Impact of climate change on water resources in Kabul city

Submitted in partial fulfillment of the requirements of the award of the degree of

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by

STUDENT NAME (Rahimullah Alokozay)

(**18SOCE2020005**)

Under the guidance of

Guide Name (Asst. Prof : Jagan.J)

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CERTIFICATE

This is to certify that the project work entitled " **…………………..**" submitted by **…………….. (18SOCE202005)** to the School of Civil Engineering, Galgotias University, Greater Noida, for the award of the degree of **Master of Technology in Civil Engineering** is a bonafide work carried out by him/her under my supervision and guidance. The present work, in my opinion, has reached the requisite standard, fulfilling the requirements for the said degree.

The results contained in this report have not been submitted, in part or full, to any other university or institute for the award of any degree or diploma.

(Mr/Ms Name of guide)

Asst. Professor
Guide

(Prof. (Dr) Manju Dominic)

Dean,

School of Civil Engineering

External Examiner

DECLARATION

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Date: **(Rahimullah Alokaozay)**
Place: **18SOCE2020005**

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ABSTRACT

Afghanistan is located in the center of Asia, it is called the heart of Asia it's a developing country, and it's because of interposing of neighbor countries, it has experience of more than three decades of brawl and war. Afghanistan has 34 provinces, Kabul is the capital of Afghanistan and it is the main and more inhabited city. Approximately the estimated population of Kabul in 2019 is 4.1 million. Kabul city in Afghanistan is selected to represent the high hazard region.

In Kabul city water resources have been increasingly stressed duo to population growth and climate change. These research is about to know the present and future impact of climate change on water resources, in this study region and global data is collected and the soil and water assessment tools (SWAT2012) was applied to evaluate the water availability in the Kabul river basin. In this study the simulated analyses period was (2008-2012), two most sensitively parameter was considered temperature and precipitation. Three deferent climate change scenarios (A1, B1 and A1B) being applied to the model for simulation of past and future water availability. Snowfall, rainfall, evaporation, surface water and evapotranspiration is investigated hydrodynamic characteristic.

Based on the result a warmer climate is expected for the study area with a projected change of temperature between 1.5°C and 2.90°C for winter and summer season. Based on A2 scenario the snowfall is expected to decrease for the months of November, December, January, and February especially between 20% to 40% due to increasing temperature in the mentioned months. The output of (SWAT2012) model was showed that the stream runoff in the months of January, February, March and April is increasing between (35% to 45%) and runoff is expected to decrease in the months of June, July, August, and September between (40% to 50%).

This paper explores the Impact of climate change on water resources in Kabul river. The various authors has already been published their article in this area. As there review studied under this paper. Further this paper also investigates the basic parameter related to evaluate the impact of climate change on water resources.

Keyword: climate change, water availability, drought, global warming, temperature, precipitation.

CHAPTER 1

INTRODUCTION

1.1 Background

Climate change is very big challenge to the world us we know those country which they are new in development they need to energy to reach their high energy requirement for developing, so its producing the greenhouse gases which affect the atmosphere layer and affecting the water resources. Climate change affects global hydrological cycle, which increases the risk of drought and flood.

Climate change effects on water hydrology system which increase the average level of ocean, melting of ice, air temperature, sea level and other factors. By affecting these factors its predicate that water resources will be affected in future by global warming. Climate change also effect on runoff, evaporation and evapotranspiration, it’s the big problem to the water hydrology system. Many studied shows that the potential impact of climate change effects on agriculture sector and food production.

Duo to climate change hydrological cycle will change and also effect water resource availability, in region there impact is differ. For usage of water resources high temperature and precipitation pattern are major concern for irregular distribution. However water is important factor for reviving the earth it show many cases or effect of climate change on energy sector, agriculture and society. To make efficient use of water management, water availability for society and ecosystem.

For water resources manager it’s very important to manage the water stresses duo to climate change, because of water importance for human activities the impact of climate change is active research subject in term of resources and risk factor. Most of the climate change impact with respect to biogeochemical water quality dependant either discharge, which control velocity of flow, dilution and time of residence in water temperature. Human activity is also heavily impact on river water quality; this impact depends on the climate change impact. Human activity (withdrawal, pollution) is direct effect of climate change may end up small in relative terms. (stefaan.vc 1998, and ducharne et al, 2007).

Increasing of climate variability due to global change of climate water scarcity is aggravate by reflected drought with drying of river and lakes, declining of decay water quality and ground water resources in the country (j.Environ. stud. Sci. 2014). In address to this issue in order to develop resilience and adaption strategies the impact of climate change on water resources is more important, for anthropogenic climate change projection performed general circulation model as describe in 5th assessment report issued by intergovernment panel on climate change (Ipcc, 2013). Climatic impact usually assessed by forcing hydrological model with down scaled output from climatic model and many studies flow this approach. Most of this studies have employ conceptual hydrologic model, which present only limited groundwater. (Bosshrd et al. 2013)

Such order to take the impact of climate change on stream flows in such a region, it is therefore important to force the dynamically consistent representation of ground water and surface water interaction offered by fully integrated model. Just a few studies have been employed an integrated models to study impact of climate change; some of them used RCMs forcing (Goderniaoux et al., 2009).

However increase in the average level of sea, ocean level, air temperatures, general melting of ice, sea level and many other factors leads to climate warming (IPCC, 2007). These predictions indicate that water resources would be affected by climate change (IPCC, 2008),which in turn affect the components of water cycle such as evapotranspiration, precipitation, and evaporation and thus result in a large scale alteration in represent of water in lakes, river, glaciers and oceans (Paanwar and Chakrapan 2103). Precipitation coupled with high temperature reduction have a negative on ground water and surface water (Loaiciga et al, 2000; Bachu and Adams, 2003, Brouyere et al. 2004, Nistor, 2019).

The global hydrological cycle duo to climate change likely to amplify, which its increase the risk of drought and floods. Climate change is also effect the function, management and operation practices of existing water infrastructure. Harmful impact of climate change on water resource system amplifies the effect of other factor such as increased population, land use change and heightened. Global duo to growth of population and increase influence for water projected demand increase the future decades and regionally change the demand of water for irrigation (Bates et al. 2008).

In many regions has been widely studied potential impact of climate change on production of food, result is suggest that the change in production which related on location, may be aggravate or improved. It may be keep change in the agriculture production sector around the earth. The impact of climate change will be also deferent for the various products. So it’s suggest that there is more need for adoption strategies to helpful for agriculture and formers. (e.g., Parry et al, (2004).

1.2 Problem statement

According to the survey Afghanistan is dry and mountains country which face to the global warming in a large scale. In (2007) UNIP is identified that the country is vulnerable to climate change duo to impact of climate change in the region, While the averaged nationwide water availability is 2776 m3 /cap.yr (Favre and Kamal, 2004), the country is considered water insecure because of mismanaged land and water resources, which have caused a decline in water quality and availability (Beekma and Fiddes, 2011). According to Mcseeny at al. (2007), mean annual temperature increased in Afghanistan by 0.60˚C with average rate of 0.13˚C of per decade since 1960s. the value of precipitation slightly decrease in average rate of 0.50mm per decade per months since 1960s. for the future suggest projection of mean anuual tempreture increase by 1.40 to 4.0˚C by the 2060, and 2.0 to 6.20˚C by the 2090.

In addition, the Industrial Revolution in the latter half of the 18th century led to unprecedented changes in land-use patterns and influence the climate around the world (Meinshausen *et al*., 2009).Last century witnessed a substantial change in global mean temperature and sea level. From the late 20th century, every passing decade has been warmer than the preceding one (Frich et al., 2002; Quirk, 2012); the last five decades are the successively hottest decades in 1,400 years of climate events' recorded history. At present, the warming climate is leading towards less mean precipitation and higher mean temperatures. Many of the worldwide debates are addressing the spatiotemporal impacts (Chattopadhyay and Hulme, 1997; Parry et al., 2004) of global warming on climatic variables and dependent ecosystems.

1.3 Objectives of the study

The overall objective of the research was to analyze the impacts of climate change on water resources in Kabul city. The specific objectives of study are as follows:

1. To estimate the impact of climate change on water resources in Kabul city for the last five years. (Whole Kabul river basin)

2. To estimate the future water availability based in climate change scenario analysis till 2064.

3. Estimation of current available water resource and main sources of ground water for Kabul city.

4. To evaluate the performance of global precipitation and temperature datasets/remotely sensed products for the Kabul city.

CHAPTER 2

LITERATURE REVIEW

2.1 Climate change Scenarios

Global climate change impact on both social and natural system, water resources and ecosystem partially both affected by climate change. Global warming can sooner hydrological cycle by increasing both evapotranspiration and evaporation rates. In present scenario by mitigate the greenhouse gases can decrease the effect of climate change on water hydrological system, evapotranspiration and evaporation is both important variable can be vary by changing temperature.

The first and primary anthropogenic source for the greenhouse gases to emitting the pollution to the environment its carbon di oxide (CO2), which is producing by burning the fossil fuel. However scientists are assured about the effect of climate change and global warming duo to human activities that haw large warming will be and what will be the impact of climate change in deferent part of the earth. In present time climate change is one of the big environment challenges to the earth, rising temperature, milting polar ice, increasing the world free water and changing the waterway from its consequences.

Figure 2.1 climate changes in region.

One of the important impacts of changing climatic conditions is the distribution of precipitation, the spread of droughts and their continuity, and to a large extent, the negative impact on global water resources. Rising up the temperature and amount of evapotranspiration and also decreasing rainfall increases the phenomenon of desertification and salinity of the soil. Increasing temperature and rising winter temperatures mean that winter and summer temperatures will decrease, including the consequences of reducing groundwater injection and reducing water resources. The issue of climate change affects the quantity and quality of water resources and affects the needs of industries, agriculture, and drinking water supply.

It is have a close connection between the climate system and hydrological cycle. Any change in the climate changes all the elements of hydrology, conversely is also happens. Flood waters, river discharge, groundwater, flood and drought are all affected by rainfall, which is one of the most important climatic elements.

Due to the human activity increase in CO2 and consequently global warming and its impact on national and regional water resources, it seems necessary to consider the impact of the above changes on water resource management planning. Increasing the temperature of the globe between 1 and 4 degrees in the present century reflects the dimensions of the frequency of disasters such as droughts and floods that can affect surface water, underground, land drainage, and so on, Kabul has little role in climate change and greenhouse gas contamination, but it is more harmful than other parts of the area, Climate change affects Kabul province in 3 parts; first, surface and underground water resources; second agriculture; and third, forests and grasslands, it is a concern that with further climate change, Kabul faces more problems such as the water crisis and food supply.

Climate change affects Kabul province in three stages; first stage, surface and underground water resources; second stage agriculture; and third stage, forests and grasslands, it is a concern that with further climate change, Kabul faces more problems such as the water crisis and food supply.

2.1.1 Climate change

The hydrological cycle is intimately linked with changes in atmospheric temperature and radiation balance. In recent decades the climate systems changing is very clear. Some of the evidence consists of observations of increases in global average air temperatures, extensive melting of snow and glaciers, and rising sea level (Abadzadesahraei and Sui, 2016). To assess hydrological changes resulting from climate change or other factors, long-term observations are necessary to form baseline conditions and to detect any changes over time.

From monitoring network these observations are also important to fully understand the hydrological response of a basin and to calibrate and validate models used to project future conditions. The information obtained from such studies regarding possible changes in future hydro-climatic conditions is necessary for planning and implementing development studies and projects that incorporate reasonable strategies for adapting to changing climate (Brekke, 2009). Trend detection of hydro-climatic parameters is a challenging task as many other factors might be involved such as land use changes, changes in water infrastructure etc. (Cohn and Lins, 2005).

2.1.2 Future climate impacts on groundwater systems

As irrigation dominates current groundwater use and depletion, the effects of future climate variability and change on ground water may be greatest through indirect effects on irrigation-water demand. Substantial uncertainty persists about the impacts of climate change on mean precipitation from general circulation models (GCMs), but there is much greater consensus on changes in precipitation and temperature extremes, which are projected to increase with intensification of the global hydrological system. Longer droughts may be interspersed with more frequent and intense rainfall events. These changes in climate may affect ground water initially and primarily through changes in irrigation demand, in addition to changes in recharge and discharge. A global analysis of the effects of climate change on irrigation demand suggests that two thirds of the irrigated area in 1995 will be subjected to increased water requirements for irrigation by 2070 (ref. 54).

2.2 Water resources

The snow pack in the mountains in the north and northeastern regions in the river basin constitutes the major runoff in the basin so water supply varies from year to year. In general, more than 72 percent of the runoff occurs between May and September and 40 percent occurs between October to April.

A trans- Basin division also transports water from the Chateral valleys, Pakistan to the Kabul river basin Figure 4.

There are four aquifers in the Kabul area. The Paghman-Darulam area has 2 aquifers lying along the course of the Paghman river and the upper Kabul river. The two other aquifers are located in the Logar sub basin. The main sources of recharge for this aquifer are infiltration of surface water from the river, irrigation and the ditches and canals. These aquifers are the main source of domestic water supply and supplemental for irrigation purpose. There are dams and reservoirs and lakes in the basin and their functions for generating electricity, irrigation and domestic water use are important. During June and July the peak runoff increasing due to snow melt while the peak demands for water usually is during July and August because of demand from the Agriculture sector. Further there are more some reservoirs and lakes are used for irrigation, domestic purposes.

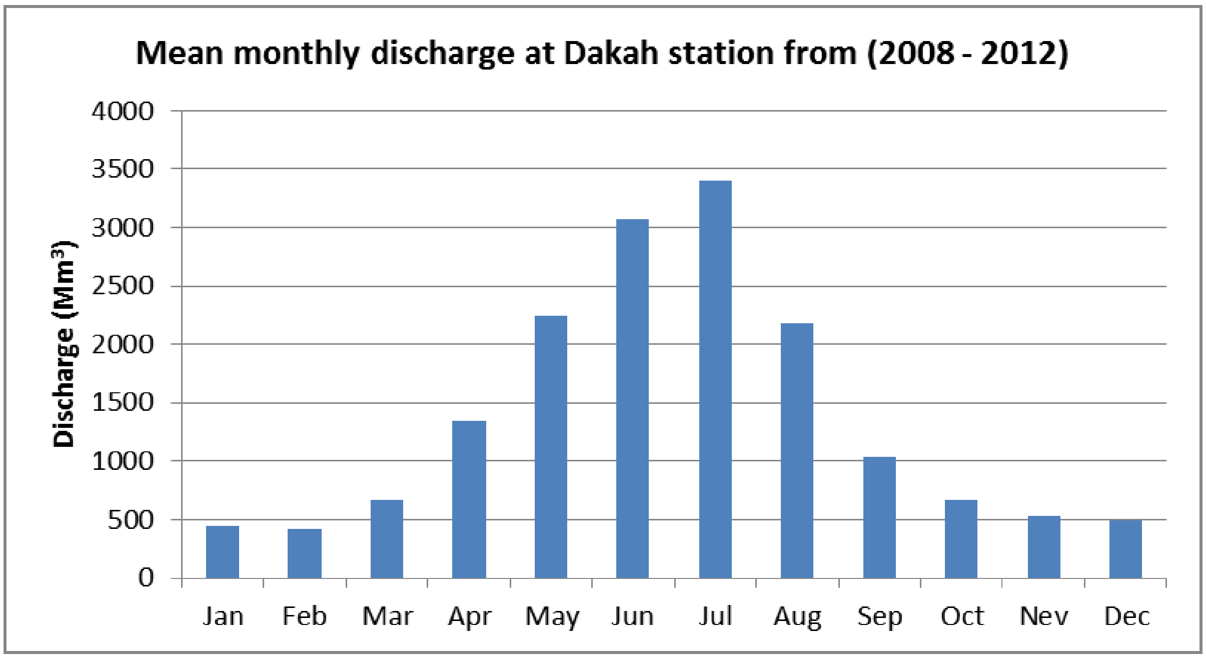


Figure 2.2 Mean monthly discharge at Dakaha station in the period of 2008 – 2012. Data source: Ministry of Energy and Water.

2.2.1 Water availability in the Kabul city

In estimated survey during (2019) identified that the Kabul city has population of around 4.1 million it's growing rapidly, by growing of population increase the demand of water in current city, In Afghanistan the Kabul city is first growths population city. Water availability in the Kabul city the availability of water resources is biotic to economic and social wellbeing and rebuild of Afghanistan.

In present years the population of Kabul city is growing, its effects on the water availability and recent drought placed new stress to Kabul city. Population growth and recent drought both caused many wells to become contaminated and dry in the future. According to (Milly and others, 2005) there will be for long time drought, dry will, in future if the global warming is rapidly on Afghanistan Kabul city.

Table 2.1: Impact climate of climate change on water resources anticipate with change of climate

Sources	major impact component	potential effect of CC
Aquatic system	• Level of water in aquifer • Level of water in surface water • Stream flows • Flux of water in subsurface	• Duo to flood fail of dam • Duo to sedimentation fail of dam • Drought
Water supply system	• Per capita water demand • Demand for agriculture	• Increasing the level of water demand behind the project
Quality of water	• Temperature of water • Brininess water • Concentration of contaminate	• Duo to flood fail of dam • Duo to sedimentation fail of dam • Drought
Water managing system	• stream flow • Level of water in surface water • Level of water in aquifer	• Reducing the water supply system • On water treatment system reduce the load • Change in production of hydropower
Hydrologic sources	• Runoff water • Transpiration • Recharge of contaminate water • temperature • Evaporation	• Duo to flood fail of dam • Duo to sedimentation fail of dam • Change in soil moisture • Shortage of water

2.3 Protection and resolution of future climate change challenge

However the climate change is the big challenge to the world, Resolution is also important to the present time, the firs important way to control the future climate impact of climate change its mitigate the greenhouse gases (GHG), (CO_2, CO, SO_2, SO……) which helps to the global warming. There is few ways to control the global warming, those country which is need high amount of energy for development, use friendly and environmentally energy to reduce the emission of greenhouse gases.

1. Use of renewable energy in country.

Substitution of non-renewable energy to renewable energy, reducing usage of fossil fuel in country, develops of new technology like electronic metro station and other electronic services.

2. Global action to climate change.

UNFCCC is focus on to reduce the greenhouse gases from the sources, and mitigate the greenhouse gases emission. Face to this problem the first conference was in Kyoto protocol in 1997, this protocol set target for 37 industrialized countries to reduce their emission.

3. Sustainable forest management and agriculture

All country government has responsibility to save their environment and forest, reduce emission from deforestation

4. Sustainable transportation
5. Sustainable infrastructure

2.4 Climatic Hazards

A valid survey during (2000-2002) estimated that Afghanistan will be facing a wide range of new and increasing climatic hazards. In Afghanistan the most adverse impact of climate change is drought, including land degradation and dynamic desertification.

Duo to unseasonable rainfall flood in general increase and temperature is also important for this event, however this impact may be magnified duo to more repeat snowfall, rainfall, snow melt as it's the result of high temperature combined with the downstream effect of land degradation, land mismanagement and loss of herbal cover.

In Afghanistan more than 27 province have been impacted in wide range of natural disasters, its including drought, landslide, flood, heat extreme and freezing weather.

Figure2.3- Climatic Hazards in the region.

2.5 Impact of climate change on Food Security

To finally identify those area which is impacted livelihood by climate hazards in last 30 years, we overly the subsistence and climatic hazard from vulnerability maps.

Then we use food security trend between (2008-2012) years based on data to known about those area which is together have high level of water scarcity and food insecurity, where climatic hazards have high impact on livelihood.

In Afghanistan food insecurity was obviously taken by many non-climatic factor, it's allowed us to see obviously to reduce climate risks in highlight areas, it will be improve significantly food security.

Figure 2.4- Impacts on Food Security.

2.6 Impact of Drought due to climate change in Kabul city

The word drought is refer to metrological drought (below average of precipitation) hydrological drought (in river, groundwater and lakes low level of water and flows), environmental drought (combination of all this) and agricultural drought (law level of soil moisture). From the interaction of human induced climate change factor and natural condition the socioeconomic impact of climate change is rise like change is landecover, landuse and demand for use of water.

