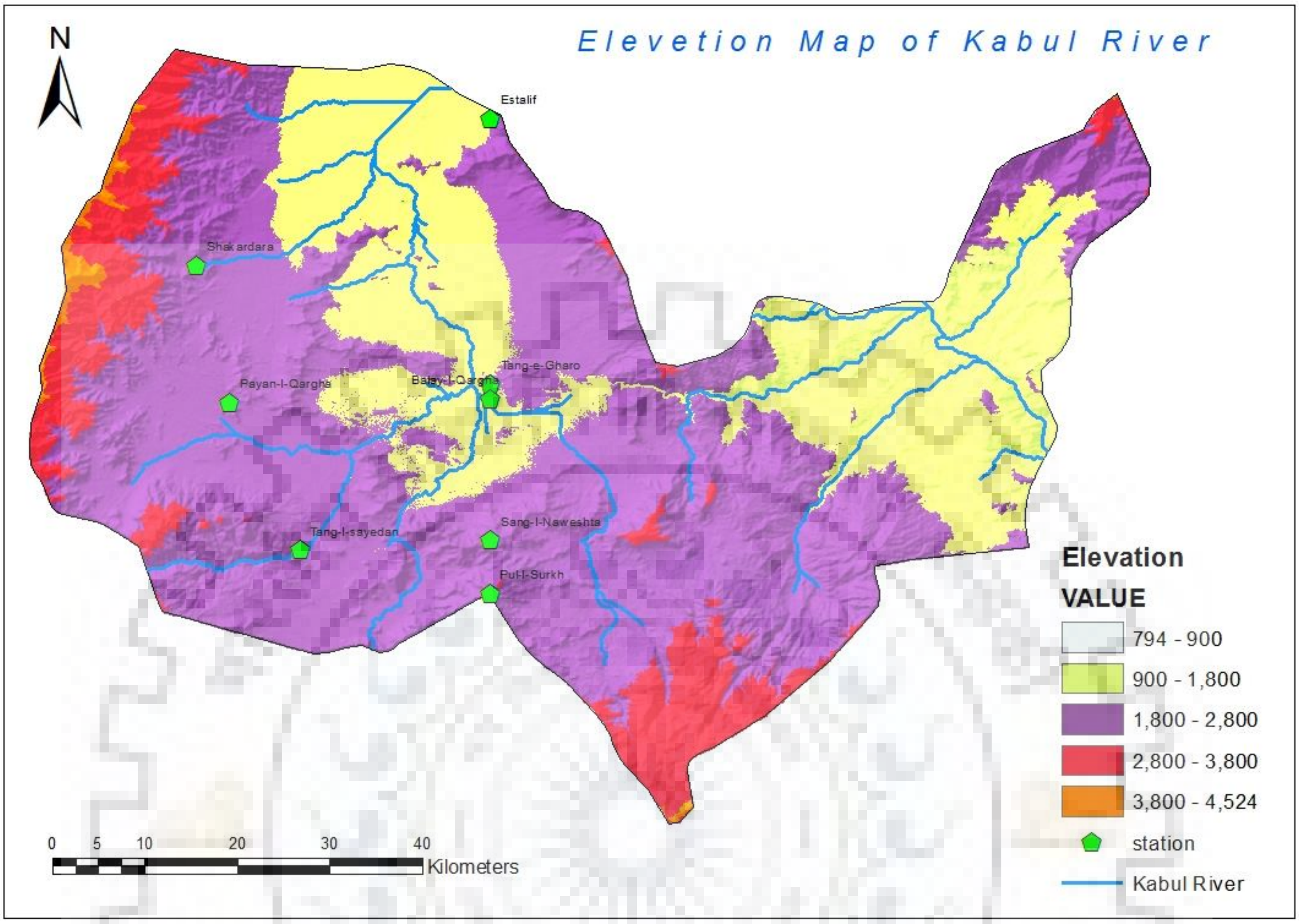


Figure 3.4 Kabul city Elevation Map

Table 3.5 Geographic characteristics of metrological Station

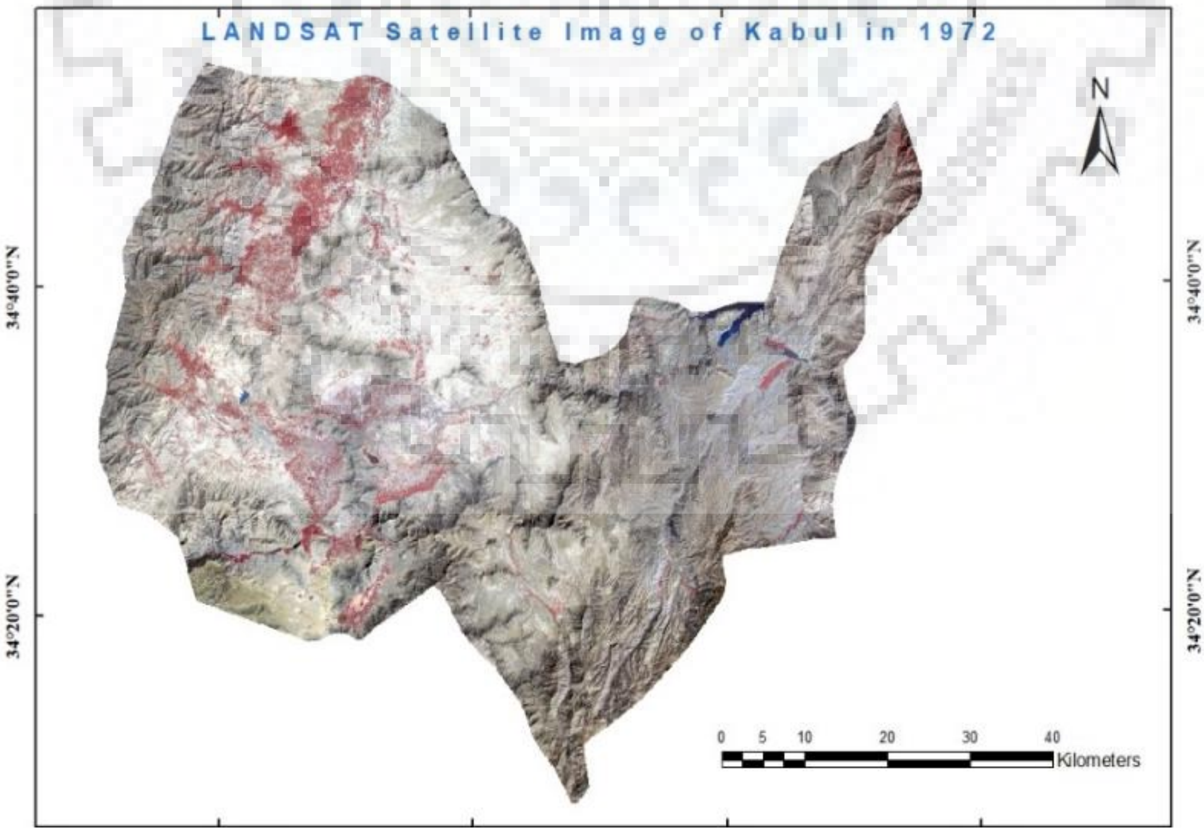
Geographic characteristics of the weather station sites used in this paper				
No	**Name of Station**	**Longitude**	**Latitude**	**Elevation**
1	***Payan - I - Qargha***	69° 2' 8.68"	34° 33' 9.14"	1970 m
2	***Pul - I - Surkh***	69° 17' 19.26"	34° 22' 0.63"	2216 m
3	***Tang - I - Sayedan***	69° 6' 15.88"	34° 24' 32.31"	1870 m
4	***Shakardara***	69° 0' 13.03"	34° 41' 7.75"	2168 m
5	***Estalif***	69° 17' 19.26"	34° 49' 42.06"	1821 m
6	***Teng -e-gharo***	69° 17' 19.26"	34° 34' 11.57"	1775 m
7	***Balay - I - Qargha***	69° 17' 19.26"	34° 33' 21.93"	2007 m
8	***Sang - I - Naweshta***	69° 17' 19.26"	34° 25' 5.48"	1813 m

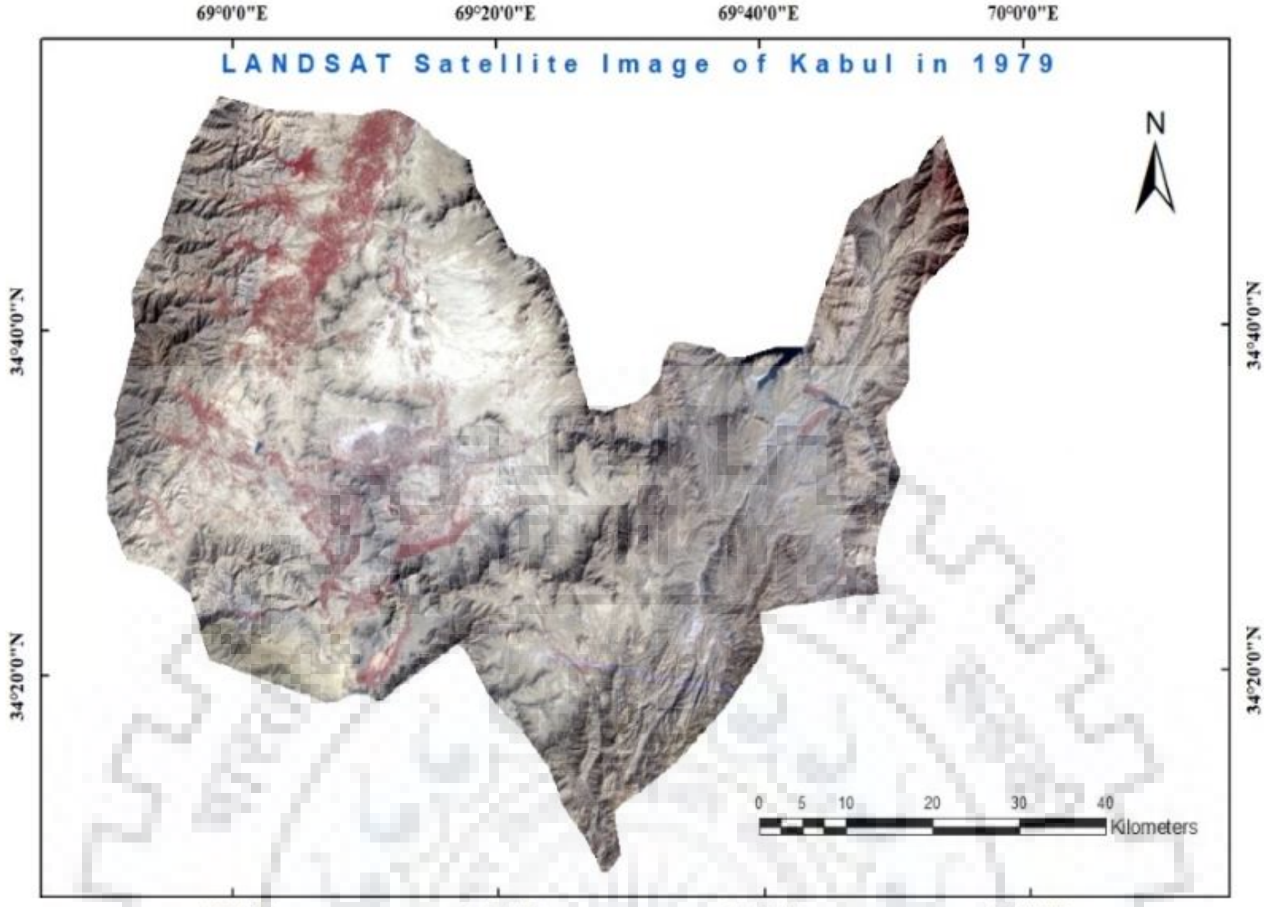
3.3.2 Spatial Data:

The study area satellite images were obtained from USGS Earth Explorer (https://earthexplorer.usgs.gov), for 1972, 1979, 1990, 2000, 2008 and 2018 years with the details shown in Table 3.6. The downloaded satellite images were modified in Arc GIS version 10.4.1 after that ERDAS Imagine 2018 software was used for enhancement and classification of these satellite images as shown in Fig. 3.5.

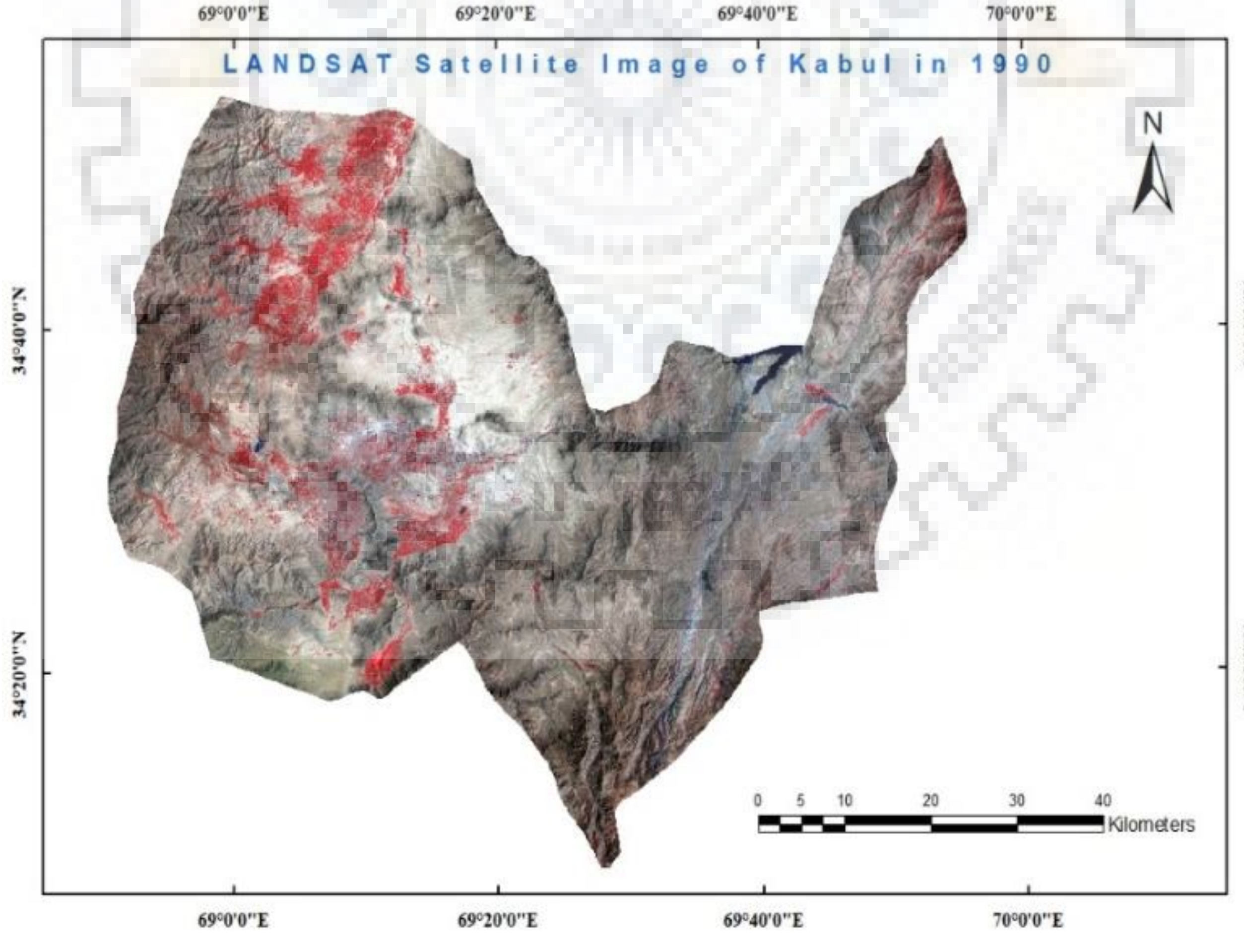
Table 3.6 Spatial Data sources

SI/No	Sensor/Satellite	Date	Path and Row	Source
1	Landsat 8 OLI/TURS C1 Level1	May/7/2018	164/036	USGS
		13-Jul-18		
2	Landsat 4 -5 TM C1 Level1	30-Sep-08	164/036	USGS
		21-Sep-08		
3	Landsat 4 -5 TM C1 Level1	14-Aug-00	164/036	USGS
		29-Jul-00		
4	Landsat 4 -5 TM C1 Level1	12-Aug-90	164/036	USGS
		25-Jun-90		
5	Landsat 1 -5 MMS C1 Level1	16-Oct-79	164/036	USGS
6	Landsat 1 -5 MMS C1 Level1	10-Sep-72	164/036	USGS

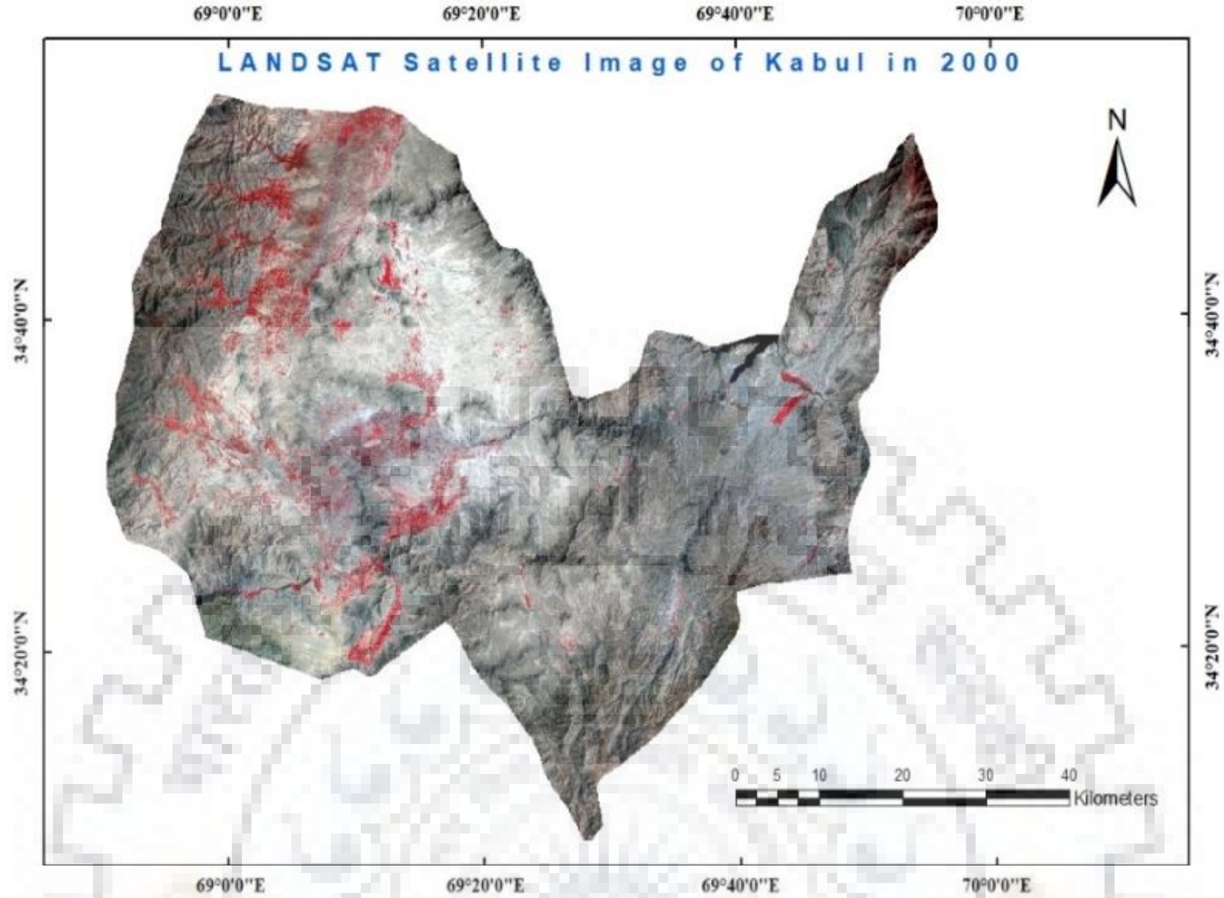


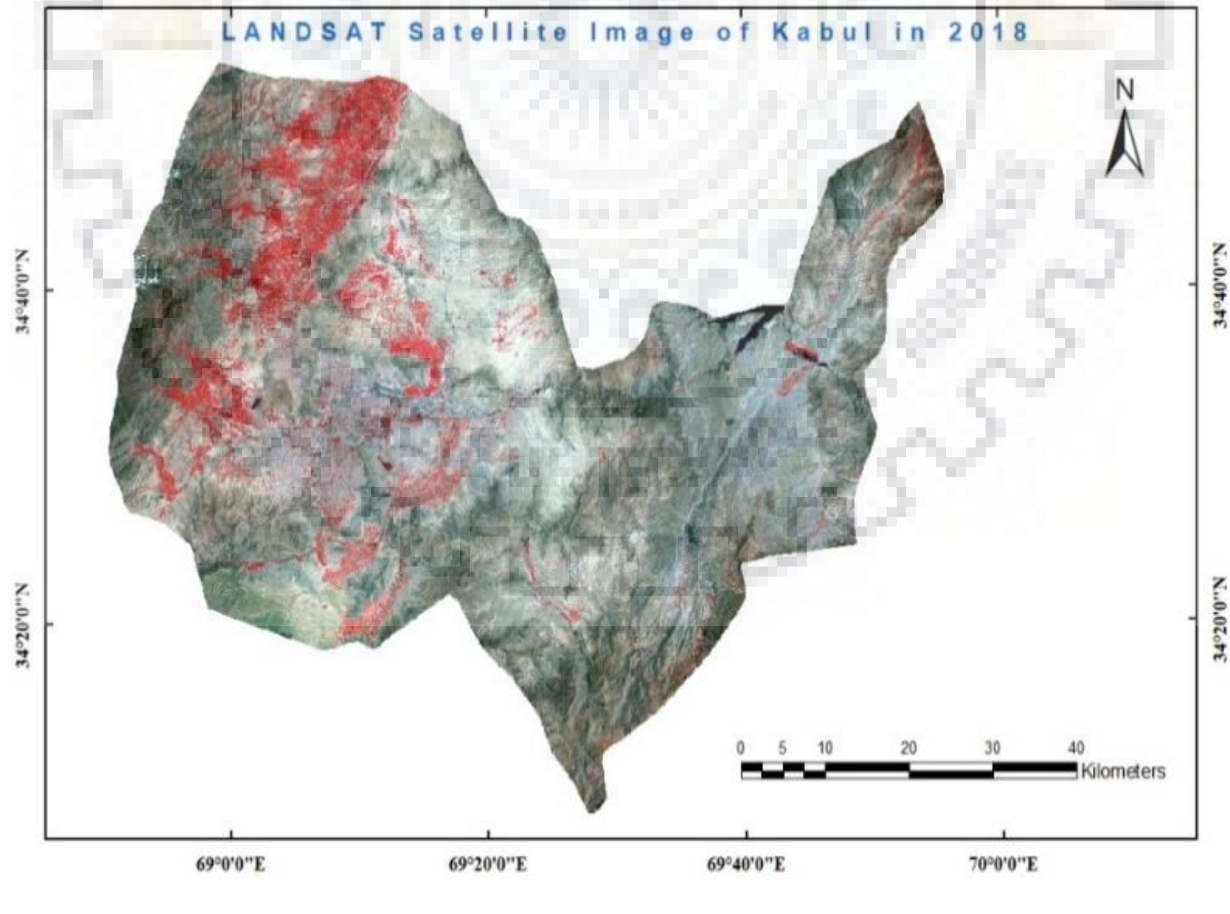


LANDSAT Satellite Image of Kabul in 1979
69°0'0"E
69°20'0"E
69°40'0"E
70°0'0"E
34°40'0"N
34°20'0"N
N
0 5 10 20 30 40
Kilometers