In Afghanistan current and future impact of drought is after analyzed it's not only on the context of country history of disquiet and war, it's also in the context of agricultural statics. The statistics cover land of detailed pooled provincial is gives follow information.

Table 2.2 Land cover of Afghanistan (Anonymous 1999).

Land covers	Area (in hector)	Area of the country (in %)
Municipal	29,495	0.07
Gardens	94,216	0.10
Agricultural land irrigate	3,207,791	4.0
Intensive	1,559,655	2.3
Intermittent	1,648,135	2.6
Agricultural land rain-fed	4,517,713	6.0
Forests	1,337,583	2.10
Rangeland	29,176,731	45.20
Barren lands	24,067,015	37.30
Marshland	417,564	0.60
Water bodies	248,186	0.40
Snow-covered area	1,463,100	2.30
Total	64,559,396.00	100.00

The land cover area of Afghanistan covered by agriculture land is 12.0%. It's equal to 7,725,502 hectares. 7.0% land of agriculture is under rain fed and 5.0% is under irrigation. So it is clear from this data in the above table that the contribution from animal husbandry to livelihood in Afghanistan is substantial although it naturally differs between provinces.

2.7 Change in Temperature

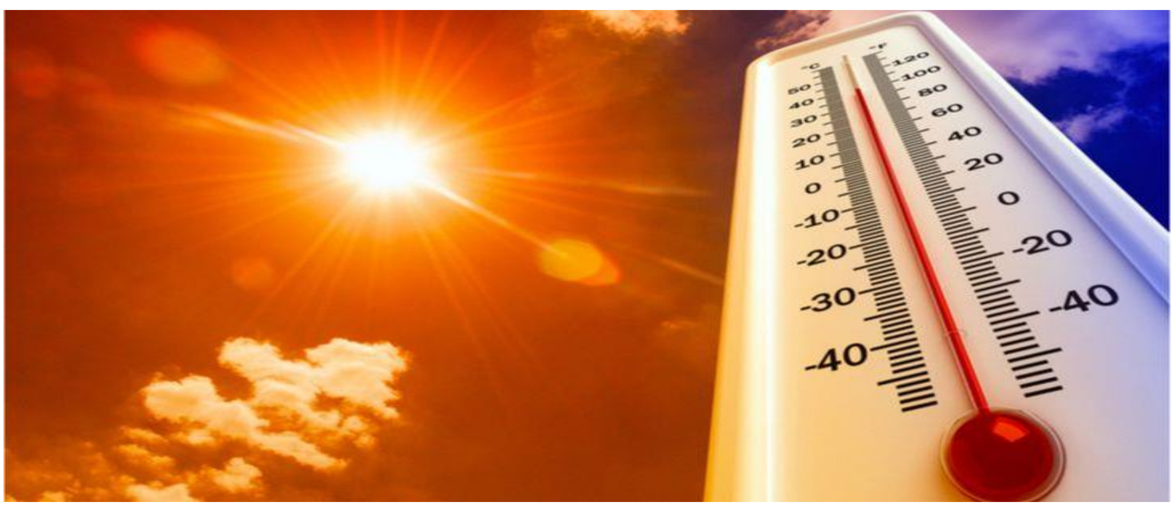


Figure 2.5- Changes in Temperature.

Depended on global emission scenario all region of Afghanistan indicate significant warming increase with the average of temperature between 2.0°C and 6.1°C, up to 2062s.warming is the most big challenge to the north and central plains of Afghanistan during Sumer, this increase of temperature is also observed trend in center Asia. During summer months climate frequency of days and night are considered hot and increasing in the trend of temperature.

If become Changes in rainfall and temperature the quantity of evapotranspiration and on both quantity and quality of the runoff have direct effect .subsequently, the temporal and spatial of water resources, or in general the water balance, can be significantly altered with any changes in temperature. The Indian Ocean and subsequently Warming will increase the intensity of tropical frequency and storms, to flooding due to increase sea levels may be subject those coastal areas.

Of increases temperature However, different regions are characterized by different ranges, with the near equator wet tropical areas (parts of DRC and Zambia) changes as compared to the dry regions having a lower temperature of Botswana, UAE Namibia and parts of South Africa and Zimbabwe. Projections have shown that, the semi-arid and arid areas are likely to get drier due to climate change than more humid areas in countries such as Zambia and Tanzani

However, in the different climate models used the different scholars global in their projections. Moreso, others relied on use of a single GCM.

Additionally, only a few studies used RCM (e.g. Taydross et al. (2005) Schulze et al. (2005); Engelbrecht (2005)) for better temperature projections need to despite these having a better spatial resolution. Most studies terminated that, modeling results, have based on future climate southern Africa's climate will become drier and hotter. This warming will be greatest over the semiarid margins and interior of southern Africa, the central and Sahel Africa. Expulsion show if that temperature changes it will not be uniform over the region: the central, southern land mass extending over Botswana, parts of Namibia Zimbabwe and north-western South Africa, are likely to experience the greatest warming of 00.2 - 00.5^{0}C per decade.

2.8 Precipitation

Figure 2.6- Precipitations trend.

In assessing impacts of climate change have been extensively studied water resources Rainfall trends. climate change even without scholars concu, southern Africa space over rainfall exhibits extreme variability in time. While there is uncertainty on the magnitude of climate change impacts on rainfall in southern Africa, the IPCC (2007) suggest rainfall will decrease with climate change

2050 the interior of southern Africa show models project that by will experience rainfall during the growing season decreased due to reductions in soil moisture and runoff. Additionally, many climate change models, predict a 5.0 to 15.0% decrease in southern Africa of growing season rainfall. Hulme (1992) predicted a 5.0 – 10.0% reduction in rainfall and Mazvimavi (2011) projected a 3.0 – 23.0% in southern Africa decrease in rainfall under climate change.

Several scholars share the same idea and have predicted that the region will be characterized by below- frequent droughts and normal rainfalls in future. Although most studies

in rainfall indicate future reduction of up to 50.0%, in southern Africa projected future changes in mean seasonal rainfall are less well defined.

for increased inter-annual variability Scientific evidence points, with more intense droughts extremely wet periods in different countries in near. with volumes, frequency and intensity also change with rainfall patterns, resulting in more longer periods and extreme events between rainfall. At that time, the need for water is increasing in the region belong due to economic development and growth of population yet, allot of livelihoods in the region, are belong to rain-fed agriculture, rainfall under climate change affected by reduction.

Chapter 3

Methodology

3.1 Hydrological model

IN Kabul rivers Basin a physically application which based watershed SWAT2012 that evaluated the influence of Topography of climate, soil, and use land satiation on stream flows. Unite for the hydrological response (HRU) based on stream flows. The application of the model involved calibration, sensitivity and uncertainty analysis. Figure 4.1 show us the step of water availability analysis.

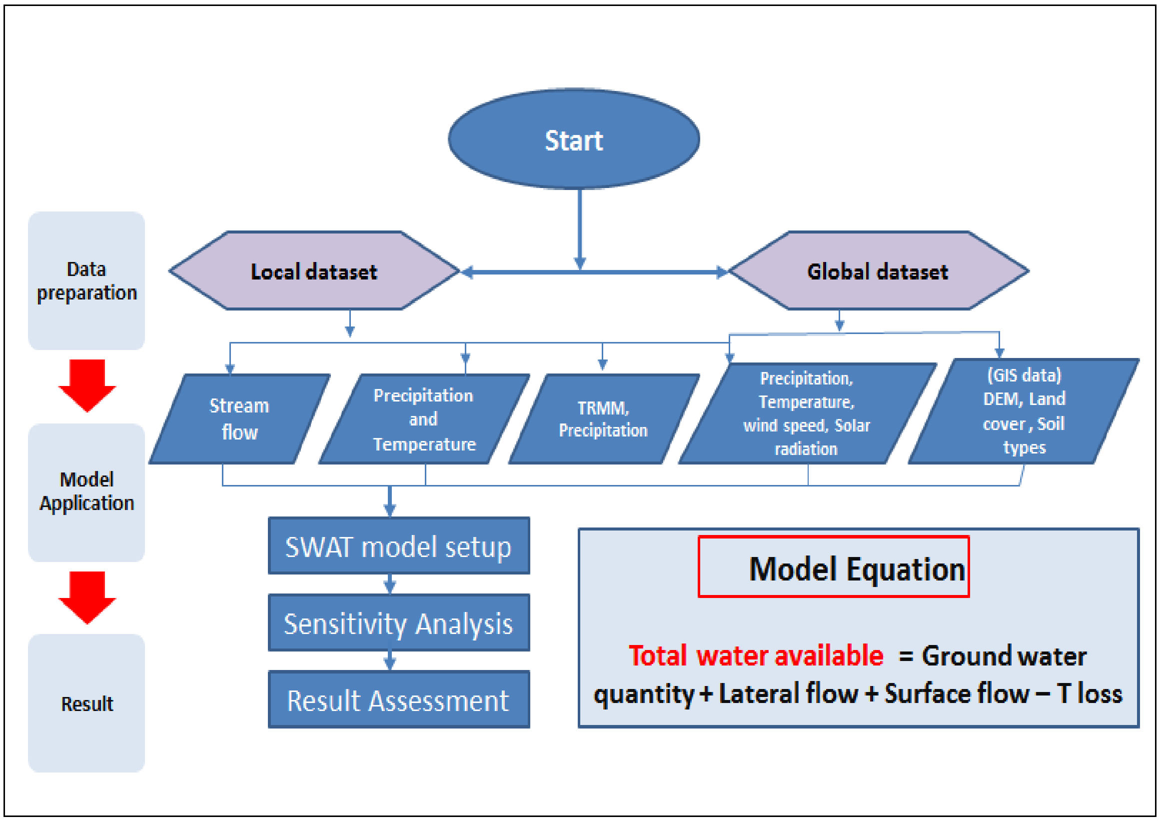


Figure 3.1- conceptual method for water availability analysis using SWAT (2012 model.

3.2 Soil and Water Assessment Tool (SWAT) background

SWAT show us tools which use for soil and water assessment. Dr.Jeff Arnold developed scale for basin river by order of USDA Agriculture Research Series [19] SWAT can do different physical processes to be simulated in a watershed which discussed in following

For more detailed discussions on these processes and procedures employed by SWAT could be consulted on the SWAT theoretical Documentation, 2005 version and SWAT user manual 2012 version. SWAT has done some process to predict he impact of land management practices on agricultural chemical yield, sediment and water in large basins 28 over a considerable period of time [20] It is a physically based model, ex. it requires specific data about topography and property of soil weather, vegetation occurring in the watershed. Using these input data, SWAT (2012) will directly model the physical process associated with recycling of nutrient, movement of sediment, movement of water, etc. This approach has two benefits:

1. To amount of the relative impact of alternative data (Stream gauge data)

2. To quantify the relative impact of alternative data’s (land use, changes in climate, etc.) on the water amount, quality and other variable of interest.

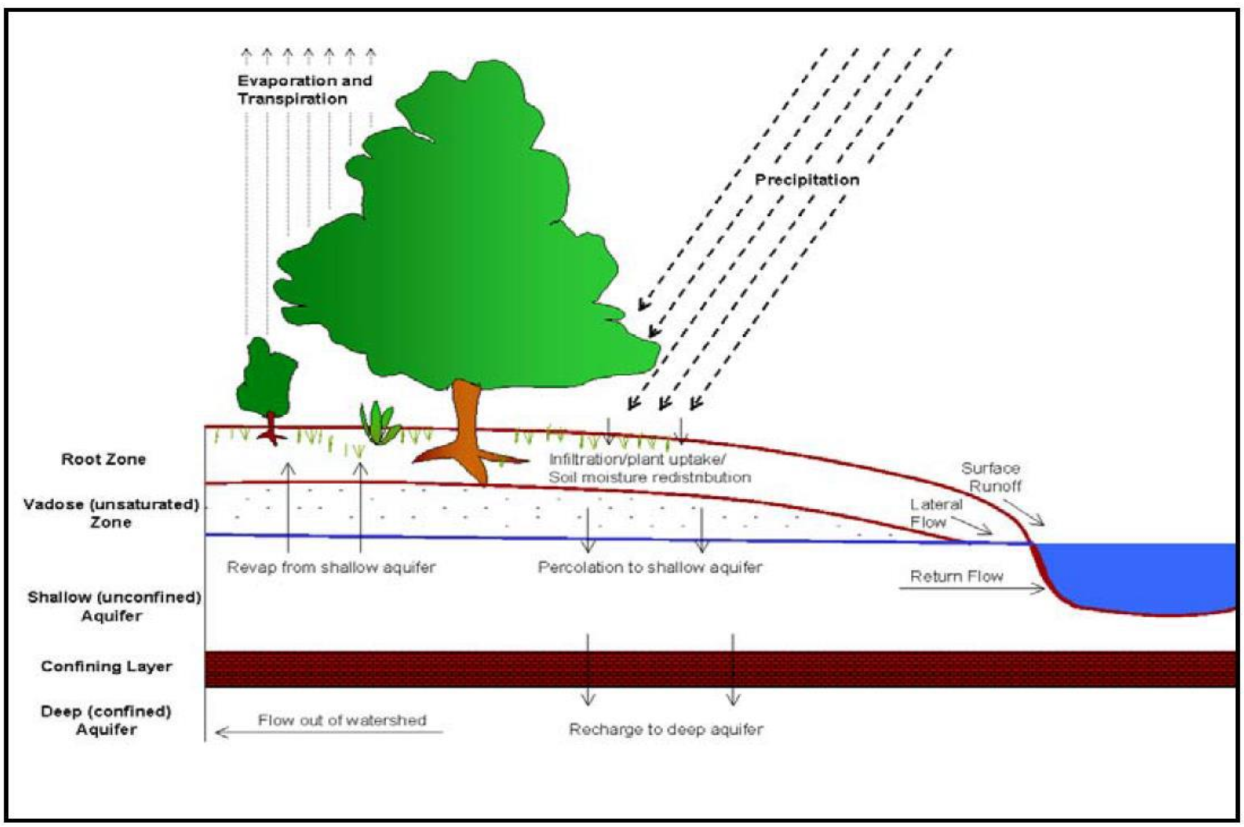


Figure 3.2- Schematic representation of upland processes of hydrological cycle in SWAT (2012)

3.3 (SWAT) model

The SWAT model for firs time developed by United states of America (USA) department of agriculture [2] SWAT (soil and water assessment tools) is based physically hydrological, water quality model this model is a continuous time, spatially for semi distributed simulator for hydrologic cycle and run annual, daily and monthly time steps.in SWAT model watershed is divided into multiple sub watershed, which is further divided into hydrologic response unit (HRUs), its consist of soil types and homogeneous land and tharin characteristic. The SWAWT model is based on following water balance equation.

$$SW_t = SW_0 + \sum_{i=1}^{t} (\mathrm{Rday} - \mathrm{Qsurf} - Ea - \mathrm{Wseep} - \mathrm{Qgw})$$

In this equation SWt the final soil water content(H2O mm), *Ea* is the total amount of evapotranspiration, Qgw is the total amount of return flow in day, t is the time (day), Wseep it's the total amount of water entering to the vadose zone from soil profile on the day and Rday is the total amount of precipitation on day *(H2O mm)*. The subdivision of the watershed is enabling to the model it's reflect difference in evapotranspiration for defiance soil and crops. Snow melt for day is added to rainfall for day i in the computation of surface infiltration and runoff.

In this pattern Surface runoff is the successful flow path of most snow melts event. Infiltration is limited for this when the superficial soil profile layers is frozen through adjustment of the retention parameters in the soil conservation services (SCS) curve number procedure is (SCS, 1972) used to identify the surface runoff. Then no lateral flow or percolation is allowed when the soil profile layer is frozen. It's the method of (Williams. 1969), in this formula it's not consider ice influence on stream flows and require calibration. For (HRU) scale snow hydrology is realized. If the delay values (in SFTMP) parameter then precipitation within the (HRU) is considered to snow. The mass balance for snow pack is below:

$$SNO_t = SNO_o + \sum_{i=1}^{t} (\mathrm{Pi} - \mathrm{Esubi} - \mathrm{SNOMLTi})$$

In this formula SNOo and SNO_t are snow water equaling in time (t) and initial time, respectively (for water mm) ; and Pi is the water equaling for snow precipitation on dayi (water in mm) these all variable are expressed as depth of water equivalent in mm over the total (HRU) area. In the SWAT model snow present in areal coverage in the basin is define using areal depletion curve which it's describe the recession function of the of the amount of snow present in current basin [2] its defined as follows:

$$SNOCOV_1 = \frac{SN01}{SNOCOVMX}\left[\frac{SNOi}{SNOCOVMX} + \exp\left(cov1 - cov2 \times \frac{SNOi}{SNOCOVMX}\right)\right]$$

In this formula for (HRU) area $SNOCOV_1$ is the fraction which is covered by snow on dayi ; SNOCOVMX is the min snow water content that corresponds to 100.0% snow cover (water in mm); (cov1) and (cov2) are the coefficient define the shape of the curve. Which values is used for (cov1) and (cov2) are determining by solving equation 4 using two known points: (1) 95% (SNOWCOVMX), specific by the (SNO50COV) parameters snowmelt is control by snowpack temperature and air the melting rate and areal coverage of snow. A temperature index, (SNOMLTi) is used for determining the amount of snowmelts on day it's defined below:

$$SNOMLT_1 = bmlti \times SNOCOVi \times \left(\frac{Tsnowi + Tmaxi}{2} - TMTMP\right)$$

In this formula for (HRU) area $SNOCOV_1$ is the fraction which is covered by snow on dayi ; Tmaxi is the max air temperature on a given day (°C); Tsnowi is the snowpack temperature on day i(°C); (SMTMP) is the base temperature above which snowmelt is allowed to (°C) and bmlti is the melt factor account for the increase in the length of the days as the season progresses. A minimum (SMFMX) and maximum (SMFMN) melt factor occur at the summer and winter solstices, respectively, control the seasonal variations on the day j of the year as defined below:

$$bmltj = \left[\left(\frac{SMFMX + SMFMN}{2} + \frac{SMFMX + SMFMN}{2}\right)\sin\frac{2\pi}{365}(j - 81)\right]$$

(T_{snowi} -1) is used to show pervious day snowpack tempruture, T_{snowi} is used to show us currnt day snowpack tempruture, T_{auri} is used to show snowpack density and water content which must specified by TIMP parameter and SMFMX and SMFMN are used to show maximum and manimam snowmelt (mm of water day-1c^0-1) . The snowpack temperature is calculated as:

Tsnowi = [(1 - TIMP) × Tsnowi] + [TIMP × Tairi]

Runoff is predicted separately for each HRU and routed to obtain the total runoff for the watershed. We can calculate Runoff for surface as a bellow :

$$\text{Qsurf} = \frac{(Rday - 0.2S)2}{(Rday - 0.8s)}$$

Rday is used to show in above formula rainfall depth for one day which measured by (mm), Q_{surf} is used to show us the accumulated rainfall for a day that measured by (mm).

$$S = 25.4(\frac{100}{CN} - 10)$$

Through SCS predicate we can show of describe antecedent soil water condition, soil permeability and land use . SCS mainly describe three things first show wilting point or dry second show wet or field capacity (when rain fall come down the land which we see is called wet land) and 3th one show average of moisture in dry condition 1 curve will show the lowest value. The curve number for moisture conditions 2 and 3 are calculated from equations 8 and 9.

$$\text{CN1} = \text{CN2} - \frac{20\times(100 - \text{C}N_2)}{(100 - \text{C}N_2 + \exp[2.534 - 0.0637\times 100 - \text{C}N_2])}$$

$$\text{CN3} = \text{CN2} \times \exp[0.00674 \times (100 - \text{CN2})]$$

In above formula the CNi used to show the moisture condition 1 curve number CN2 is the moisture condition 2 curve number, and CN3 is used to show us the moisture condition 3 curve number. Typical curve numbers for moisture condition 2 are listed in tables 2:1-1, 2:1-2, and 2:1-3 for various land covers and soil types[swat theory pp114], which are appropriated to slope less than 5%. To adjust the curve number for higher slopes than we use the bellow equation.

$$\text{SN2s} = \frac{(\text{CN3} - \text{CN2})}{3} \times [1 - 2 \times \exp(-13.86.\,\text{slp})] + \text{CN2}$$

3.4 Model Input

If we want to run SWAT we must have diversity of information and useful data. Specially distributed data (GIS input) needed for the Arc SWAT interface include the following important things like Digital Elevation Model (DEM), Land use, stream network layer, weather data such as precipitation, soil Data , temperature, solar radiation, wind speed, relative humidity, river discharge were required for Hydrological modeling and calibration purposes.

3.4.1 Digital Elevation Model

Topography was defined by digital elevation model that show the elevation of entire the points and the area at the specific resolution. Digital elevation model with resolution of 30.0m*30.0m (As show in figure 4.4 was downloaded from SRTM (Shuttle Radar Topography Mission) website on March 2014. The data sets are masked and projected in UTM projection using GIS10.2. The Digital elevation model was used to delineate the watershed and to analyze the drainage patters of the land surface terrain. Sub basin parameters such as slope percentage, slope length, and stream network characteristics such as primary, secondary streams and rivers which were derived from the Digital elevation model.

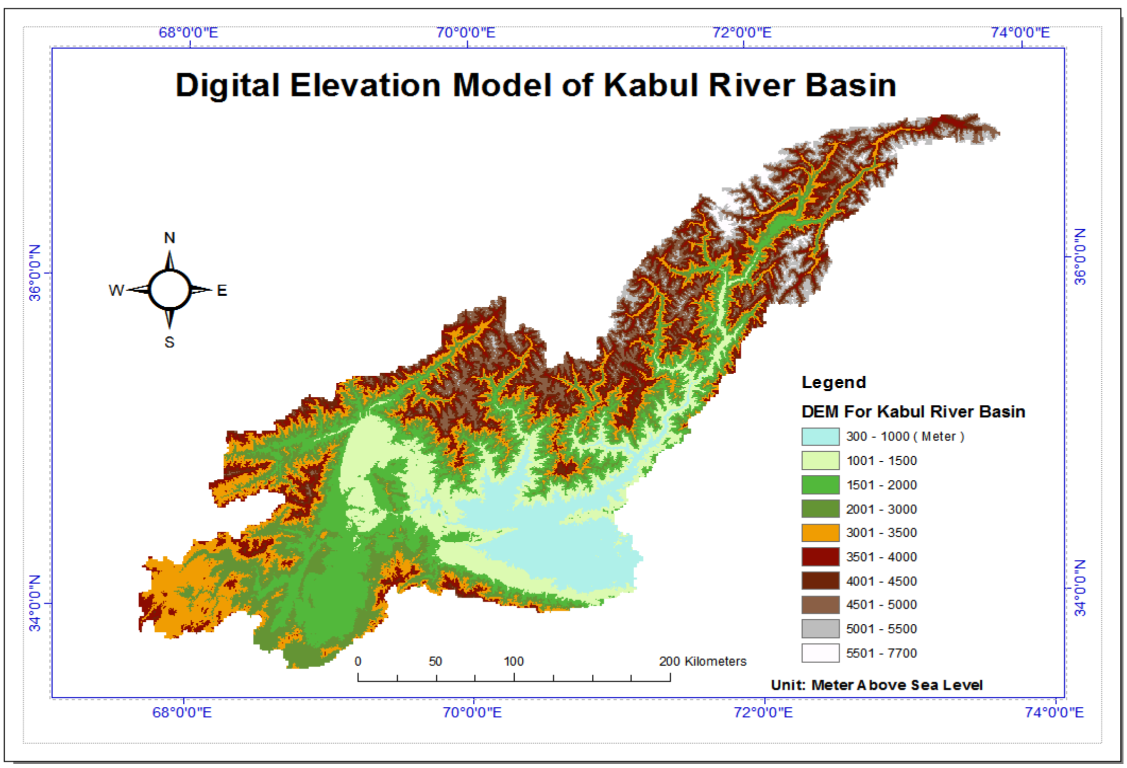


Figure3.3- Digital Evaluation Model of Kabul river Basin. Source: NASA

3.4.2 Land cover/ land use (LC/LU) data

Most important points in watershed are Land cover and land use which we usually show by LC/LU. The land cover datasets for the study area has been downloaded from Global Land Cover Facilities (GLCF). The dataset is derived from ($1km^2$) advanced very high resolution radiometer (AVHRR) and projected based on UTM projection using GIS10.2. The reclassification of the land use map was made to represent the land use according to the specific LULC types and the respective crop parameter for SWAT database. Bellow we describe the table which written about SWAT land use and land cover classes.

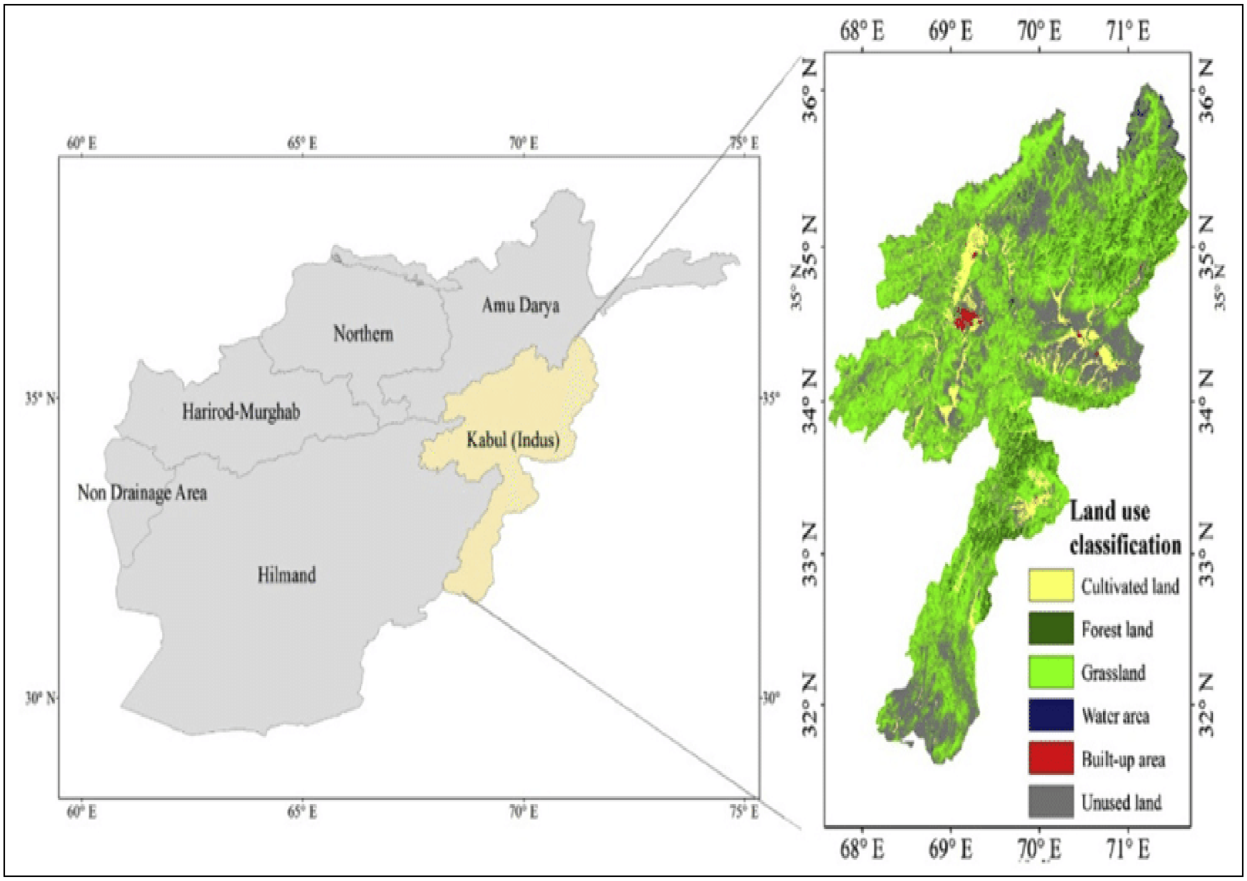


Figure3.4- Land cover changes in 28 years in the Kabul river basin

Table 3.1- Land cover/land use changes in the Kabul river basin. Land cover Baseline (sources: GLCF and LCI- 1982-2010).

Number	Land cover/ land use categories	Land cover / land use area (1000 hectare)		Percentage of Changes (1982-1992 to 2000-2010)
		(1982 –1992)	(2000 –2010)	
1	Water	9.10	7.80	–14..60
2	Urban/ Built up	11.30	14.60	29.20
3	Urban/ Built up	3653.50	2848.60	–22.0
4	Mixed forest	448.30	195.70	–56.40
5	Grassland	1413.80	1586.60	12.20
6	Cropland / Irrigated area	94.20	264.10	183.80
7	Barren	891,0	1599.60	79.50

3.4.3 Soil classification

SWAT require texture soil and soil which have chemical properties like soil textural, water content density and carbon content of different layer of soil. In this study, soil dataset obtained from FAO/UNESCO-ISWC (FAO/UNESCO-ISWC, 1998) with the resolution of 90m*90 meter and projected based on UTM, and then applied in SWAT model in the stage of Hydrological Respond Unite (HRU). Definition of soil characteristics in shown in figure 4.6.

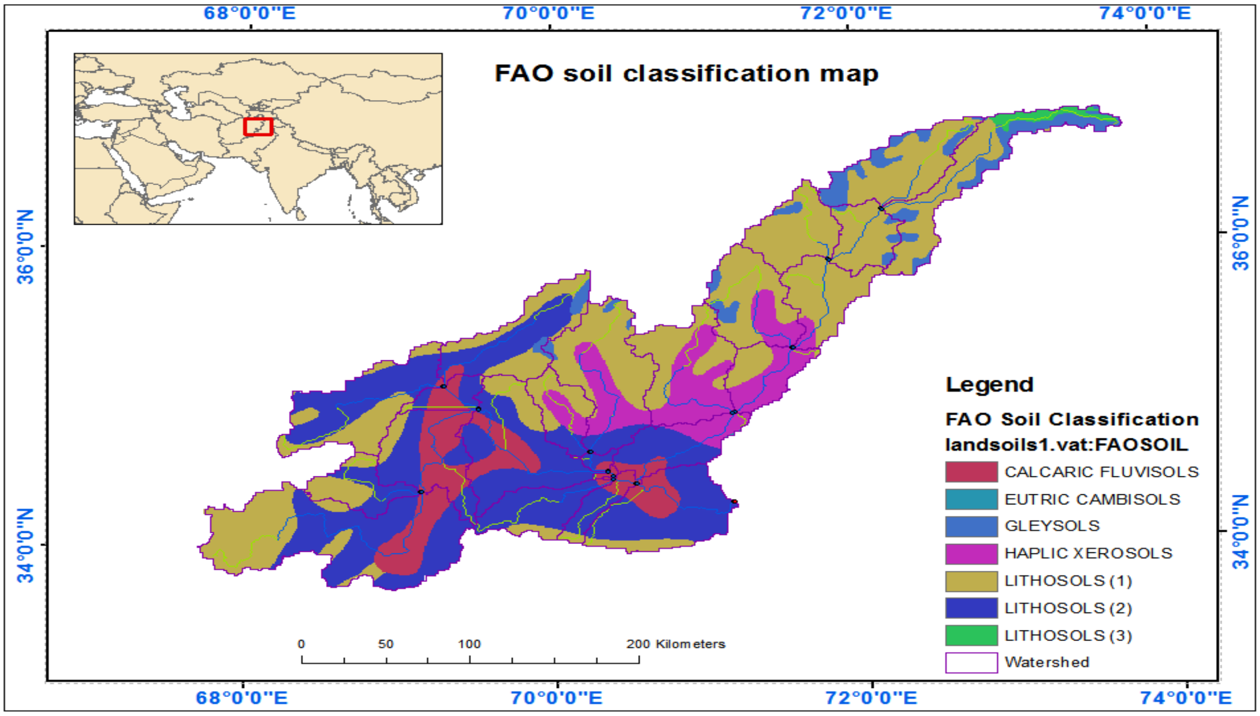


Figure 3.5- Soil classification map of Kabul river basin

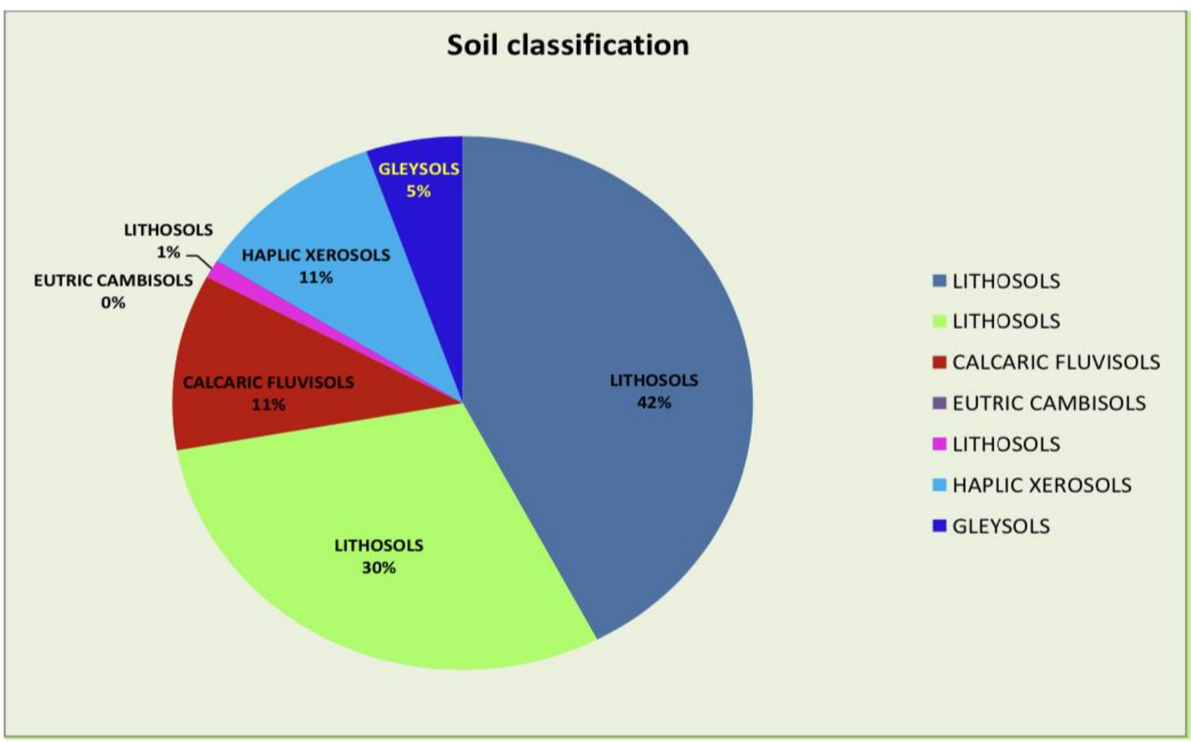


Figure 3.6- Soil classification pie chart based on percentage in the Kabul river basin.

3.4.4 Meteorological Data

For model we must count daily metrological data which generated by weather model include , maximum and minimum air temperature, in the present study, in Kabul province taken 12 point of rainfall for test between (2002-2012) which done these tests by Japan and Us and also 64 temperature points record downloaded from National center for Environment in Kabul river basin predication (NCEP) and applied in the model for present hydrology modeling in Kabul river basin, as shown in figure 4.8. The Hargreaves method which utilized maximum, minimum and mean temperature and solar radiation records employed for estimation of potential evapotranspiration (PET) for this specific study area. The typical quality of rainfall data was checked by cross correlation between the stations.

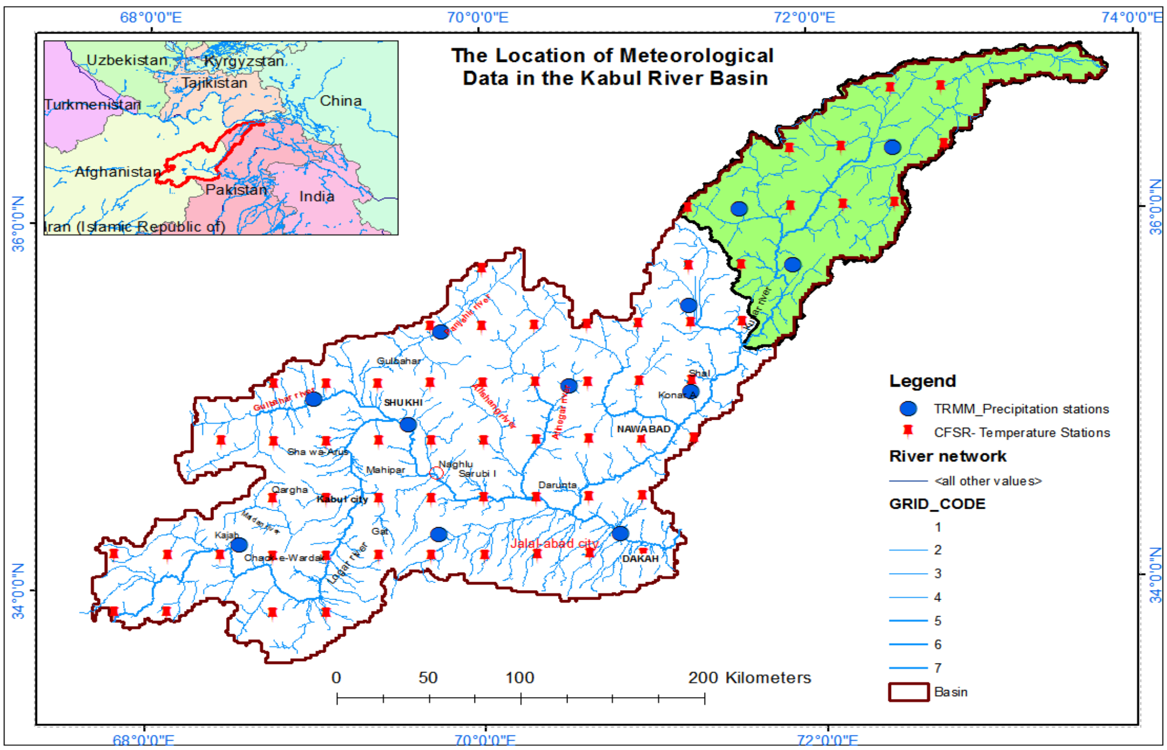


Figure 3.7- Location of meteorological data sets from two sources: Precipitation from TRMM and Temperature from NCEP.

3.4.5 Stream runoff data

We have taken daily discharge data of 8 stream gauge station from water resource department, ministry of water and energy figure 4.9 The discharge data applied for performing sensitivity analysis, calibration of SWAT model. An automated base flow separation and recession analysis technique applied to separate the base flow, ground water flow and surface flow from the total daily and monthly stream flow records. This data and information then used in order to get SWAT correctly reflect basic observed water balance of the watershed.