LANDSAT Satellite Image of Kabul in 1990
69°0'0"E
69°20'0"E
69°40'0"E
70°0'0"E
34°40'0"N
34°20'0"N
N
0 5 10 20 30 40
Kilometers


69°0'0"E
69°20'0"E
69°40'0"E
70°0'0"E
LANDSAT Satellite Image of Kabul in 2000
N
34°40'0"N
34°20'0"N
0 5 10 20 30 40
Kilometers


69°0'0"E
69°20'0"E
69°40'0"E
70°0'0"E
LANDSAT Satellite Image of Kabul in 2018
N
34°40'0"N
34°20'0"N
0 5 10 20 30 40
Kilometers

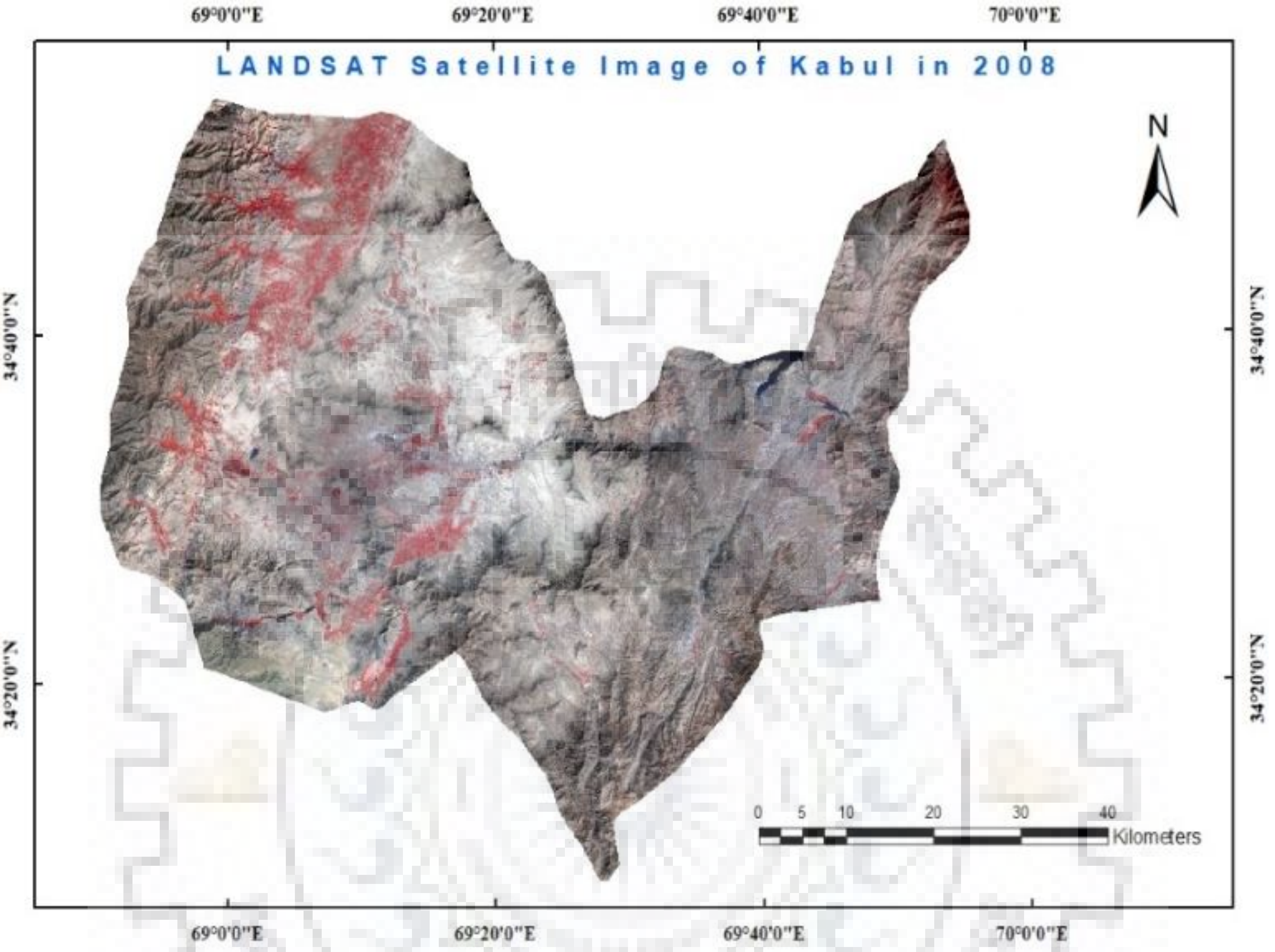


Figure 3.5 Satellite Images

3.4 SWAT Model Data:

3.4.1 DEM Map:

The 90m Digital Elevation Model (DEM) image downloaded from this website (http://srtm.csi.cgiar.org) for making the watershed delineation in Arc SWAT 2012.

Arc GIS 10.4.1 used for generating the DEM map as shown in Fig 3.6.

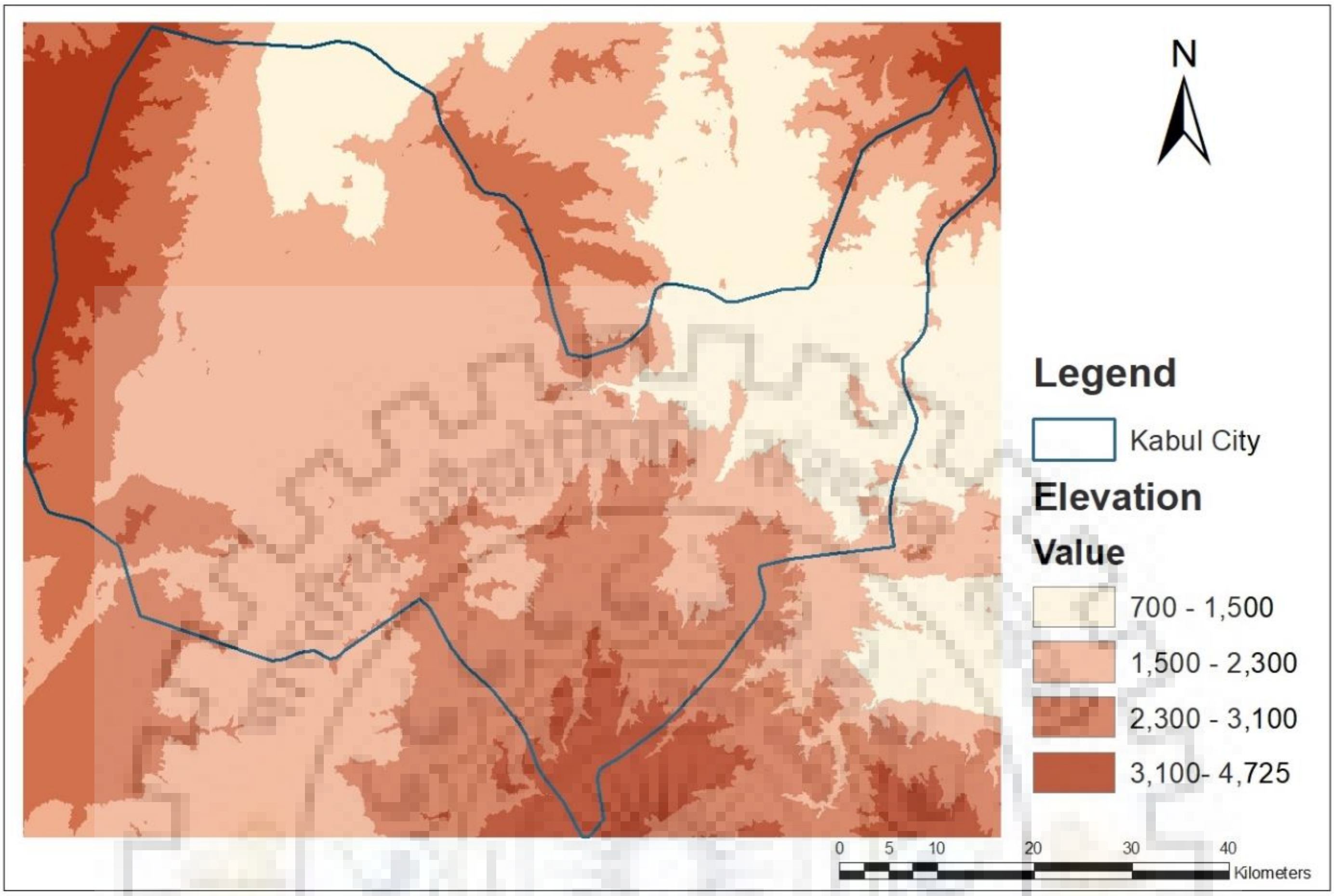


Figure 3.6 Kabul DEM map

3.4.1 Land Use Land Cover Map:

Landsat data for the study area downloaded from the website (https://earthexplorer.usgs.gov/) as given details in Table 3.7. Arc GIS 10.4.1, Google Earth Pro and ERDAS Imagine 2018 used for generating the LULC map. Classification process through ERDAS Imagine 2018 done with a hybrid classification which is the combination of supervised and unsupervised classification. Accuracy assessment showed 86.67 percent and kappa coefficient 0.84 for Kabul LULC map. Fig 3.6. is showing Kabul LULC map of 2018.

Table 3.7 Satellite Image Source

SI/No	Sensor/Satellite	Date	Path and Row	Source
1	Landsat 8 OLI/TURS C1 Level1	May/7/2018 13-Jul-18	164/036	USGS

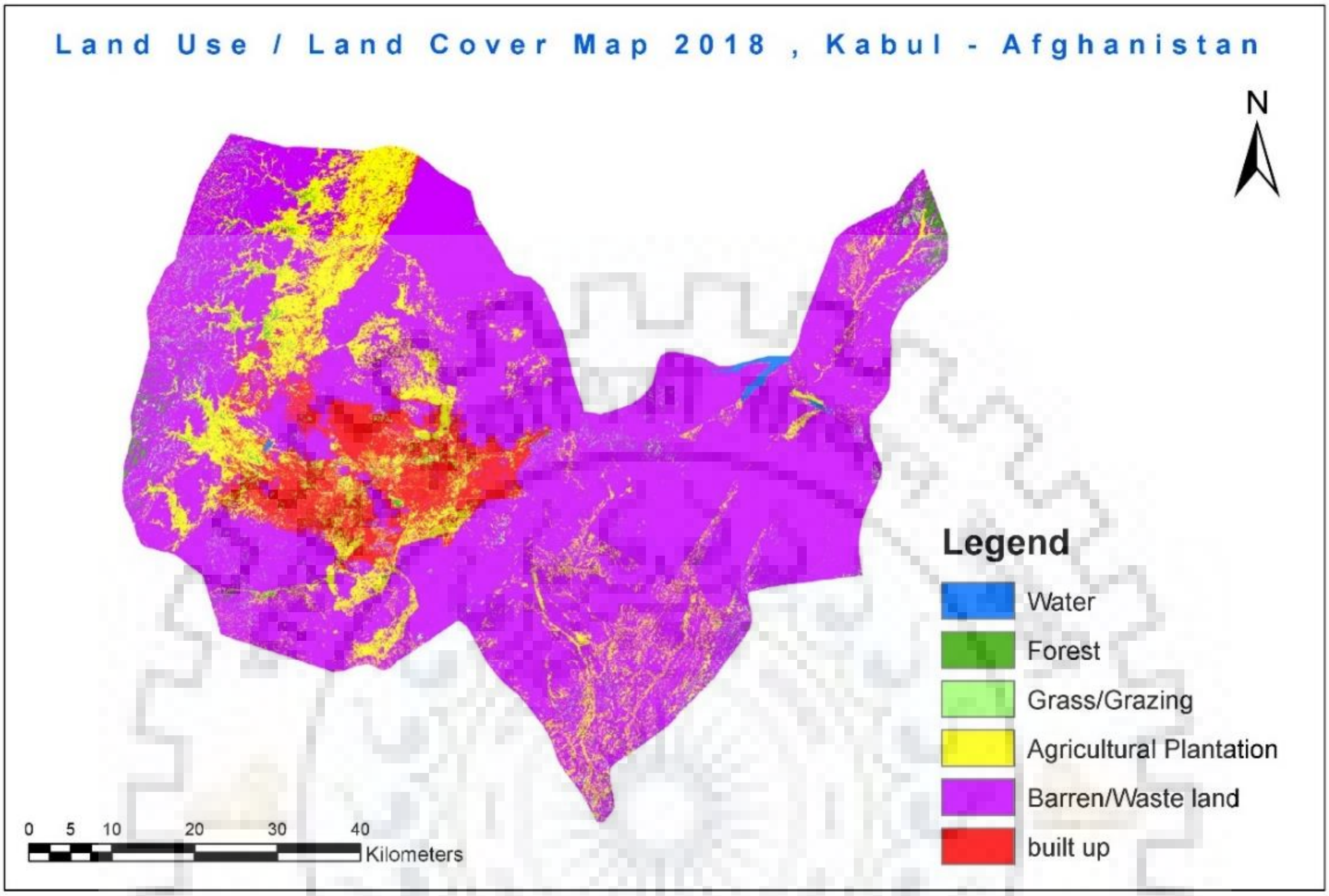


Figure 3.7 - Land Use Land Cover Map

3.4.1 Soil Map:

World soil map downloaded from the United Nation Food and Agriculture Organization (FAO) website (http://www.fao.org/geonetwork/srv/en/metadata.show%3Fid=14116).

Arc GIS 10.4.1 used to edit the soil map of the study area. Kabul soil map has three different types of soils as shown in Fig 3.8.

Soil type has a direct impact on stream flow due to Physical and chemical properties of soil such as water content availability, hydraulic conductivity, texture and bulk density in each layer of soil are determining surface runoff factors.

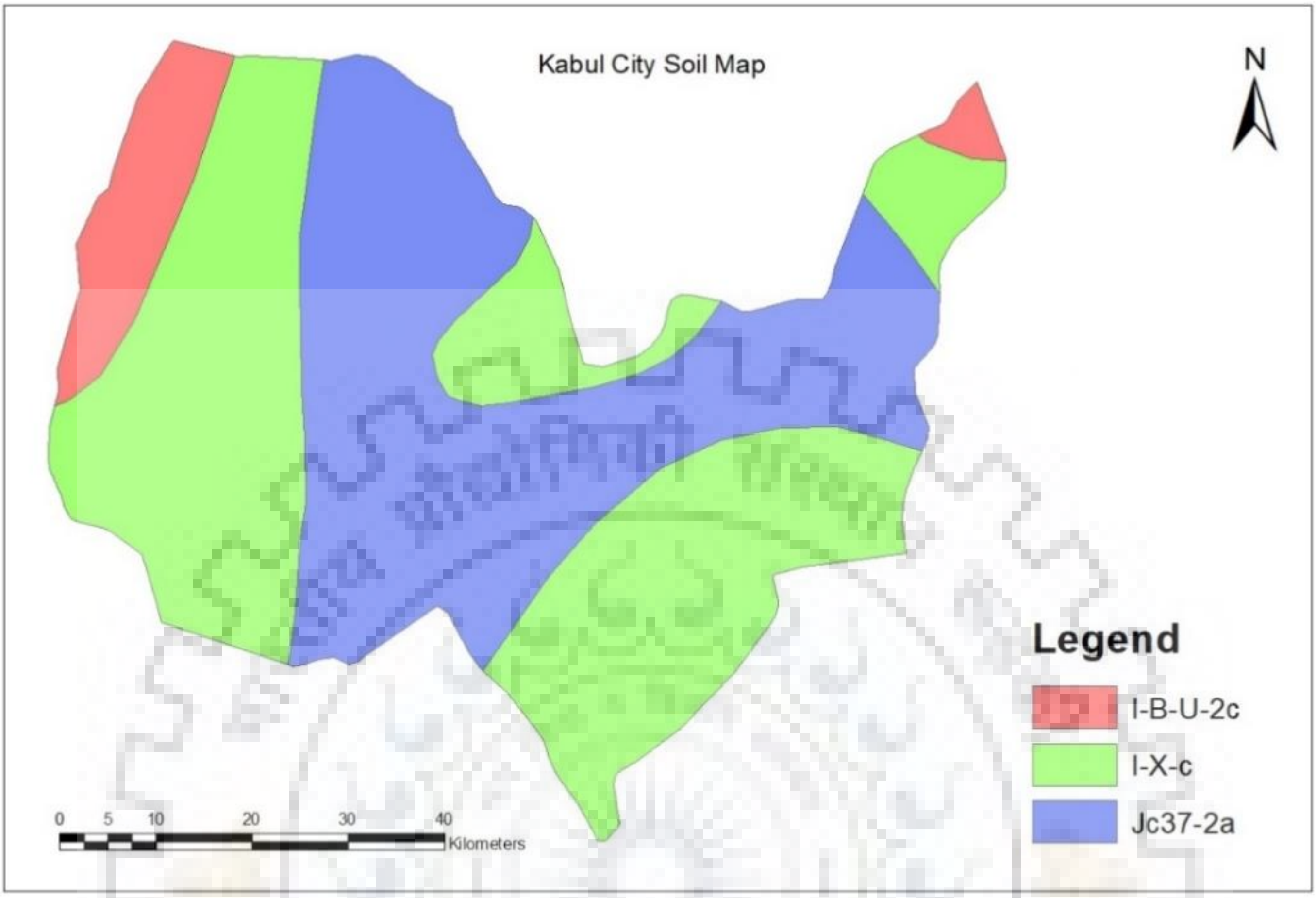


Figure 3.8 - Kabul City Soil Map

CHAPTER 4: METHODOLOGY

4.1 General:

The methodology of this study divided in three part, the first step is to review the climate change by using statistical method to evaluate the patterns of behavior that the climate has exhibited in the past in order to determine whether recent climate change behaviors are normal or anomalous, second step is to assess the effect of land use land cover changes on hydrological processes and the third step is climate change impacts on the river basin using a hydrological model. The flow chart of methodology is presented in Fig 4.1.

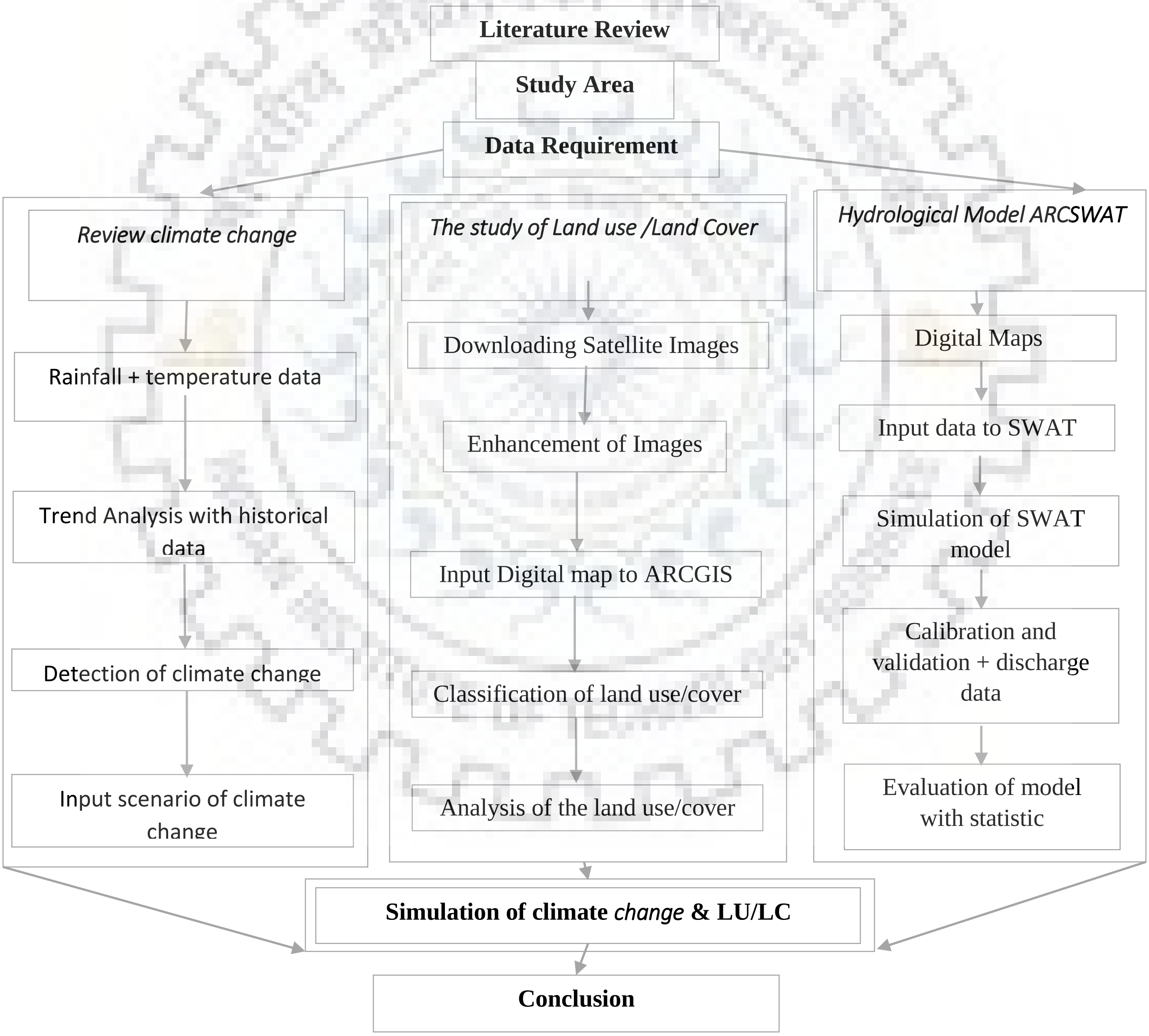


Figure 4.1 Methodology flow chart

4.2 **Statistical Method:**

For determining trends in hydrological and hydro-meteorological time series, different statistical test methods are used. Generally, these methods are classified into two categories as parametric and nonparametric tests. Parametric tests are based on the normal distribution series; therefore, it is always more powerful but due to rare probability of normal distribution in hydrological time series data it is not used, so in case of analysis, mostly nonparametric tests are used. One of the most important and common nonparametric tests methods in trend is the Mann-Kendall and Spearman's rho tests. Most of the researchers to analyze the monotonic trends in meteorological data using Mann Kendall test and less common, Spearman's who are used to detect monotonic trends in hydrometeorological data. Ahmad *et al*., (2015).

4.2.1 Mann Kendall Test:

Mann-Kendall is the non-parametric test which had been developed by Mann (1945) for trend identification of metrological data and the test statistic distribution had been instigated by Kendall (1975) for detecting a non-linear trend.
The Mann-Kendall test statistic is calculated according to the below Equations:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sig(xj - xi) \qquad (4.1)$$

With

$$sgn\ (xj - xi) = \begin{cases} +1 \ \ if\ (xj - xi) > 0 \\ \quad 0 \quad if\ (xj - xi) = 0 \\ -1 \ \ if\ (xj - xi) < 0 \end{cases} \qquad (4.2)$$

or a time, series, X_i, i=1,2,3…………, n

$$Var(S) = \frac{1}{18}\left[n(-1)(2n+5) - \sum_{p=1}^{q} tp(tp-1)(2tp+5)\right] \qquad (4.3)$$

where q is the number of the tied groups in the data set and t_p is the number of data points in the p^{th} tied group. The statistic (Z) is approximately normal distributed provided that the following Z-transformation is employed:

$$Z = \begin{cases} \frac{s-1}{\sqrt{VAR(s)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{s+1}{\sqrt{VAR(s)}} & if\ S < 0 \end{cases} \qquad (4.4)$$

The statistic (S) is closely related to Kendall's τ is given by:

$$\tau = \frac{S}{D} \quad (4.5)$$

Where

$$D = \left[\frac{1}{2}n(n-1) - \frac{1}{2}\sum_{p=1}^{q} tp(tp-1)\right]^{\frac{1}{2}} \left[\frac{1}{2}\, n(n-1)\right]^{\frac{1}{2}} \quad (4.6)$$

The standardized Mann Kendall test statistics (Z) is always a function of the standard normal distribution which means the value is zero and variance is 1. There is no trend if $\pm Z \leq Z_{1-\frac{\propto}{2}}$, in a two-sided test for trend if $\pm Z \geq Z_{1-\frac{\propto}{2}}$ the null hypothesis for the no trend is rejected. Moreover, it is not always true that if the evidence available then there is a trend. Meena *et al*., (2015). The standardized Mann Kendall test statistics (Z) with positive values showing increasing trends, while The standardized Mann Kendall test statistics (Z) with negative values indicate the decreasing trends. Significant of the trend is dependent on the absolute value of Z if an absolute value of Z is greater than the standard normal deviate $(Z_{1-\frac{\propto}{2}})$ for the desired value of ∝ then there will be significant in trend Chattopadhyay *et al*., (2017).

4.2.2 Sen's Slope Estimator:

Sen's slope estimator (Sen, 1968) is a non-parametric method for trend analysis. The MK test and Sen's slope estimator are complementary methods for trend detection and to calculate its magnitude respectively.
This means that linear model $f_{(t)}$ can be described as below:

$$f(t) = Q_t + B \quad (4.7)$$

where Q is representing the slope and B is as a constant. Temporal trends if expressed as a linear regression model of the form $\log(D) = a + bY$, then the back-transformed regression coefficient is ($B = 10^b - 1$). This provides an estimate of the percent increase per year, as predicted by the regression.
For calculating the slope Q, then necessary to calculate slopes of all data pairs as below:

$$Q_i = \frac{X_j - X_K}{j-k} \quad , i = 1, 2, \dots N \, , j > k \quad (4.8)$$

The number of slopes is belonging to the number of x_j values, therefore If there are n values x_j in the time series, then ($N = \frac{n(n-1)}{2}$) slope estimates Q_i. Median of the N of Q_i is indicating the Sen's estimator of the slope. The N values of Q_i are sorting from the smallest to the largest and the Sen's estimator is Drapela, et al., (2011):

$$Q = \begin{cases} Q_{\frac{N+1}{2}} & if\ N\ be\ odd \\ \frac{1}{2}\left(Q_{\frac{N}{2}} + Q_{\frac{N+2}{2}}\right) & if\ N\ be\ Even \end{cases} \quad (4.9)$$

In this study, MAKESENS 1.0 an excel sheet template used for the MK test and Sen's Slope estimator, which is useful to analyze the hydrologic and meteorological data and compared with hand calculation.

4.2.3 The Percentage of Changing Over the time series:

To find the change percentage through the time period, the first trend should be assumed as linear then calculate the magnitude by using Theil and Sen's median slope and assessing the mean over the period as mentioned in the below Meena *et al.*, (2015).

$$\%\ change = \frac{Median\ Slope\ (B)\ x\ length\ of\ period\ (n)}{Mean} \quad (4.10)$$

4.2.4 Standard Deviation:

The characteristic of scattering measure in a dataset which is the root of variance as shown in equation XI is called standard deviation and to find the primary statistic parameters needed.

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(xi - \bar{x})^2}{n-1}} \quad (4.11)$$

where

X_i = The observed data

$\bar{x}$ = The mean value of observed data which is equal to $\bar{x} = \frac{\sum_i^n xi}{n}$

n = no of observed data

4.2.5 Skewness and Kurtosis Formula:

Skewness coefficient is the degree of distribution from a symmetrical data point curve or a normal distribution in a statistic method. it can be either positive or negative and according to its value it is determined as follow:

- If Skewness is between -0.5 and 0.5 then it shows the fairly symmetrical series.
- If Skewness is between -1 and -0.5 or 1 and 0.5 it is moderately skewed.
- If Skewness is greater than 1 or less than -1 series is highly skewed.

The Skewness is defining by the following equation.

$$Cs = \frac{\sum_{i=0}^{n}(xi - \bar{x})^3}{n \times SD^3} \quad (4.12)$$

Where
X_i = Observed data
$\bar{x}$ = mean value of observed data
SD = Standard Deviation

Kurtosis is determining the peak and frequency of extreme values in a distribution dataset series, the high value of Kurtosis is describing that data has the heavy tails or outliers, the low Kurtosis is the characteristic of the light tail or lack of outlier. Due to the above definitions, we have the following.

- if kurtosis is 3 then the data set of the series is a normal distribution and it is called Mesokurtic
- if Kurtosis is greater than 3 it shows the sharper peak which is called Leptokurtic
- if Kurtosis is less than 3 then it indicates the lower peak that called Platykurtic

kurtosis is defined by the following equation.

$$Ck = \frac{\sum_{i=0}^{n}(xi - \bar{x})^4}{n \times SD^4} \qquad (4.13)$$

4.3 **LULC change:**

As shown in Fig 4.2. LULC change process is containing the following steps.

1. Image Enhancement
2. Image classification process
3. Classification Accuracy Assessment
4. Classification Change detection

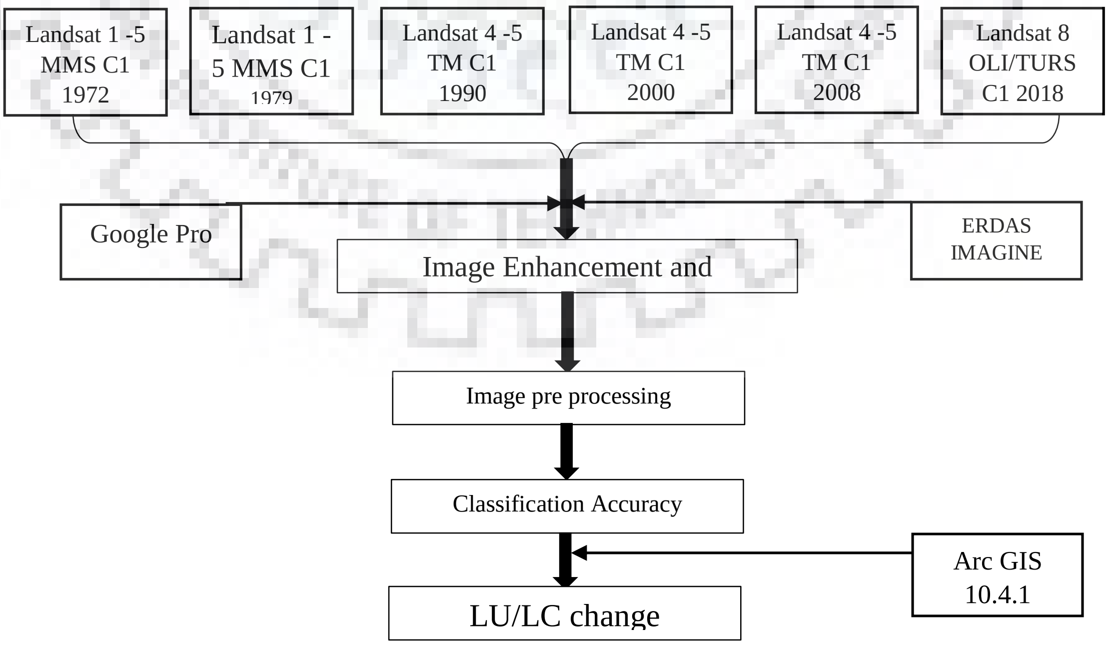


Figure 4.2 Flow Chart of Methodology

4.3.1 Image Enhancement:

Image enhancement is a pre-process of classification for making an image perspicuous. This technique makes easy the satellite images to analyze for human eyes. Enhancement techniques are often used instead of classification techniques for feature extraction studying and locating areas and objects on the ground and deriving useful information from images.

4.3.2 Image classificaton Process:

In this paper, the hybrid classification technique (Teferi et al., 2010; Afify, 2011; Gashaw et al., 2018) used for image classification, which this technique is a combined of supervised and unsupervised classification. The LULC classes were the Forest, Water, Grass/Grazing, Agricultural plantation, Urban area, and Barren land/ wastelands area as detail given in Table.4-1. Arc GIS and ERDAS Imagine are the most powerful software for generating LULC map, therefore all thematic maps and classification done through this software.

Table 4.1 LULC classess

Water	River, permanent open water, lakes, ponds and reservoirs
Forest	dense forest, trees
Grass/Grazing	All grass which covered
Agricultural Plantation	Agricultural area, crop fields, fallow lands and vegetable lands
Barren/Waste land	Permanent and seasonal wetlands, low-lying areas, marshy land, rills and gully, swamps
Urban	Residential, commercial and services, industrial, transportation, roads, mixed urban, and other urban

4.3.3 Accuracy Assessment:

Classification accuracy assessment is a method, which an image has compared to the corresponding reference data. One of the most common means of expressing classification accuracy is the preparation of a classification error matrix or confusion matrix. Error matrices compare, on a category by category basis, the relationship between known reference data (ground truth) and the corresponding results of automated classification. All the non-diagonal elements are expressing the omission (column) and commission (row) errors. Overall accuracy is calculated through the summation of entire diagonally elements divided by the summation of row or column. Another method for accuracy assessment is the Kappa coefficient. Kappa coefficient is a measure of how the classification results compare to values assigned by chance. The Kappa coefficient value is between 0 and 1, where 0 indicates no agreement between the classified image and the reference image, while 1 presents the classified image and ground truth are totally match. Results of the Kappa coefficient is a KHAT statistic which drives by the Eqs.1, 2 and 3. (Afify, 2011; Andualem, et al., 2018)

$$\hat{K} = \frac{p_0 - p_c}{1 - p_c} \quad \text{... (4.14)}$$

Where

$$p_0 = \sum_{i=1}^{r} p_{ii} \quad \text{... (4.15)}$$

$$p_c = \sum_{i=1}^{r} (p_{i+} x\, p_{+i}) \quad \text{... (4.16)}$$

r = The number of rows in the confusion matrix.

p_{ii} = The proportion of pixels in row i and column i.

p_{i+} = The proportion of the marginal total of row i.

p_{+i} = The proportion of the marginal total of column i.

The kappa coefficient statistic and overall classification accuracy have obtained from Eqs. 4.14, 4.15 and 4.16 through ERDAS Imagine 2018 software. Table 4.2 is presenting the accuracy of LULC classification.

Table 4.2 Accuracy Analysis Report

Years	Overall Accuracy	Kappa Coefficient
1972	*91.67%*	*0.9*
1979	*85.42%*	*0.825*
1990	*88.89%*	*0.866*
2000	*88.89%*	*0.866*
2008	*90.00%*	*0.88*
2018	*86.67%*	*0.84*

4.4 **SWAT Model:**

The impacts of the climate change, land use land cover change and soil condition on surface flow (discharge) of Kabul River Sub-basin analyzed through the application of Arc SWAT 2012 model. The methodology flow chart for hydrological modeling is presented in Fig 4.3.

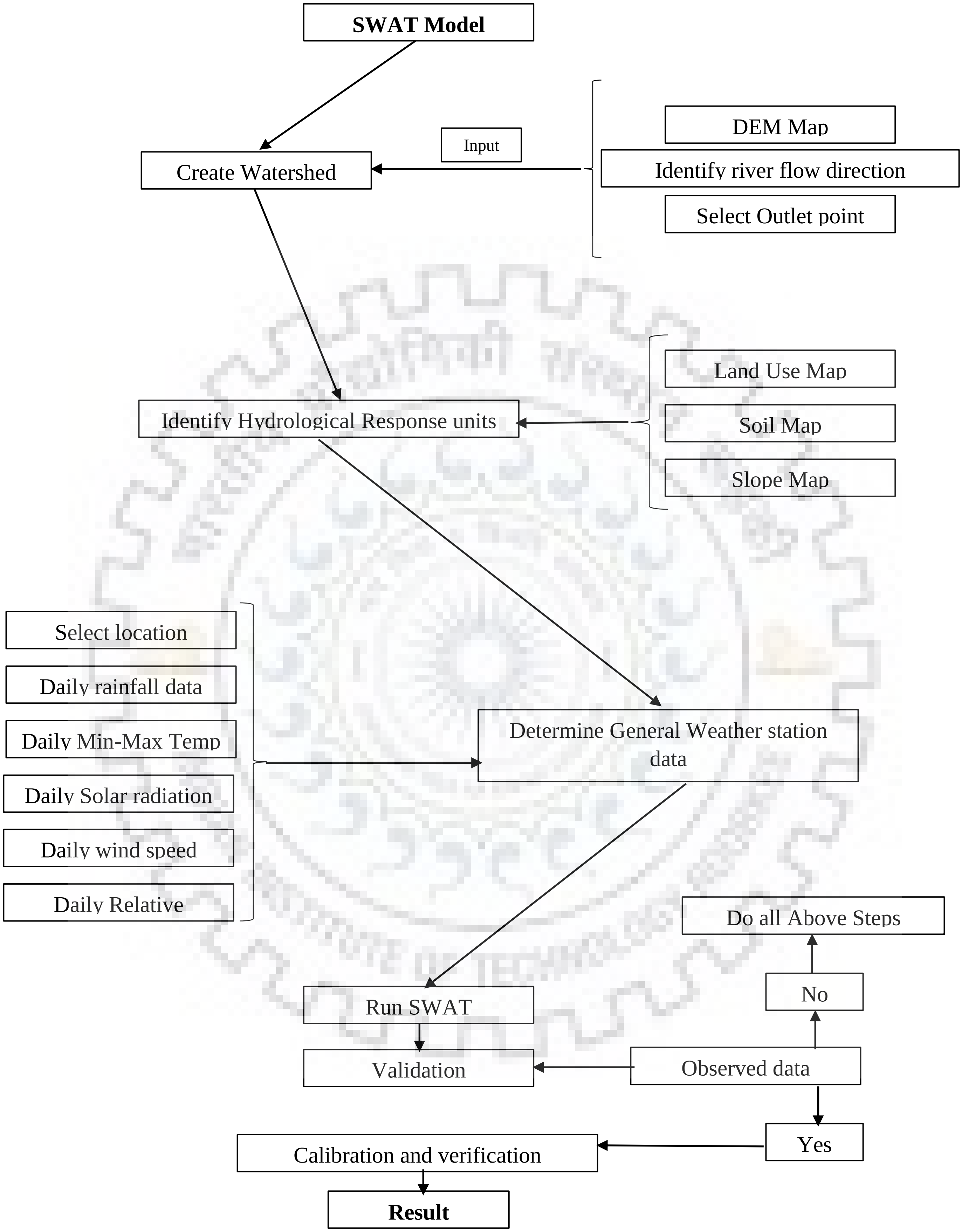


Figure 4-3 Methodology for hydrological model flow chart

4.4.1 Description of the SWAT Model:

Soil Water Assessment Tool (SWAT) is a model which designed on continuous time and spatially distributed for simulate of water, sediment, and nutrient, and pesticide transport at a catchment scale on a daily time step. (Setegn, et al., 2008; Winchell et al., 2007). The SWAT model is using to predict the influence of land use and land cover change on water in a huge watershed over a long time with different conditions. Gashaw et al., (2018)

In 1990s first version of SWAT 94.2 developed and released, and for the first time, Arnold in 1994 published peer-reviewed description of a geographic information system (GIS) interface for SWAT. United State Department of Agriculture (USDA) has developed the SWAT model in the Agricultural Research Service (ARS), which has over 30 years' experience of modeling. The current SWAT model contains the key elements which contributed by USDA-ARS model. (Arnold, 1998; S. Hansen et al., 2013).

The purpose use of the SWAT model is to predict the impact of climate on water resources, as well as sediment and chemical yield in a large scale of the ungauged basin Holeček., (2001).

The SWAT model is based on a water balance equation in the soil profile where the simulation process is containing the surface flow, runoff, evapotranspiration, precipitation, infiltration, and percolation as shown in Eq. 4.17.(Arnold, 1998; Gashaw et al. 2018; Holeček 2001; Quyen, et al., 2014; Setegn, et al., 2008; Tibebe, et al., 2011; Ghoraba 2015).

$$SW_t = SW_0 + \sum_{i=0}^{t} (R_{day} - Q_{Sur} - E_a - W_{Seep} - Q_{gw}) \qquad \dots (4.17)$$

Where:

SW_t indicate the final soil water content which is in (mm)

SW_0 showing the initial soil water content with (mm) unit

R_{day} determine the rainfall amount on day i in (mm)

Q_{Sur} present the surface Runoff on the day i in (mm)

Ea is the evapotranspiration amount on day i in (mm)

W_{Seep} showing the seepage water amount on the day i in (mm)

Q_{Gw} is the return flow on day i which presented in (mm)

t present the time in (days)

In this research Soil Conservation Service (SCS), Curve Number (CN) method has used in the SWAT model for assessing the surface runoff in the watershed.

SCS - CN equation is one of the most powerful and efficient methods for predict runoff from the given daily precipitation data as shown in Eq.4.18. (Arnold, 1998; Gashaw et al. 2018; Setegn, et al., 2008; Tibebe, et al., 2011; Ghoraba., 2015).

$$Q_{Sur} = \frac{(R_{day} - 0.2S)^2}{(R_{day} - 0.8S)^2} \qquad \text{... (4.18)}$$

Where Qsur is a daily surface runoff in (mm) and Rday is the depth of daily rainfall (mm).

S is the retention parameter in (mm), which find out by Eq. 4.19.

$$S = 254\left(\frac{100}{CN} - 1\right) \qquad \text{... (4.19)}$$

Where CN is Curve Number which has a range of $100 \geq CN \geq 0$. Where CN = 100 value is presenting the zero potential retention and CN = 0 represents an infinitely abstracting catchment with S = ∞.

4.4.2 Sensitivity Analysis:

The method which indicates the significant parameter that has the most effect on streamflow in the calibration and validation process through the SWAT model is called sensitivity analysis. (Arnold, 1998; Zhang, et al., 2009; Tang, et al., 2012; Vilaysane et al., 2015; Khalid et al., 2016; Shrestha et al., 2016; Ang et al, 2018).

Accuracy assessment with selected ten different parameters which have a direct influence on streamflow was analyzed through SWAT CUP 2012 as shown in Table 4.3.