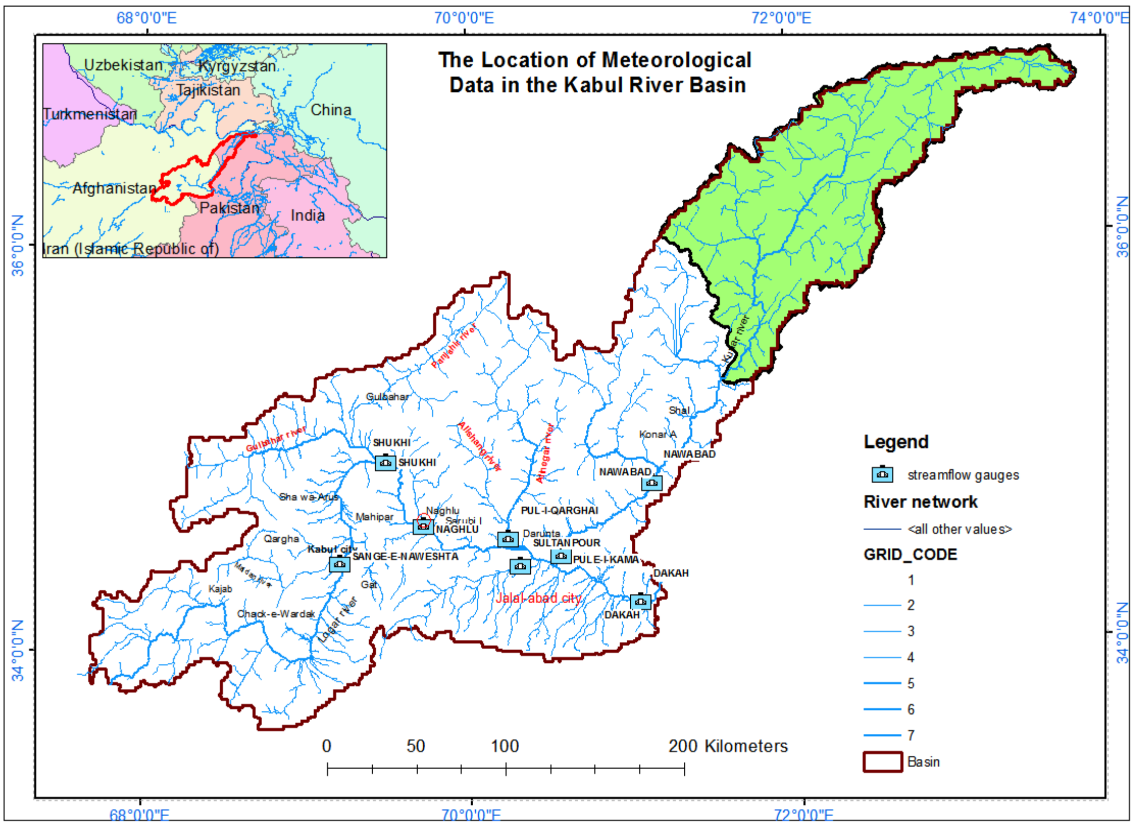


Figure 3.8- Location of Stream run off stations in the Kabul river basin, data source: MoEW.

3.5 Model setup

3.5.1 Watershed delineation

If we want to make SWAT watershed so first step is watershed delineation from digital elevation model (DEM) we must enter special character for SWAT watershed and most important and basic steps are (HRUs) , DEM that projected into the UTM zone with N42, which are projection parameters for Afghanistan. Watershed partitioned into 23 sub-basins for modeling purposes as shown in figure 4.10 The watershed delineation process include five major steps, DEM setup, Stream definition, outlet and inlet definition, watershed outlets definition the threshold based steam definition options were applied to define the appropriate size of the sub-basins.

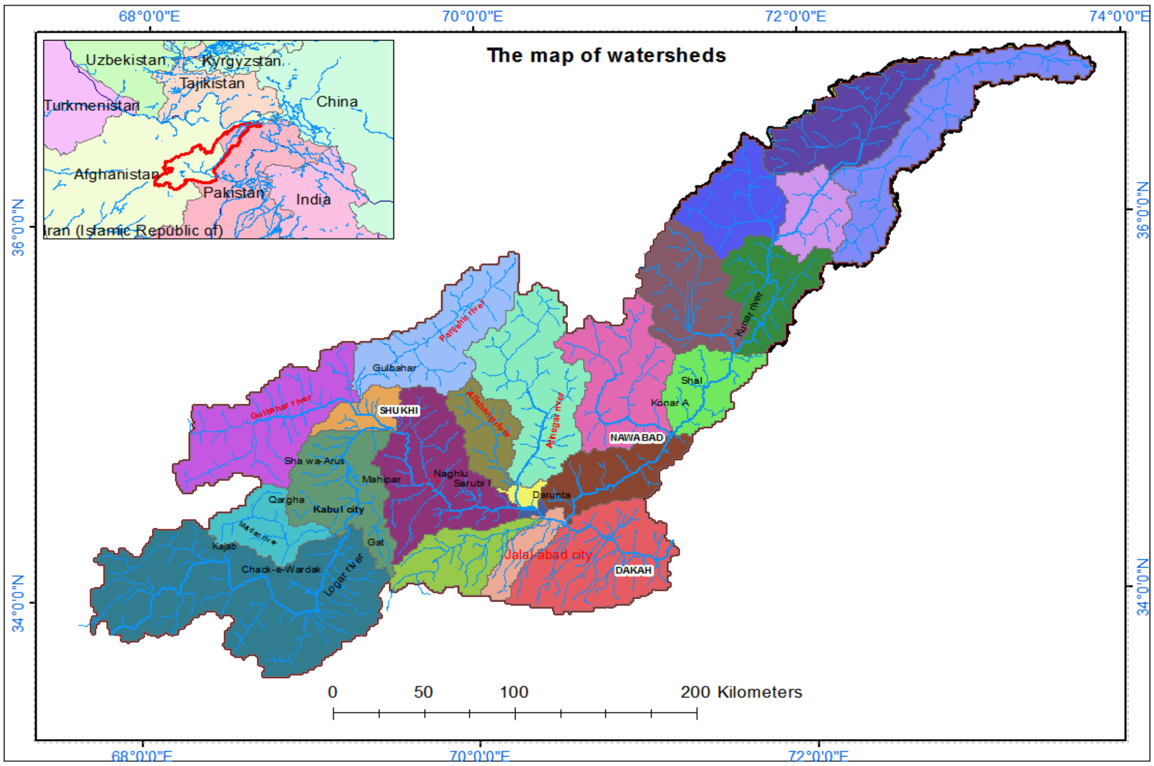


Figure 3.9- Watershed delineation, 23 watersheds in the Kabul river basin, generated by (SWAT) model

3.5.2 Defining climate database

Climate data is main step of input of watershed of SWAT we take daily weather precipitation points include minimum and maximum. . these record taken between 2002-2012 and 6 years warm for hydrological cycle . The write input table menu contains items that all building database files containing the information needed to generate default input for SWAT. The write command become enabled after weather data were successfully loaded. These commands were enabled in sequence and need to processed only once for a project.

Before SWAT run, the initial watershed input values have been defined. These values were set properly based on the watershed delineation, land use, soil and slope characterization. There are two ways to build the initial values: activate the write all commands or the individual write commands on the write input table menu. Finally, the other key aspects of the

SWAT simulation performed for the watershed are listed below:

1- Output time step: daily and monthly

2- Simulation period: 11 years (2002-2012)

3- Rainfall distribution: skewed normal.

4- Runoff generation: CN method.

3.6 Model output

3.6.1. Primary output

The primary result showed that, the model had a sensitivity with several elevation zones, precipitation in the form of snow, temperature based snow melting and snowmelt runoff. For simplification, assumed that, all the components of SWAT model are constant that were calculated from the water balance equation. In this cause the interaction of the model with the snow is same as rain, without consideration of snow melt base temperature and snow melt maximum and minimum factors properly, the primary output compared with observed runoff in the figure 4.12 and 4.13.

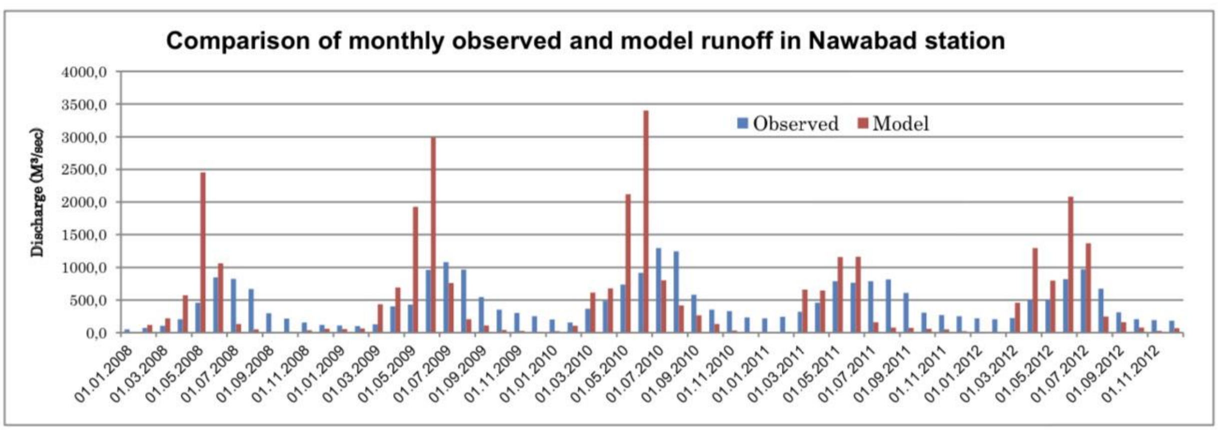


Figure 3.10- Comparison of monthly observed and model runoff in Nawabad station

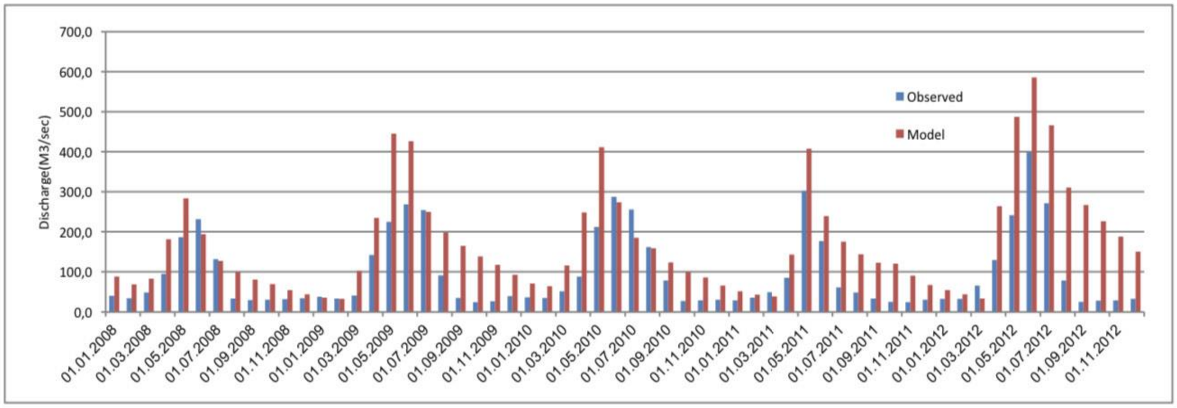


Figure 3.11- Monthly observed and model runoff in shukhi station.

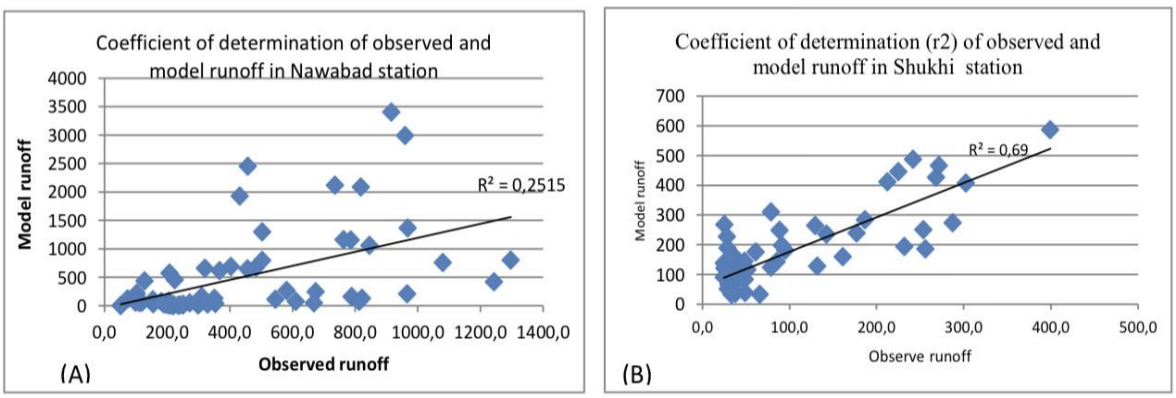


Figure 3.12- Regression coefficient of monthly observed and simulated stream flows at (A) Nawabad, (B) Shuki river gauging stations, during 2008-2012.

3.7 SWAT Calibration

SWAT input parameters are process based and must be held within a realistic uncertainty rang. The first step in the calibration process in SWAT is the determination of the most sensitive parameters for a given watershed or sub-watershed. The SWAT user must determine which variables to adjust based on expert judgment or no sensitivity analysis. Sensitivity analysis is the process of determining the rate of change in model output with respect to changes in model inputs (parameters), [24] .it is necessary to identify key parameters and the parameter precision required for calibration. In a practical sense, this first step helps determine the predominant processes for the component of interest. Two types of sensitivity analysis are generally performed widely in the SWAT model: local, by changing values one at a time, and globally, by allowing all parameter values to change. In this study, I have applied local sensitivity analysis. Sensitivity of one parameter often depends on the value of other related parameters; hence, the problem with one-at-a-time analysis is that the correct values of the other parameters that are fixed. Calibration is an effort to better parameterize a model to a given set of local conditions, thereby reducing the prediction uncertainty. Model calibration is performed by carefully selecting values for model input parameters (within their respective uncertainty ranges) by comparing model predictions (output) for a given set of assumed conditions with observed data for the same conditions. Calibration can be accomplished manually or using auto-calibration tools in the SWAT model as shown in figure 4.15.

3.8 Study area and Data

3.8.1 Afghanistan

Afghanistan is a country which have majority Muslims and this country located in Asia which has 655000 km^2 areas this country past 40 years big war and a lot of people were died and injure also majority infrastructure such as building, road, bridge, dams, houses, villages, and etc. damaged and destroyed bid big malls and trading centers.

From 2003 the government of Afghanistan starts basically works and tries to start reconstruction and rebuild dams, canals, roads, malls, and also has serviced in health, education and porosity parts. Afghanistan spent a lot of money for education of police army and other high ranking people.

Afghanistan is a landlocked country. A part of the country lies within the Hindu-Kush Himalayan region. About ten percent of this territory is arable. One quarter of the country Has elevation higher than 2500miles. Rain and snow fall are the main sources of river flow in Afghanistan. The high altitudes of the Pamir and Hindu-Kush mountains are the original potential for several river basins in Afghanistan (Habib, 2014). Afghanistan has main 5 revier and these can green and electric all Afghanistan land and people (Figure 3.1):

1. The Amu Darya basin
2. The Helmand basin
3. The Kabul (Indus) basin
4. The Harirod -Morghab basin
5. The Northern basin

According to the sources of irrigation water, the Government of Afghanistan has divided irrigation water into four classes; they are:

- River and Streams: 84.61%
- Springs: 7.90%
- Karezes (kanats): 7.0%
- Shallow and deep wells: 0.50%

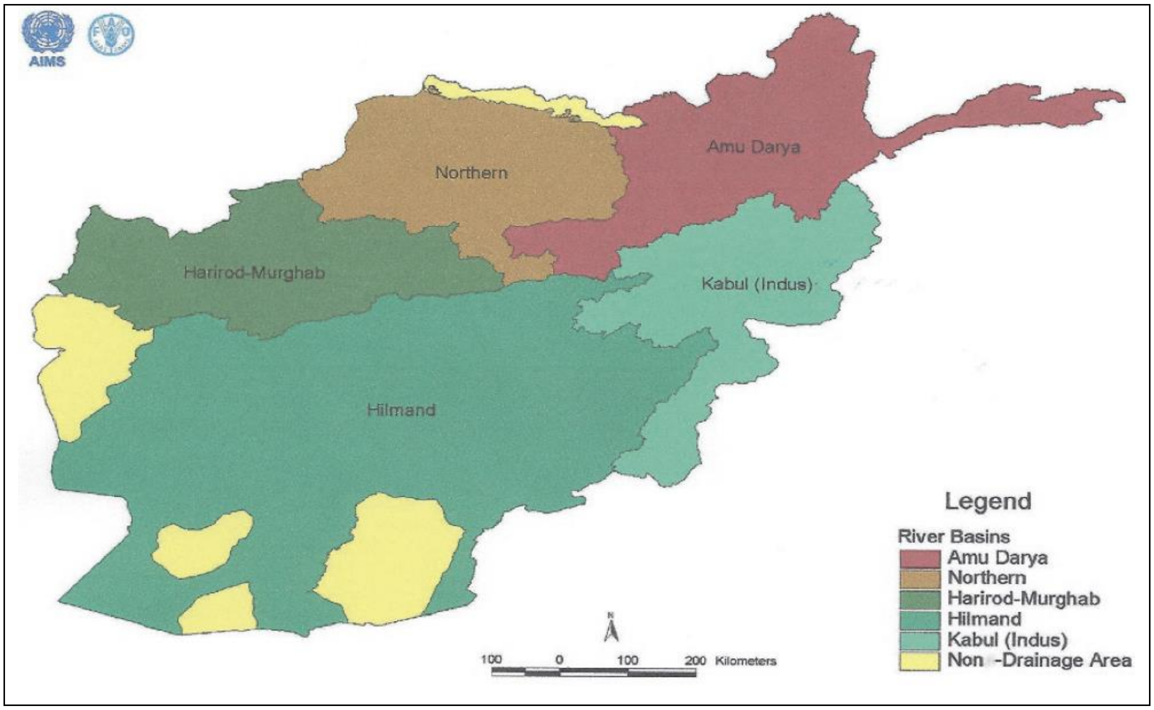


Figure 3.13- Location map of Afghanistan's river basins

Afghanistan also features extremes of temperature, ranging from -50°C on mountain peaks during winter and +50°C across its deserts during summer (Azizi, 2002). Among the reasons For this extreme temperature range is the absence of large water bodies that could have Ensured a more constant temperature through heat exchange and these extreme temperatures Are amplified by the correlation between the decline in temperature and the incline in Elevation (Pedersen, 2009).

3.8.2 Study area

Kabul river basin is trans-boundary catchment. Its located in the east part of Afghanistan and Chatral valleys of Pakistan. North latitude is between (33° - 37°) and east longitude is 67° -74 ° as shown in figure 1.2 with drainage area of 65202 km^2. This basin is divided into 23 sub-basin and 10 provinces, including Kabul, located in this drainage area. The upper catchment of the Kabul river basin consist of steep mountains valleys in the Hindokash mountain range, which reach over 7500 m above the sea level. The Kabul river basin is divided into four distinct areas.

1. The logar-maidan Kabul areas
2. Panjshir-Ghorband areas
3. Lower Kabul comprises areas
4. Loghman and kunar area

Finally all these tributaries and river joint in the Aba area of Nangarhar province and pass the border throughout the Pakistan territory.

3.8.3 Kabul basin

Kabul is the capital of Afghanistan and development province in all Afghanistan according to the report of the Guardian Kabul is the fifth fastest growing city in the world (the Guardian, 2014). Kabul has experienced fast and uncontrolled population growth in consequence of due great population growth in Afghanistan and its population was 2,268,300 in 2005 as estimated by the Central Statistics Office (CSO) and increased to 4.221 million in 2008, the municipality area has expanded to 1,022.7km2 as estimated at this time. Therefore, according to the Central Statistics Organization (CSO) of the Islamic Republic of Afghanistan around the estimated population of Kabul in 2017 is 4.86 million. It is equal to 16% of the whole population of the country, (CSO, 2018) and (JICA, 2014).

The Kabul basin is surrounded by mountains located in the eastern and central part of the country. The Afghanistan capital is located in this basin and the main river here is called the Kabul

River, which is the most important (although not the largest) river in Afghanistan. This river is made from melting of snow and rain during the winter and spring seasons

winter season in the mountains. However, winter rains, which are common in late winter and early spring, falling on a ripe snow pack in the highlands can greatly augment the flow of the main streams (Lashkaripour and Hussaini, 2007).

The Kabul River includes all Afghan rivers that join the Indus River in Pakistan. The Indus empties into the Arabian Sea of the Indian Ocean. The Kabul basin covers twelve percent of the national territory of Afghanistan, but alone it drains one-fourth (twenty six percent) of the total annual water flow of the country. As per the information obtained from the

Afghanistan Central Statistics Organization (CSO), provinces in the Kabul basin account for thirty five percent of the nation's population, and this region has the fastest population growth rate in the country.