4.4.3 Calibration and Validation:

The process which adapts or alters the model parameter with accordance their range value based on observed data to confirm the same response over time is called calibration. Where the validation is a process which indicates the relative between simulated and observed data in a specific time interval without adjusting the parameters. Abbaspour., (2015).

4.4.1 Model performance list:

The SWAT Performance on surface flow simulation analyzed with the coefficient of determination (R2), Nash Sutcliffe efficiency (NSE) and Present bias (PBIAS) parameters as per recommended of several researchers. (Yuemei et al., 2008; Abbaspour, 2015; Meaurio et al., 2015; Moriasi et al., 2015; Leta et al., 2018).

Table 4.3 Sensitivity Parameters

No	Parameter	Description	classification	Range of initial value	
				Min	Max
1	**R__CN2.mgt**	SCS runoff curve number for moisture condition II	Surface runoff	35	98
2	**V__SURLAG.bsn**	Surface runoff lag time		0.05	24
3	**V__GW_DELAY.gw**	Groundwater delay (days)	Groundwater	0	500
4	**V__GWQMN.gw**	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)		0	5000
5	**V__ALPHA_BF.gw**	Base flow alpha factor (days)		0	1
6	**V__SOL_AWC(..).sol**	Available water capacity of the soil layer	Soil	0	1
7	**V__SOL_K(..).sol**	Saturated hydraulic conductivity		0	2000
8	**V__TLAPS.sub**	Temperature lapse rate	Temperature	-10	10
9	**V__EPCO.hru**	Plant uptake compensation factor	Evapotranspiration	0	1
10	**V__ESCO.hru**	Soil evaporation compensation factor		0	1
V__ is represent the parameter value which is replaced with the given value					
R__ is showing the parameter value that multiplied with the (1 + given value)					

Coefficient of determination, Nash Sutcliffe efficiency, and Present bias parameters are determined by using Eqs. 4.20, 4.21 and 4.22 respectively.

$$R^2 = \frac{\sum_{i=1}^{n}(Q_{o,i} - \overline{Q_o})(Q_{s,i} - \overline{Q_s})}{\sqrt{\sum_{i=1}^{n}(Q_{o,i} - \overline{Q_o})}\sqrt{\sum_{i=1}^{n}(Q_{s,i} - \overline{Q_s})}} \quad \ldots (4.20)$$

$$\text{NSE} = \frac{\sum_{i=1}^{n}(Q_{s,i} - Q_{o,i})^2}{\sum_{i=1}^{n}(Q_{o,i} - \overline{Q_{o,}})^2} \quad \ldots (4.21)$$

$$\text{PBAIS} = \frac{\sum_{i=1}^{n}(Q_{s,i} - Q_{o,i})}{\sum_{i=1}^{n}(Q_{o,i})}\, x100 \quad \ldots (4.22)$$

Where:

R2 is the coefficient of determination

NSE is Nash Sutcliffe efficiency

PBAIS is Present bias, n is time period

Q_o and Q_s are observed and simulated streamflow respectively.

$\bar{Q}_o$ and $\bar{Q}_S$ are the mean value of observed and simulated discharge respectively.

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CHAPTER 5:
RESULTS AND DISCUSSIONS

5.1 **Trend Analysis:**

All primary statistical parameters such as mean (average), standard deviation (SD), coefficient of skewness (Cs), coefficient of kurtosis (Ck), median Slope (B), percentage change over the period (%change) and coefficient of variation (Cv) of annual rainfall in a period of 2000 to 2018 as well as for annual min and max temperature from 2008–2018 were computed through the equations 6, 7 and 8, and shown in Tables 5.1 to 5.3.

Table 5.1 Statistic parameters for Rainfall

Primary statistic parameters value of Annual Precipitation (mm)									
SN	Station	Mean	SD	Cv	Cs	Ck	B	n	% change
1	*Payin-i-Qargha*	311.75	107.86	34.60	-0.476	1.639	8.87	18	0.51
2	*Pul Surkh*	299.17	94.72	31.66	-0.387	1.889	4.88	18	0.29
3	*Tang - I - Sayedan*	287.53	90.63	31.52	-0.119	2.043	4.94	18	0.31
4	*Shakardarah*	460.31	261.63	56.84	0.235	1.478	25.28	18	0.99
5	*Estalif*	460.31	261.63	56.84	0.235	1.478	25.28	18	0.99
6	*Tang-i-Gharo*	460.31	261.63	56.84	0.235	1.478	25.28	18	0.99
7	*Balaye - I - Ghrgha*	460.31	261.63	56.84	0.235	1.478	25.28	18	0.99
8	*Sang - Naweshta*	527.20	315.93	59.93	0.239	1.400	30.42	18	1.04
SD = standard deviation, Cv = coefficient of variance, Cs = coefficient of skewness, Ck = coefficient of kurtosis, B median slope, n = length of period, % change= percentage change over the period									

Table 5.2 Statistic parameters for Min Temp

Primary statistic parameters value of Min Annual Temperature (C°)									
SN	Station	Mean	SD	Cv	Cs	Ck	B	n	% change
1	*Payin-i-Qargha*	-16.506	4.953	30.007	0.003	2.760	0.710	11	-0.473
2	*Pul Surkh*	-11.600	4.173	35.973	-1.178	5.120	0.030	11	-0.028
3	*Tang - I - Sayedan*	-14.600	6.337	43.403	0.958	4.402	-0.020	11	0.015
4	*Shakardarah*	-14.235	1.993	13.998	0.296	2.667	0.280	11	-0.216
5	*Estalif*	-14.235	1.993	13.998	0.296	2.667	0.250	11	-0.193
SD = Standard Deviation, Cv = Coefficient of Variance, Cs = Coefficient of Skewness, Ck = Coefficient of Kurtosis, B median Slope, n = length of Period, % change= percentage change over the period									

Table 5.3 Statistic parameters for Max Temp

Primary statistic parameters value of Max Annual Temperature (C°)									
SN	Station	Mean	SD	Cv	Cs	Ck	B	n	% change
1	*Payin-i-Qargha*	32.831	2.116	6.446	-0.256	1.832	0.200	11	0.067
2	*Pul Surkh*	36.650	3.476	9.485	0.768	2.036	-0.060	11	-0.018
3	*Tang - I - Sayedan*	30.011	5.806	19.346	-1.728	4.660	-0.040	11	-0.015
4	*Shakardarah*	22.514	0.876	3.890	-0.951	2.975	0.050	11	0.024
5	*Estalif*	22.044	0.794	3.601	-1.426	4.939	0.050	11	0.025

In Table 5.1. shown the min mean annual rainfall is received at Tang -I– Sayedan station with the value of *287.53 mm* and max mean annual precipitation is in Sang–Naweshta, which located in the middle of the basin with *527.20 mm*. Standard deviation (SD) is varied between *90.63 and 315.93 mm* for Tang - I - Sayedan and Sang – Naweshta stations respectively. According to the annual rainfall data the C_k and C_s is varying between *1.40 to 2.04, and -0.476 – 0.235* respectively. The ratio of standard deviation (SD) to the average of the dataset presents the coefficient of variation (CV that its varies between about *31.52 %* (Tang - I - Sayedan) to *59.93 %* (Sang – Naweshta) stations.

As per Table 5.2. min minimum annual temperature is shown at Payan–I-Qragha station with the value of *-16.506 °C* and max Minimum annual temperature is in Shakardara, with *1.691°C*. Standard deviation (SD) is varied between *1.012 – 6.337 °C*. C_k and C_s are varying between *2.550 to 5.120, and -1.170 – 0.958* respectively and finally Cv is varied between *7.285 – 22.638*.

Table 5.3. is showing the max annual temperature statistical parameters with the following details; min temperature is at Estalif station with 22.044 mm and max is 36.650 mm at Pul-Surkh, SD is varying between 0.794 – 5.806, as well as Cv, is 3.602 – 19.346 mm at station Estalif and Tang-I-Saydan respectively.

5.1.1 The trend in annual and monthly precipitation:

In this study for trend detection of precipitation, the Mann Kendall test and Sen's Slope Estimators application have applied by the Eqs. (4.1, 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7, 4.8, 4.9) respectively for Mann Kendall test and Sen's slope estimator, which the result of applied is shown in the (Table 5.4 – 5.9) for monthly and annual precipitation of each station.

Generally, all stations in annual rainfall trends indicate *the positive* in the time interval of 2000–2018 and the maximum rate of change in mean values of precipitation was *30.42 mm/year* for Sang - Naweshta station as shown in Table 5.9. In Table 5.4 - 5.7. it is indicated that from June to December there is to trend significant at the level of α = 0.01, 0.05 and 0.1. Fig. 5.1 showing the mean annual precipitation for all stations of Kabul subbasin.

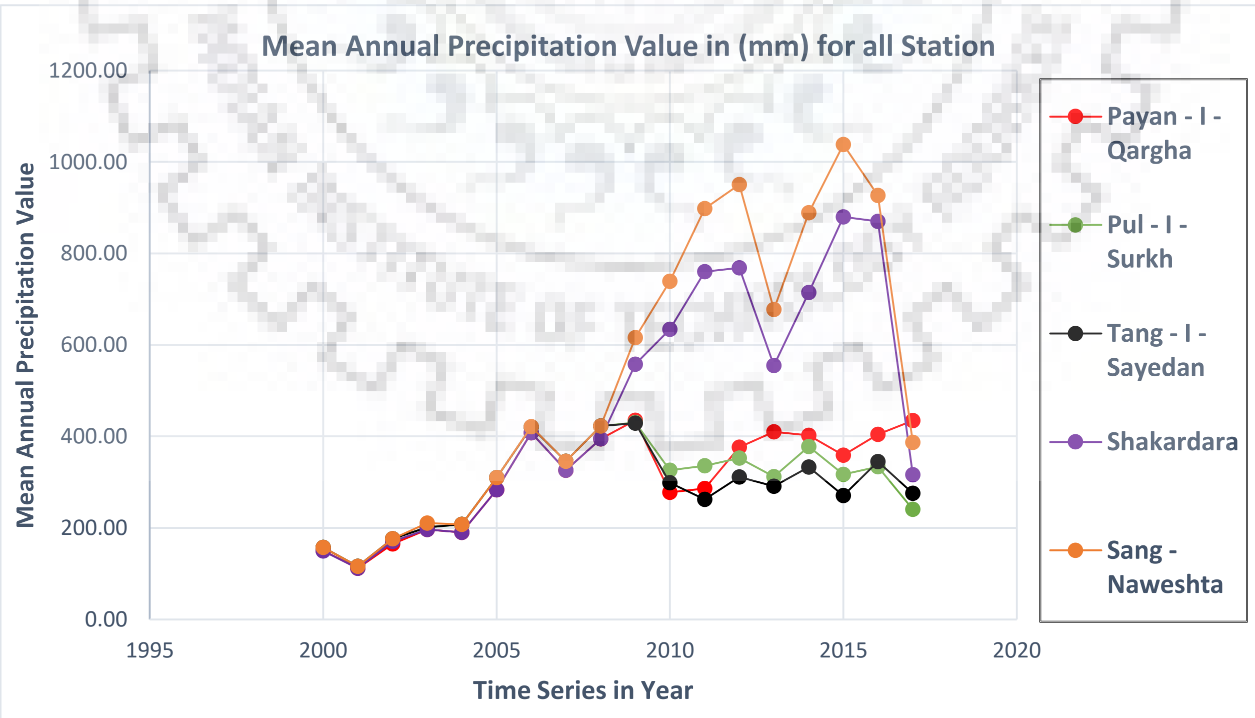


Figure 5.1 Mean Annual Precipitation graph for all stations

Table 5.4 MK test for station Payin - i – Qargha

Monthly precipitation Applied MK test & Sen's slope for station Payin - i – Qargha, at significant of 95% (α = 0.05) results								
Months	**No of Data**	**Minimum Value**	**Maximum Value**	**Mann Kendall Statistic (S)**	**Normalized Test Statistic (Z)**	**VAR(S)**	**Sen's Slope**	**Trend**
Jan	18	3.69	75.87	57.00	2.12	26.38	1.46	Yes
Feb	18	1.00	143.32	73.00	2.73	26.38	2.73	Yes
Mar	18	0.83	145.47	91.00	3.41	26.38	2.44	Yes
Apr	18	1.87	107.87	75.00	2.80	26.38	1.41	Yes
May	18	1.01	57.07	43.00	1.59	26.38	0.76	No
Jun	18	0.57	38.35	9.00	0.30	26.38	0.05	No
Jul	**18**	**0.42**	**38.36**	**9.00**	**0.30**	**26.38**	**0.08**	**Yes**
Aug	18	1.33	58.18	-37.00	-1.36	26.38	-0.41	No
Sep	18	0.20	41.83	-45.00	-1.67	26.38	-0.41	No
Oct	18	0.00	47.25	13.00	0.45	26.38	0.10	No
Nov	18	4.42	62.51	19.00	0.68	26.38	0.22	No
Dec	18	0.00	72.99	23.00	0.83	26.38	0.32	No
Annual	*18*	*111.46*	*435.05*	*95*	*3.56*	*26.38*	*8.87*	*Yes*
The bold numbers indicate significant at α = 0.1								

Table 5.5 MK test for Station Pul Surkh,

Monthly precipitation Applied MK test & Sen's slope for Station Pul Surkh, at significant of 95% (α = 0.05) results								
Months	**No of Data**	**Minimum Value**	**Maximum Value**	**Mann Kendall Statistic (S)**	**Normalized Test Statistic (Z)**	**VAR(S)**	**Sen's Slope**	**Trend**
Jan	18	1.30	67.00	49.00	1.82	26.38	0.68	No
Feb	18	2.09	102.30	67.00	2.50	26.38	2.50	Yes
Mar	18	0.21	131.50	37.00	1.36	26.38	1.57	No
Apr	**18**	**1.51**	**113.55**	**49.00**	**1.82**	**26.38**	**1.43**	**Yes**
May	18	2.05	85.10	59.00	2.20	26.38	1.24	Yes
Jun	18	0.75	49.30	-17.00	-0.61	26.38	-0.07	No
Jul	18	0.76	46.75	5.00	0.15	26.38	0.04	No
Aug	18	0.80	81.31	-35.00	-1.29	26.38	-0.58	No
Sep	18	0.00	51.95	-39.00	-1.44	26.36	-0.40	No
Oct	18	0.22	33.17	42.00	1.56	26.33	0.23	No
Nov	18	0.46	48.10	21.00	0.76	26.38	0.41	No
Dec	18	0.12	73.34	-21.00	-0.76	26.38	-0.19	No
Annual	*18*	*115.90*	*430.38*	*55.00*	*2.05*	*26.38*	*4.88*	*Yes*
The bold numbers indicate significant at α = 0.1								

Table 5.6 MK test for Station Tang – e – Sayedan

Monthly precipitation Applied MK test & Sen's slope for Station Tang – e – Sayedan, at significant of 95% (α = 0.05) results								
Months	**No of Data**	**Minimum Value**	**Maximum Value**	**Mann Kendall Statistic (S)**	**Normalized Test Statistic (Z)**	**VAR(S)**	**Sen's Slope**	**Trend**
Jan	18	1.00	92.50	47.00	1.74	26.38	0.78	Yes
Feb	18	1.45	117.05	51.00	1.90	26.38	1.90	Yes
Mar	18	0.21	123.85	57.00	2.12	26.36	1.76	Yes
Apr	18	1.51	127.95	61.00	2.27	26.38	1.38	Yes
May	18	2.05	61.01	39.00	1.44	26.38	0.72	No
Jun	18	0.00	49.30	-30.00	-1.10	26.36	-0.16	No
Jul	18	0.00	46.75	-18.00	-0.64	26.36	-0.18	No
Aug	**18**	**0.51**	**81.31**	**-45.00**	**-1.67**	**26.38**	**-0.72**	**Yes**
Sep	18	2.60	51.95	-27.00	-0.99	26.36	-0.25	No
Oct	18	0.22	35.20	23.00	0.83	26.38	0.16	No
Nov	18	2.90	51.30	31.00	1.14	26.38	0.46	No
Dec	18	0.54	73.34	10.00	0.34	26.36	0.08	No
Annual	*18*	*115.90*	*428.95*	*53.00*	*1.97*	*26.38*	*4.94*	*Yes*
The bold numbers indicate significant at α = 0.1								

Table 5.7 MK test for Station Shakardara, Estalif, Tang- I – Gharo & Balaye – I – Ghargha

Monthly precipitation Applied MK test & Sen's slope for Station Shakardara, Estalif, Tang- I – Gharo & Balaye – I – Ghargha, at significant of 95% (α = 0.05) results								
Months	**No of Data**	**Minimum Value**	**Maximum Value**	**Mann Kendall Statistic (S)**	**Normalized Test Statistic (Z)**	**VAR(S)**	**Sen's Slope**	**Trend**
Jan	18	3.69	126.02	81.00	3.03	26.38	1.59	Yes
Feb	18	6.33	122.25	81.00	3.03	26.38	3.03	Yes
Mar	18	0.83	156.36	77.00	2.88	26.38	3.75	Yes
Apr	18	1.87	179.12	81.00	3.03	26.38	4.69	Yes
May	18	1.01	137.14	89.00	3.34	26.38	3.23	Yes
Jun	**18**	**0.57**	**174.32**	**45.00**	**1.67**	**26.38**	**0.93**	**Yes**
Jul	18	0.42	95.53	67.00	2.50	26.38	1.84	Yes
Aug	18	1.73	105.96	29.00	1.06	26.38	0.77	No
Sep	18	1.43	96.06	41.00	1.52	26.38	0.87	No
Oct	**18**	**0.34**	**111.20**	**45.00**	**1.67**	**26.38**	**0.79**	**Yes**
Nov	18	4.89	108.28	15.00	0.53	26.38	0.16	No
Dec	18	3.32	72.99	-7.00	-0.23	26.38	-0.06	No
Annual	*18*	*111.46*	*879.97*	*111.00*	*4.17*	*26.38*	*25.28*	*Yes*
The bold numbers indicate significant at α = 0.1								

Table 5.8 MK test for Station Sang – Naweshta

Monthly precipitation Applied MK test & Sen's slope for Station Sang – Naweshta, at significant of 95% (α = 0.05) results								
Months	**No of Data**	**Minimum Value**	**Maximum Value**	**Mann Kendall Statistic (S)**	**Normalized Test Statistic (Z)**	**VAR(S)**	**Sen's Slope**	**Trend**
Jan	18	1.30	135.00	81.00	3.03	26.38	1.76	Yes
Feb	18	3.89	138.65	85.00	3.18	26.38	3.18	Yes
Mar	18	0.21	192.31	59.00	2.20	26.38	3.62	Yes
Apr	18	1.51	220.42	83.00	3.11	26.38	5.67	Yes
May	18	1.70	164.85	87.00	3.26	26.38	3.71	Yes
Jun	**18**	**0.75**	**223.98**	**45.00**	**1.67**	**26.38**	**1.03**	**Yes**
Jul	18	0.76	116.92	73.00	2.73	26.38	2.57	Yes
Aug	18	2.07	150.87	29.00	1.06	26.38	1.51	No
Sep	18	3.62	120.56	39.00	1.44	26.36	0.89	No
Oct	18	0.22	147.29	53.00	1.97	26.38	0.93	Yes
Nov	18	3.97	120.02	23.00	0.83	26.38	0.24	No
Dec	18	1.17	73.34	-11.00	-0.38	26.38	-0.07	No
Annual	*18*	*115.90*	*1037.84*	*115.00*	*4.32*	*26.38*	*30.42*	*Yes*
The bold numbers indicate significant at α = 0.1								

Table 5.9 MK test for station Payin - i – Qargha

Monthly Min Temperature Applied MK test & Sen's slope for station Payin - i – Qargha, results								
Months	**No of Data**	**Minimum Value**	**Maximum Value**	**Mann Kendall Statistic (S)**	**Normalized Test Statistic (Z)**	**VAR(S)**	**Sen's Slope**	**Trend**
Jan	11	-21.27	-5.90	28.00	2.13	12.70	0.63	Yes
Feb	11	-26.24	-8.40	35.00	2.69	12.66	4.58	Yes
Mar	11	-14.96	-2.45	-4.00	-0.24	12.70	-0.17	No
Apr	11	-5.05	4.70	10.00	0.71	12.70	1.47	No
May	11	-1.41	16.06	14.00	1.02	12.70	1.48	No
Jun	11	2.59	10.40	19.00	1.42	12.66	1.80	No
Jul	11	6.76	15.40	24.00	1.81	12.70	2.61	No
Aug	11	6.00	11.50	10.00	0.71	12.70	1.28	No
Sep	11	-0.51	10.10	20.00	1.50	12.70	3.25	No
Oct	11	-2.37	8.30	32.00	2.44	12.70	3.36	Yes
Nov	11	-8.87	-0.50	20.00	1.50	12.70	2.81	No
Dec	11	-16.86	-6.20	32.00	2.44	12.70	2.95	Yes
Annual	*11*	*-26.24*	*-8.40*	*35.00*	*2.69*	*12.66*	*0.71*	*Yes*
The bold numbers indicate significant at α = 0.1								

5.1.2 Trend Analysis of T_{min} and T_{max} :

Annual T_{min} and T_{max} for the period 2008–2018 were analyzed by Mann Kendall Test through five stations by using Eq. 1 up to 9. As representing the result of MKT in Tables 5.9 – 5.19, for minimum annual temperature out of five stations three have significant trends and two rest don't have a trend. For max mean annual temperature, no trend was shown with all three levels of significance. Figs 5.2 and 5.3 are showing the min and max annual precipitation for all stations of Kabul subbasin.

Table 5.10 MK test Station Pul Surkh

Monthly Min Temp Applied MK test & Sen's slope for Station Pul Surkh, at significant of 95% (α = 0.05) results								
Months	No of Data	Minimum Value	Maximum Value	Mann Kendall Statistic (S)	Normalized Test Statistic (Z)	VAR(S)	Sen's Slope	Trend
Jan	11	-17.70	-4.40	13	0.940	12.767	0.14	No
Feb	11	-22.60	-4.20	9.00	0.62	12.81	0.20	No
Mar	11	-9.30	3.40	-11.00	-0.78	12.81	-0.14	No
Apr	11	-1.40	5.50	-7.00	-0.47	12.81	-0.10	No
May	11	3.80	9.80	-17.00	-1.25	12.81	-0.14	No
Jun	11	7.10	13.50	10.00	0.70	12.81	0.10	No
Jul	11	10.80	15.00	-3.00	-0.16	12.81	-0.03	No
Aug	11	11.00	14.00	-18.00	-1.33	12.81	-0.04	No
Sep	11	5.40	14.60	8.00	0.55	12.81	0.06	No
Oct	11	0.90	4.30	3.00	0.16	12.81	0.01	No
Nov	11	-11.10	-0.40	13.00	0.94	12.81	0.09	No
Dec	11	-11.60	-4.40	9.00	0.63	12.77	0.07	No
Annual	*11*	*-22.60*	*-4.90*	*4.00*	*0.24*	*12.70*	*0.03*	*No*

Table 5.11 - Min Temp Applied MK test for Station Tang- I -Sayedan

Monthly Min Temp Applied MK test & Sen's slope for Station Tang- I -Sayedan, at significant of 95% (α = 0.05) results								
Months	No of Data	Minimum Value	Maximum Value	Mann Kendall Statistic (S)	Normalized Test Statistic (Z)	VAR(S)	Sen's Slope	Trend
Jan	11	-17.10	-10.98	3	0.156	12.806	0.06	No
Feb	11	-24.30	-9.10	14.00	1.02	12.81	0.30	No
Mar	11	-12.20	-1.90	4.00	0.23	12.81	0.05	No
Apr	11	-3.50	1.40	10.00	0.70	12.77	0.04	No
May	11	-1.10	4.10	-15.00	-1.10	12.77	-0.10	No
Jun	11	1.90	7.10	14.00	1.02	12.81	0.12	No
Jul	**11**	**4.80**	**8.10**	**25.00**	**1.87**	**12.81**	**0.15**	**Yes**
Aug	11	4.40	7.30	-1.00	0.00	12.81	0.00	No
Sep	11	-1.00	3.40	12.00	0.86	12.81	0.06	No
Oct	11	-7.50	-0.30	6.00	0.39	12.77	0.03	No
Nov	11	-11.90	-5.20	16.00	1.17	12.81	0.06	No
Dec	11	-17.30	-10.90	11.00	0.78	12.77	0.07	No
Annual	*11*	*-24.30*	*1.40*	*-4.00*	*-0.23*	*12.81*	*-0.02*	*No*
The bold numbers indicate significant at α = 0.1								

Table 5.12 Min Temp Applied MK test for Station Shakardara

Monthly Min Temp Applied MK test & Sen's slope for Station Shakardara, at significant of 95% (α = 0.05) results								
Months	No of Data	Minimum Value	Maximum Value	Mann Kendall Statistic (S)	Normalized Test Statistic (Z)	VAR(S)	Sen's Slope	Trend
Jan	11	-13.50	-6.60	15	1.093	12.806	0.17	No
Feb	11	-17.90	-5.00	13.00	0.94	12.81	0.32	No
Mar	11	-9.20	1.10	1.00	**0.00**	12.81	0.02	No
Apr	11	-1.40	3.90	-10.00	-0.70	12.81	-0.06	No
May	11	2.70	8.60	-5.00	-0.31	12.81	-0.03	No
Jun	11	8.30	12.50	-15.00	-1.09	12.81	-0.11	No
Jul	11	10.50	13.60	8.00	0.55	12.81	0.05	No
Aug	11	10.25	13.20	11.00	0.78	12.81	0.05	No
Sep	11	6.10	14.00	22.00	1.64	12.81	0.18	No
Oct	11	1.10	4.30	-8.00	-0.55	12.81	-0.05	No
Nov	11	-3.90	-0.70	0.00	**0.00**	12.81	0.00	No
Dec	11	-11.60	-4.10	-7.00	-0.47	12.81	-0.11	No
Annual	*11*	*-17.84*	*-10.37*	*27.00*	*2.03*	*12.81*	*0.28*	*Yes*
The bold numbers indicate significant at α = 0.1								

Table 5.13 Min Temp Applied MK test for Station Estalif

Monthly Min Temp Applied MK test & Sen's slope for Station Estalif at significant of 95% (α = 0.05) results								
Months	**No of Data**	**Minimum Value**	**Maximum Value**	**Mann Kendall Statistic (S)**	**Normalized Test Statistic (Z)**	**VAR(S)**	**Sen's Slope**	**Trend**
Jan	11	-13.50	-6.60	15	1.093	12.806	0.17	No
Feb	11	-17.90	-5.00	13.00	0.94	12.81	0.32	No
Mar	11	-9.20	1.10	1.00	**0.00**	12.81	0.02	No
Apr	11	-1.40	3.90	-10.00	-0.70	12.81	-0.06	No
May	11	2.70	8.60	-5.00	-0.31	12.81	-0.03	No
Jun	11	8.30	12.50	-15.00	-1.09	12.81	-0.11	No
Jul	11	10.50	13.60	8.00	0.55	12.81	0.05	No
Aug	11	10.25	13.20	11.00	0.78	12.81	0.05	No
Sep	11	6.10	14.00	22.00	1.64	12.81	0.18	No
Oct	11	1.10	4.30	-8.00	-0.55	12.81	-0.03	No
Nov	11	-3.90	-0.70	0.00	**0.00**	12.81	0.00	No
Dec	11	-11.60	-4.10	-7.00	-0.47	12.81	-0.11	No
Annual	*11*	*-17.84*	*-10.37*	*27.00*	*2.03*	*12.81*	*0.28*	*Yes*
The bold numbers indicate significant at α = 0.1								

Table 5.14 Max Temp Applied MK test Station Payan – I - Qargha

Monthly Max Temp Applied MK test & Sen's slope for Station Payan – I - Qargha, at significant of 95% (α = 0.05) results								
Months	**No of Data**	**Minimum Value**	**Maximum Value**	**Mann Kendall Statistic (S)**	**Normalized Test Statistic (Z)**	**VAR(S)**	**Sen's Slope**	**Trend**
Jan	11	5.04	13.40	28	2.126	12.702	0.248	Yes
Feb	11	2.33	17.44	14.00	1.02	12.70	0.08	No
Mar	11	13.84	23.07	4.00	0.24	12.70	0.05	No
Apr	11	17.95	29.90	20.00	1.50	12.70	0.35	No
May	11	23.41	30.60	16.00	1.18	12.70	0.14	No
Jun	11	27.33	34.70	14.00	1.02	12.70	0.18	No
Jul	11	28.96	34.90	12.00	0.87	12.70	0.12	No
Aug	11	27.72	35.50	10.00	0.71	12.70	0.24	No
Sep	11	26.64	30.80	26.00	1.97	12.70	0.21	Yes
Oct	11	21.19	29.00	10.00	0.71	12.70	0.19	No
Nov	11	14.58	23.00	16.00	1.18	12.70	0.24	No
Dec	11	10.30	17.53	11.00	0.79	12.66	0.11	No
Annual	*11*	*28.96*	*35.50*	*16.00*	*1.18*	*12.70*	*0.20*	*No*
The bold numbers indicate significant at α = 0.1								

Table 5.15 Max Temp Applied MK test for Station Pul-Surkh

Monthly Max Temp Applied MK test & Sen's slope for Station Pul-Surkh, at significant of 95% (α = 0.05) results								
Months	**No of Data**	**Minimum Value**	**Maximum Value**	**Mann Kendall Statistic (S)**	**Normalized Test Statistic (Z)**	**VAR(S)**	**Sen's Slope**	**Trend**
Jan	11	8.40	19.50	19	1.406	12.806	0.142	No
Feb	11	6.00	22.60	13.00	0.94	12.81	0.21	No
Mar	11	19.40	36.10	7.00	0.47	12.81	0.07	No
Apr	11	23.70	40.50	11.00	0.78	12.81	0.20	No
May	11	28.30	41.00	-5.00	-0.31	12.81	-0.05	No
Jun	11	30.60	39.40	3.00	0.16	12.81	0.01	No
Jul	11	32.40	42.70	-12.00	-0.86	12.81	-0.10	No
Aug	11	32.90	42.40	7.00	0.47	12.81	0.08	No
Sep	11	27.30	34.70	5.00	0.31	12.81	0.08	No
Oct	11	27.50	40.20	-5.00	-0.31	12.81	-0.03	No
Nov	11	17.10	35.50	3.00	0.16	12.81	0.01	No
Dec	11	10.60	35.80	-3.00	-0.16	12.81	-0.11	No
Annual	*11*	*32.40*	*42.70*	*-9.00*	*-0.62*	*12.81*	*-0.06*	*No*

Table 5.16 Max Temp Applied MK test for Station Tang – I - Sayedan

Monthly Max Temp Applied MK test & Sen's slope for Station Tang – I - Sayedan, at significant of 95% (α = 0.05) results								
Months	**No of Data**	**Minimum Value**	**Maximum Value**	**Mann Kendall Statistic (S)**	**Normalized Test Statistic (Z)**	**VAR(S)**	**Sen's Slope**	**Trend**
Jan	11	7.70	14.20	19	1.406	12.806	0.159	No
Feb	11	4.30	21.40	14.00	1.02	12.81	0.30	No
Mar	11	13.40	27.00	-10.00	-0.70	12.81	-0.17	No
Apr	11	21.30	28.40	17.00	1.25	12.81	0.10	No
May	11	22.20	30.60	-1.00	**0.00**	12.81	-0.02	No
Jun	11	29.60	32.60	18.00	1.33	12.81	0.07	No
Jul	11	32.10	33.70	-14.00	-1.02	12.73	-0.03	No
Aug	11	30.10	34.30	0.00	**0.00**	12.81	0.00	No
Sep	11	28.70	31.00	8.00	0.55	12.81	0.01	No
Oct	11	26.20	28.60	-3.00	-0.16	12.81	0.00	No
Nov	11	16.50	22.40	-1.00	**0.00**	12.81	0.00	No
Dec	11	10.70	27.00	12.00	0.86	12.81	0.16	No
Annual	*11*	*14.80*	*34.30*	*-4.00*	*-0.24*	*12.73*	*-0.04*	*No*

The bold numbers indicate significant at α = 0.1

Table 5.17 - Max Temp Applied MK test for Station Shakardara

Monthly Max Temp Applied MK test & Sen's slope for Station Shakardara, at significant of 95% (α = 0.05) results								
Months	**No of Data**	**Minimum Value**	**Maximum Value**	**Mann Kendall Statistic (S)**	**Normalized Test Statistic (Z)**	**VAR(S)**	**Sen's Slope**	**Trend**
Jan	11	5.30	11.50	30	2.265	12.81	0.26	Yes
Feb	11	5.20	14.40	11.00	0.78	12.81	0.20	No
Mar	11	15.10	25.50	1.00	**0.00**	12.81	0.01	No
Apr	11	18.90	27.20	15.00	1.09	12.81	0.20	No
May	11	25.60	30.12	-15.00	-1.09	12.81	-0.17	No
Jun	11	28.10	33.00	-7.00	-0.47	12.81	-0.02	No
Jul	11	31.60	34.12	-13.00	-0.94	12.81	-0.05	No
Aug	11	30.50	33.70	5.00	0.31	12.81	0.04	No
Sep	11	27.30	30.10	9.00	0.63	12.77	0.02	No
Oct	11	23.20	27.70	-21.00	-1.56	12.81	-0.09	No
Nov	11	13.80	20.80	-1.00	**0.00**	12.81	-0.02	No
Dec	11	10.60	16.70	-9.00	-0.62	12.81	-0.10	No
`	*11*	*20.53*	*23.61*	*17.00*	*1.25*	*12.81*	*0.05*	*No*
The bold numbers indicate significant at α = 0.1								

Table 5.18 Max Temp Applied MK test for Station Estalif

Monthly Max Temp Applied MK test & Sen's slope for Station Estalif, at significant of 95% (α = 0.05) results								
Months	**No of Data**	**Minimum Value**	**Maximum Value**	**Mann Kendall Statistic (S)**	**Normalized Test Statistic (Z)**	**VAR(S)**	**Sen's Slope**	**Trend**
Jan	11	5.30	11.50	30	2.265	12.806	0.265	Yes
Feb	11	5.20	14.40	11.00	0.78	12.81	0.20	No
Mar	11	15.10	25.50	1.00	**0.00**	12.81	0.01	No
Apr	11	18.90	27.20	15.00	1.09	12.81	0.20	No
May	11	25.60	30.12	-15.00	-1.09	12.81	-0.17	No
Jun	11	28.10	33.00	-7.00	-0.47	12.81	-0.02	No
Jul	11	31.60	34.12	-13.00	-0.94	12.81	-0.05	No
Aug	11	30.50	33.70	5.00	0.31	12.81	0.04	No
Sep	11	27.30	30.10	9.00	0.63	12.77	0.02	No
Oct	11	23.20	27.70	-21.00	-1.56	12.81	-0.09	No
Nov	11	13.80	20.80	-1.00	**0.00**	12.81	-0.02	No
Dec	11	10.60	16.70	-9.00	-0.62	12.81	-0.10	No
Annual	*11*	*20.53*	*23.61*	*17.00*	*1.25*	*12.81*	*0.05*	*No*
The bold numbers indicate significant at α = 0.1								

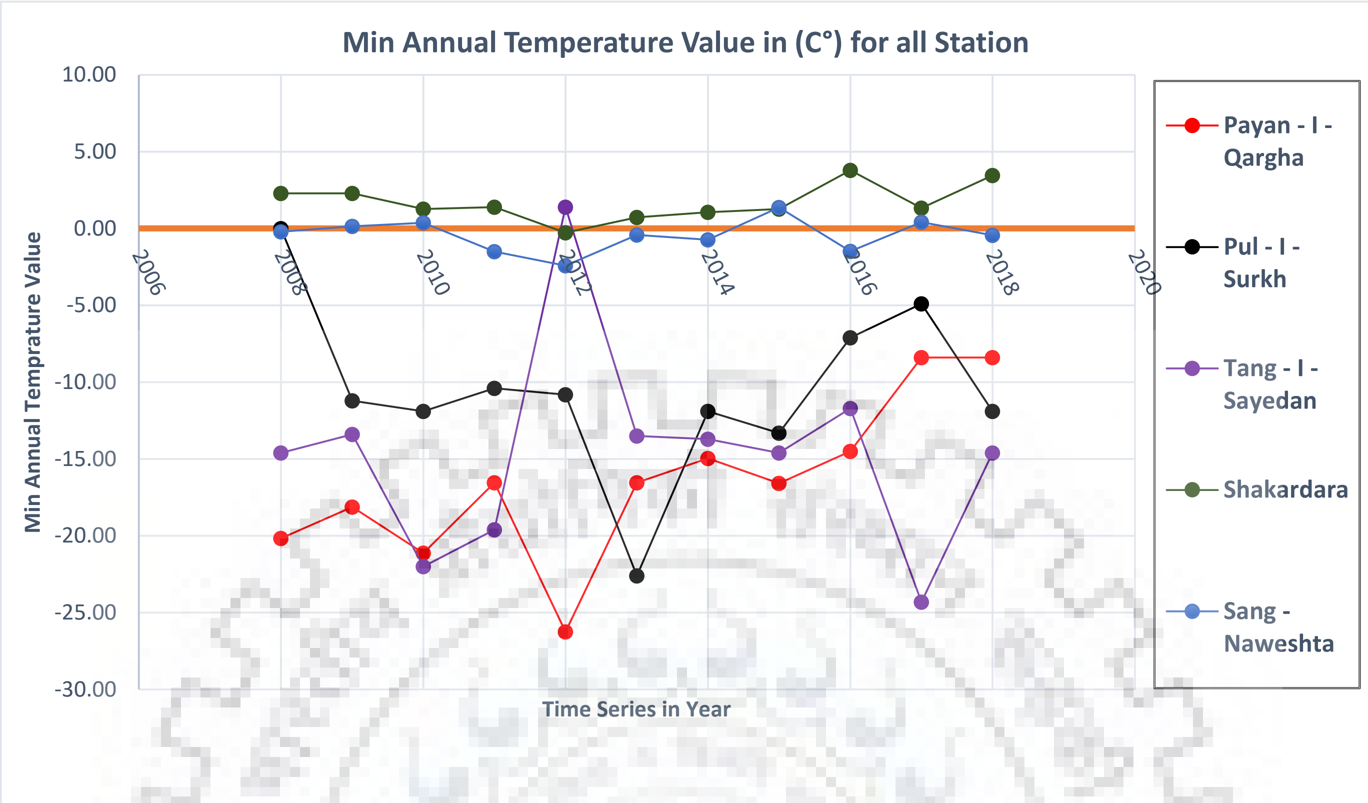


Figure 5.2 Min Annual Temperature Value in (C°) for all Station

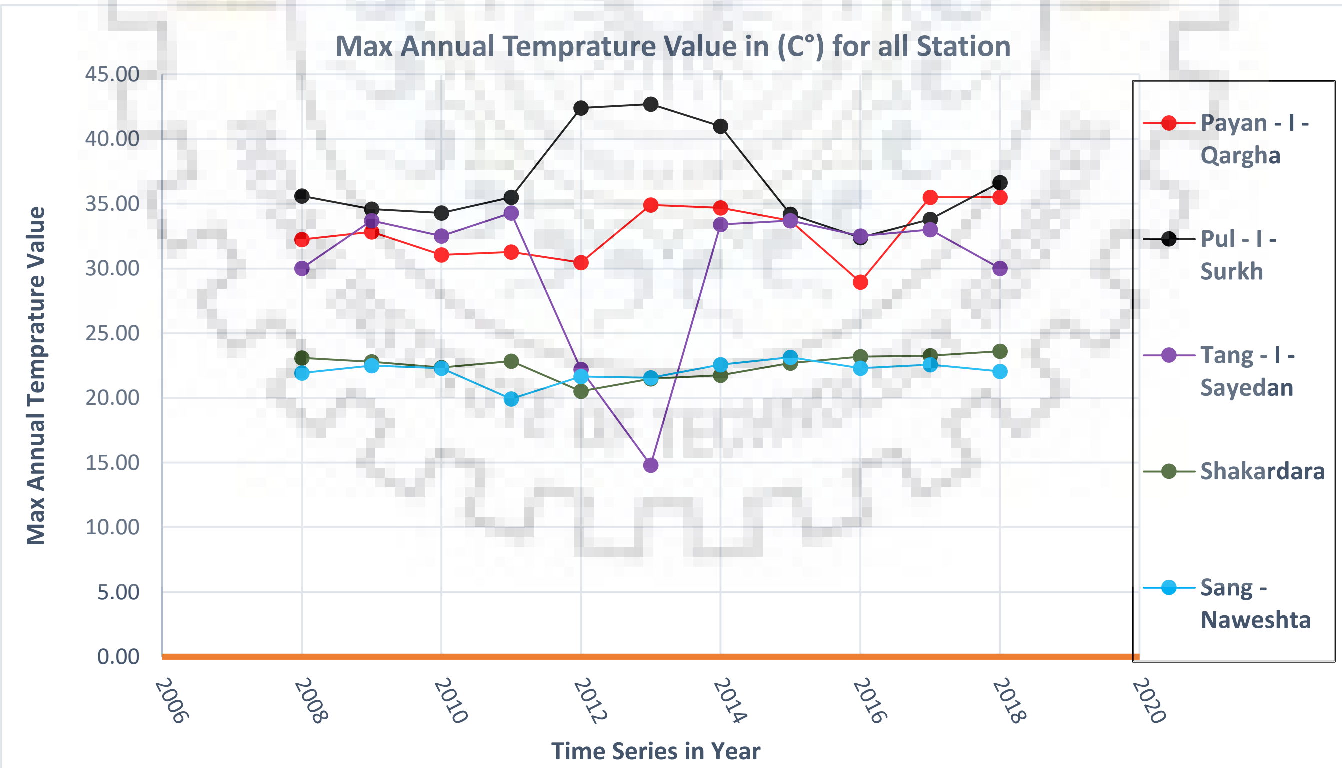


Figure 5.3 Max Annual Temperature Value in (C°) for all Station

5.2 LULC change detection in Pre and post of Civil war:

During the 25 years of the Civil War in Afghanistan, about two million people died, one million disabled and three million displaced and resettled in other countries. In 1997, the FAO / UNDP assessed the effect of civil war and insecurity in Afghanistan. They considered around 34,000 square kilometers of arable land for the survey. The results showed ten percent of the land was damaged during the war likewise, 40 percent destroyed due to lack of maintenance. While 20 percent refer to the lack of water management the only 30 percent of the land was ready for cultivation. Alim, et al., (2002). In 1979, the Soviet Union entered Afghanistan, and after the devastating war, this occupation ended in 1991. This war had a direct effect on social, environmental, economic and political systems. For instance, destroying all trees along the roads in Kabul is the impact of war on the environment. During the war, almost all structures facilities built for irrigation purposes in the rivers destroyed as well as all metrological stations. Formoli., (1995).

By comparing the LULC change maps of pre-civil war and post-civil war it would clear the impact of civil war on the water resources in Kabul. Almost all of the forest area in Kabul was destroyed as a result of the war due to firing, as shown in Table 5.19 and 5.20. The forest area declined from 170.4 square kilometers to 0.4 square kilometers.