In this study, the Kabul basin has been divided into nine main subbasins, which are shown in Figure 3.2. The total area of the basin is almost 69,269 km2 and the main subbasins and outlets are described in Table 3.1.

Table 3.2 Characteristics of the sub basins of the Kabul basin.

ID	Sub basin				Outlet			
	Area (Km^2)	Elevation (meter)			Name	Lat	Long	Drainage Area Km^2
		Mean	Min	max				
1	3537	3643	1616	5718	Gulbhar-panjshir	35.170	69.290	3538.20
2	4031	3068	1614	4809	Pul-i-Asawa	35.070	69.140	4032.80
3	7176	2191	977	4828	Naghlu band	34.640	69.730	27837.70
4	6206.20	2826	647	5420	Pul-i-Qargha	34.550	70.230	6206.10
5	26913	3436	553	7603	Pul-i-Kamaa	34.440	70.540	25913.50
6	1634.10	2856	1887	4506	Tang-i-Maidan	34.400	69.080	1635.90
7	9311.80	1593	400	4697	Dakah station	34.230	71.040	69269.20
8	6546.90	3096	2044	4736	Shekhabadh	34.070	68.760	6546.90
9	4906.60	2399	1800	4260	Sang-i-Naweshtaa	34.430	69.20	11453.50

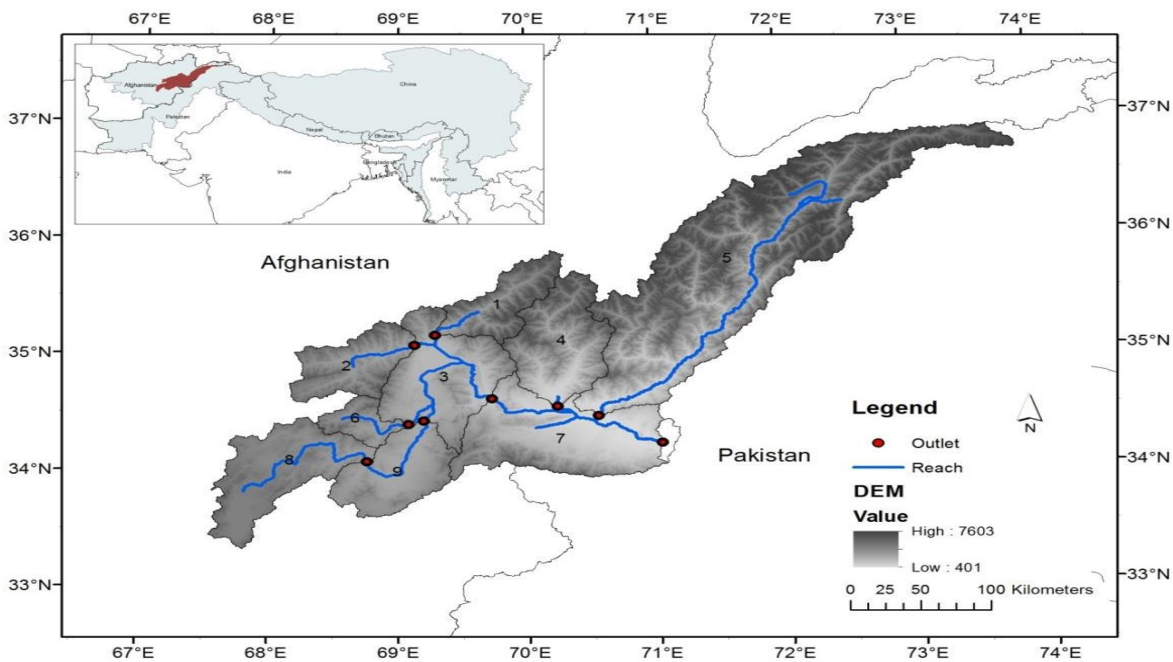


Figure 3.14- Location map of the Kabul basin, Afghanistan

3.9 Hydrological data

For first time in Afghanistan, river discharge start in 1940 that cross a few cities and number of stations increased over the year until late 1970

We did not have record of measurement of river in Afghanistan up to 1978 after that by the help of world bank and FAO began and reestablished hydraulically network in Afghanistan Afghanistan had a network of approximately 160 river gauging stations. Figure 3.2 shows the locations of some of the hydrometric stations on the main rivers inside the Kabul basin which have been used in this study to delineate the sub basins. The mean annual discharge of these stations was calculated from the available daily data and is shown in Table 3.2.

Table 3.3 Mean annual runoff of gauging stations in the Kabul basin

ID	Name	Runoff (m^3/s)	
		(1960-1979)	(2008-2012)
1	Gulbahar_Panjshire	54.90	46.30
2	Pul-i-Asawa	23.10	20.50
3	Naghlu band	112.1	86.30
4	Pul-i-Qargha	59.1	50.80
5	Pul-i-Kamaa	482.1	443.40
6	Tang-i-Siaidan	3.90	2.90
7	Dakaha	633.10	522.50
8	Shekhabade	8.00	--
9	Sang-i-Naweshtaa	9.70	7.60

3.10 Meteorological data

While Afghanistan's meteorological stations were established during the 1950s, once the war started, data recording stopped everywhere except for the Kabul airport, which has long-term data available. As is shown in Figure 3.3, the long term average precipitation for the Kabul airport station was 330 mm/yr and the average temperature for the same period was 10.8°C. Figure 3.4 shows long term seasonal average precipitation and evapotranspiration for the Kabul airport station.

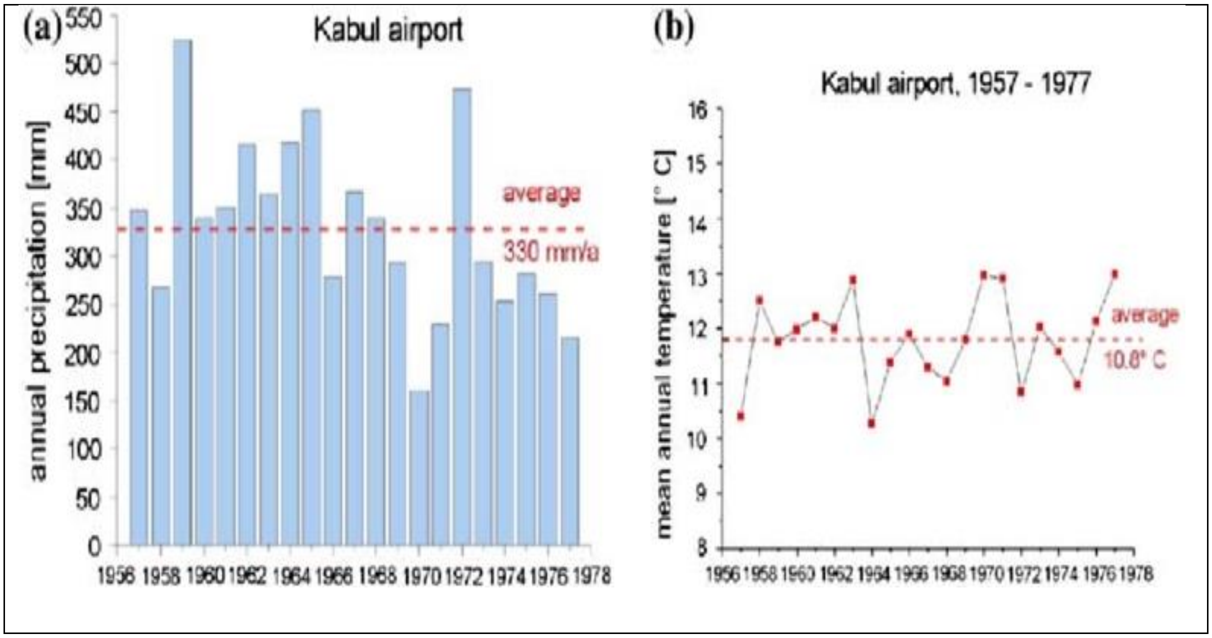


Figure 3.15- Mean annual precipitation (a) and temperature (b) at the Kabul airport station Source: (Tunnemeier & Houben, 2005)

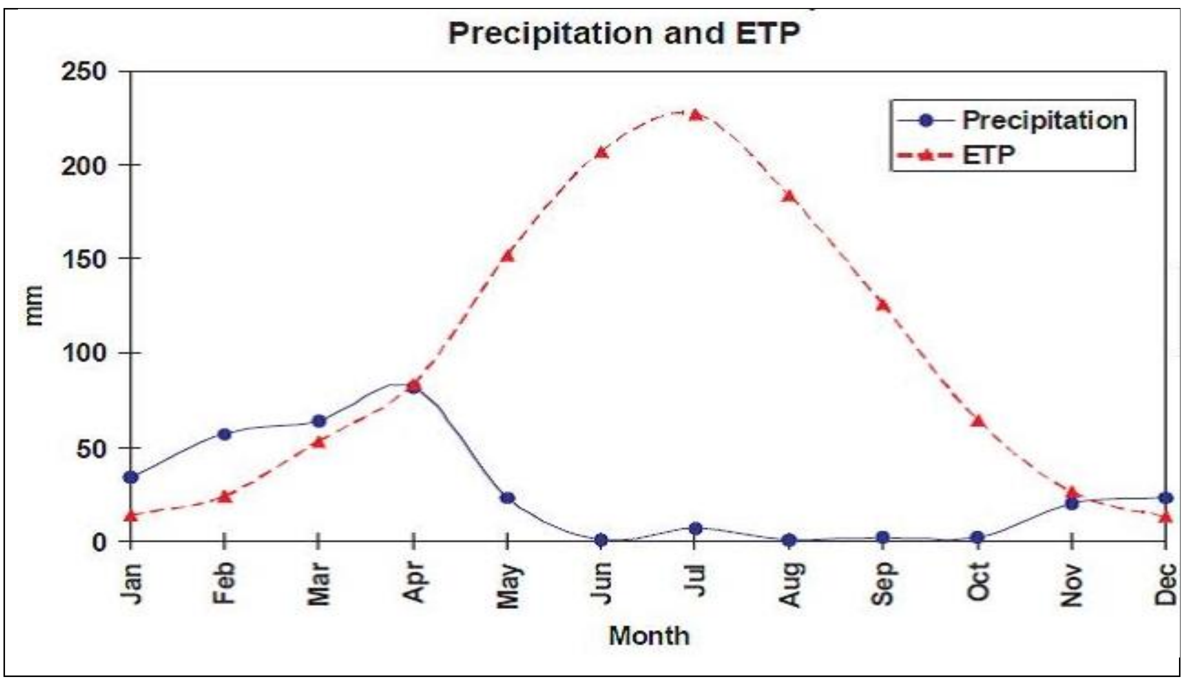


Figure 3.16- Long-term averages of precipitation and evapotranspiration at the Kabul airport Station Source: (Favre and Kamal, 2004).

Data collection activities gradually restarted after 2003. For this study, the available data for recent years (since 2003) were acquired from relevant ministries and organizations in Afghanistan. Figure 3.5 shows the reestablished meteorological stations for the Kabul basin which were used to develop the hydrological model in this study.

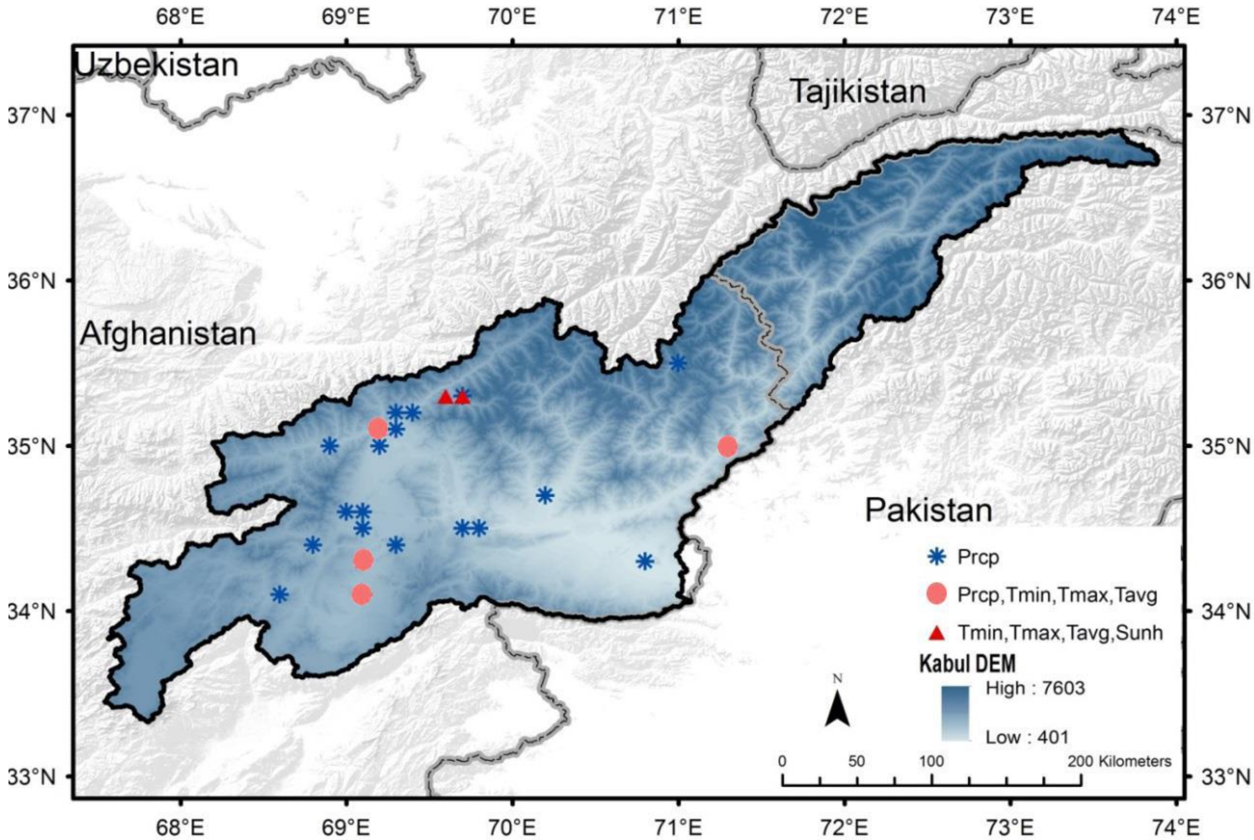


Figure 3.17- Location map of weather stations for the Kabul basin used in this study

3.11 Landscape features

The landscape features (Figure 3.6) for hydrological modeling were also obtained from Different sources and for some of them, a combination of two sources was used:

- Physiography and Geology

Based on DEM, a profile graph was obtained and three main classes were defined for the Physiography of the basin. Moreover, based on the geological map of Afghanistan (USGS, 2006), the dominant lithology type of each of these physiography classes was determined.

- Soil

The Harmonized World Soil Database (HWSD), combined with the USDA soil map, was used to specify the soil types of the basin.

- Land use

The new Glob cover 2009 Map of the European Space Agency (ESA) was applied to specify the different land use and land cover types. For the glacier extent of the basin, the map provided by ICIMOD was used.

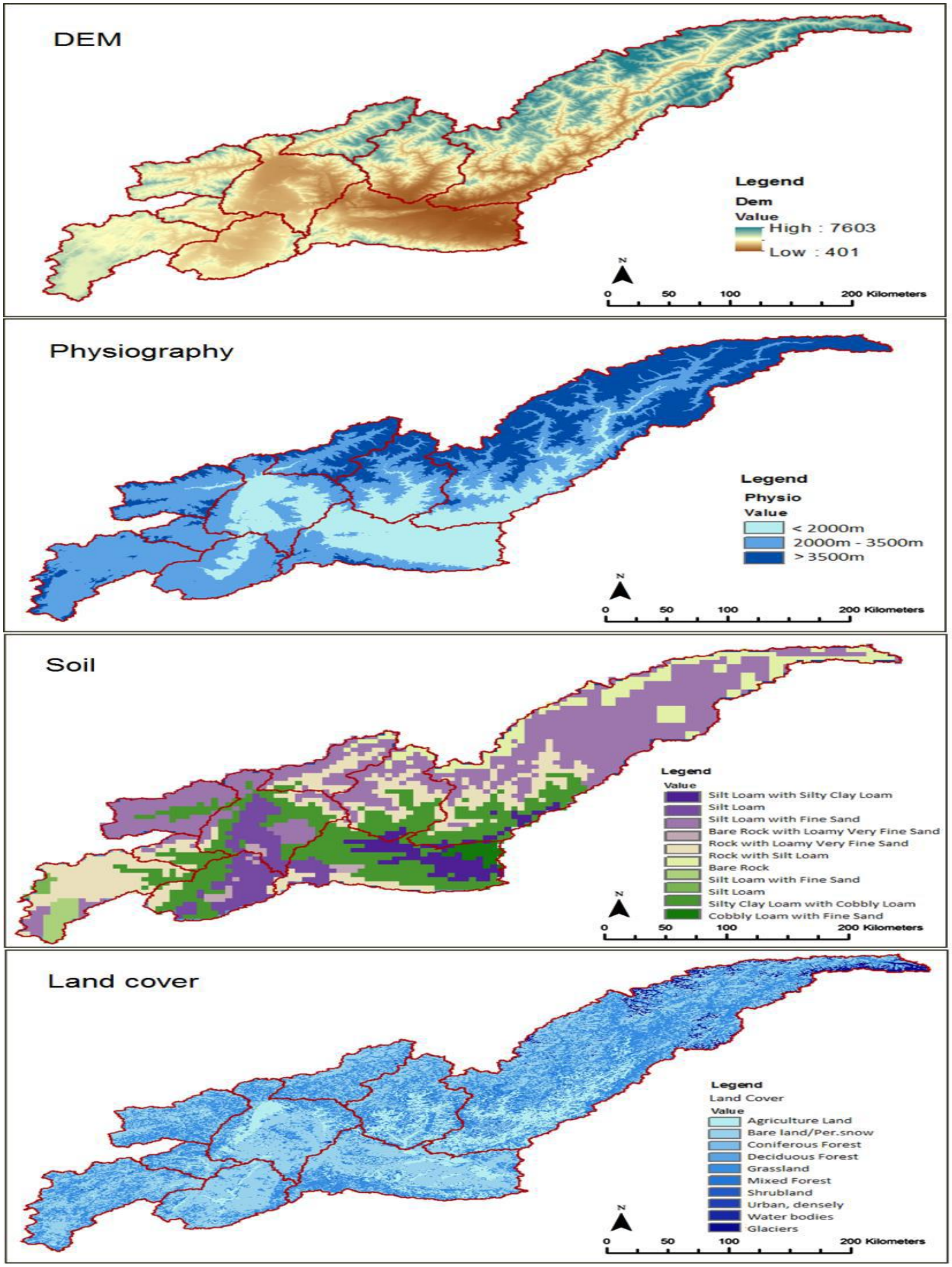


Figure 3.18- Landscape features of the Kabul basin.

3.12 Data collection

For collection the data and method two steps were applied step one of the study, collections of primary data through the serving of area and second step is collection of secondary data form the relevant ministry of water and energy and published studies.

- primary data

1. observation of field
2. questionaries'

- secondary data

1. Demographic data
2. Hydro climatic data

To understand the current situation and previous work done on the subject in Afghanistan, a Literature review was done and available socio-economic and agricultural profiles of the Kabul basin was collected. These included data on such diverse aspects as population Density, population growth, level of education, key livelihood items, cropping patterns, etc. However, the problem that arose was these data are not available on a long term basis, especially at the provincial or district levels.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Precipitation consistency analysis

Although based on observed available meteorological data with the shorter time for the series period of (2008- 2012) for consistency were used to evaluate three different data sources from Ministry of Agriculture, Irrigation and Livestock (MAIL) Ministry of Energy and Water (MoEW), and non-observed data Tropical Rainfall Measuring Mission (TRMM) compared yearly and monthly are compared in the CHP three in the FIG 03.2, 03.3 and 03.4 respectively. Primary result given to us, in these three data sources, TRMM and MAI has so close similarity in annual precipitation records. TRMM and MAIL compared from 2004 to 2010 in four plots, For the 2nd time annual precipitation records. respectively, comparison and evaluated based the result of the annual precipitation on Difference index (D %) the period of (2004 – 2010) showed that, there is acceptable consistency between two data sets. in records as shown in figure 7.1 and Table 7.1 and then applied the TRMM data source hydrology modeling in the Kabul river basin using SWAT model.