Table 5.19 LULC change detection in Pre – civil war

SI/No	LU/LC	Pre-civil war					
		1972		1979		1990	
		Sq.Km	%	Sq.Km	%	Sq.Km	%
1	**Water**	21.17	0.48	18.68	0.42	12.57	0.28
2	**Forest**	170.28	3.86	137.48	3.12	73.72	**1.67**
3	**Grass/Grazing**	220.42	4.99	123.75	2.80	139.09	3.15
4	**Agricultural Plantation**	323.24	7.32	423.38	9.59	463.95	**10.51**
5	**Barren/Waste land**	3582.40	81.12	3586.36	81.26	3585.08	81.18
6	**Urban**	98.43	2.23	123.58	2.80	141.74	3.21
Total		**4415.93**	**100**	**4413.23**	**100**	**4416.16**	**100**

Table 5.20 LULC change detection in post – civil war

Sl/No	LU/LC	post-civil war					
		2000		2008		2018	
		Sq.Km	%	Sq.Km	Sq.Km	%	Sq.Km
1	Water	10.66	0.24	10.43	10.66	0.24	10.43
2	Forest	0.49	0.01	45.06	0.49	0.01	45.06
3	Grass/Grazing	132.87	3.01	62.96	132.87	3.01	62.96
4	Agricultural Plantation	328.34	7.44	376.99	328.34	7.44	376.99
5	Barren/Waste land	3770.37	85.38	3721.94	3770.37	85.38	3721.94
6	Urban	173.43	3.93	198.77	173.43	3.93	198.77
	Total	4415.93	4416.16	100	4416.16	4416.16	100

5.3 Land use land cover change detection in case of drought:

Drought as a natural disaster in Afghanistan is the reason for the displacement of 700,000 people, as well as many agricultural lands, have been destroyed because of this catastrophe. Due to drought groundwater level has been decreased, while the tube well drilling is increasing. Uhl., (2006). About 60 - 70 percent of Qanats as well as 85 % of the shallow in Kabul already dried. Alim, et al. (2002).

Drought has direct repercussions on the water resources as LULC change from 1972 to 2018 shown. water area has decreased from 21.17 Km^2 to 11.74 Km2 from 1972 to 2018 respectively as shown in *Table 5.20.*

5.4 Impact of the population in water resources:

As shown in Tables 5.19 and Fig 5.7 LULC change between the periods (1972-1979, 1990-1990, 1990-2000, 2000-2008, and 2008-2018), the change in percentage and rate of change were computed. Fig 5.4. shows the increasing of the built-up area from 2.23 % to 7.15% from 1972 to 2018 respectively. Fig 5.5. Present the percentage of LULC in 1972 and 2018 regarding the Kabul area. Fig 5.6. Present the percentage of change and rate of change from 1972 to 2018, which showing a decrease in the area of water, forest, grass, and Barren land/ wasteland, while the urban and agricultural plantation area is increasing.

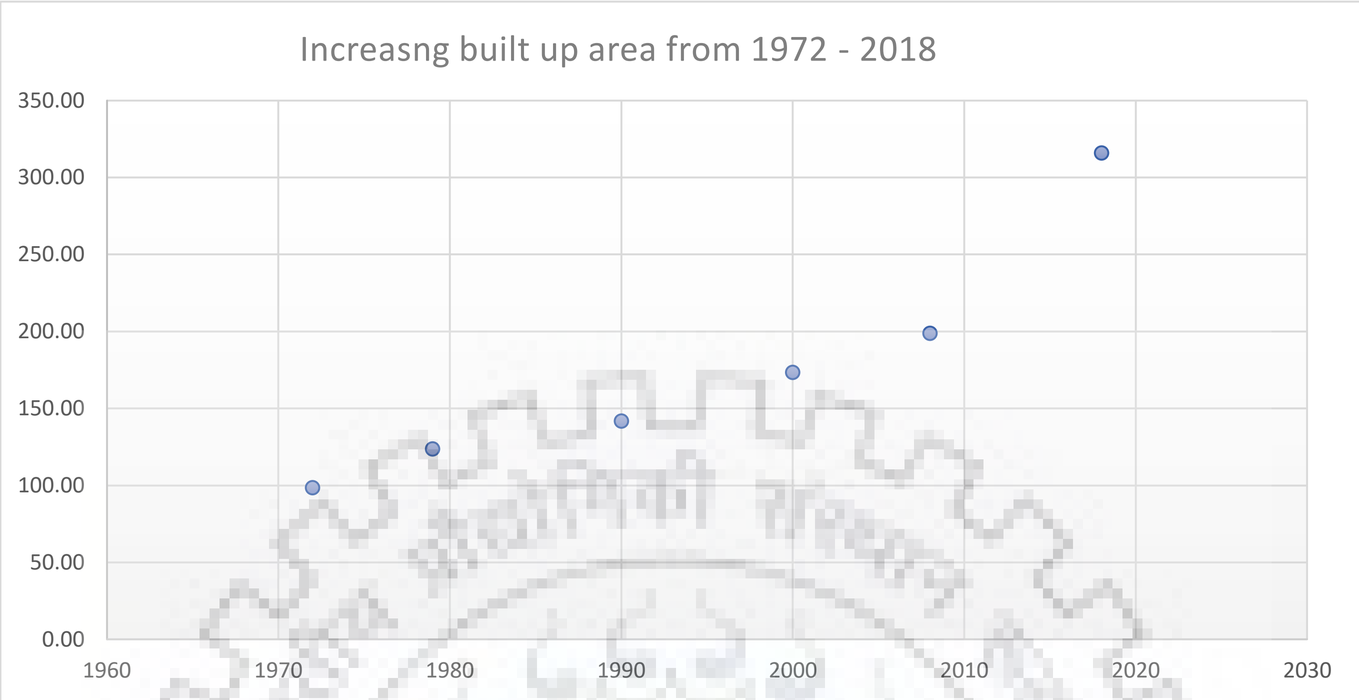


Figure 5.4 Built up area graph

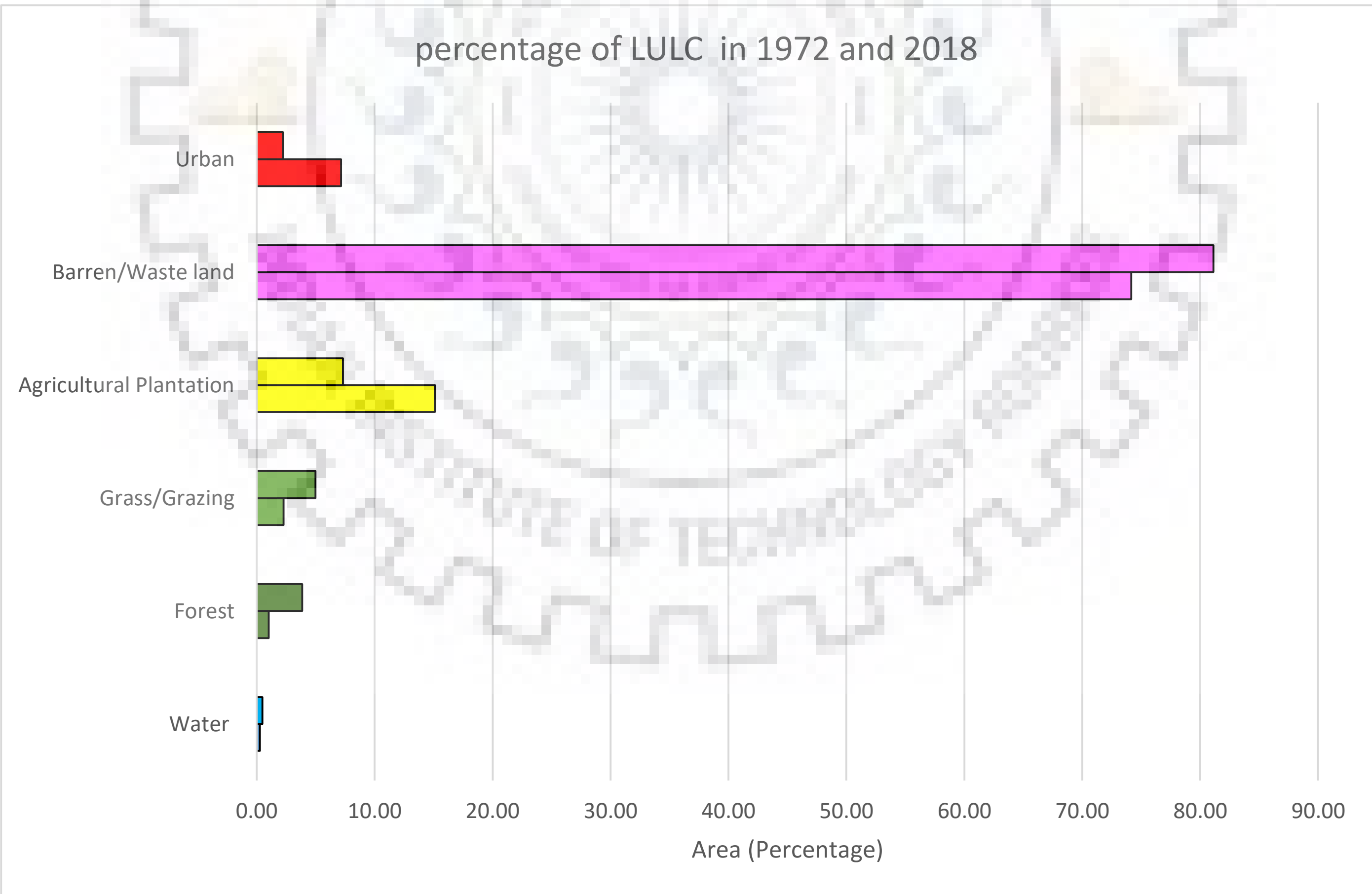


Figure 5.5 Land use Land cover changes in 1972 - 2018

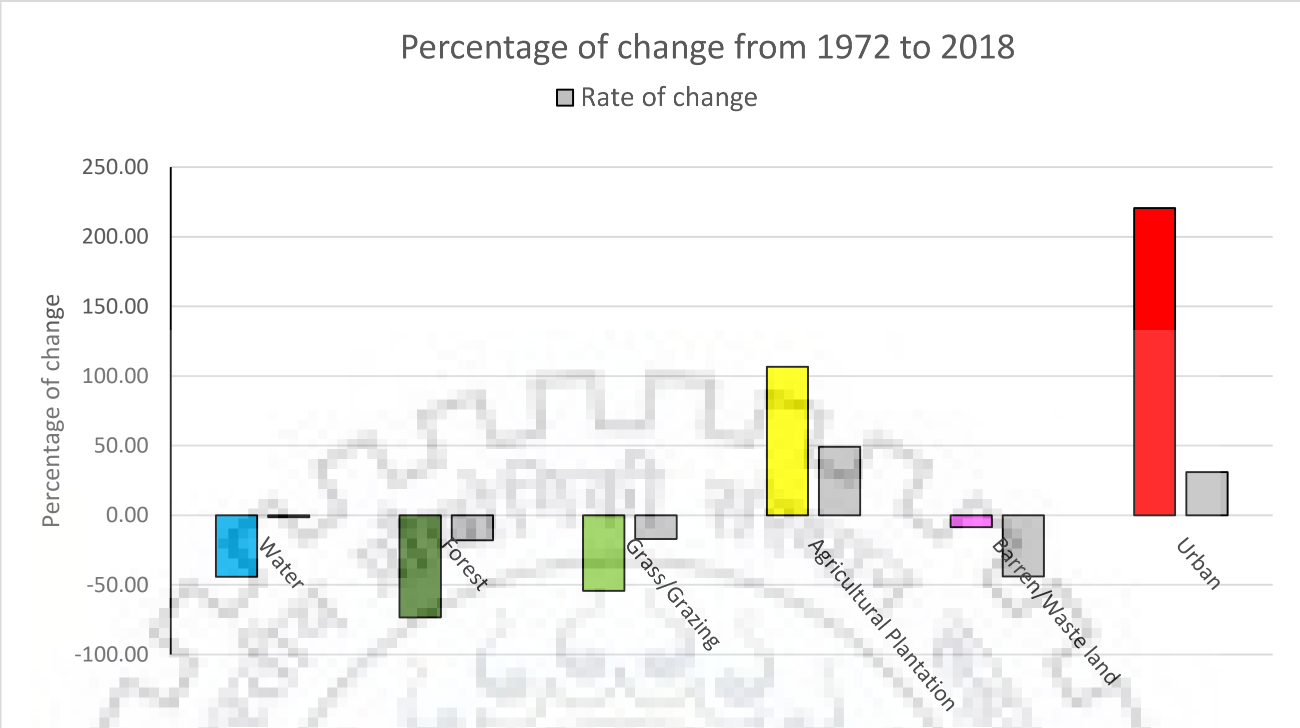
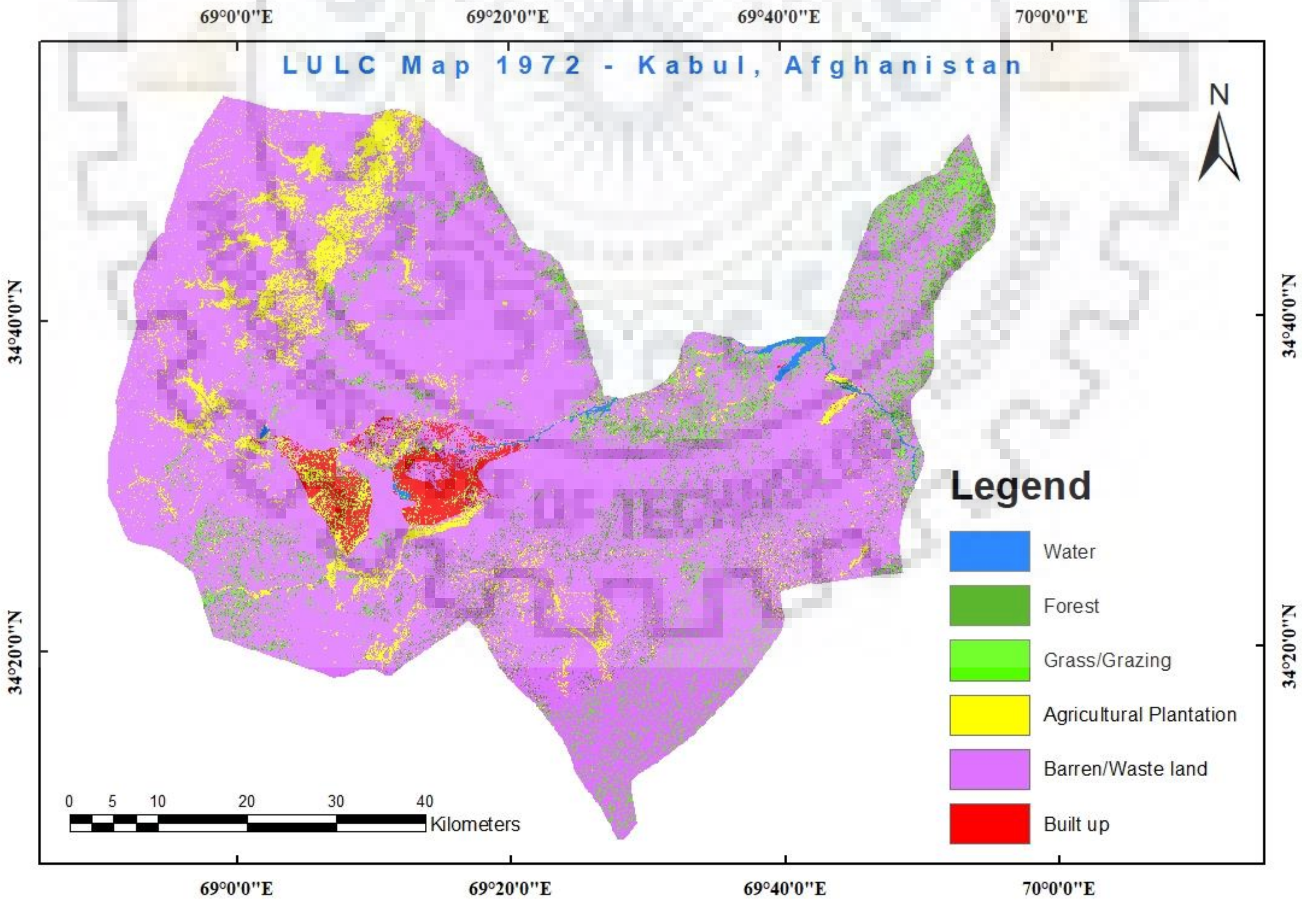
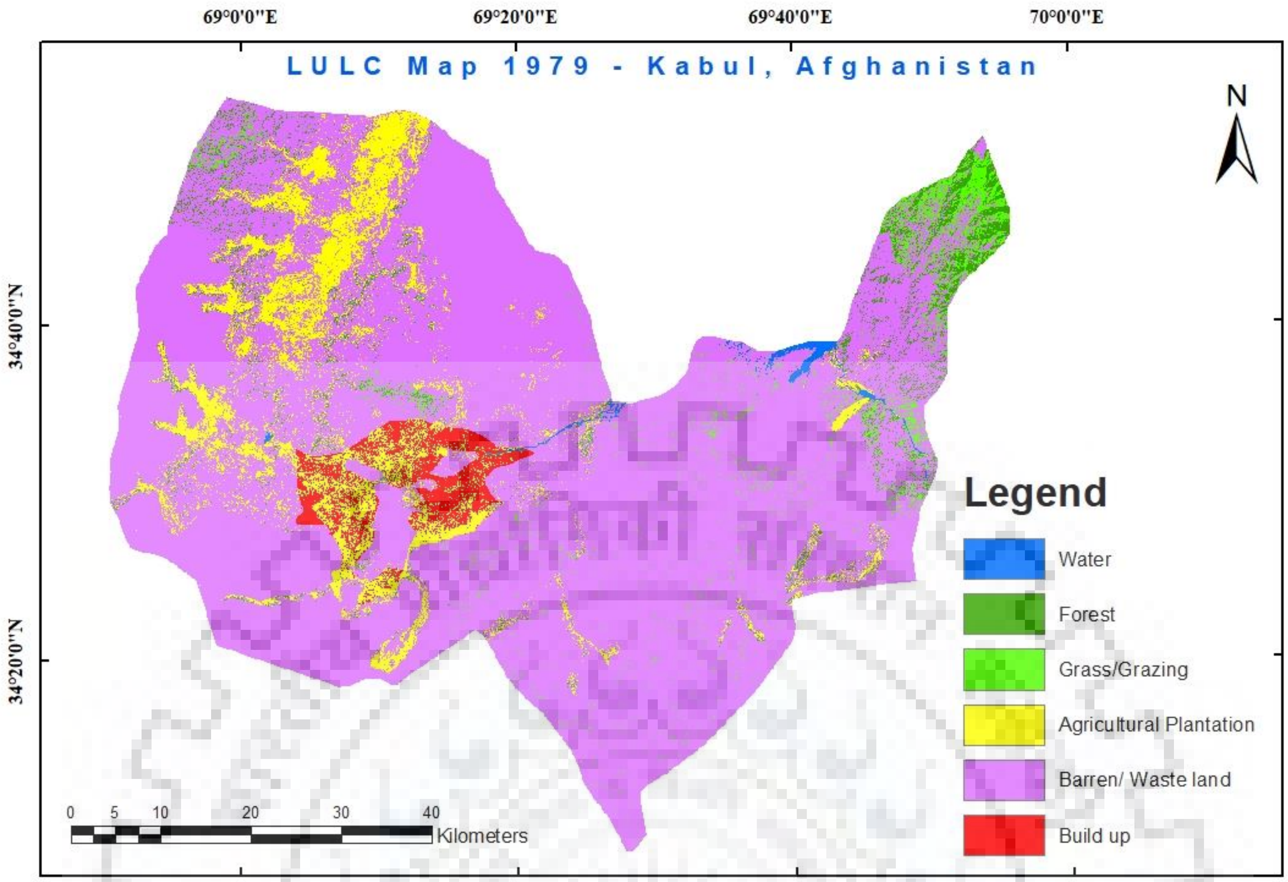
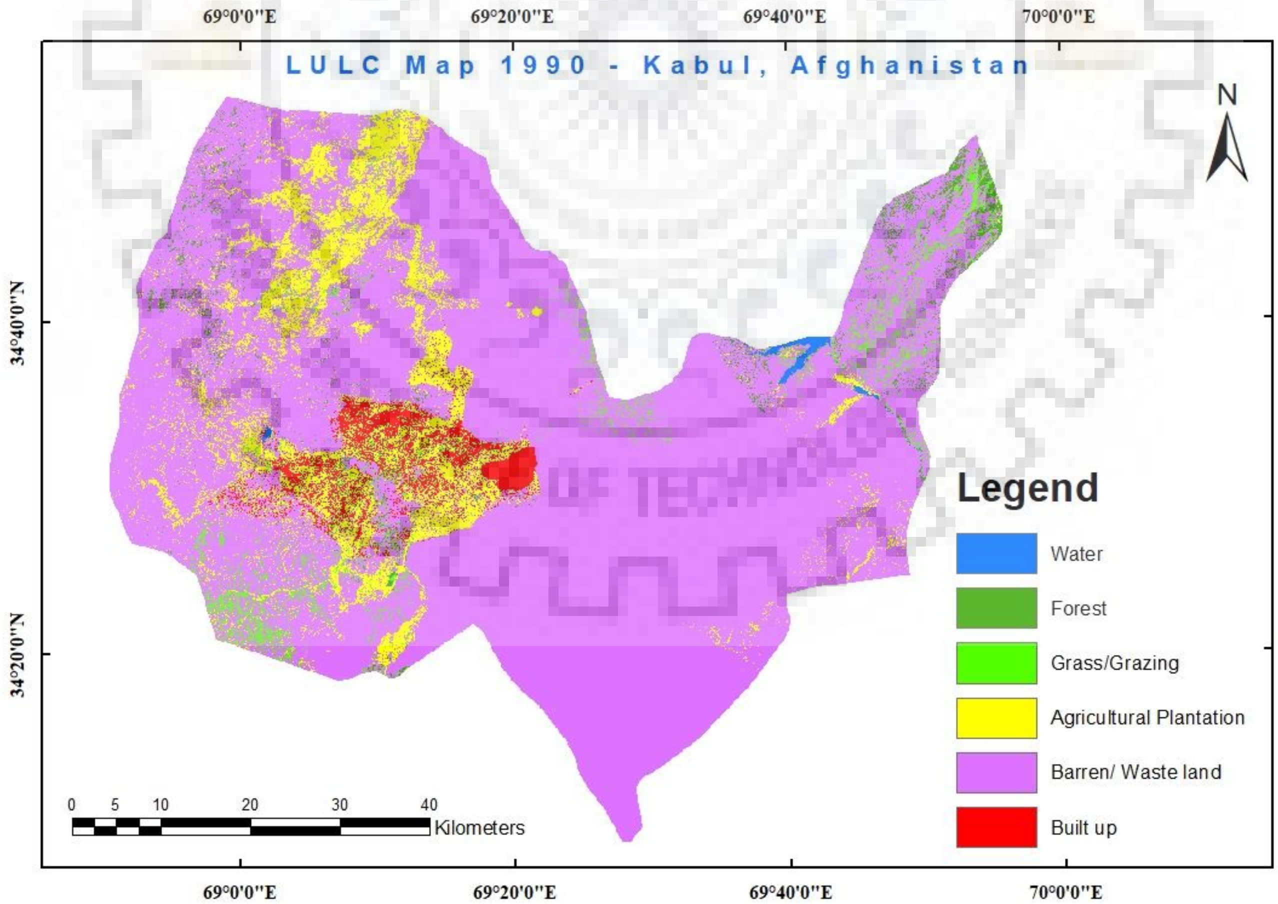


Figure 5.6 Land Use Land Cover net Percentage

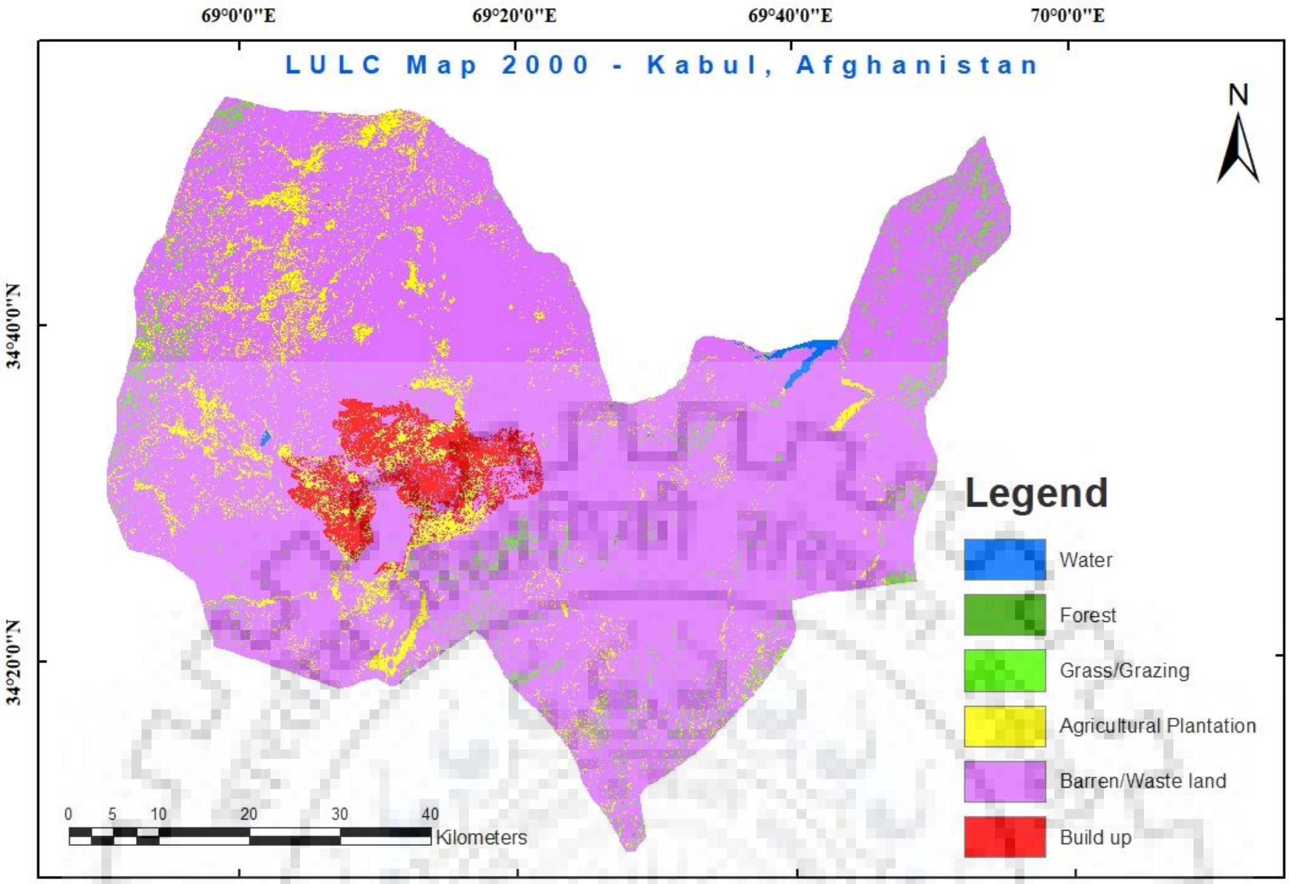




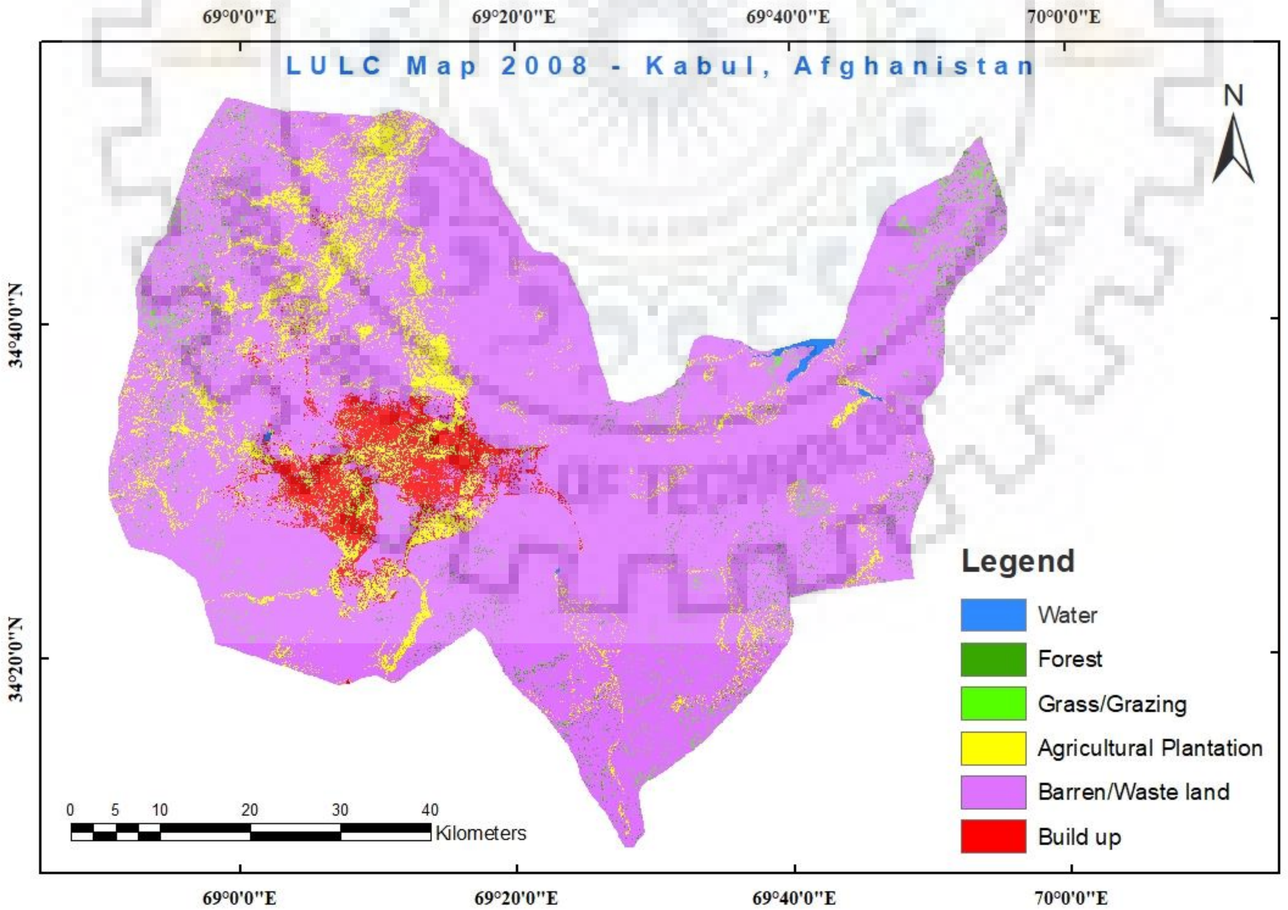
69°0'0"E
69°20'0"E
69°40'0"E
70°0'0"E
LULC Map 1979 - Kabul, Afghanistan
N
34°40'0"N
34°20'0"N
Legend
Water
Forest
Grass/Grazing
Agricultural Plantation
Barren/ Waste land
Build up
0 5 10 20 30 40
Kilometers



69°0'0"E
69°20'0"E
69°40'0"E
70°0'0"E
LULC Map 1990 - Kabul, Afghanistan
N
34°40'0"N
34°20'0"N
Legend
Water
Forest
Grass/Grazing
Agricultural Plantation
Barren/ Waste land
Built up
0 5 10 20 30 40
Kilometers



69°0'0"E
69°20'0"E
69°40'0"E
70°0'0"E
LULC Map 2000 - Kabul, Afghanistan
N
34°40'0"N
34°20'0"N
Legend
Water
Forest
Grass/Grazing
Agricultural Plantation
Barren/Waste land
Build up
0 5 10 20 30 40
Kilometers



69°0'0"E
69°20'0"E
69°40'0"E
70°0'0"E
LULC Map 2008 - Kabul, Afghanistan
N
34°40'0"N
34°20'0"N
Legend
Water
Forest
Grass/Grazing
Agricultural Plantation
Barren/Waste land
Build up
0 5 10 20 30 40
Kilometers

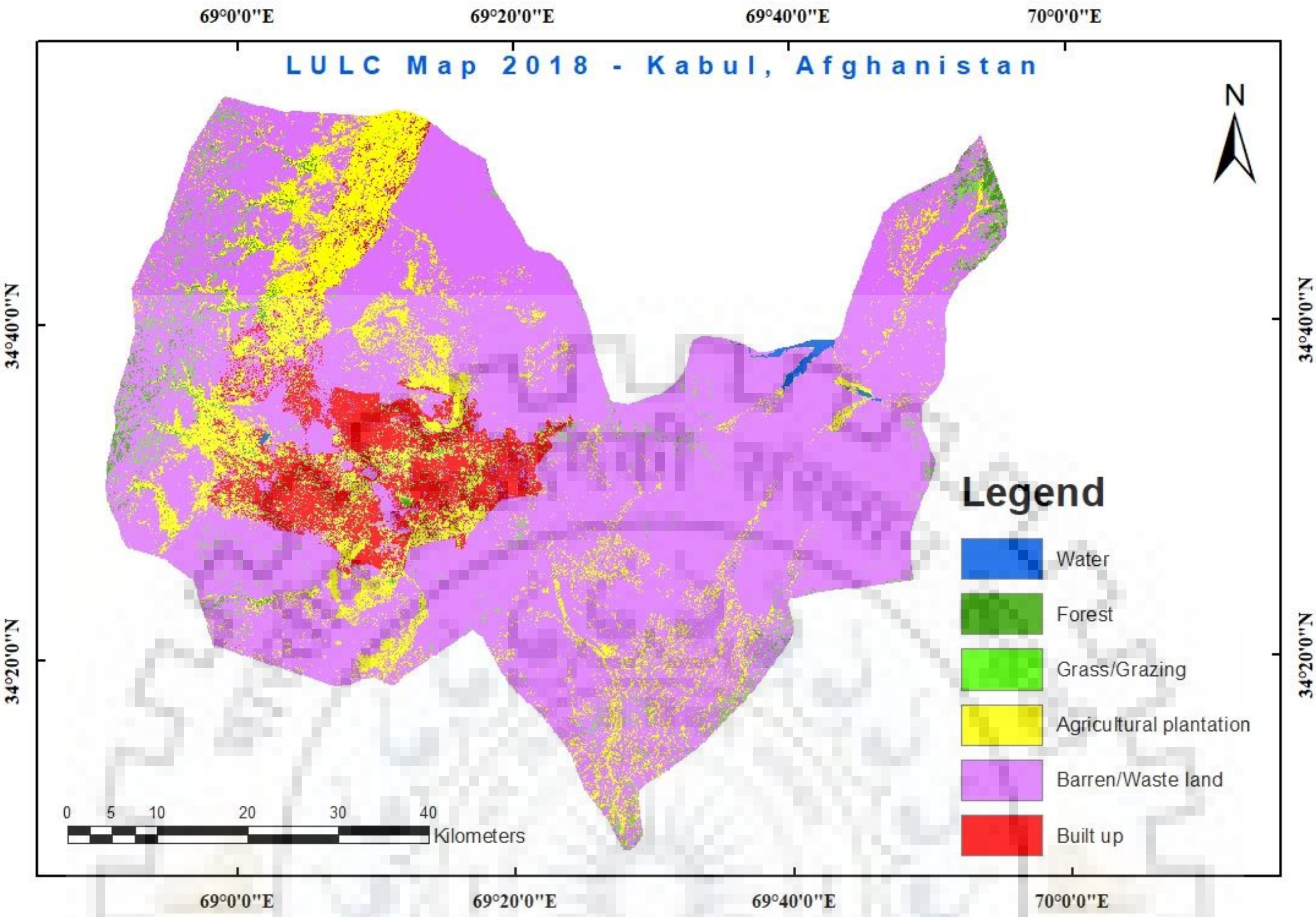


Figure 5.7 LULC changes process from 1972 to 2018

Table 5.21 LU/LCC 1972 & 1979

Classes	Water	Forest	Grass/ Grazing	Agricultural Plantation	Barren/Waste land	Urban	**1979**	Area %	change of Percentage	Rate of change
Water	11.71	1.93	2.02	0.29	2.76	0.11	18.82	***0.43***	**-11.09**	**-0.34**
Forest	0.96	18.96	22.67	5.09	88.63	1.35	137.65	***3.12***	**-19.16**	**-4.66**
Grass/Grazing	0.79	10.75	30.30	2.47	78.67	0.90	123.89	***2.81***	**-43.79**	**-13.79**
Agricultural Plantation	1.70	8.62	5.63	208.27	171.58	27.59	423.39	***9.59***	**30.98**	**14.31**
Barren/Waste land	5.44	127.56	158.02	94.70	3194.84	8.04	3588.61	***81.26***	**0.17**	**0.89**
Urban	0.57	2.47	1.78	12.42	45.91	60.44	123.58	***2.80***	**25.55**	**3.59**
1972	21.17	170.28	220.42	323.24	3582.40	98.43	4415.93		Negative sign present the decreasing	
Area Percentage	***0.48***	***3.86***	***4.99***	***7.32***	***81.12***	***2.23***				

Table 5.22 LU/LCC 1979 - 1990

Classes	Water	Forest	Grass/ Grazing	Agricultural Plantation	Barren/Waste land	Urban	1990	**Area %**	change of Percentage	Rate of change
Water	**10.08**	0.20	0.22	0.22	1.74	0.11	12.57	***0.28***	**-32.70**	**-0.56**
Forest	1.03	**25.25**	7.19	3.36	35.50	1.17	73.50	***1.67***	**-46.54**	**-5.82**
Grass/Grazing	0.91	5.23	**11.39**	19.39	91.05	10.96	138.94	***3.15***	**12.27**	**1.38**
Agricultural Plantation	0.45	5.33	1.98	**231.80**	179.42	44.92	463.90	***10.51***	**9.57**	**3.68**
Barren/Waste land	5.80	99.31	102.27	144.88	**3215.08**	15.23	3582.58	***81.18***	**-0.11**	**-0.34**
Urban	0.41	2.15	0.70	23.73	63.56	**51.19**	141.74	***3.21***	**14.70**	**1.65**
1979	18.68	137.48	123.75	423.38	3586.36	123.58	**4413.23**		Negative sign present the decreasing	
Area Percentage	***0.42***	***3.12***	***2.80***	***9.59***	***81.26***	***2.80***				

Table 5.23 LU/LCC 1990 – 2000

Classer	Water	Forest	Grass/ Grazing	Agricultural Plantation	Barren/Waste land	Urban	2000	Area Percentage	change of Percentage	Rate of change
Water	**9.90**	0.03	0.05	0.10	0.52	0.07	10.66	*0.24*	**-15.25**	**-0.19**
Forest	0.00	**0.00**	0.00	0.00	0.49	0.00	0.49	*0.01*	**-99.34**	**-7.32**
Grass/Grazing	0.33	11.59	**8.16**	0.35	112.43	0.02	132.87	*3.01*	**-4.47**	**-0.62**
Agricultural Plantation	0.07	2.22	11.10	**159.77**	145.88	9.31	328.34	*7.44*	**-29.23**	**-13.56**
Barren/Waste land	2.18	58.69	103.12	253.15	**3303.80**	49.43	3770.37	*85.38*	**5.17**	**18.53**
Urban	0.10	1.20	16.67	50.59	21.96	**82.92**	173.43	*3.93*	**22.36**	**3.17**
1990	12.57	73.72	139.09	463.95	3585.08	141.74	**4416.16**		Negative sign present the decreasing	
Area Percentage	***0.28***	***1.67***	***3.15***	***10.51***	***81.18***	***3.21***				

Table 5.24 LU/LCC 2000 – 2008

Classes	Water	Forest	Grass/ Grazing	Agricultural Plantation	Barren/Waste land	Urban	2008	Area Percentage	change of Percentage	Rate of change
Water	8.99	0.00	0.28	0.05	1.12	0.00	10.43	***0.24***	**-2.13**	**-0.03**
Forest	0.01	0.04	4.26	3.89	36.85	0.01	45.06	***1.02***	**9137.45**	**5.57**
Grass/Grazing	0.01	0.00	3.97	1.82	57.16	0.00	62.96	***1.43***	**-52.61**	**-8.74**
Agricultural Plantation	0.12	0.00	1.56	134.64	211.20	29.47	376.99	***8.54***	**14.81**	**6.08**
Barren/Waste land	1.37	0.45	122.69	166.08	3399.51	31.85	3721.94	***84.28***	**-1.28**	**-6.05**
Urban	0.17	0.00	0.10	21.86	64.53	112.11	198.77	***4.50***	**14.61**	**3.17**
2000	10.66	0.49	132.87	328.34	3770.37	173.43	4416.16		Negative sign present the decreasing	
Area Percentage	***0.24***	***0.01***	***3.01***	***7.44***	***85.38***	***3.93***				

Table 5.25 LU/LCC 2008 - 2018

Classes	Water	Forest	Grass/ Grazing	Agricultural Plantation	Barren/Waste land	Urban	2018	Area Percentage	change of Percentage	Rate of change
Water	9.99	0.00	0.01	0.13	1.50	0.11	11.75	***0.27***	12.63	0.13
Forest	0.04	1.04	1.00	16.62	25.80	0.90	45.39	***1.03***	0.74	0.03
Grass/Grazing	0.01	3.18	4.61	8.49	81.98	2.42	100.69	***2.28***	59.93	3.77
Agricultural Plantation	0.10	1.41	6.64	216.36	403.05	39.96	667.51	***15.12***	77.06	29.05
Barren/Waste land	0.30	39.43	50.69	103.74	3060.54	20.40	3275.09	***74.16***	-12.01	-44.69
Urban	0.00	0.00	0.02	31.65	149.06	134.99	315.72	***7.15***	58.83	11.69
2008	10.43	45.06	62.96	376.99	3721.94	198.77	4416.16		Negative sign present the decreasing	
Area Percentage	***0.24***	***1.02***	***1.43***	***8.54***	***84.28***	***4.50***				

5.5 **Hydrological Modeling:**

5.5.1 SWAT Model Sensitivity analyze:

Accuracy assessment with selected ten different parameters which have a direct influence on streamflow was analyzed through SWAT CUP 2012. The result shows out of 10, four parameters are the most sensitive parameters as shown in Table 5.26.