Table 4.1 The result of precipitation analysis based on percentage

Years	2004	2005	2006	2007	2008	2009	2010
MAIL	487	496	493	506	494	515	505
TRMM	402	394	438	492	455	493	480
Difference in %	21.10%	24.90%	11.90%	3.0%	8.0%	5.0%	4.98%

4.2 Regression method

in climatic variables identify changes by trend analysis was performed for long period of time. for the trend analysis results from the regression method

in Figures 6.1 and 6.2. are shown Kabul airport station’s data.

Temperature has been increasing over the last five decades but an equally clear trend for Precipitation was not detected It show the results suggest.

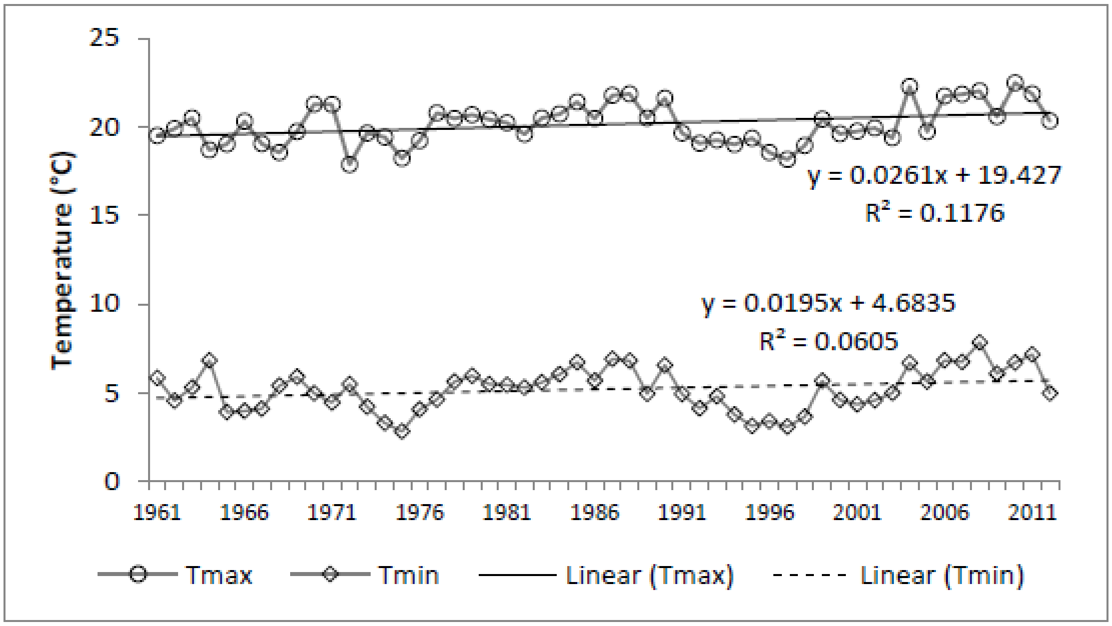


Figure 4.1- Linear trend analysis of max/min temperature for the Kabul Airport Station.

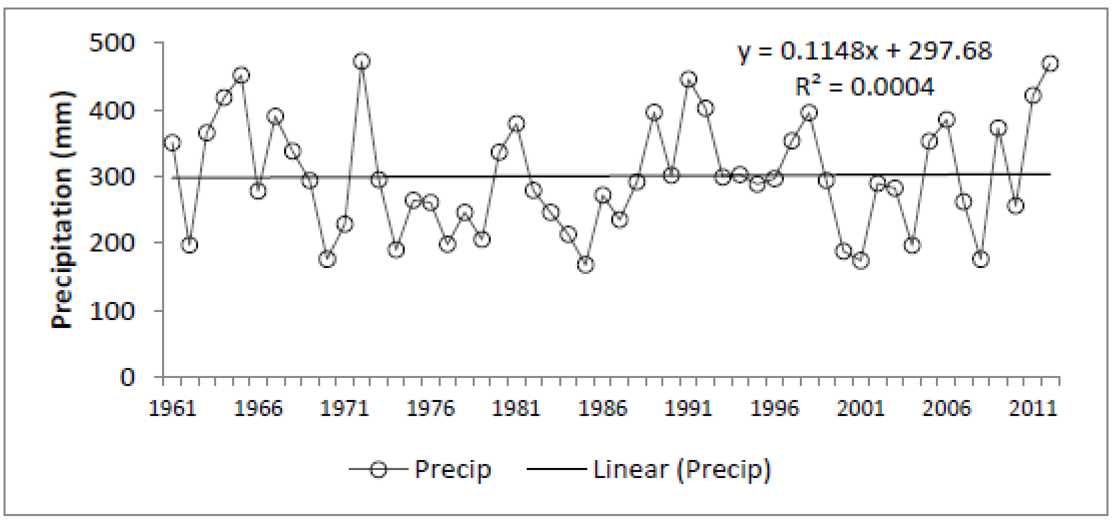


Figure 4.2- Linear trend analysis of precipitation for the Kabul Airport Station.

4.2.1 The Mann-Kendall test

Test series monotonic trends are usual employed to detect the non-parametric Mann-Kendall, environmental data, hydrological data, or climate data. The null hypothesis, the data come from a population with independent realizations H0,

Signifies that and data are

H0 indicates Rejecting Identically distributed. that a trend in the time series was detected, No trend was detected when accepting H0 indicates. The data show a significant positive Trend if the p-value is less than 0.05 [α (alpha): significance level]. Tau is the Kendall rank Correlation (the similarity of the orderings of the data when ranked by each of the quantities) Coefficient. S is the Mann-Kendall statistic and varS is the variance of S. Z is the normalized Test statistic.

Table 6.2 presents the results of the univariate Mann-Kendall test. The p-value indicates that The null hypothesis was rejected only in the case of maximum temperature. It can be Concluded that the trend was detected for Tmax but not for Tmin and precipitation. The Results of the Nonparametric Estimate of Trend in Table 6.3 present Sen's slope for the linear Rate of change and the corresponding intercept.

Table 4.2 Trend detection: The univariate Mann-Kendall test (annual values)

Total series	S	varS	Z	Tau	P-value	Test Interpretation
Tmax	288	16059	2.3	0.217	0.02354	Reject H0
Tmin	226	16059	1.8	0.070	0.0758	Accept H0
Precip	28	16059	0.2	0.021	0.83128	Accept H0

Table 4.3 Magnitude of trend: Sen's slope and intercept

Sen's slope and intercept	Tmax	Tmin	Precip
Slope	0.0260	0.0210	0.17
Intercept	19.4390	4.7860	287.1830
Nr. of observations	52.0	52.0	52.0

Mukherjee et al. (2015) based on APHRODITE precipitation data reported that trends are not significant for most of the Himalayan region. A significantly decreasing trend was also found by Palazzi et al. (2013) over Himalayan region in the APHRODITE dataset for 1951–2007 period.

4.3 The hydrology modeling

The SWAT model is a parametric model requiring a formal calibration procedure to optimize the parameter values using observed stream runoff. Parameters have physical meanings in the field, allowing parameters to be set using these databases for land use /land cover, soil type, topography, and climate statistics. The model simulation was executed for 11 years. The first five years were selected as warm up period. Stream flow is the most important element of calibrated in this model. After the successful run of SWAT model, average monthly hydrological components in the basin shown in the Table 7.2.

Table 4.4: Average monthly hydrology components of the Kabul river basin using SWAT model.

Month	Rainfall	Snowfall	Surf(Q)	Lat(Q)	Yield	ET	PET	Yield (T/HA)
Jan	53.50	49.40	1.10	0.110	8.60	3.60	14.10	0.20
Feb	55.40	50.50	1.70	0.20	8.00	6.60	16.60	0.70
Mar	47.60	33.60	13.40	1.00	20.40	15.20	39.60	12.00
Apr	74.70	32.60	22.30	2.20	31.00	25.30	62.10	46.10
May	49.60	10.50	48.60	4.70	51.00	36.60	109.60	90.10
Jun	40.00	3.50	35.70	4.80	39.00	34.90	138.50	88.40
Jul	32.30	0.00	1.10	2.70	24.00	33.20	145.30	1.10
Aug	32.80	0.00	0.30	1.70	19.00	30.50	139.50	0.20
Sep	33.30	1.60	0.30	1.50	13.00	25.70	114.20	0.30
Oct	33.90	7.60	0.80	1.20	12.00	21.10	81.00	1.20
Nov	41.70	21.20	1.20	0.70	10.20	15.10	42.00	0.80
Dec	22.20	20.30	0.10	0.20	8.50	7.40	26.00	0.10

In accordance with (C.H.Green, 2005) , the SWAT 's runoff simulation data were tested against measured runoff data. The annually averaged simulated stream discharge (244 mm) is 86% of the measured average value (284 mm).

Table 4.5: Comparison of measured and simulated annual stream discharge for the Kabul river basin for the period of (2008 – 2012).

Years	Precipitation (mm)	Measured stream flow (mm)	Simulated stream flow (mm)
2008	453.80	228.40	219.640
2009	560.10	265.500	273.390
2010	629.410	256.270	329.300
2011	484.10	257.100	187.0

2012	450.40	414.640	211.120
Total	2577.90	1422.200	1220.550
Average	515.50	284.450	244.100

The SWAT model simulated water yield or (available water resources) based on the following formula: Model Equation

Annual water yield (Water resource available) = Precipitation - ET ± Total losses.

Table 4.6: Simulated hydrologic budget for the Kabul river basin from 2008 to 2012 using SWAT.

Years	Perspiration (mm)	Water yield (mm)	Evapotranspiration (mm)	± Losses
2008	453.870	219.640	231.0	3.210
2009	560.100	273.390	289.0	-2.270
2010	629.410	329.320	297.0	4.060
2011	484.140	187.0	294.0	3.090
2012	450.420	211.120	234.0	5.30

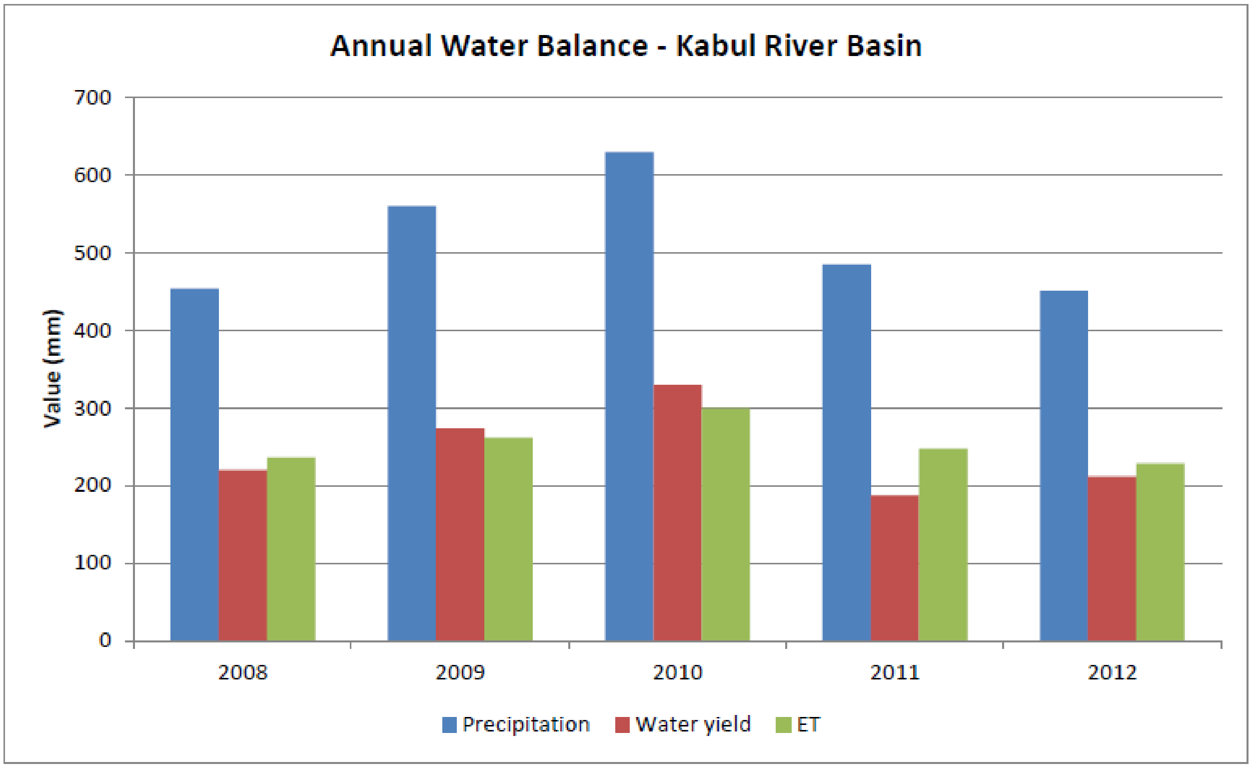


Figure 4.3- Annual water balances in the Kabul river basin.

4.4 Flow duration and hydrology alteration

A basic flow duration curve measures flow regime in the rivers, such as high flows to low flows to indicate or determine flooding and drought in the stream based on monthly flow. The result of mean monthly flow in the three stations illustrated in figure 7.3. The X-axis represents he percentage of time (Known as duration or frequency of occurrence) that a particular flow value is equaled or to the highest stream discharge in the record and 100 to the lowest such as drought condition. Exceeded the Y-axis represents the quantity of flow at a given time by cubic meters per second, associated with the duration, flow duration intervals are expressed as percentage of exceed with zero corresponding to the highest stream discharge in the record and 100 to the lowest such as drought condition.

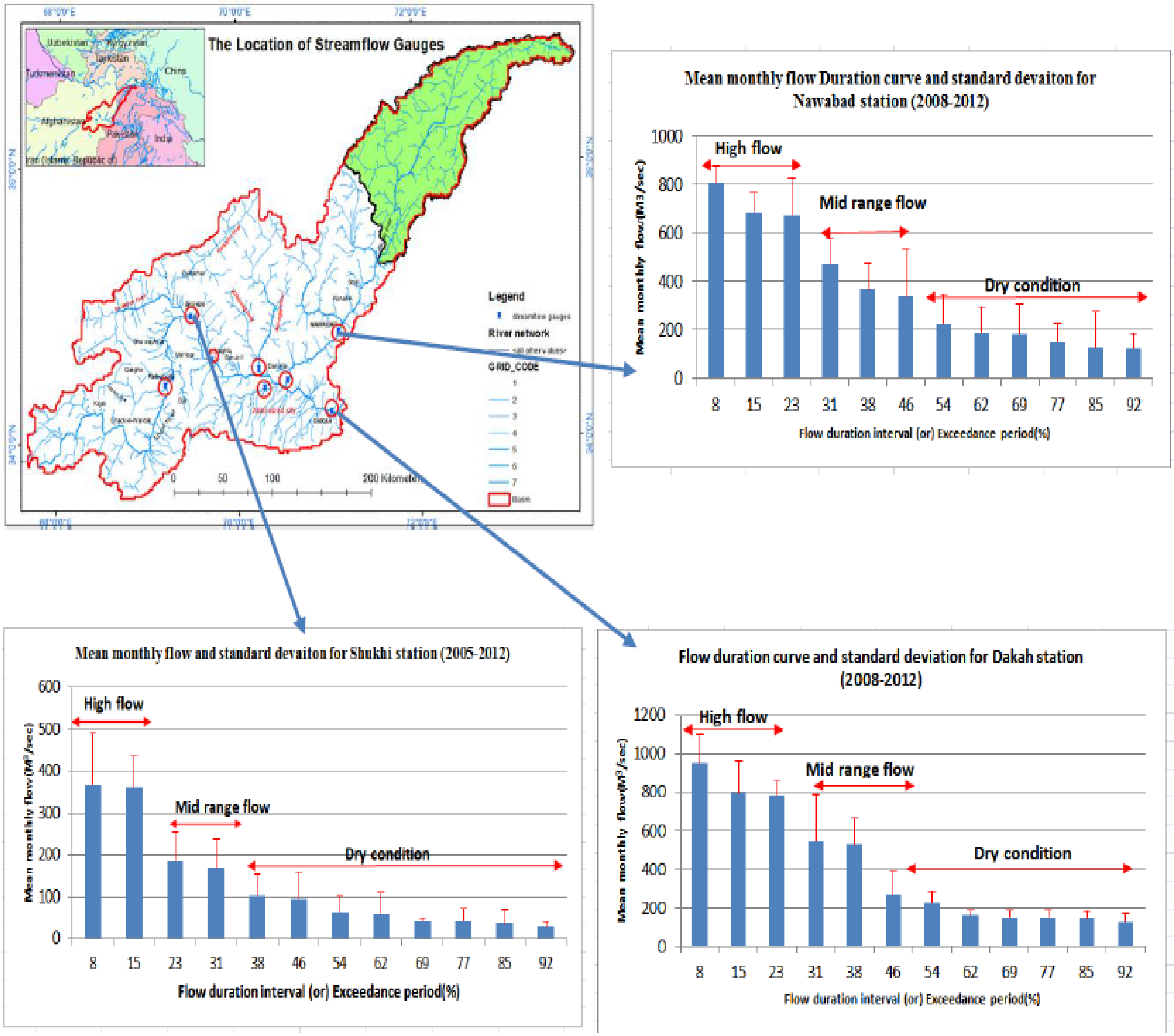
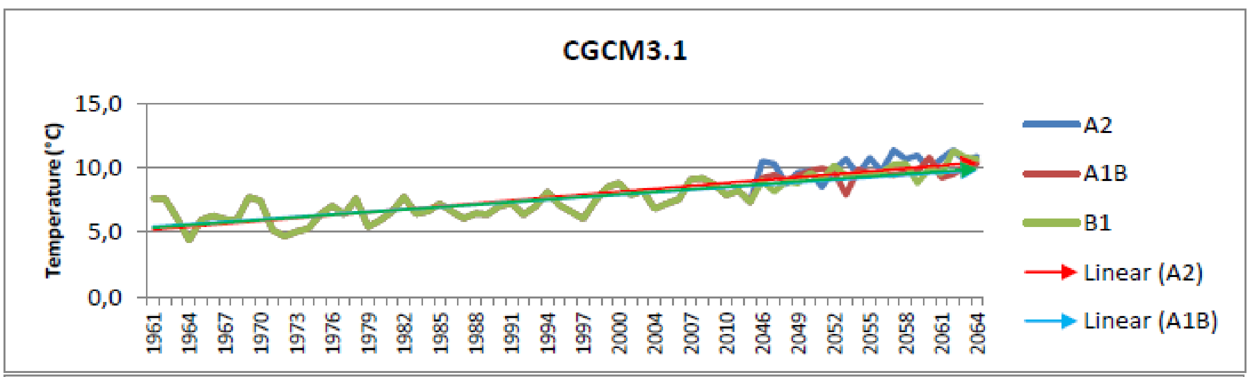


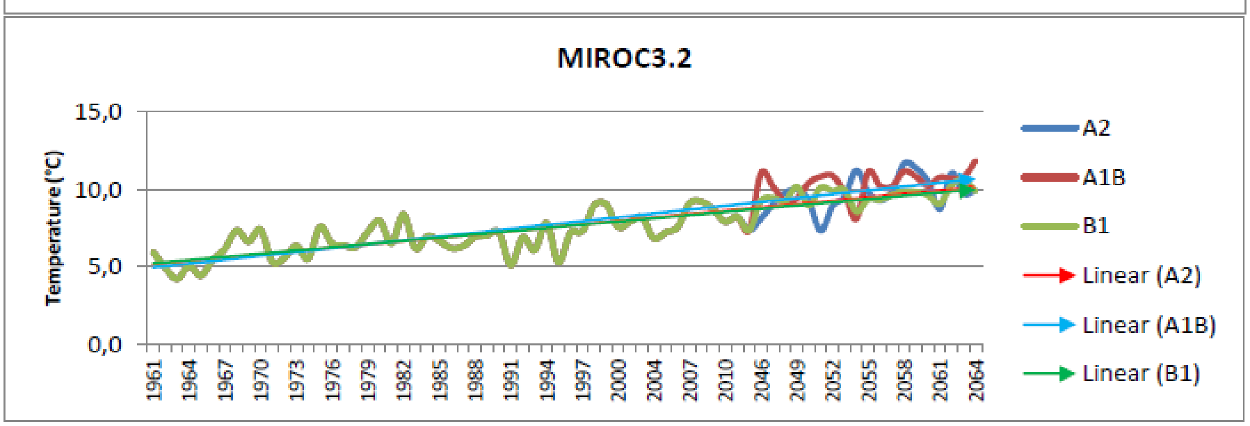
Figure 4.4- Flow duration curve.