CN2 is a function of watershed properties, which is used to calculate the depth of runoff from total precipitation depth. watershed properties are dependable on soil moisture condition, soil type, and land use condition. Gdp, et al., (2007)

Table 5.26 Sensitive Flow Parameter

Rank of sensitivity	Parameters	T-state	P-value	Min value	Max value	Fitted value
1	1. CN2.mgt	22.66	0.00	-0.5	0.5	-0.02
2	10. ESCO.hru	1.02	0.31	0	1	0.88
3	5. SURLAG.bsn	0.58	0.56	0.05	24	20.766
4	4. GWQMN.gw	0.01	0.99	0	1000	517

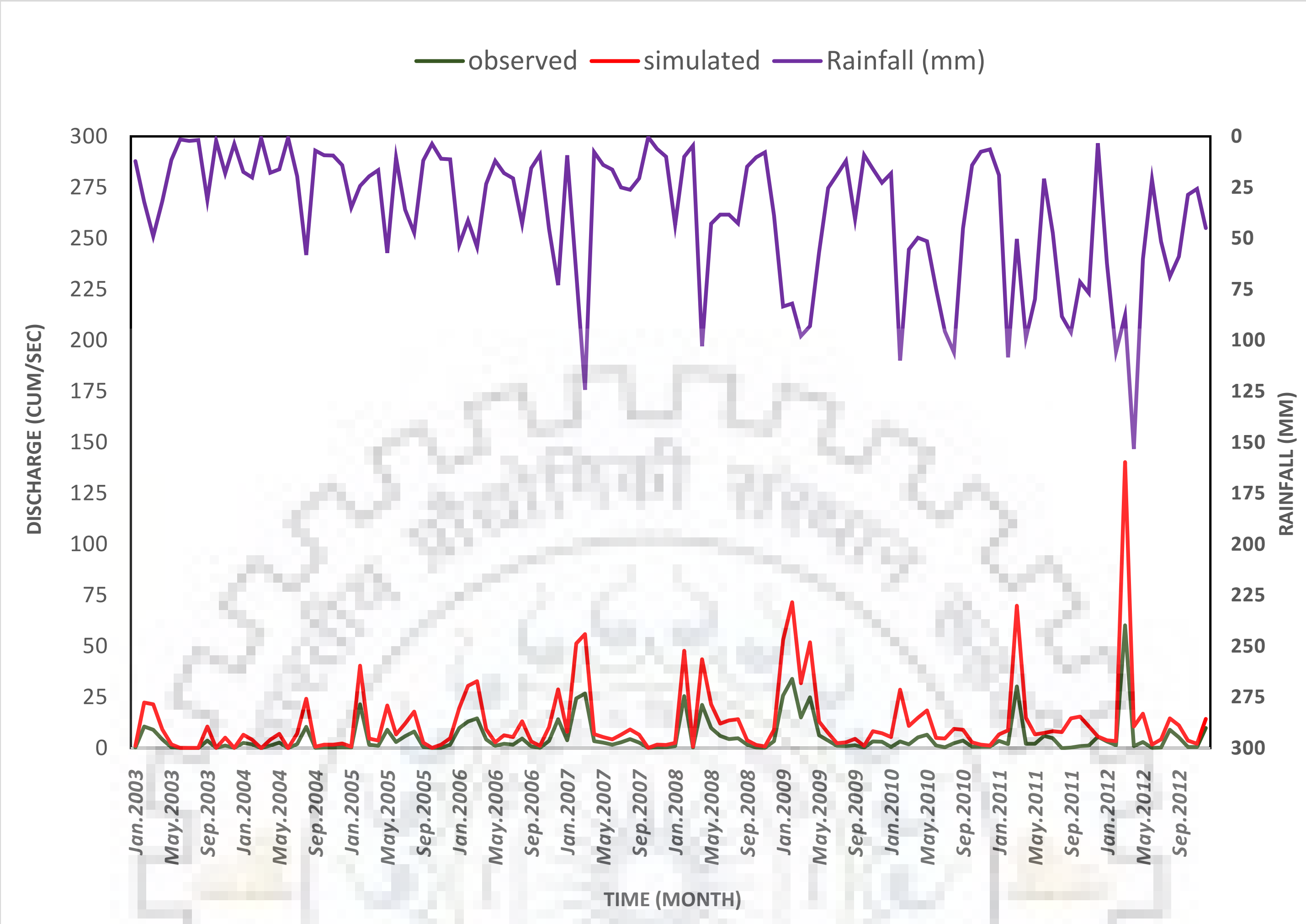
5.5.2 Calibration and Validation:

The observed discharge data was analyzed with simulation data for calibration and validation through SWAT – CUP 2012 by applying the most effective parameters on surface flow. Table 5.26 is presenting the result of calibration and validation.

The graphical comparison of monthly observed data with simulated streamflow data for calibration and validation with the time interval of 01.01. 2010 to 31.12.2017 and 01.01.2003 to 31.12.2013 respectively is shown in Fig 5.8 and 5.9.

Table 5.27 Model performance statistic for the calibration and validation periods

Name of watershed	station	period				Evaluated Statistic					
		Calibration		Validation		R2		NSE		PBIAS	
		From	To	From	To	Cal	Val	Cal	Val	Cal	Val
Kabul River Sub-basin	Estalif	2010	2017	2003	2012	0.83	0.86	0.57	0.73	69.7	41.2



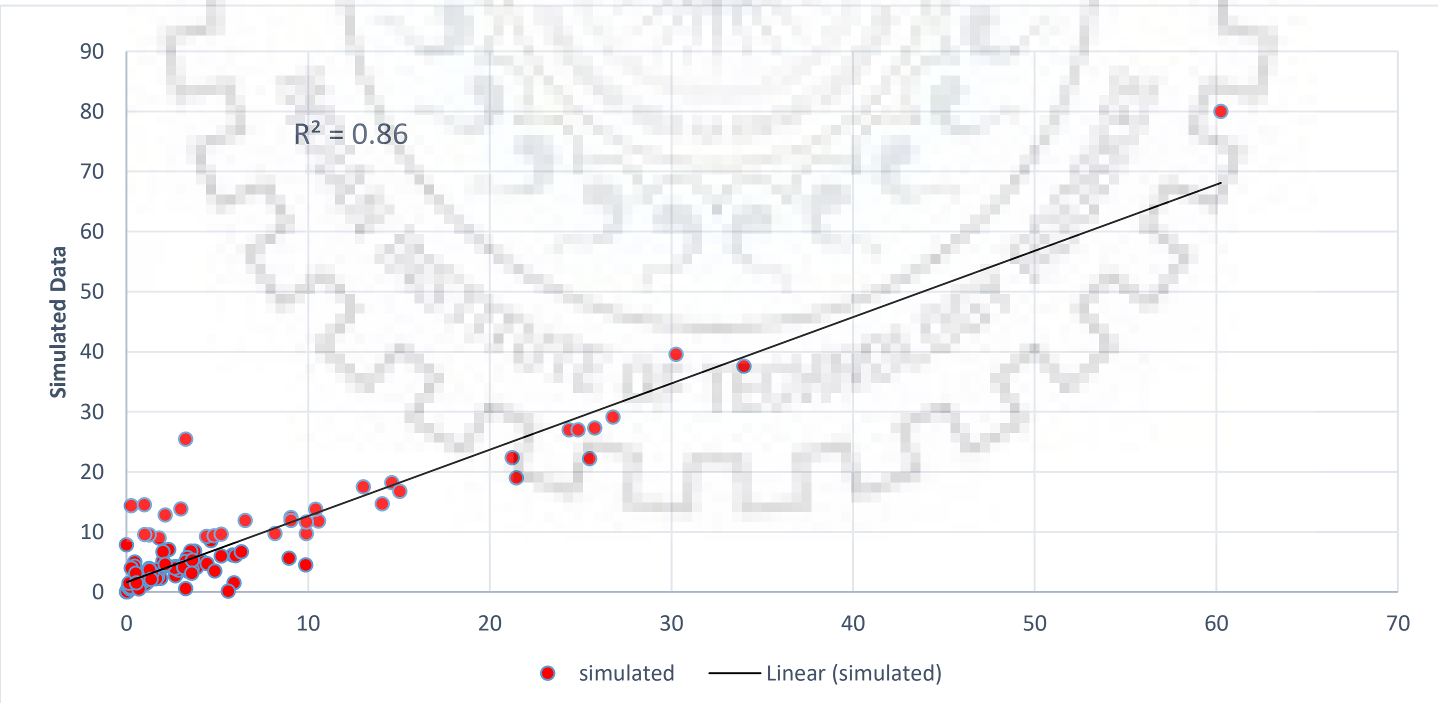
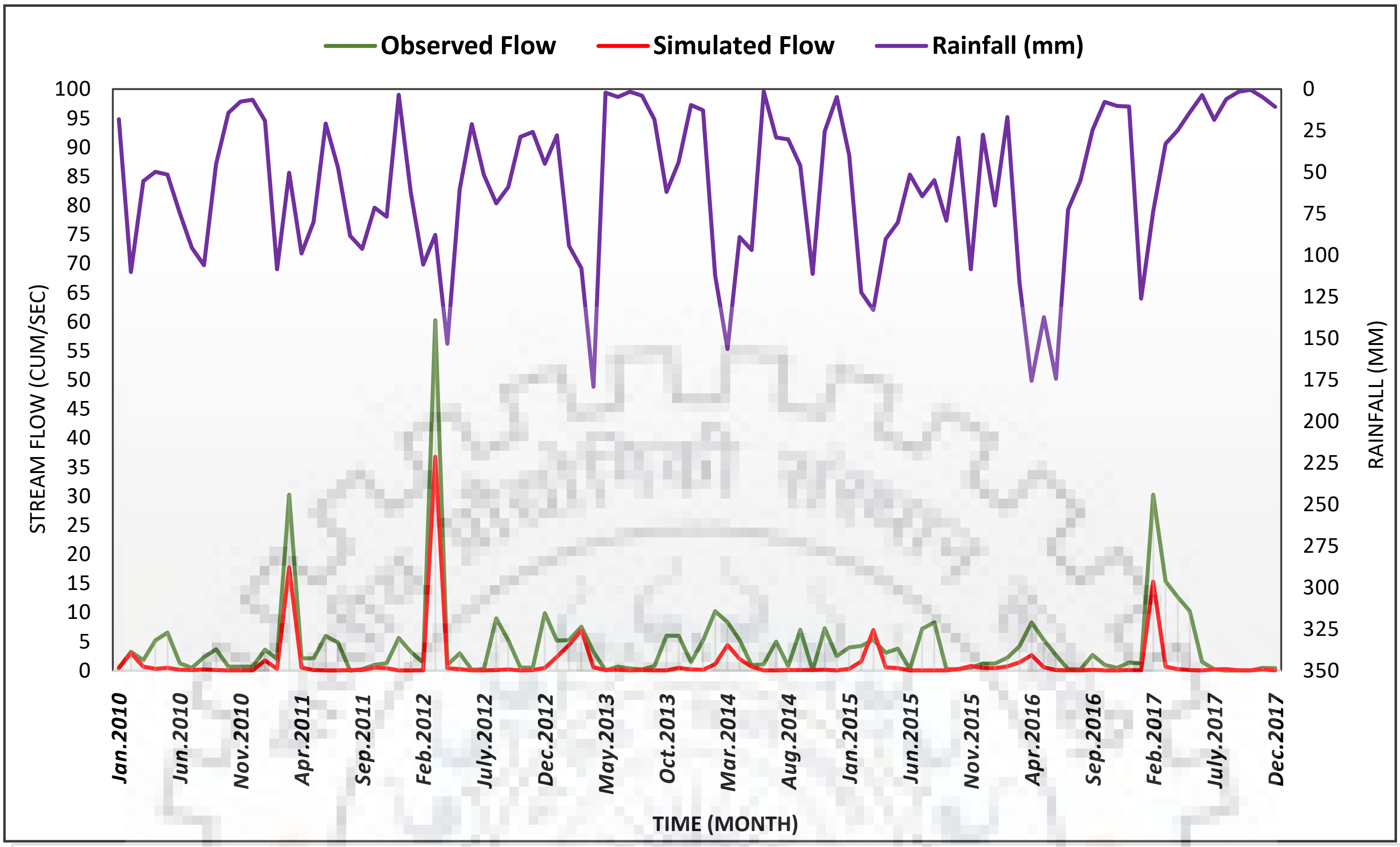


Figure 5.8 Graphical comparison of Monthly observed data with simulated stream flow data for Validation as well as monthly Rainfall data



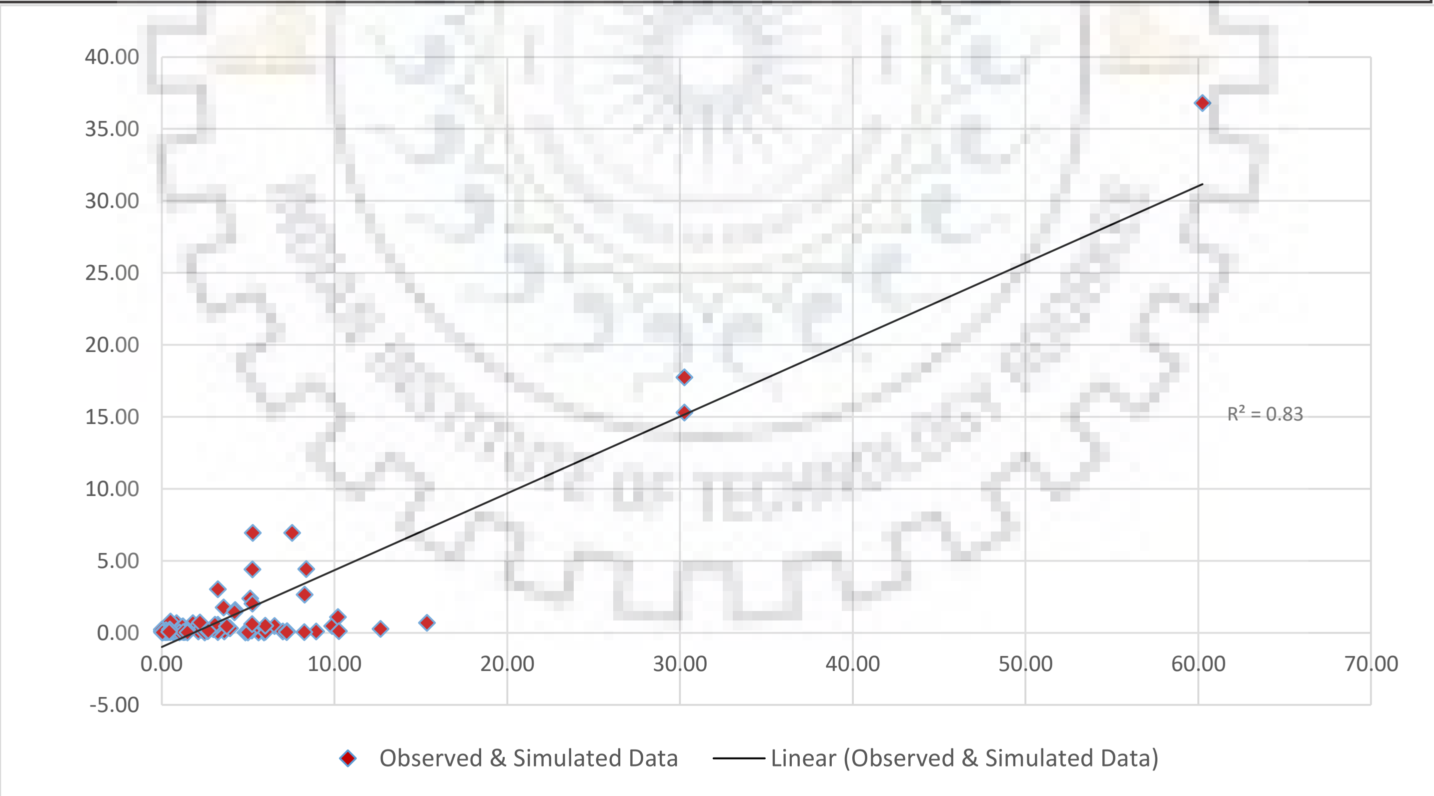


Figure 5.9 Graphical comparison of Monthly observed data with simulated stream flow data for Calibration as well as monthly Rainfall data

CHAPTER 6:
CONCLUSIONS

6.1 **Summary:**

On the basis of historical hydro-meteorological data combined with satellite data, the impact of climate change has been considered in the present study.

The precipitation and temperature trends were studied from a different site of Kabul River Sub-basin for the first time. Temperature and precipitation trends are very helpful for further knowledge and understanding of climate change in the study area. Precipitation which is the most important factor of climate is under the influence of ecosystem and land use, while the temperature is the function of a green area, solar radiation, type of land use and humidity. In this study for analyzing the trend of precipitation, annual and monthly data used, while for the temperature trend detection used max and min annual and monthly data as shown in Figures 8to10. Mann Kendall test is the method which used for finding the temperature and rainfall trends in the Kabul river basin likewise, Sen's Slope estimator is used to indicates the magnitude of the slope.

It is clear to gain a more occurrence trend need more data as well as different stations in annual rainfall and annual temperature. The trend result showed that both, precipitation and temperature, are variables. After applying the Mann Kendall Test and Sen's slope estimator fewer changes found in mean precipitation value at lower altitude region (Pul–I–Surkh, around 0.29%), and significant changes found in the (Sang-Naweshta Station with 1.04 %) that showing the increasing trend with the magnitude of 4.88 – 30.42 mm/year for annual precipitation. The result of MKT in minimum annual temperature trends shows an increasing variation between 0.02 – 0.71 C°/Year in the study area. The MKT showed no trend for the maximum temperature in monthly as well as annual because the data time interval was very less. Thus rainfall value is one of the most significant sources of water, therefore the results of this study may be very useful for better management of water resources in the Kabul river basin.

Although, by increasing the minimum annual temperature it would be clear that climate has been changed and it is going to be colder than previous. As the temperature interval data was only 11 years the result of this trend was not determine any trend, therefore for the better and accurate result need more historical data. With the prevailing conditions in the country, the present study may prove to be a beginning and with more data extensions of studies would be possible. Under the limited data availability, the output of the study may be very useful for water resources managers of the country to plan better management strategies in changing the climate.

LULC change detection in Kabul – Afghanistan was investigated through the hybrid classification in ERDAS Imagine 2018 and Arc GIS 10.14.1, from the satellite Landsat images with a time interval of 1972, 1979, 1990, 2000, 2008 and 2018. In this paper, LULC classified into six classes as Forest, Water, Grass/Grazing, Agricultural plantation, Urban area, and Barren land/ wastelands. After generating the LULC maps, showing water surface is decreasing from 21.17 Km^2 to 11.74 Km^2, whereas built up zone is increasing from 98.43 Km^2 to 315.71

Km^2 from 1972 to 2018 respectively. LULC maps show an increase in agricultural plantation from 1972 to 1990 years, but due to civil war and natural disaster such as drought, it has decreased from 463.95 Km^2 to 328.34 Km^2 from 1990 to 2000 respectively, and again it has started increasing from 2000 up to 2018. During the war in Kabul, almost all forests destroyed as presented in LULC map forests area is decreased from 73.71 Km^2 in 1990 to 0.48 Km^2 in 2000. studying the LULC change in Kabul from 1972 to 2018 shows rapid growth in the population as the built-up area is increasing. LULC map shows a decrease in the water area, which is a concern point in the future. As growing the population is the reason for water scarcity, therefore managing the demand and supply of water is recommended. Water resources directly influenced by decreasing the forest and grass area which the result is showing a decrease in the groundwater level. LULC maps showing the parameter which has a direct effect on water resource, therefore study of LULC is an essential task for analyzing the impact of LULC change in water resources. By the study of LULC change from 1972 to 2018, it defined that water, population, forest, grass and agricultural area are varied. As these features are water resources component, therefore it is highly recommended a long term strategic plan of management for each category in Kabul, Afghanistan.

In the present study, an effort has done to pretend the impact of climate, LULC, soil and topographic condition on Kabul River sub-basin, by the input of long-term metrological data, satellite images, soil data, and DEM Image, correspondingly through Arc SWAT 2012. Kabul River sub-basin model was calibrated and validated through SUFI-2 algorithm of SWAT CUP to optimize the output so that it matches the observed discharge, available at Estalif gauging station. To check the performance of the model, coefficient of determination (R^2), Nash Sutcliffe efficiency (NSE) and Present bias (PBIAS) parameters are considered as main parameters. The R^2 values were around 0.82 percent for calibration and 0.86 percent for validation which represents more than ¾th of the observed variation illuminated by the model's inputs. The NS efficiency, whose value should ideally be one, was calculated to be 0.73 for validation and 0.57 for calibration, that it shows approximately 60 percent match of modeled discharge to the observed data. PBIAS parameter presents the difference between the simulated and observed amount and its ideal value is 0. A positive value of the model represents underestimation whereas a negative value represents the model overestimation, therefore 69.7 and 41.2 percent for calibration and validation respectively is showing underestimation.

Result of the simulated model indicates which a small part of a basin has a high impact on the water balances, while the uncertainty of the outcome is hight. Illustration of calibration is realistic but it would never be the best fit due to the non-uniqueness of effective parameters.

Model efficiency has been evaluated through a good calibration from 2003 to 2014 and validation from 2010 to 2017 results. The calibrated model can be used for further investigation of the effect of climate and land use change as well as other different management scenarios on stream flow and of soil erosion.

6.2 **Conclusions:**

Based on the study following conclusions can be drawn;

I. A significant monotonic trend has occurred in the annual precipitation regarding the past 18 years, a noticeable positive trend at 5% confidence level was detected. Mostly, monthly rainfall trends are increasing through all stations, while no trend is observed in minimum and maximam temperatures.

II. Trend analysis indicated a positive or negative slope which is expressing the increasing and decreasing respectively. The result of trend analysis in this study shows increasing rainfall in Kabul, while no trend is in maximam and minimam temperatures. No trend is indicating no change.

III. During 42 years, Land use and Land cover have changed in the Kabul River basin area. LULC 2018 maps show a significant change in the Agricultural area as well as urban area. The agricultural area has increased by 7.8 percent and urban area 4.92 percent.

IV. LULC maps present a decrease in the water area, whereas the rate of change in 1979 was -0.34 and in 2018 it starts increasing with the rate of change of 0.13.

V. The major change in LULC change detection is in forest area as well as grass area, where the change of percentage in 1979 was -19.16 and -43.79 percent respectively and in 2018 it shows 0.74 and 59.93 percent respectively.

VI. Sensitivity analysis indicated four parameters, Curve Number for moisture condition 2 (CN2), soil evaporation compensation factor (ESCO), surface runoff lag time (SURLAG) and threshold depth of water in the shallow aquifer required for return flow to occur (GWQMN), which have a direct effect on surface flow.

VII. The results of the hydrological model, land use land cover change and trend analysis indicated that climate change has a direct impact on Kabul River Basin. Increasing the precipitation, population and Agricultural area indicate the change which has a significant role in River Basin management. This research would be useful for better management and development of the Kabul River Basin

6.3 **Scope for further study:**

i. Assessing climate change impacts on Groundwater is required for investigation in the study area.

ii. Evaluating water quality in the Kabul River Basin regarding the increasing population.

iii. Carrey out modeling the impact of climate change on water resources and the environment.

CHAPTER 7:
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