4.5 Climate change analysis

4.5.1 Temperature change analysis

If we want to distribute the climate of one place we must discuses about the temperature about that place so now we take about Kabul river basin so we must have enough information about this river temperature which we show through. Figure 7.4 and Figure 7.5 summarize this distribution for the study area. Future climatic prediction data of four GCMs namely MIROC 3.2 (Med), CGCM 3.1 (T47), GFDL-CM2.0 and CNRM-CM3 were analyzed statistically to identify mean temperature trend from past, current to future for this we must to analyzed three type of condition like we written above. Three emission scenarios namely A2, AIB and B1 were selected for each GCMs totaling to 12 combinations of scenarios were simulated and the results were analyzed. The mean monthly and annual temperature changes estimated by the combinations of each GCM and scenarios. It can be identified from figure 7.4 that despite an overall increase in mean annual temperature shows a decreasing pattern for the majority of the GCMs simulations (which include MIROC 3.2 (Med), CGCM 3.1 (T47), GFDL-CM2.0 and CNRM-CM3).





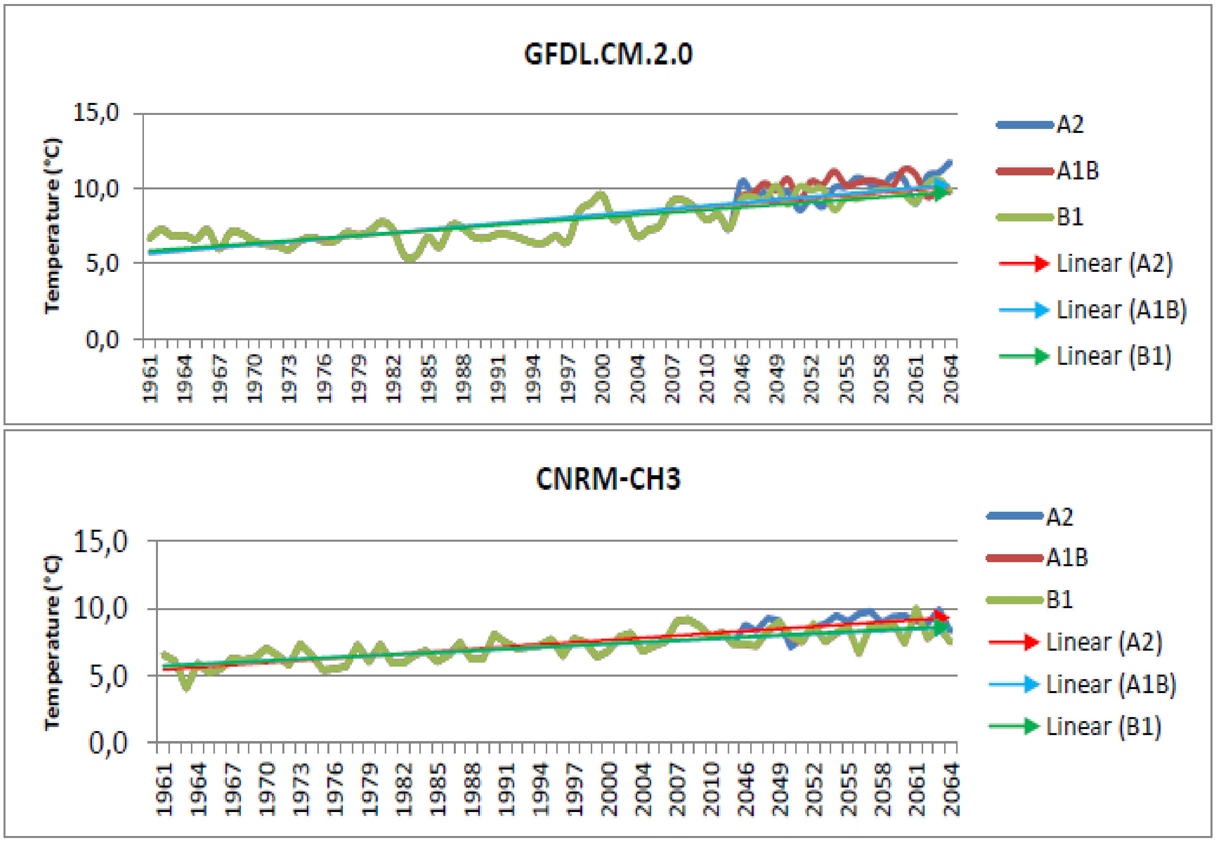


Figure 4.5- Regional trends across 23 watersheds for mean temperature from the baseline (1961 – 2000), to middle of century (2046 – 2064) in the Kabul river basin.

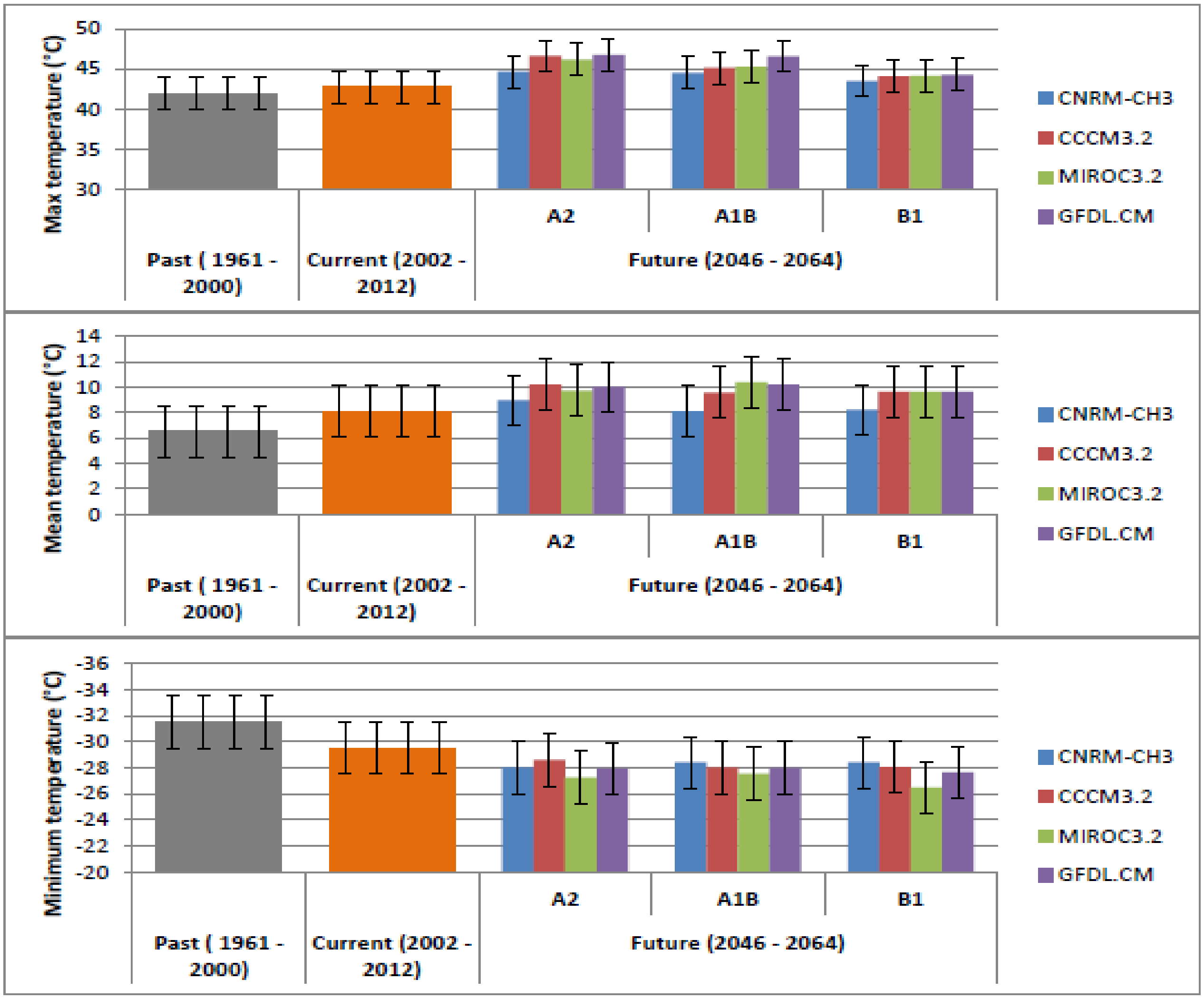


Figure 4.6- comparison of the past and current average temperatures through GCMs under three scenarios estimate temperature trends in the Kabul river basin. Daily data set downloaded based on CMIP3 from Climate change data for SWAT.

Table 4.7: Annual mean temperature change based on scenarios

Mean temperature trend by (°C)					
		Past (1961-2000)	Current (2008-2012)	Future (2046-2064)	Δ T
CNRM-CH3	A2	6.5	8.09	8.960	2.460
	A1B	6.5	8.09	8.120	1.620
	B1	6.5	8.09	8.200	1.700
CCCM3.2	A2	6.570	8.09	10.230	3.670
	A1B	6.560	8.09	9.580	3.020
	B1	6.560	8.09	9.650	3.090
MIROC3.2	A2	6.530	8.09	9.730	3.210
	A1B	6.530	8.09	10.390	3.870
	B1	6.530	8.09	9.630	3.100
GFDL.CM	A2	6.8	8.09	10.010	3.210
	A1B	6.8	8.09	10.200	3.400
	B1	6.8	8.09	9.630	2.830

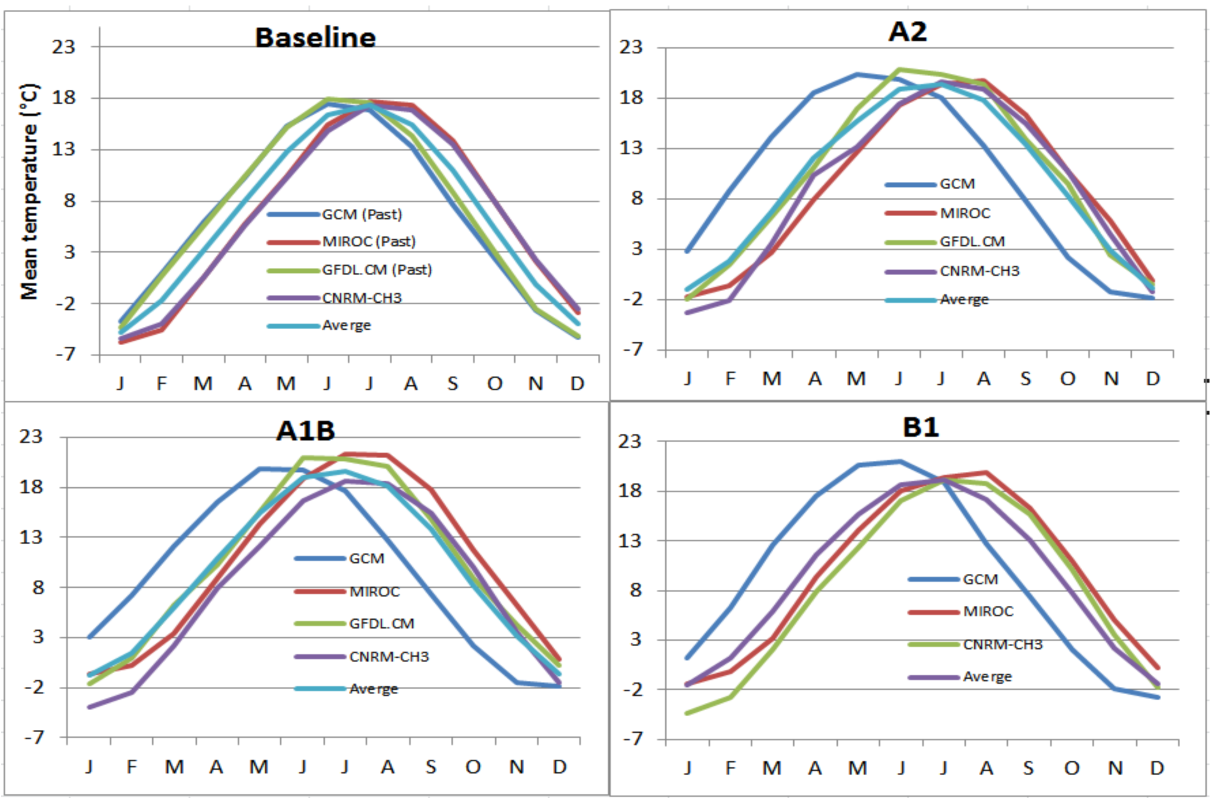


Figure 4.7- Description of monthly climate element analyzing over the river basin for the baseline (1961-2000), middle of the century (2046-2064) periods, under 3 scenarios.

4.6 Precipitation trend analysis

Future precipitation (2046 – 2064) present (2002 – 2012) and Past (1961 – 2000), data of four GCMs namely CGCM 3.1 (T47), MIROC 3.2 (Med), CNRM-CM3)and GFDL-CM2. in the Kabul river basin with 0were analyzed using the SWAT model. the results were analyzed were then simulated with Three emission scenarios. With the combining of GCMs precipitation monthly changes estimated and Out (SWATOutput.mdb) directly employed on the Table by scenarios Then on each model based monthly precipitation and yearly combined by scenarios and to identify the bias of past to future applied formula percent bias (PBIAS). in figure 7.11. demonstrated Detail description of model analysis.

Table 4.8: Precipitation trend analysis based on four GCMs and three scenarios in the Kabul basin.

GCMs	Scenario	Annul precipitation (mm)			
		Past (1961-2000)	Present (2002-2012)	Future (2046-2064)	PBIAS (%)
CNRM-CH3	A2	525	517	554	5..0
	A1B	525	517	555	6.0
	B1	525	517	542	3.0
CCCM3.2	A2	523	517	502	-4.0
	A1B	523	517	528	1.0
	B1	523	517	447	-15.0
MIROC3.2	A2	493	517	575	17.0
	A1B	491	517	473	-4.0
	B1	491	517	453	-8.0
GFDL.CM	A2	522	517	413	-21.0
	A1B	522	517	468	-10.0
	B1	522	517	405	-11.0

4.6.1 Stream flow analysis

The results of observed and simulated stream flow afterwards were analyzed by only considering the outlet of sub-watershed 23 which lies outlet of the Kabul river basin in Afghanistan. This has been done for a couple of reasons:

- The Kabul river basin is located in the upstream of Indus catchment, the Dakah station, which is located at sub-watershed 22 recording stream runoff of whole the Kabul river basin. This station tells us the volume of water flowing from the Kabul basin to the Indus, Pakistan territory.
- Dakaha station, which is installed in the sub-watershed of 22, recording daily, monthly and annual flow rate, it is very important for water development in the upstream.
- Data collaboration between upstream (Afghanistan) and downstream (Pakistan) for the purpose of negotiation on water allocation.
- Long term stream flow analysis for climate change impact assessment.
- Time is also the other reason in which incorporating more than one outlet will need a longer period as it need to look each outlet separately and as a master 's thesis this could be difficult to achieve.

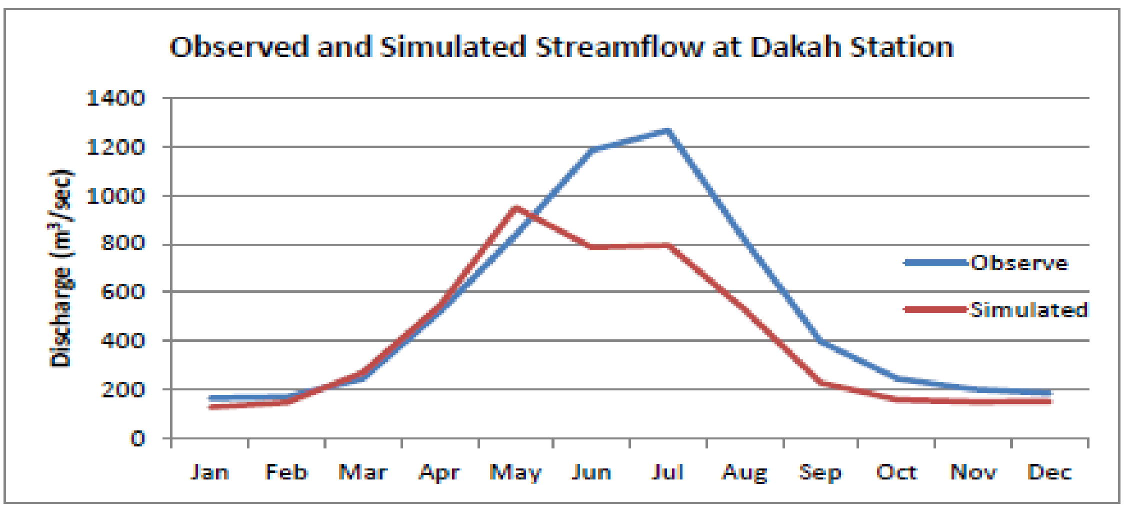
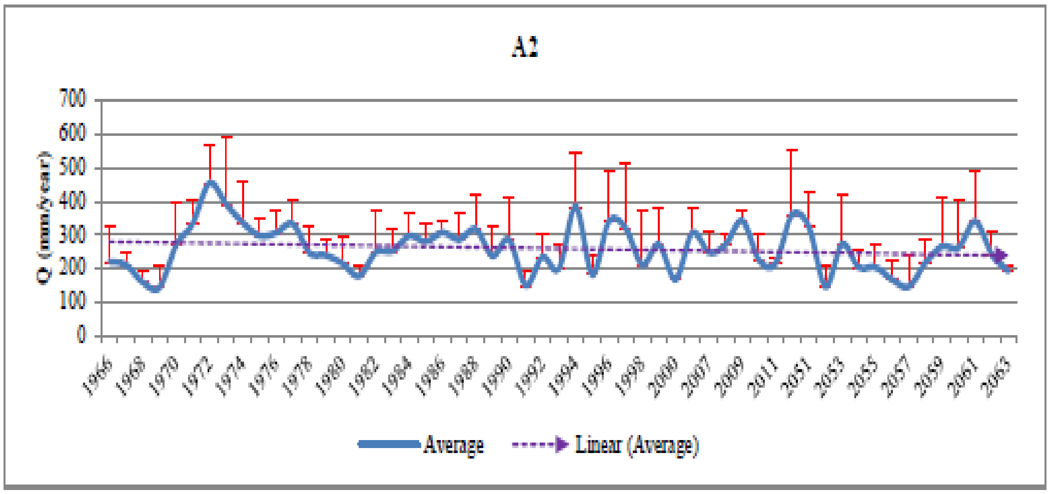


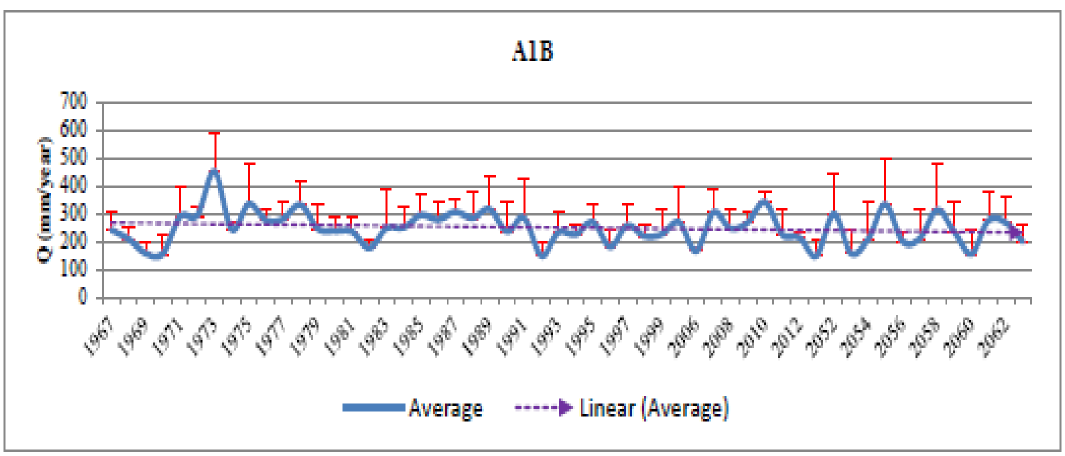
Figure 4.8- simulated stream flow (2008-2012) at Dakah station and Monthly distribution of observed (2008- 2012).

4.6.2 Projected future runoff

in figure 7.13.shown that the runoff changes are The patterns of projected For the whole the basin, with averaging across stream flow calculated the value of mean annual stream flow for the SWAT model using different GCM applied as input to projection obtained. in the runoff regime chaging to The runoff is likely to decrease in most of the model output in the outlet (Dakah station).in the pattern of stream flow changes in precipitation Although the spatial pattern, stream flow decrease the resulted in this time when changing and decrease in precipitation patterns and changing the runoff regime in the Kabul river basin.

from 23 watersheds Using stream flow projection and (based on averages across stream flow projections from four GCMs) wirh three future scenarios, 11 combinations I have. after simulating average yearly flow converted by the scenario The result of monthly flow series for each model. At last, annual runoff quantify the variation of by   the average of the yearly flows, trend show standard deviation applied Linear regression.





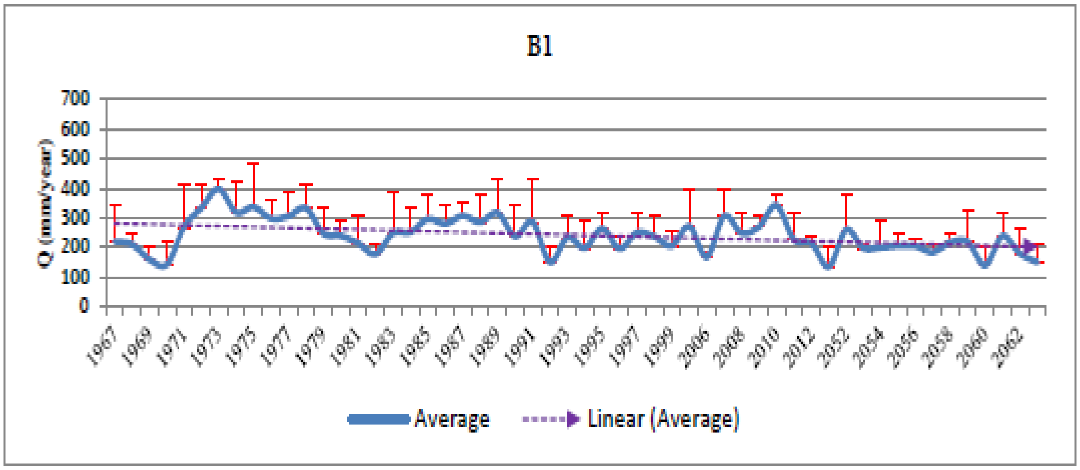
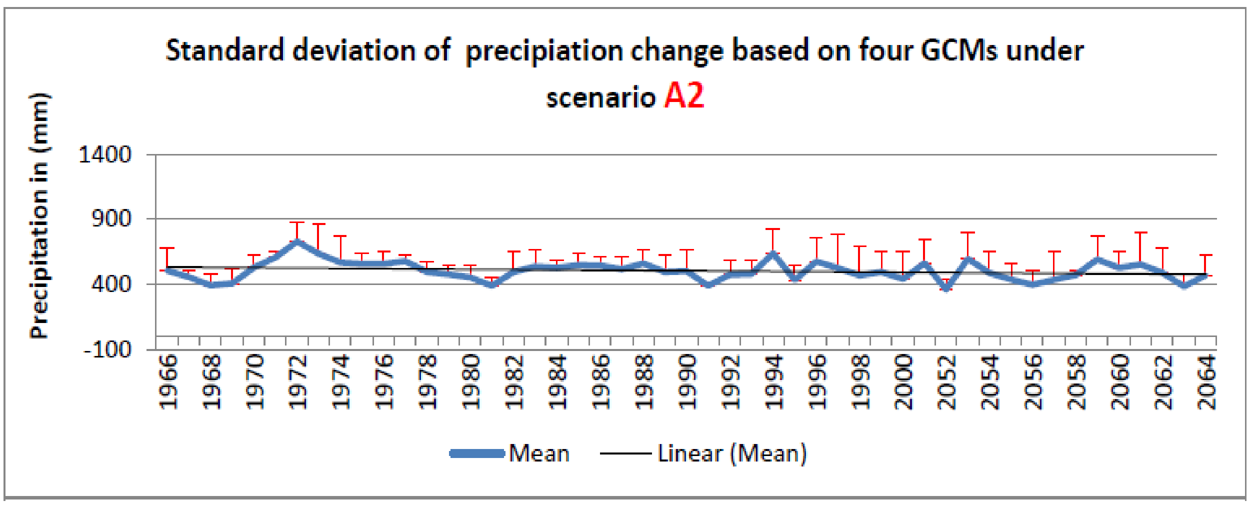


Figure 4.9- Line chart present change in projected mean annual stream flow from baseline (1961 – 2000) to middle of century (2046 – 2064) for future emission scenarios A2, A1B and B1 for all watersheds and GCMs.

4.6.3 Projected future monthly runoff

in figure 7.14. shows The monthly distribution of flow has been Generally presented monthly changes illustrates figure on flow regimes under three scenarios estimated four GCM and past observed stream flow (1969 – 1979) in Dakah station compared with GCM, pour point of the Kabul river basin.The result shown that pick of stream flow in the months of June and July with change to the month of May at the middle of the twenty first century.



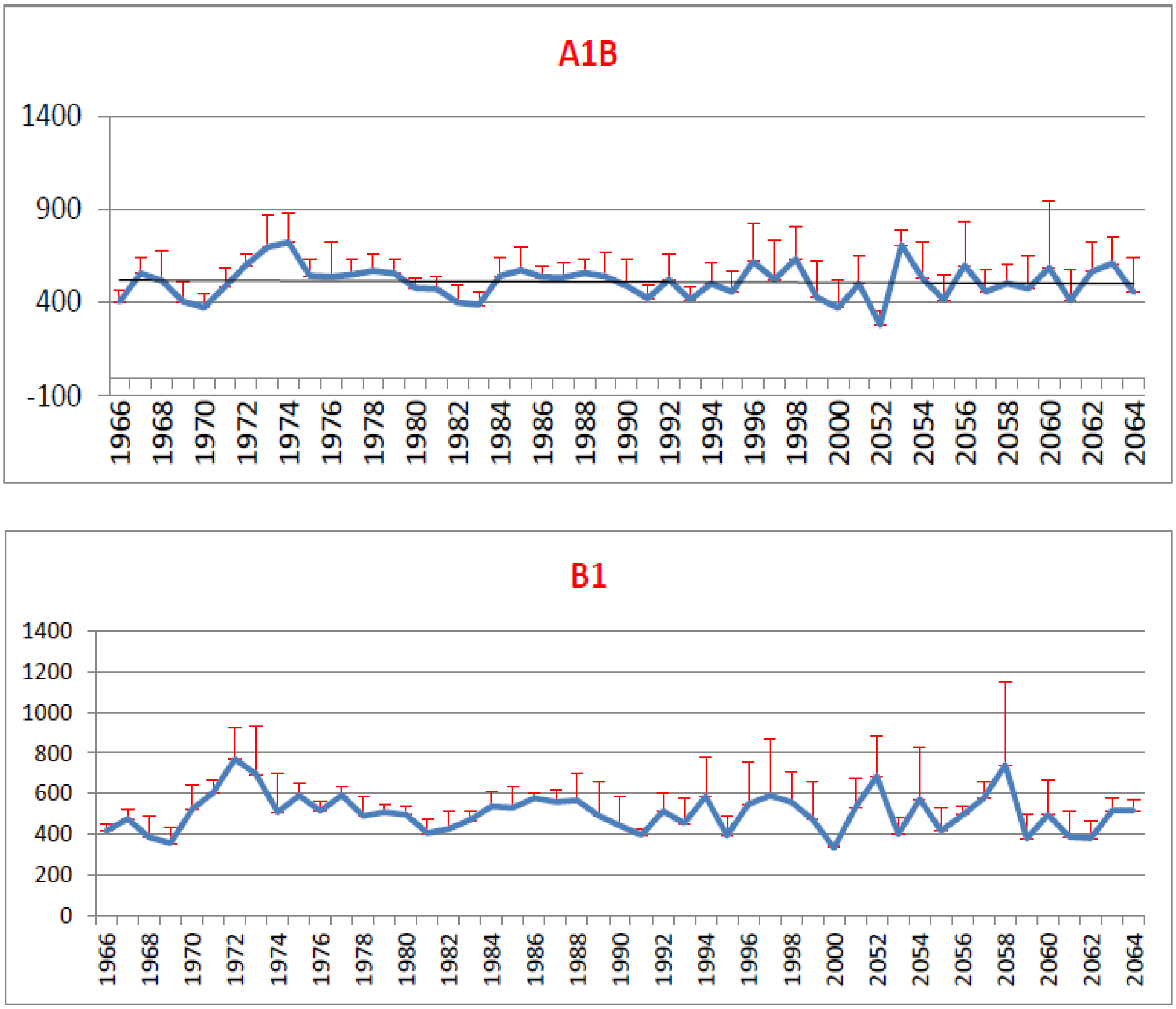


Figure 4.10- Change in projected mean annual monthly stream flow regime based on observed dataset (1966 – 1992) to middle of the century (2046 – 2064) for future emission scenarios with four GCMs.

4.7 Projected Future Water Availability

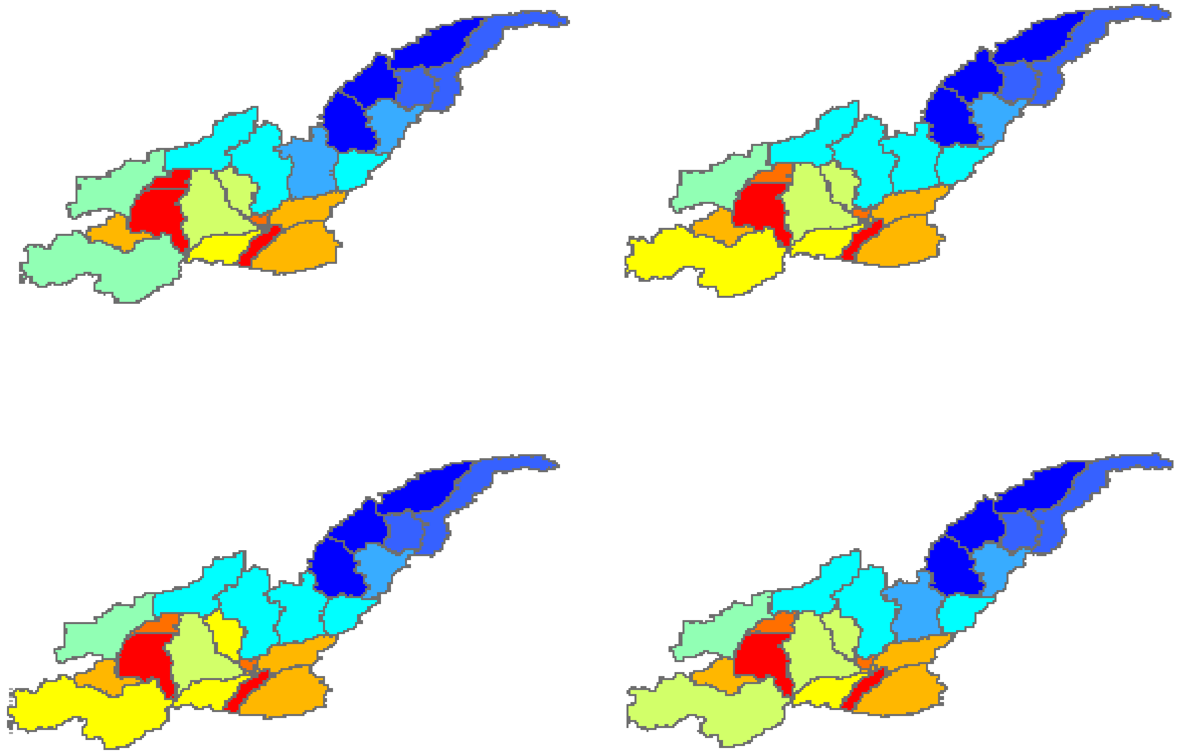
Four GCMs namely Future climate prediction data, MIROCS.2 CGCM3.2 CNRM-CH3, and GFDL.CM , the Kabul river basin were examine and occupied on the SWAT model.for Scenarios three emission namely, A1B' B1 and A2 it was selected from B1 to GCMs except for GFDL.CM, totaling 11 combinations of scenarios were then simulated and the results were analyzed. Eleven years (01969 – 01979) for Dakah station Observational stream runoff data converted from((m3/sec)) to millimeter it belon to the catchment area and in the Table 7.70 shown the result compared with the Future projected stream runoff. in the Table 7.70. shown trend assessment in table7.70noticed the GCMs shows a decreasing pattern That the annual water availability the fact for mainly due to that the precipitation for decrease in will eventually on the increase be compensated increase due to temperature increase by Evapotranspiration. Kabul river basin have global temperature rise in the annual water availability this is an indicative of the vital impact.

Table 4.9: Projected Future water availability based on GCMs fewer than three scenarios.

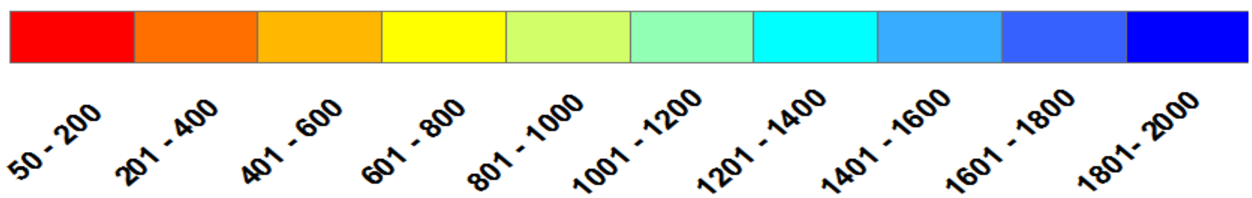
GCMs	Scenario	Annul water availability (mm)				
		Past (1961-2000)	Present (2002-2012)	Future (2046-2064)	Treand (mm)	ΔAWA %
CNRM-CH3	A2	289	246	266	22.0	-7.4.0
	A1B	289	246	262	28.0	-9.7.0
	B1	289	246	271	18.0	-6.3.0
CCCM3.2	A2	289	246	196	92.0	-31.80
	A1B	289	246	246	42.0	-14.50
	B1	289	246	235	53.0	-18.30
MIROC3.2	A2	289	246	246	43.0	-14.50
	A1B	289	246	221	67.0	-23.20
	B1	289	246	194	94.0	-32.50
GFDL.CM	A2	289	246	187	104.0	-36.0 0
	A1B	289	246	220	68.0	-23.50
	B1	289	2466	X	X	x

4.8 Water stress assessment

With the climate change and growth of population To evaluate water stress,in every watershed calculated   exponential population growth on statistics till 02045. evaluated based on projected climate data ((CMIP3)) and weather data using for Present and future water availability using SWAT model 2012, with four GCMs namely GFDL.CM, CNRM-CH30, MIROCS.02 and and CGCM3.20three scenarios such, A1B., B1 and A2, in figure 007.15 shown then the present and future freshwater availability in every sub-watershed divided by the number of present and projected future population.



Legend: Annual renewable freshwater (m3/person/year)



Absolute water stress	Chronic water stress	Regular water stress	No water stress

Figure 4.11- Consideration of present and Future water stress indicator in each sub-watershed , Kabul river basin.

4.9 Land cover analysis

Two land use data sets have been used In this study, MODIS and GLCF based global land cover data sets. GLCF((1982- 1992)) with a resolution of (01km) was used as baseline and MODIS based global land cover dataset((2001 -2010)) for land cover changes have been applied in SWAT model. in seven categories aggregated All land use and land cover classes for hydrologic properties it according. These are included grassland, rangeland, mixed forest, barren, cropland, settlement and water. in table 7.8. showed The overall result of the analysis.

Table 4.10: Land cover/land use changes in the Kabul river basin. Land cover Baseline (sources: GLCF and LCI- 1982-2010).

Number	Land cover/ land use	Land cover / land use area (Thousand hectare)		Percent of Changes (1982-1992) to (2000-2010)
		(1982 – 1992)	(2000 – 2010)	
1	water	9.10	7.80	-14.30
2	Urban/ Built up	11.30	14.60	29.30
3	Rangeland	3651.50	2848.70	-22.00
4	Mixed forest	448.40	195.70	-56.30
5	Grassland	1413.90	1586.70	12.20
6	Cropland / Irrigated area	94.30	254.20	180.40
7	Barren	891.0	1602.80	79.90

After 20 years According to the output of land cover analysis, 180 % increased shows cropland or irrigated land if we project the land cover changes, projection of irrigation in contrast to the two data sets, the cropland assumed 496000 (hectare), for projection of irrigated area by 2045 land could be significant.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

In this study the concept of vulnerability impact for water resources duo to climate change, future water availability based on climate change was assessed. Observe and dependable metrological and hydrological data sets were the main hurdle toward the present research. Dynamic and regression method have been applied for gap filling of existing metrological data which I have been obtained during data collection, all observed station located in the flat areas of the basin.

Then the observed precipitation in four stations compared with tropical rainfall measuring mission (TRMM) precipitation data set based on blocking method, the R^2 applied for total variation in the both data sets the result evaluated satisfactory with R2 = 0.80, eventually tropical rainfall measuring mission (TRMM) identified as acceptable precipitation data sets. Extension of hydro metrological networks in whole the basin is essential to create precise and dependable data base for future planning, research and development.

SWAT2012 model and GIS used for modeling hydrology spatially estimation of current (2008-2012) available water resources in the Kabul river basin, Afghanistan. For this research the SWAT model applied to quantify the current water availability, calibration scenario tested. The optimal scenario result for the simulated monthly and yearly flow the SWAT runoff simulation were tested again measured runoff data.

Then the annually simulated averaged stream discharge (244.0 mm) is 86% of the measured average value (284.0 mm). so the water yield results of simulation shown underestimate less than 14.1% of observed annual stream discharge.

In this study totally 11 combination were applied in the SWAT model to project future monthly and yearly water availability based on high, medium and law emission greenhouse gases (GHG) till 2064 to assess change in temperature, precipitation and hydrology component in the study area.

For future projected temperature, precipitation and water stream runoff four GCMs and three climate scenario (A2, A1b and B1) were used in the Kabul river basin for the period of (1961-2065). Based on the results of the 3 climate scenarios, the trend of impact of climate change is similar.

A warmer climate is expected for the study area with a projected change of temperature between 1.5°C and 2.90°C for winter and summer season. Based on A2 scenario the snowfall is expected to decrease for the months of November, December, January, and February especially between 20% to 40% due to increasing temperature in the mentioned months.

Generally based on these three scenario rainfall expected to increase slightly and snowfall is anticipated to decrease significantly in 2064. The output of (SWAT2012) model was showed that the stream runoff in the months of January, February, March and April is increasing between (35% to 45%), and runoff is expected to decrease in the months of June, July, August, and September between (40% to 50%).

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